Science of Technology and Innovation T-I

Handbook

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Strategies and successful practices of innovation in the automotive industry

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ISBN: 978-607-8534-65-4
Editorial Stamp ECORFAN: 607-8534
HCS Control Number: 2018-04
Clasification HCS (2018): 091018-0104

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ECORFAN Science of Technology and Innovation

Volume I

The Handbook will offer the volumes of selected contributions of researchers who contribute to the scientific dissemination activity of the Universidad Politécnica de Tlaxcala in its area of research in Technology Sciences and Innovation. Besides having a total evaluation, in the hands of the directors of Universidad Politécnica de Tlaxcala, quality and punctuality are collaborated in its chapters, each individual contribution was arbitrated to international standards (RESEARCH GATE , MENDELEY, GOOGLE SCHOLAR and REDIB), The Handbook thus proposes to the academic community, the recent reports on the new developments in the most interesting and promising areas of research in Technology Sciences and Innovation.

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Editors

Science of Technology and Innovation T-I
Handbooks

Universidad Politécnica de Tlaxcala. September 2018.

Foreword

The automotive sector in the states of Puebla and Tlaxcala has represented an important source of jobs and economic development, for this industry betting on innovation is undoubtedly a crucial element in its business strategy, since the high levels of rivalry and competitiveness move to the industry towards a constant renewal to respond to new competitive strategies, and key factors such as costs and efficiency.

Thus, for the automotive sector innovation plays a very important role, and this can be enriched by generating better results if it is carried out coloratively, it is in this space of opportunity that higher education institutions (HEIs) must have a much more participatory role to support with talent and knowledge, however, experience indicates that collaboration is scarce.

It is clear that there are great challenges to be addressed in this issue, to maintain a close link between these two important entities (industry and academia) in the knowledge economy. Despite these challenges that have not yet been overcome, collaboration, although limited and isolated, is consolidated with impact projects.

This paper represents an effort to show evidence of collaboration in the development of projects in the automotive industry, which nine HEIs from the states of Tlaxcala and Puebla carried out (Universidad Politécnica de Tlaxcala, Universidad Tecnológica de Puebla, Benemérita Universidad Autónoma de Puebla, Universidad Politécnica de Tlaxcala Región Poniente, Universidad Popular Autónoma del Estado de Puebla, Instituto Tecnológico de Apizaco, Universidad Tecnológica de Tlaxcala and Universidad Tecnológica de Huejotzingo) is another example of how the private sector and academia work to address challenges significant, represents further evidence that HEIs have the potential to sustain a greater link with the industry, sharing, generating and gaining knowledge; and offering alternative support and talent.

This paper shows applied and basic research projects, developed under the research line of innovation in integral manufacturing systems and predominantly under the case study methodological approach, in which teachers, students and industry personnel contributed. The purpose was to generate value through innovation projects in processes and products of the automotive sector to support their competitive advantage, through the rigorous application of a well-designed methodology to achieve impact results.

This is how innovation strategies and actions are documented in test devices, technological applications, use of statistical methods to improve products, diagnosis of logistics in the sector, long-term training programs based on competencies, redesign of warehouses in the chain of supply, technological innovation projects financed by CONACYT, among others.

The research presented here is undoubtedly a success in the company-academia link, in which thanks to various factors positive results were achieved, some of these factors were: a high level of commitment, collaborative synergy, win-win thinking, clear and transparent rules, a common interest in addressing problems and generating mutually enriching experiences, where the benefits are shared between the parties, not only at the organizational-institutional level, but in specific for the main actors as they are the professors, students and collaborators of the companies. In many cases, the projects were the result of the effort of research professors who collaborate closely with the industry and generate a wide margin of trust between the interested parties, which allows closer ties in a much more effective way. In this order of ideas, it is not possible to ignore the important activity that in many cases had the authorities of the HEIs, which under a clear mentality regarding their mission to carry out projects that favor the local industry, promoted and gave institutional support to teachers and students to carry out these activities.

Ideally, this type of factor to generate collaboration was the common denominator, but there is still much to do to achieve this systematically, this work shows the pattern towards a much closer collaboration between the company and the academy that is sorely needed theme of innovation in Mexico.

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Tlaxcala de Xicohténcatl, Mexico, September 2018

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J. Tolamatl, D. Gallardo, J. Varela y J. Méndez. (Dir.) Strategies and successful practices of innovation in the automotive industry, Science of technology and innovation. Handbooks-©ECORFAN-Mexico, Tlaxcala, 2018

Abstract

The quality of a product in the Automotive Industry demands that its suppliers comply with the requirements in each of its mobile, rigid or joining components between the elements that make up the function and operation of an automotive device; so in this study the adhesion operation of a mixture of additives, catalysts and solvents for adhesion of microfibers (flock) of automotive parts is analyzed, applying an Experiment Design (DoE) that allows an adhesion response and the final product present an aesthetic and functional sensation to the geometry of the piece. The methodological process consists of the application of the DoE that Montgomery (2005) proposes, the use of basic quality tools including the analysis of the effect of failure in the operational process of adherence of the materials and the support of the software Minitab 17 Statistical. The results obtained when implementing the DoE was a mixture of 1100 ml for the adhesive, 900 ml for the catalyst and 1000 ml for the solvent to obtain a flock adhesion of microfibers of a height of 0.9 mm in a time interval of 50 to 60 seconds.

Design of experiments, Flocking parts, Full factorial design

1. Introduction

In the Automotive Industry the manufacture of a product requires compliance with the Quality in each of its components of an automotive device; so in this chapter; the problem that is the lack of adherence of micro-fibers in the flock process, which requires optimizing the mixture of adhesion products on the surface of the geometry of the piece. Flocking is the process of depositing microfibers on a surface. It can also refer to the texture produced by the process, or to any material used mainly for surface adhesion of the process. The flocking of an article can be done in order to increase its value in terms of tactile sensation, aesthetics, color and appearance. It can also be performed for functional reasons such as insulation, sliding friction, grip and low reflectivity. In the automotive industry flocking is used for decorative purposes and can be applied to a number of different materials. The flock is the process of adhering adhesives synthetic fibers with the appearance of fluff or microfibers in the geometry of interest of the automotive component, once the impression of the flock to the touch feels velvety and with a certain height. The length of the fibers can vary in thickness, which determines the appearance of the flocked product.

A recurring problem detected in the flocking process is the detachment of microfibres allowing to solve this lack of adherence by applying a factorial design in order to respond to this problem and to define the reaction thickness (u) versus adhesive (ml), catalyst (ml) and Solvent (ml) for different levels of the factor, identifying the optimal mixture of the adhesive, a problem that was decided to be addressed by means of a 2^K factorial design. The determination of the noise variables in the manufacturing process, and the expected quality of the product were carried out, for this purpose statistical tools of quality, analysis of the mode and effect of failure and a design of experiments were applied, later with the use of the statistical package minitab version 17, the respective analyzes were performed determining the response of the noise variables. Considering that a 2^K factorial design is a methodological process that can be defined as a test or series of tests in which deliberate changes are made in the input variables of a process or system to observe and identify the reasons for the changes that could be observed in the output response (Montgomery, 2005), derived from this conceptualization the response to an experiment of this nature is the improvement to the process by detecting and minimizing the effects of the variance in the factorial experiment. And as Correa and Medina (2011) says, the first step is to estimate the effect of the factors, examine their signs and magnitudes; in this way the experimenter obtains preliminary information about the factors and interactions that may be important and in which directions they should adjust to improve the response.

1.1 Theoretical revision

The design of experiments according to Montgomery (2005), can be defined as a set of methods that are used to manipulate a process in order to obtain information on how to improve it, in this way it is possible to observe and identify the factors of changes in the response of departure. With this technique you can get, for example, improve the performance of a process and reduce its variability or production costs. Its application in the industry includes fields such as Chemistry, Mechanics, Materials, Industrial Engineering or Electronics used in experimental sciences.

1.1.1 Historical review of the design of experiments

The design of experiments was applied for the first time by the statistician and biologist R. A. Fisher in England in the 1920s in the field of agriculture; his experiences led him to publish in 1935 his book Design of Experiments (DoE). Since then, several researchers have contributed to the development and application of the technique in different fields. According to Montgomery, it is considered that there have been four stages in the development of experimental design. The first stage initiated in the twenties by Fisher is characterized by the systematic introduction of scientific thought and the application of complete and fractional factorial design and analysis of variance in scientific experimental investigations. The second stage - initiated by Box and Wilson 1951 - is characterized by the development of the response surface (RSM). In their article Cervantes and Engstrom (2004) noted that industrial experiments differed from those of agriculture in two aspects:

- Immediateness, because the answer can be observed quite quickly, without having to wait as long as in agriculture.
- Sequentiality: the experimenter can perform a few experiments and plan the following depending on the results.

In this last stage, designs like:

- Central composite designs (CCD).
- Central composite designs centered on the faces by three factors (CFD).
- Box-Behnken designs, response surface methodology (RSM) allows to optimize the experimental process and other design techniques were extended to the chemical industry and industrial processes, especially in the areas of research and development (R & D).

The third stage begins at the end of the seventies with the growing interest of the industries in the improvement of their processes. The works of Taguchi on robust design of parameters (RPD) served to spread the interest and the use of the Design of Experiments (DoE) other areas like automotive, aerospace industry, electronics or semiconductor industry. According to Kackar (1989), although the analyzes proposed by Taguchi were strongly criticized for being inefficient and in some cases ineffective, they served to develop the concept of robustness and extend the use of the design of experiments to other areas, which has started at the beginning of the fourth stage of experimental design in the nineties; in it, optimal designs emerge and numerous software tools have been developed for the analysis of the DoE. The analysis of the variance for an experimental design 23 involves calculating the effects from the construction of signs in Table 1.1 since it is of interest to the analyst.

Table 1.1 Construction of signs

Contrasts A = [a + ab + ac + abc - (1) - b - c - bc]
Contrasts B = [b + ab + bc + abc - (1) - a - c - ac]
Contrasts C = [c + ac + bc + abc - (1) - a - b - ab]
Contrasts AB = [ab - b - a + abc + (1) - bc – ac + c]
Contrasts AC = [(1) - a + b - ab - c + ac - bc + abc]
Contrasts BC = [(1) + a - b - ab - c - ac + bc + abc]
Contrasts ABC = [abc - bc - ac + c - ab + b + a - (1)]

Source: Self made adapted from Gutiérrez and De la Vara, 2008

For the 3-factor experiment with a single experimental run per combination, one could use the analysis of table 1.1 with n = 1 and using the sum of squares of the ABC interaction for the sum of SCE squares. In this case we assume that the effects of the interaction $(\alpha\beta\gamma)_{ijk}$ are all equal to zero, so that:

$$\left[\frac{SC(ABC)}{(a-1)(b-1)(x-1)}\right] = \sigma^2 + \frac{n}{(a-1)(b-1)(c-1)} \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{K=1}^{c}(\alpha\beta\gamma)_{ijk}^2 = \sigma^2 \quad (1)$$

Formulas used in the Anova table for the sum of squares for a three-factor experiment.

$$SC(BC) = an\sum_{j}\sum_{k}(\bar{y}_{.jk.} - \bar{y}_{.j..} - \bar{y}_{..k} + \bar{y}_{....})^2 \quad (2)$$

$$SC(AC) = bn\sum_{i}\sum_{k}(\bar{y}_{.ik.} - \bar{y}_{.i...} - \bar{y}_{..k} + \bar{y}_{....})^2 \quad (3)$$

$$SC(AB) = cn\sum_{i}\sum_{j}(\bar{y}_{.ij.} - \bar{y}_{.i...} - \bar{y}_{..j} + \bar{y}_{....})^2 \quad (4)$$

$$SCA = bcn\sum_{i=1}^{a}(\bar{y}_{i...} - \bar{y}_{....})^2 \quad (5)$$

$$SCB = acn\sum_{j=1}^{b}(\bar{y}_{.j..} - \bar{y}_{....})^2 \quad (6)$$

$$SCC = abn\sum_{k=1}^{c}\overline{(y}_{..k.} - \bar{y}_{....})^2 \quad (7)$$

$$SC(ABC) = n\sum_{i}\sum_{j}\sum_{k}(\bar{y}_{ijk.} - \bar{y}_{.ij..} - \bar{y}_{.ik..} - \bar{y}_{.jk.} - \bar{y}_{.i..} - \bar{y}_{.j..}\ \bar{y}_{..k.} - \bar{y}_{....})^2 \quad (8)$$

$$STC = \sum_{i}\sum_{j}\sum_{k}\sum_{l}(\bar{y}_{ijkl} - \bar{y}_{....})^2 \quad (9)$$

$$SCE = n\sum_{i}\sum_{j}\sum_{k}(\bar{y}_{ijkl} - \bar{y}_{ijk.})^2 \quad (10)$$

The averages in the formulas are defined as follows:

$\bar{\bar{y}}_{...}$ = Average of all abcn observations:
$\bar{y}_{i...}$ = Average of observations for the i-th level of factor A
$\bar{y}_{.j..}$ = Average of observations for the j-th level of factor B,
$\bar{y}_{..k.}$ = Average observations for the kth level of factor C,
$\bar{y}_{ij..}$ = Average of the observations for the i-th level of A and the j-th level of B,
$\bar{y}_{i.k.}$ = Average of the observations for the i-th level of A and the kth level of C,
$\bar{y}_{.jk.}$ = Average of the observations for the j-th level of B and the kth level of C.
$\bar{y}_{ijk.}$ = Average of the observations for the (ijk)-th treatment combination.

Table 1.2 ANOVA for the 3-factor experiment

Source of Variation	Sum of squares	Degrees of freedom	Media square	F Calculated	Value p
Main effect:					
A	SCA	a - 1	S_1^2	$f = \frac{s_1^2}{s^2}$	$p(f > fo$
B	SAP	b - 1	S_2^2	$f = \frac{s_1^2}{s^2}$	$p(f > fo$
C	SCC	c - 1	S_3^2	$f = \frac{s_1^2}{s^2}$	$p(f > fo$
Interaction of 2 factors:					
AB	SC(AB)	(a - 1)(b - 1)	S_4^2	$f = \frac{s_1^2}{s^2}$	$p(f > fo$
AC	SC(AC)	(a - 1)(c - 1)	S_5^2	$f = \frac{s_1^2}{s^2}$	$p(f > fo$
AB	SC(AB)	(a - 1)(b - 1)	S_4^2	$f = \frac{s_1^2}{s^2}$	$p(f > fo$
Interaction of 3 factors:					
ABC	SC(ABC)	(a - 1)(b - 1)	S_7^2	$f = \frac{s_1^2}{s^2}$	
Error	SCE	abc(n -1)			
Total	STC	abcn -1			

Source: Adapted from Walpole, Ronald 2012

A factorial experiment 2^3 is analyzed which provides eight different treatment combinations represented as follows: (1), a, b, c, ab, ac, bc and abc; applying the Yates notation proposed by the English Statistician "Frank Yates" (1992-1994) in factorial effects where the contrasts of the structured factorial experiment are represented in Table 1.3, the combinations of treatments and the appropriate algebraic signs for each contrast are presented. they are used in the calculation of the sums of the squares for the main effects and the interaction effects. Its geometric representation is a regular cube centered on the origin (0,0,0) and whose vertices indicate the eight treatments observed in figure 1.1.

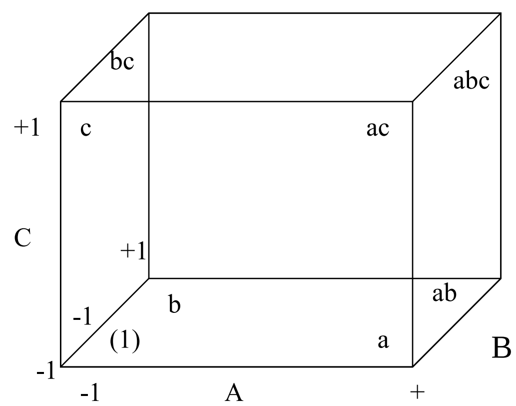
Table 1.3 Signs of contrasts in a factorial experiment 2^3

	Factorial effect						
Combination of treatments	A	B	C	AB	AC	BC	ABC
1	-	-	-	+	+	+	-
a	+	-	-	-	-	+	+
b	-	+	-	-	+	-	+
c	-	-	+	+	-	-	+
ab	+	+	-	+	-	-	-
ac	+	-	+	-	+	-	-
bc	-	+	+	-	-	+	-
abc	+	+	+	+	+	+	+

Source: Adapted from Walpole and Myers 2012

For design 2^3, the eight design points represent the vertices of a cube, as shown in figure 1.1. The interactions in this factorial design yield 8 effects: three main A, B, C

Figure 1.1 Geometric view 2^3



Source: Adapted from Walpole and Myers 2012

For the test of hypotheses as Melo and Falia (2015) mention, a linear statistical model is proposed that allows to write each one of the answers obtained in the experiment, through the sum of a common parameter to the combinations of the levels of the factors, a single parameter for each of them (treatment effect) and a random error component.

1.1.2 Analysis of the mode and effect of faults, AMEF or FMEA

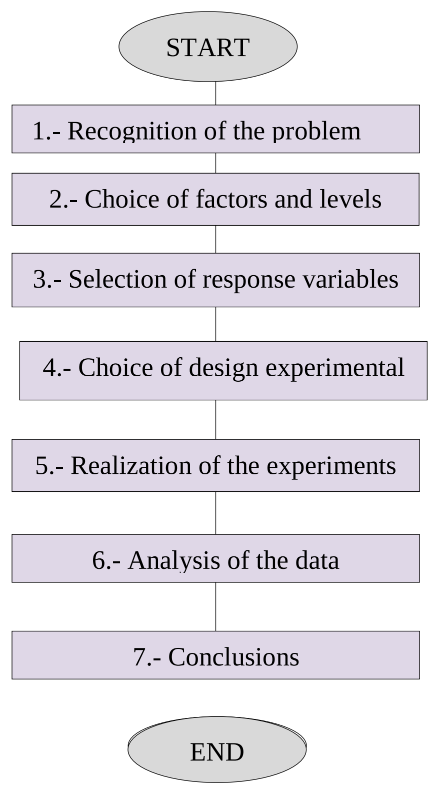
The Failure Mode and Effect Analysis AMEF, also known as FMEA for its acronym in English (Failure Mode Effect Analysis), was born in the United States at the end of the 40s by the military standard 1629. This methodology developed by NASA and applied in the Aerospace industry. Currently the AMEF is applied in the automotive industry integrated in the QS 9000 standard (ISO/TS 16949). And as commented by Chen and Ko (2009), this tool has been widely applied in the design of the product and the planning of the manufacturing process; for Pillay and Wang (2003), the FMEA could help managers to assess the risks of failures and provide managers with guidelines for improvement. After the system was improved, a re-evaluated version could be implemented. New fault RPNs will be generated. The cycle would continue until the system reached a low or acceptable level of risk. With the exception of FMEA applications in the aircraft industry, the use of FMEA has been introduced to many other industries. The purpose of the AMEF is to evaluate the reliability and control of the system, insofar as it determines the potential effects of the failures, ranges of severity, occurrence and detection of the same.

This section considers that the Failure Mode and Effect Analysis tool is carried out in order to identify in the output process the failure and the effect of experiencing those factors that impact the specifications of the product in order to provide in the process productive an immediate and anticipated response to the detected fault.

1.2 Materials and methods

A design of experiments involves much more than deciding what are the conditions in which each of the experiments necessary to achieve the objective will be carried out; In addition, several stages must be considered before and after the execution of such experiments. Throughout history several authors have classified in different ways the necessary stages to apply the DoE (Drain, 1997). For the present chapter it has been decided to follow the methodology of Montgomery (2005), the basis of many others, which consists of the seven stages shown in the following diagram.

Figure 1.2 Methodology for the design of an Experiment



Source: Adapted from Montgomery 2014

Before explaining the necessary steps to apply the DoE, some recommendations are made that Montgomery himself suggests to take into account during the entire process of experimentation:

- Use previous knowledge about the problem: knowledge of the process acquires a significant importance in each of the design stages.

- Keep the design and analysis as simple as possible: if the steps established for the design of the experiment are carried out correctly, a simple design will be obtained that, in general, leads to a simple analysis that is easier to interpret.

- Understand the difference between statistically significant and significant in practice: although the new conditions produce better results, this does not mean that they are applicable in practice. Sometimes it often happens that changing the operating conditions of a variable is more expensive than the advantages obtained with the change.

- Remember that the experiments are iterative: generally, at the beginning of all experimentation you do not have enough information to perform a completely correct analysis. Therefore it is recommended not to invest more than 25-40% of the budget in the first experiments.

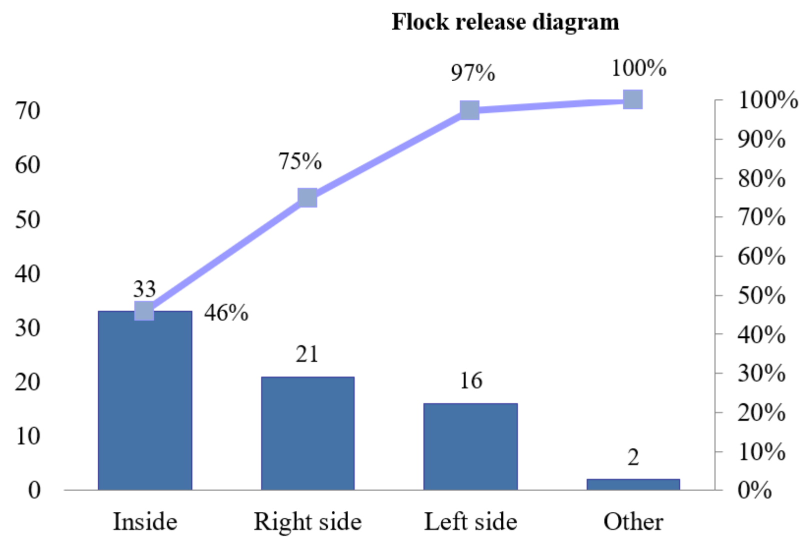
To better understand each of the stages of the methodology, these will be described in detail along with some tips that can help carry them out (Montgomery, 2014).

1.2.1 Recognition of the problem

The first step to do a DoE is to recognize the problem. An undesirable situation in which something is not working is understood as a problem. For Pande and Neuman (2000), the formulation of the problem must be a concise and focused description of what is wrong; Whenever possible, it will be convenient to quantify the problem in terms of cost, as this will make it possible to quantify the improvement achieved at the end of the process. According to the problem raised, an analysis of the rejected lot was carried out by the company, which consisted in carrying out a visual inspection. In accordance with the inspected areas of the pieces, the areas where they presented the detachment are summarized with the help of a Pareto diagram the areas where they had the flock release.

The total number of defective parts was 288 for the three shifts, which is equivalent to 57.6% in a production of 500 pieces in a shift, this was alarming for the company, so a revision of a batch of 4 equivalent containers was carried out to 72 pieces so that they were re-processed of which the results are shown in graphic 1.1:

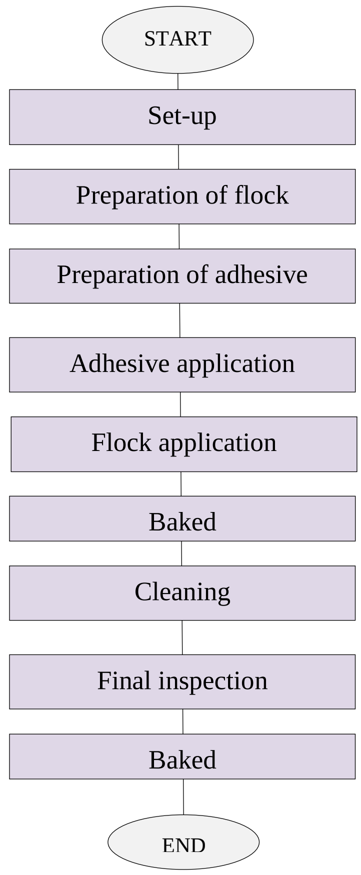
Graphic 1.1 Flock detachment



Source: Self made with company data

As shown in graphic 1.1, the area with the greatest detachment was inside the piece, which should be analyzed to determine how much the adhesive affects this defect. Once the situation has been analyzed, the characteristics of the piece that are integrated in the work instruction are reviewed, with the objective of analyzing the problem more easily. Next, figure 1.3 of the general flow of the process is presented, showing the operations necessary to carry out the adhesive operation.

Figure 1.3 Flow of the Flockado process



Source: Self Made with company data

Characteristics: this section presents a list of materials, accessories and equipment related to the flow of the adhesive process.

1. Materials for the process
   - Flock 0.9mm 3.3 Dtex FPA-B-0.9MM-3.3DTXABC
   - Glue: Mix of ABS-A + FIX-B+ SLV-C

2. Adhesive application

2.1. Production parameters
   - Application of glue with spray gun manually.
   - Pressure cooker (8kg adhesive container).
   - Gun: XYZ with pressure cooker.
   - Spray nozzle: nozzle and nozzle set of 0.8 or 1.5 mm fan jet.
   - Equipment pressure: 4 kgf/cm^2 +/- 1 kgf/cm^2
   - System pressure: 7 kgf/cm^2 +/- 1 kgf/cm^2

3. Flock application

3.1. Parameters of production of manual flocking (electro pneumatic).
   - Air doser: 4 +/- 1
   - Flock doser: 3 +/-

4. Drying oven

4.1. Production parameters
   - Drying temperature: 115°C +/- 10°C
   - Drying time: 20 min +/- 5 min

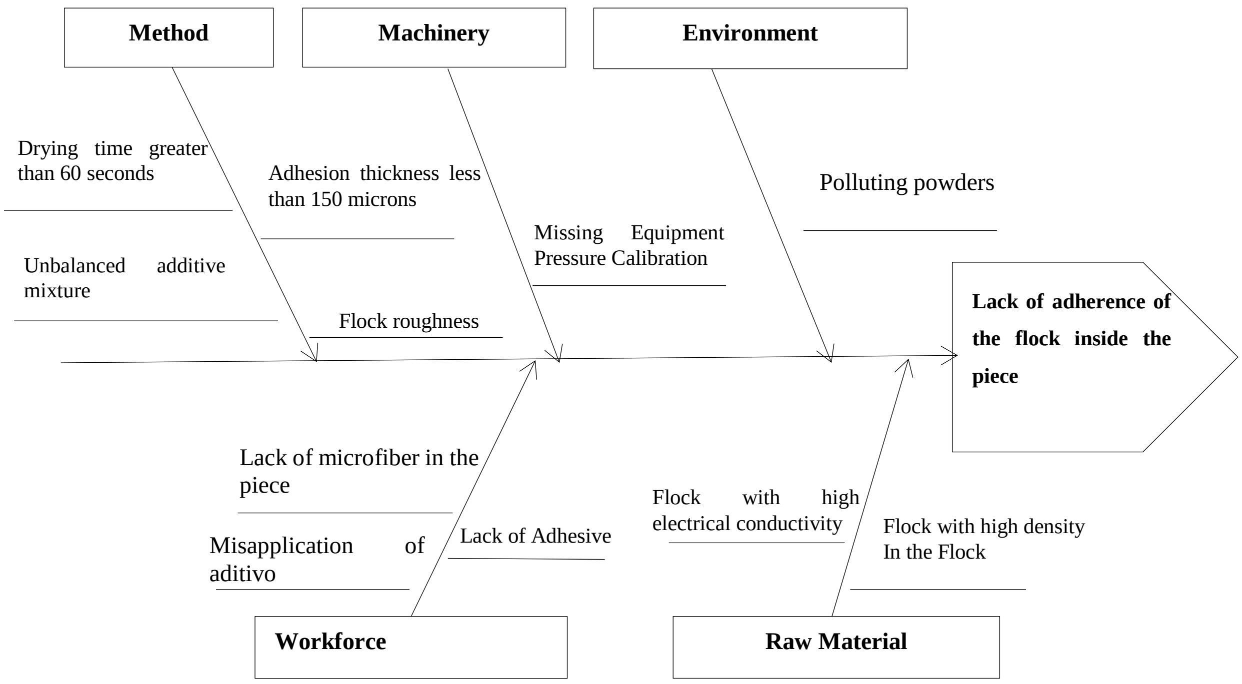
5. Parts cleaning
   - Cleaning the parts with compressed air after flocking to remove excess loose Flock.
   - Equipment pressure: 5 kgf/cm^2 +2/-1 kgf/cm^2

6. Safety equipment

1.2.2 Choice of factors and levels

The use of the Ishikawa 1.4 figure, also known as the cause-effect diagram, clearly identifies the factors that influence the flock adhesion problem. At this stage, it is vital to involve personnel close to the process using the brainstorming technique in order to identify the causes and effects of the problem.

Figure 1.4 Ishikawa of the main problem



Source: Self Made con datos de la empresa

The causes that were considered that can affect the quality of the product are the following:

- Bad application of adhesive: this was due to the fact that in certain areas of the piece they had a shine after being flocked.
- Adhesive below 150 microns thick: when there is little adhesive in the piece, it generates a faster drying time, which means that the flock does not stick on the piece.

The process of control is through a register called "Process verification sheet", it consists of two parts "Tuning" and "Verification sheet" in which the first consists in checking that there is material to be worked with , the work team, the number of workers, the start time and the time the line ended, in addition to making reports on the situation of the line and the process; On the other hand, the second contains the data of the piece to flock, the batches of the piece, the batch of the adhesives, the batch of the flock, as well as a record where in each given hour flock conductivity and thickness tests are carried out adhesive but also verifies the parameters in which the work equipment is working as well as the temperature of the environment and the humidity percentage are checked.

In this case, reviewing the FMEA of the piece the characteristic "Application of adhesive", and "Correct application of adhesive of the plastic piece", shows two potential effects of the failure to consider which are "Lack of adhesive" and "Thickness" of thin adhesive ", in them indicates those activities of detection and prevention for said problem, based on this the immediate actions are carried out so that the problem is diminished or solved.

In the registers of flock booth parameters, flock conductivity, furnace temperature and air pressure, recorded on different days, it is shown that the parameters agree with the characteristics of the piece to flock, so that it is discarded that the flock has low conductivity, that the pressure is low and that the oven is below the indicated temperature. There is also evidence that the preparation of the adhesive is correct and corresponds to the "Work instruction preparation of solvent-based adhesive", so it is ruled out that the adhesive preparation is incorrect.

It can also be verified that the tests of thickness of adhesive comply with the established in quality, of which the thickness of adhesive should be between 150 to 250 micrometers.

Once discarding the variables that do not affect the quality problem, a design of experiments is carried out using the factorial design method 2^3 establishing as factors the mixture of the components and levels of factor represented in Table 1.4 that are used for the preparation of adhesive, which are the adhesive (A), the catalyst (B) and the solvent (C)).

Table 1.4 Factor Levels

	Levels of the factor	
Factors	Low (ml)	High (ml)
A (Adhesive)	900	1100
B (Catalyst)	900	1100
C (Solvent)	800	1000

Source: Self made with company data

With this method you want to know what is the optimal amount in the preparation of the adhesive to obtain a range of thickness between 200 to 250 microns, it will also help the piece does not dry quickly and can be evenly covered the piece.

In the problem raised is an experiment involving three factors A Adhesive (ml), B catalyst (ml) C Solvent (ml), each with levels -1 and +1. The interactions in factorial design 2^3 obtain 8 effects: three main A, B, C; which would correspond to: A Adhesive, B catalyst, Solvent C, three double interactions, AB (A Adhesive, B catalyst), AC (A Adhesive, C Solvent) and BC (B catalyst, C Solvent) and a triple ABC interaction (A Adhesive, B catalyst, C Solvent).

1.2.3 Selection of the response variable

It is called response or dependent variable to the variable with which the problem is evaluated. As mentioned by Montgomery (2005) in practice this stage is usually done in conjunction with the previous one and, in many cases, even in reverse order. Ideally, the response should be continuous, easy and precise to measure, being somewhat difficult to obtain all these characteristics simultaneously (Meyers & Montgomery, 2002). In practice, it is usual not to be able to establish a single answer for a problem, since, for example, it may be necessary to optimize two variables at the same time. For Lorenzen and Anderson (1993), this leads to the performance of multiple response experiments that require special analysis, although the previous stages are the same. For the present case, for the optimization of the flocking process the response variable is the thickness of the adhesive.

1.2.4 Choice of experimental design

Having established the factors and levels with which it experiments, it is necessary to select the conditions in which the experiments must be carried out: number of experiments to be carried out, experimental conditions for each experiment and order in which they should be carried out. The experience and theoretical knowledge on different designs are of great help in this stage; To a large extent, they determine the number of experiments that will be performed. The choice of a design is directly associated with a mathematical model that relates the response to the analyzed factors. Most of the designs used factorial, multifactorial, orthogonal Taguchi, Placket-Burman (Plackett & Burman, 1946) represent a linear model in the response.

If significant non-linearity is anticipated; you must resort to designs that allow you to adjust higher order models. Second-order designs such as central composite designs (CCD) and Box-Behnken designs (2012), for example, are widely used in the Response Surface Methodology (RSM), in areas near the optimum. Finally, it should be mentioned that if it is known that the existing relationship is not polynomial, the design and analysis must accommodate this non-linearity by making transformations in the response function. Once the design is selected, the minimum number of experiments required will be determined. The three basic principles for the design of experiments must also be carefully analyzed: obtaining replicas, randomness and block analysis; These principles are fundamental conditions that allow reducing the effect of variations introduced by noise and unknown factors.

For the experiment 5 replicas were made with 8 runs in which the microns of the thickness of the piece is measured as shown in table 3.4, this with the aim of having a better precision in the results that are obtained, the results that were obtained were the following:

1.2.5 Conducting the experiments

To perform the experiments, you must first make sure that all necessary resources are available; In the areas of manufacturing and R & D, the logistical and planning aspects of the design of experiments are often underestimated (Montgomery, 2005). For the application of the methodology of the factorial analysis in the flocking company, the existence of all the materials was carefully planned, the preparation of the mixture in the different amounts of adhesive, catalyst and solvent and the pieces for the flocking (Console for the Cadillac), in the same way the knowledge of operators, quality manager and manager to monitor the development of the experiment and their respective observations at the same.

Coleman and Montgomery (2012) suggest that prior to conducting the experiment it may be convenient to carry out pilot tests that provide information about the consistency of the experimental material and check the measurement systems to make a first estimate of the experimental error. If something unexpected happens, the pilot tests allow to modify previous decisions. Once the previous stages have been completed, the experiment is carried out and information gathered. According to Lorenzen and Anderson (1993), despite the apparent simplicity of this stage, it is necessary to take special care so that the experiment and the data collection are carried out properly, following the lay-out of the design and avoiding possible human errors in the experimentation itself or in measurement. The experiments must be carried out in random order to avoid drawing erroneous conclusions, due to the presence of some factor not considered (Montgomery, 2005).

In the realization of the experiment, the pilot test was not carried out since the operation is carried out by operators with sufficient experience and it is a standardized operation (application of the adhesive) that has no problem; As mentioned previously, the problem is the composition of this one, which is about obtaining the best combination. 40 pieces were taken identifying run and replica, they were passed to the operator in a random way to apply the mixture with the different combinations of solvent, adhesive and catalyst previously determined. After the application, an inspector proceeded to measure the microns obtained in each run and replica application recording the obtained data summarized in table 1.5.

Table 1.5 Experimental design

Run	Adhesive (ml)	Catalyst (ml)	Solvent (ml)	Replica 1	Replica 2	Replica 3	Replica 4	Replica 5
1	900	900	800	200	150	150	150	150
2	1100	900	800	150	200	150	150	200
3	900	1100	800	200	150	200	200	150
4	1100	1100	800	250	200	200	250	200
5	900	900	1000	150	150	150	200	200
6	1100	900	1000	150	250	200	200	250
7	900	1100	1000	200	200	200	250	150
8	1100	1100	1000	250	250	200	200	250

Source: Self Made

1.2.6 Analysis of data

This is the stage that requires more statistical knowledge. Statistical methods are used to analyze the data, ensuring that the results and conclusions are objective. The diversity of software allows to perform the mathematical calculations and the necessary graphics; in this case MINITAB 17 has been used. This article focuses on detailing the steps to make a DOE; consequently, the data analysis will be presented briefly. In Anthony (2002) you can find a detailed description of the data analysis in an experimental design. To formally determine the effects it is usual to use the ANOVA test (Analysis of variance). In general, the method consists of obtaining the total variability of the process and classifying it into several groups, performing tests with statistical validity to know the effects that significantly influence the response, with a certain level of confidence.

1.3 Results

Once the sampling is done, the necessary calculations are carried out with the help of Minitab, with this Software it will facilitate the analysis of the results as well as save time in its preparation. For the hypothesis test, an ANOVA test is carried out with the objective of identifying those factors or interactions that significantly affect the adhesive mixture. See results on table 1.6.

Table 1.6 Analysis of variance

Factorial Regression: Thickness (u) versus Adhesive (ml), Catalyst (ml), Solvent (ml)					
Analysis of Variance					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	23750.0	3392.9	3.74	0.005
Linear	3	22000.0	7333.3	8.09	0.000
Adhesive (ml)	1	9000.0	9000.0	9.93	0.004
Catalyst (ml)	1	9000.0	9000.0	9.93	0.004
Solvent (ml)	1	4000.0	4000.0	4.41	0.044
2-Way Interactions	3	750.0	250.0	0.28	0.842
Adhesive (ml) * Catalyst (ml)	1	250.0	250.0	0.28	0.603
Adhesive (ml) * Solvent (ml)	1	250.0	250.0	0.28	0.603
Catalyst (ml) * Solvent (ml)	1	250.0	250.0	0.28	0.603
3-Way Interactions	1	1000.0	1000.0	1.10	0.301
Adhesive (ml) * Catalyst (ml) * Solvent (ml)	1	1000.0	1000.0	1.10	0.301
Error	32	29000.0	906.3		
Total	39	52750.0			

Source: Self made with Minitab software assistance

Once the ANOVA is carried out, the rejection criterion is taken into account:

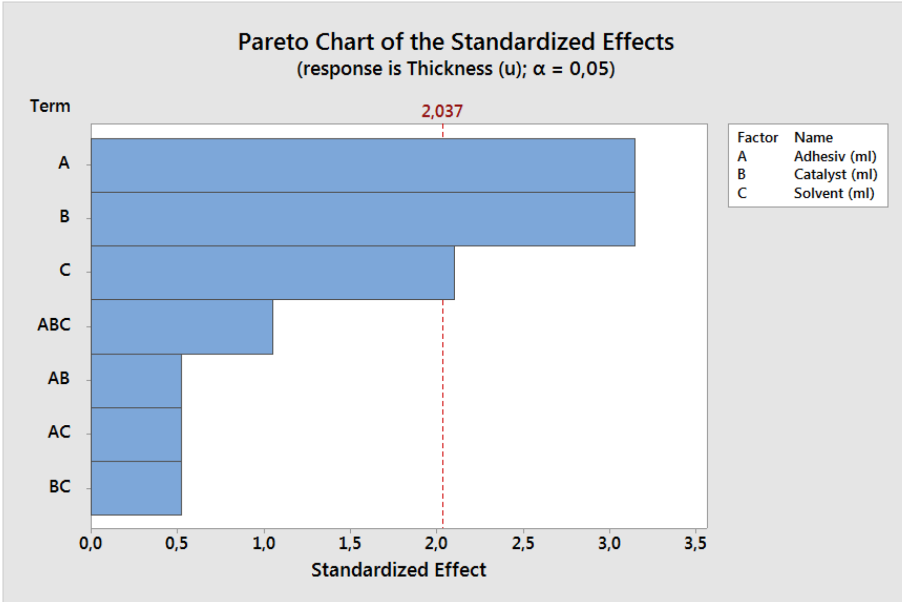
If the value P <Alpha is rejected the null hypothesis.

Having the criteria the following is to verify which hypotheses will be accepted.

A P=0.004<0.05 the null hypothesis for adhesive is rejected
B P=0.004<0.05 the null hypothesis for catalyst is rejected
C P=0.044<0.05 the null hypothesis for solvent is rejected
AB P=0.603>0.05 the null hypothesis for the interaction of AB is accepted
AC P=0.603>0.05 the null hypothesis for the interaction of AC is accepted
BC P=0.603>0.05 the null hypothesis for the BC interaction is accepted
ABC P=0.301>0.05 the null hypothesis for the ABC interaction is accepted

In summary, with a level of significance of 5%, the null hypothesis is accepted, which is defined as "There are no significant differences in the combination of the elements that make up the application" for the 4 different interactions (AB, AC, BC and ABC), that is, their interaction has no significant effect on the response variable that is the thickness of the adhesive. On the other hand, the H0 of the adhesive, catalyst and solvent are rejected, that is, these three factors individually do have a significant effect on the thickness of the adhesive.

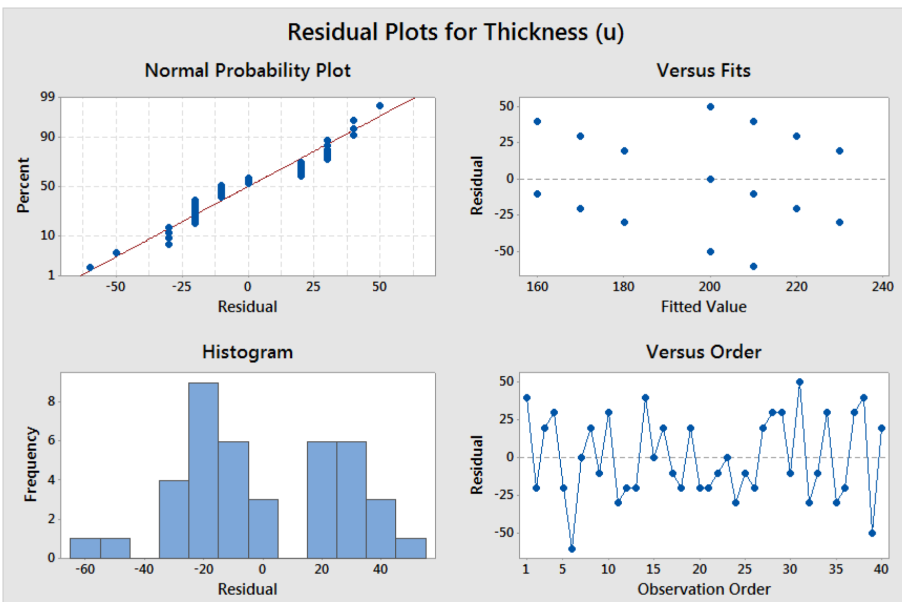
Graphic 1.2 Pareto of standardized effects



Source: Self made with Minitab software assistance

We can see that Pareto's graphic 1.2 of standardized effects confirms that the three individual factors A, B and C are those that have a significant effect since they cross the reference line that is in 2.037 and are statistically significant at the level of alpha 0.05.

Graphic 1.3 Waste Graphic



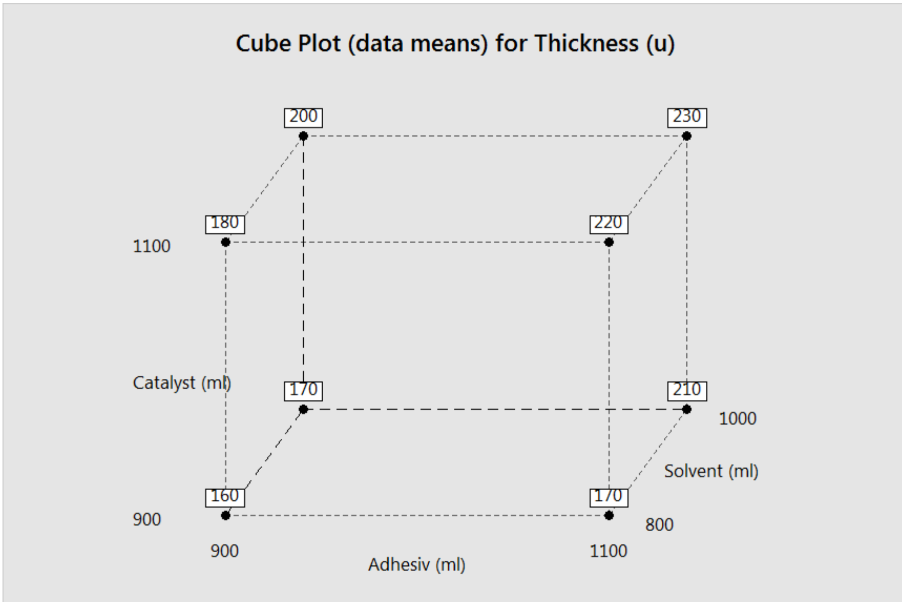
Source: Self made with Minitab software assistance

The 1.3 normal probability of effects graph is used to determine the magnitude, direction and importance of the effects. In the normal probability of effects graph, the effects that are more distant from 0 are statistically significant, also show that the data follow a normal distribution and have a positive standardized effect, that is, when the process changes from the low level to the level high of the factor, the response is increased.

In the same graphic 1.3 the so-called "versus Fits" it is observed that the values are scattered, indicating that they were obtained in a random way; since, as described by Box and Hunter (2005), the randomization of the order of the experiments ensures, as far as possible, that any uncontrolled variable (for example, laboratory temperature) contributes to the variability of repeatability and does not affect the results systematically.

Once reviewed the graphs concentrated in the 1.4, the graphic of cube is elaborated where it is possible to visualize the means of the realized runs, in this case it is necessary that the thickness of the additive is between 150 to 250 microns, the data that I throw the graphic They are the following:

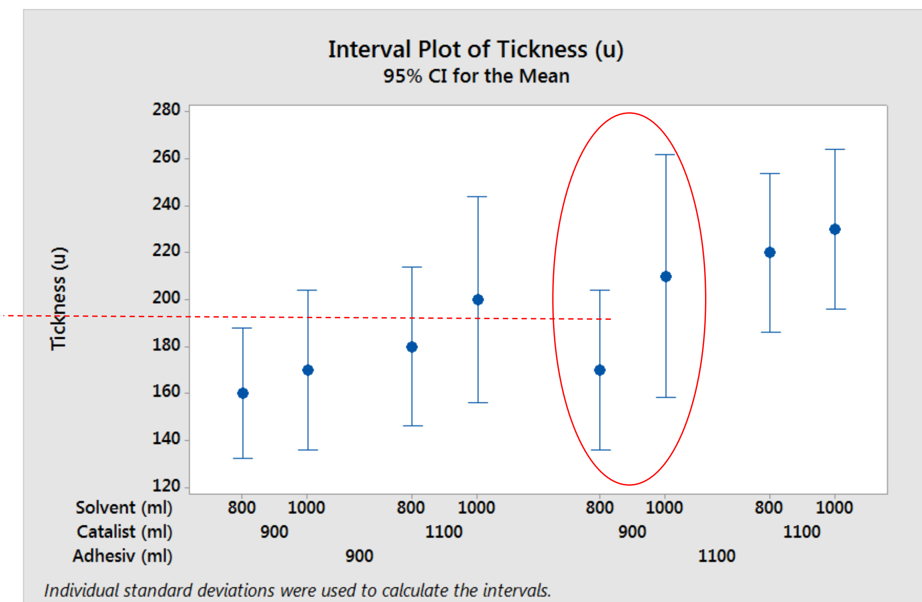
Graphic 1.4 Cube graphic



Source: Self made with Minitab software assistance

By looking at the graphic it is analyzed which is the best option we can take so that our thickness is within what we request, so our average choice is 210 which is where the level of the adhesive and the solvent is high but the level of the catalyst is low, showing that this mixture is optimal for the thickness in the piece. Another way to check which mix is better is by means of the graphic 1.5 of intervals which shows the means of the runs that were made.

Graphic 1.5 Thickness interval graphic



Source: Self made with Minitab software assistance

As seen in the previous graphic in the third interval we obtain that the type of mixture of each component must be 1100 ml for the adhesive, 900 ml for the catalyst and 1000 ml for the solvent. To avoid rapid drying ie application of between 50 and 60 sec.

1.4 Conclusions

The design of experiments is a technique that can help to know a process, it allows to find out how various factors present in it influence the response and adjust them in the levels that optimize the results. The objective of this article was to implement the DOE in a manufacturing process as part of the efforts of innovation and application of statistics in a real environment that results in an improvement through the application and verification of the usefulness of these tools. The seven steps proposed by Montgomery for the realization of an experiment, in its practical application to the case of optimization of the flocking process was a success.

In this case, through the realization of the experiments, the DOE technique allowed to determine that the factors A (adhesive), B (catalyst) and C (solvent) are the most significant to optimize the flocking of the pieces, that the three mentioned factors interact with each other, the other factors do not influence significantly and you can work at the most convenient levels.

The DoE allows designs and analysis with more factors than the one presented in this case, since in practical cases there are a number of variables to control. The planning of the experimentation, that includes the stages of selection of factors, levels, answer and the own election of the most advisable design, can be complicated in the practice; this makes it necessary to have a detailed methodology that helps and facilitates the development of each stage. The results obtained after implementing the corrective actions of the application of adhesive were favorable, since it was decreasing the pieces with lack of flock to obtain consistently the required thickness of 210 microns. With this it was possible to discard other variables such as temperature, calibration of the equipment, drying time, flock roughness and flock with high electrical conductivity.

In conclusion, it is important that each operation that adds value to the product has a procedure which indicates how it should be carried out, considering that if this is not carried out properly it will have consequences once the product is finished, in the same way it is important that the quality department has the appropriate information of what are the restrictions that a piece must meet so that it is accepted without any defect and thus avoid a claim from the client, however, controlling the variables that may affect the production will prevent them from being generated defects in the piece that occurs.

Engaging in the work method is highly recommended, because you can identify the different variables that affect the flow of the process and the quality of products and / or services, whether by labor, machinery or the environment, where there are regularly causes that cause these problems; It is worth noting that finding the root cause of a problem using quality tools can be simple or complicated to identify and solve, but thanks to the quality tools used in this case, such as the Ishikawa, AMEF and DOE diagram, several alternatives can be proposed for solve the problems in the industry.

The methodology used confirms that statistical techniques have application for solving real problems; through the analysis, management and treatment of data that involves the use of models that combine the variables that alter the response result to improve the expected quality of the products and / or services. By guaranteeing the correct thickness of the mixture, a flock adhesion of 0.9mm of uniform height was ensured in the flocked parts, thus complying with the customer's specifications; since, as described by Adams and Peppiat (1994), the classic elastic analysis predicts that the force increases with the adhesive and attribute the bond strength to the micrometric thickness. In addition, Crocombe (1999) explains that, if the adhesive becomes thicker, the plastic adhesion extension increases.

1.5 Annex 1 (Analysis of the Mode and Effect of Failure of the process of Flocking of automotive parts)

Analysis of the mode and effect of the failure (amef of the process)							
Name of the piece:	Inner retrainer LHD/RHD		Part number:	116904543, 16905993		AMEF N°: 023	Type: SERIES
Process:	Flocking of parts without pre-treatment	Model (s) / Program:	W168	Año (s):	2017	System ( ) Subsystem ( ) Component (*)	
Process manager:	Production	OEM (Fabricante):	Tier 1	Client:	XYZ	Team members:	
Drawing Level of change:	NOT AVIABLE / REF FROM MAY 2009	Date of the AMEF: 17-MARCH-17	Revision date: 22-DEC-17		Target Date:		
Supplier no:	-	Other:			Prepared by:	Reviewed by:	

Feature / Process System	Request	Potential failure mode	Potential effect (s) of the fault	Severity	Classification	Potential cause (s) of the fault	Idea	Current status of controls in process: Prevention (P)	Current status of controls in process: Detection (D)	Detection (D)	NPR	SxO	Resultados de acciones: Recommended actions	Resultados de acciones: Responsible and date of completion	Actions taken and effective date	S	O	D	NPR
(30) Adhesive application	Correct application of adhesive on the plastic part	Excess adhesive	Parts rejected by rough appearance (AEP, AGP)	6		Pot pressure parameter out of standard	4	Pot pressure check, visual verification of the piece with adhesive before going to the next process - Autocontrol- (IT2.5 / 23)	Revision of the piece with adhesive before starting the flock application (IT2.5 / 23)	7	168	24							
			Parts rejected by rough appearance (AEP, AGP)	6		Error in the application angle	4	Visual verification of the piece with adhesive before going to the next process - Self-control- (IT2.5 / 23) Application adhesive training FM3.0 / 01	Revision of the piece with adhesive before starting the flock application (IT2.5 / 23)	7	168	24							
			Parts rejected by adhesive clumps (EGA)	6		High dosage of air and / or adhesive	3	Visual verification of the piece with adhesive before going to the next process - Self-control- (IT2.5 / 23) Application adhesive training FM3.0 / 01	Revision of the piece with adhesive before starting the flock application (IT2.5 / 23)	7	128	18							
		Lack of adhesive	Parts rejected due to lack of adhesive in the required flock area (ELF)	6	*	Does not apply adhesive in required area	4	Visual verification of the piece with adhesive before going to the next process - Self-control- (IT2.5 / 23) Application adhesive training FM3.0 / 01	Revision of the piece with adhesive before starting the flock application (IT2.5 / 23)	7	168	24	Update the sequence of the adhesive application		Update of IT2.5 / 23	8	3	7	126
		Thick adhesive thickness	Parts rejected by thin adhesive that causes low flock density (EFF)	6		Error in the application angle	4	Visual verification of the piece with adhesive before going to the next process - Self-control- (IT2.5 / 23) Application adhesive training FM3.0 / 01	Revision of the piece with adhesive before starting the flock application (IT2.5 / 23)	7	168	24							
		Little adhesion of fibers	Parts rejected by flock with little penetration (adhesion) causing low flock density (EFF)	6		Adhesive drying in the piece due to weather or waiting time	4	Maintain maximum 2 pieces on the transit table before flocking (IT2.5 / 23)	Revision of the piece with adhesive before starting the flock application (IT2.5 / 23)	7	168	24							
		Exceeded flock limits	Flock in places where it is not allowed (ELF)	6	*	Failure to apply adhesive	4	Visual verification of the piece with adhesive before going to the next process -Autocontrol- (IT2.5 / 23)	Revision of the piece with adhesive before starting the flock application (IT2.5 / 23)	7	168	24							
		Areas of the piece without adhesive	Areas of the piece without flock (EFF, ELF)	6	*	Failure to apply adhesive	4	Visual verification of the piece with adhesive before going to the next process -Autocontrol- (IT2.5 / 23)	Revision of the piece with adhesive before starting the flock application (IT2.5 / 23)	7	168	24							
	Correct application of adhesive	Delay in baking, repetition of baking	Parts without correct baking (APF)	6		Failure to prepare the adhesive	4	Verificar la preparación de adhesivo (TI2.5/02)	Checking the correct baking of the piece before starting the cleaning (IT2.5 / 23)	7	168	24							

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Capítulo 2 Diseño e implementación de un dispositivo para Ablandamiento de Tubería Automotriz PA6 con base en la Norma DIN 16773-1

Chapter 2 Design and implementation of a device for Automotive Pipe Softening PA6 based on DIN 16773-1

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J. Tolamatl, D. Gallardo, J. Varela y J. Méndez. (Dir.) Strategies and successful practices of innovation in the automotive industry, Science of technology and innovation. Handbooks-©ECORFAN-Mexico, Tlaxcala, 2018.

Abstract

In the automotive industry, standardization is vital to guarantee the quality of your products. In the manufacturing processes where the same conditions are measured and maintained, it is possible to generate the same results. This rule applies to many industries in the automotive industry, where; they make and assemble different parts for the fuel tank, the engine and the interior. In the task of continuous improvement, the quality of the company detected that, in the process of softening the PA6 pipe for the assembly with filters and couplings that counts the gas tank and the engine of the car, there is no system to measure the following variables: temperature, time and length of exposure of the pipe, which caused that the mechanical properties of tension and crystallization of the pipe are not for the assembly with the filters and couplings. In the internal analysis carried out by the quality department, the need to implement a system that certifies that each pipeline is exposed to the same working conditions, to ensure that the mechanical properties of the pipe are adequate, guaranteeing the performance of the pipe at the time of its assembly in different sections of the car. Exposed the above, a device was designed and implemented that softens the PA6 pipe, achieving the control of temperature, time, and the exposure length of the pipe, preserving its mechanical properties of tension and crystallization in a temperature range from 0 to 500 ° C. In addition to covering the variables detected by the quality department, it was possible to reduce 14.3% in the time of softening and assembly of the pipe, resulting in 20 more assemblies during a day of one hour. As a result of the characteristics of the device, it provides the heating reliability for ducts of different types of polymers such as: polyethylene (PE), polystyrene (PS).

Science of the plastics, Standardization, Polyamide PA6, Thermal systems, Automation

1. Introduction

The automotive industry since its inception has been in constant technological growth, according to the new requirements of quality and standardization, in order to meet the demand of its market. Many of these companies dedicated to the automotive sector have been since 1960, which has led them to have a technological development and update within their manufacturing processes, and thus be able to compete in the market. As a result of this technological growth and quality standards, which have been made to this industrial sector is the process of assembly of filters and couplings for engines, radiators, air systems, etc., which does not cover the product specifications required by the company's quality department. This process begins with the softening of polyamide PA6 pipe ends, whose diameters vary from 1 cm to 3cm. For softening in conventional mode, the operator uses a BOSCH GHG DCE heat gun of 1500 W, with electronically constant predetermined temperature at 450 ° C, where the operator exposes the ends of the pipe to the heat gun, this exposure is It performs approximately in intervals of 2 to 5 seconds depending on the type of polyamide (PA6), geometry and its diameter, later they are assembled with the corresponding filters or couplings with the help of a pneumatic press. From the above, the process of softening the polyamide pipe that is carried out with the BOSCH heat gun is highlighted. According to the observations made by the quality department of the company, 3 important points that should be covered in the softening of the PA6 pipeline are highlighted:

1. **The exposure temperature of the duct:** it is necessary to visualize and control a range of multiple temperatures ranging from 0 to 500 ° C, which, with said heat gun used in the current process, does not comply with this section**.**

2. **The exposure time of the conduit:** you need to have a control of the time where the operator knows how long the pipe should be exposed**.**

3. **Exposure length:** in the pipeline it is required to have the exposure of the pipeline controlled.

The implications that have no control of these three variables, fall in the non-standardization of the process and also in the mechanical properties of tension and crystallization of the pipeline due to heating, which later affect the assembly with filters and Due to the lack of adequate mechanical properties in the pipe, it will cause excessive deformation, will not fit the filter or coupling and will even break and become unusable.

As a consequence of the foregoing, an automotive pipe softening device was designed, which covers all the requirements mentioned above. In section 2, we will review the theory that is necessary to support the design of the softening device and the standards corresponding to the handling of the PA 6. Section 3 explains the development of the methodology used to determine the design factors and characteristics, the measurements and the materials used for the design and manufacture of the softening device. Later in section 4 explains the development, design and manufacture of the softening device, where the analysis of modeling in the thermal calculations of the heating chamber, the design of the control system, the design of the control program and the manufacture of said device, also shows the calibrations, specifications of use and field tests carried out in one of these companies of automotive turn, in relation to this section are attached data sheets of the electronic elements for the control of the softening system. Section 5 shows the results obtained. It compares the points that are judged in the audits carried out with the softening method used with the BOSCH heat gun, and with results achieved with the softening device.

2. Theoretical Review
2.1 Polyamide (PA6)

Polyamides are manufactured on an industrial scale since 1937 and first appeared on the market as synthetic fibers, under the names of Nylon (PA 66) and Perlon (PA 6). Polyamides are suitable for injection and extrusion of technical parts.

Synthesis

The polyamides are mainly semicrystalline thermoplastics, produced from the polycondensation or ion polymerization of caprolactam. The different types of PA are differentiated by the components introduced in the synthesis. Its identification is made by number representing the amount of carbon atoms between "foreign" atoms (nitrogen) within the chain. There are two possibilities to produce polyamides, from two different components or one component with two different reactive groups. PA model masses are classified as DIN 16773 or ISO 1874-1 equivalent.

Properties

The more often the amide groups appear in the chain, the greater the intermolecular attractive forces and the more water the PA will absorb. The absorption of water is what provides the polyamide with note tenacity through its high impact resistance, high abrasion resistance and good sliding properties. In turn, it is a disadvantage that the mechanical properties and their dimensional stability depend on the moisture content.

PA can be strongly demanded in a dynamic way and show little signs of fatigue after continuous efforts. The high resistance of the PA decreases with a longer duration of the effort.

Other PA properties:

- High damping capacity
- High resistance to heat deformation
- The electrical properties are influenced by the absorption of water. However, in general they are sufficiently resistant to leakage currents.
- The different types of PA absorb different amounts of water, from 1 to 3.5%, PA 66 absorbs the maximum and PA 12 the minimum.
- The chemical resistance of PA is very good. Above all, the resistance to gasoline, oils and fats, which allows its use in the manufacture of vehicles.
- They are not especially resistant to weather or light.

Influence on the properties of PA through the actions described below

The degree of crystallization can vary significantly (up to 40%) by means of the cooling rate. With high degree of crystallization decreases water absorption, improves mechanical and electrical properties, as well as dimensional stability and abrasion resistance.

Applications

In particular, PAs find application in:

- **Construction of machines and devices:** Gears, rollers, screws, nuts, bearings, ball bearing caps, coupling parts, and self-lubricating sliding tracks made with graphite types**.**
- **Electrotechnical:** Coil reels, housings for electrical appliances, (eg hand drills), abrasion resistant cable sheaths, cable couplings and connectors, photography flashes**.**
- **Vehicle manufacturing:** Fan wheels, oil filters, locks parts, carburetor parts, cams, brake fluid containers, fuel tank floats, oil and fuel hoses, (Schwarz, 2002).

2.2 DIN 16773-1 or ISO 1874-1 equivalent

Scope

This part of ISO 1874 establishes a designation system for polyamide (PA) thermoplastic materials, which can be used as a basis for the specifications. Covers polyamide homopolymers for molding and extrusion based on PA 6, PA 66, PA 69, PA 610, PA 612, PA 11, PA 12, PA MXD6, PA 46, PA 1212, PA 4T, PA 6T and PA 9T and copolyamides of various compositions for molding and extrusion. The types of polyamide plastic differ from each other by a classification system based on appropriate levels of the indicative properties.

a. Viscosity number,

b. Module of elasticity to the traction and

c. Presence of a nucleating agent, and information on the chemical structure, the intended application, the processing method, important properties, additives, color, fillers and reinforcement materials.

The designation system is applicable to all polyamide homopolymers and copolymers. Applies to materials ready for normal use, unmodified and modified by dyes, additives, fillers, reinforcing materials, modifying polymers, etc., this part of ISO 1874 does not apply to PA 6 and PA 12 cast monomer type polyamides. It is not intended to imply that materials with the same designation necessarily give the same performance. This part of ISO 1874 does not provide engineering data, performance data or data on the processing conditions that may be required to specify a material for a particular application and / or a processing method. If such additional properties are required, they shall be determined in accordance with the test methods specified in ISO 1874-2, if appropriate, (International Organization for Standardization, 2010).

- **ISO 1874-2**
- **ISO 1874-2: 2012,** specifies the methods of preparation of the test samples and the test methods that will be used to determine the properties of polyamide molding and extrusion materials. Requirements are given to handle the test material and to condition both the test material before molding and the samples before the test.

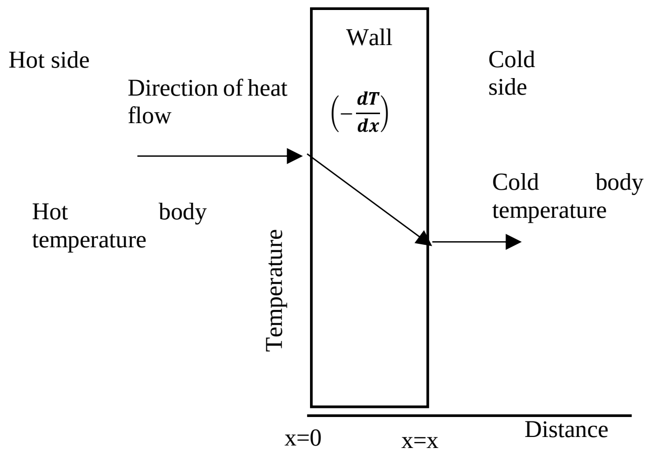
The procedures and conditions for the preparation of the test samples and the procedures to measure the properties of the materials from which these samples are made are given. The properties and test methods that are suitable and necessary to characterize polyamide molding and extrusion materials are listed. The properties have been selected from the general test methods in ISO 10350-1. Other test methods of wide use or of particular importance for these molding and extrusion materials are also included in ISO 1874-2: 2012, as well as the properties indicative of the viscosity number and tensile modulus given in ISO 1874-1, (International Organization for Standardization, 2012).

2.3 Heat Transfers

Mechanisms of heat transfer. There are three different ways in which heat can pass from the source to the receiver, even though many of the applications in engineering are combinations of two or three. These are, conduction, convection and radiation.

Conduction. The conduction is the transfer of heat through a fixed material such as the stationary wall shown in Fig. 2.1. The direction of the heat flow will be at right angles to the wall, if the surfaces of the walls are isothermal and the body is homogeneous and isotropic. Assume that a heat source exists to the left of the wall and that there is a heat sink on the right surface. It is known and then confirmed by a derivation, that the heat flow per hour is proportional to the change in temperature through the wall and the area of the wall A**.** If t is the temperature at any point on the wall and x is the thickness of the wall in the direction of heat flow, the amount of heat flow dQ is given by Eq. (1.1.).

Figure 2.1 Heat flow through a wall



Source: (Kern, 2013)

$$dQ = kA\left(-\frac{dT}{dx}\right) \quad (1.1)$$

The term -dt / dx is called a temperature gradient and has a negative sign if a higher temperature was assumed on the face of the wall where x = 0 and smaller on the face where x = X. In other words, the instantaneous amount of heat transfer is proportional to the area and the temperature difference dt that drives the heat through the wall thickness dx. The proportionality constant k is peculiar to the conduction of heat by conductivity and is known by thermal conductivity. This conductivity is evaluated experimentally and is basically defined by Eq. (1. 1).

The thermal conductivity of solids has a wide range of numerical values depending on whether the solid is relatively a good conductor of heat, such as a metal, or a bad conductor such as asbestos. The latter serve as insulators. Even though heat conduction is usually associated with the transfer of heat through solids, it is also applicable to gases and liquids, with its limitations, (Kern, 2013).

Convection. Convection is the transfer of heat between relatively hot and cold parts of a fluid by mixing. Assume that a container with a liquid is placed over a hot flame. The liquid that is in the bottom of the container heats up and becomes less dense than before, due to its thermal expansion.

The liquid adjacent to the bottom is also less dense than the cold upper portion and rises through it, transmitting its heat by means of mixing as it rises. The transfer of heat from the hot liquid from the bottom of the container to the rest, is natural convection or free convection. If any other agitation occurs, such as that caused by an agitator, the process is forced convection. This type of heat transfer can be described in an equation that mimics the shape of the driving equation and is given by:

$$dQ = hAdT \quad (1.2)$$

The proportionality constant h is a term over which the nature of the fluid and the form of agitation have influence and must be evaluated experimentally. It's called heat transfer coefficient. When Eq. (1.2) is written in its integrated form, Q = hAΔT, it is known as Newton's law of cooling, (Kern, 2013).

Radiation. Radiation involves the transfer of radiant energy from a source to a receiver. When radiation is emitted from a source to a receiver, part of the energy is absorbed by the receiver and part is reflected by it. Based on the second law of thermodynamics, Boltzmann established that the speed at which a source gives heat is:

$$dQ = \sigma * \varepsilon * dA * T^{4} \tag{1.3}$$

This is known as the law of the fourth power, T is the absolute temperature. σ is a dimensional constant, but ε is a factor peculiar to radiation and is called emissivity. The emissivity, like the thermal conductivity k or the heat transfer coefficient h, must also be determined experimentally, (Kern, 2013).

3. Methodology

The activities and procedures that are necessary to carry out the design and implementation of this softening device are summarized in eight stages, which can be observed in Figure 2.1.

Figure 2.1 Methodology used for the design of the PA6 pipe softening device

START	
Analysis of the process	The process that is currently carried out for the softening of PA 6 ducts and evaluation of the requirements that must be modified was analyzed to cover the quality standards marked by the audits carried out in the company, which stand out in 3; control of temperature, time and position of the duct.
State of the art	State of the art about the methods and standards applied in the handling and work of PA polymers, as well as the latest technologies developed for this purpose.
Best alternative evaluation	Evaluation of the best alternative solution according to the requirements that are necessary to correct the shortcomings of the current process. Where it was decided to design a device that completely replaces the part of the process that was carried out for the softening of the PA ducts.
Design factors	Factors and characteristics that must be taken into account for the design and manufacture of the device, according to the requirements and signations by the audits.
Design	Design of the PA duct softening device, where the manufacturing materials are chosen according to the: • Structural CAD design and softening chamber • Design of the control system for temperature, time and positioning of the duct • Design of the control program system
Manufacture	Manufacture of the softening device, where the materials contained in Table 3.1 are used, and thus manufacture the softening chamber and the control circuit.
Calibrations	The calibrations corresponding to the softening equipment were made with respect to the quality parameters required in the final product by the audits and the client.
Field tests	The corresponding tests of the softening device in the PA pipe assembly process were carried out and the results of production and quality of the previous process compared to the current one.
END	

Source: Self Made

Materials

Table 2.1 Materials used for the construction of the softening device

Electronic, Electrical and Control Elements		
No.	**Quantity**	**Description**
1	1	14 gauge polarized cable meter
2	1	12 gauge polarized cable meter
3	1	Voltage source of 24V-3A
4	1	Solid state relay 250VA-50A
5	1	J type thermocouple
6	1	5 positions selector
7	1	Pin 127VAC - 15A
8	1	Arduino UNO microcontroller with protector
9	1	Module of 4 SRD relays - 5VDC - 1A (5W), optocoupler drive
10	2	12 gauge cable meter
11	2	18 gauge cable meter
12	2	22 gauge cable meter
13	2	22 gauge wire meter
14	1	Micrometers
15	1	Temperature indicator
16	1	Voltage regulator Lm7805
17	2	3 way clemas
18	10	Resistors 10K ohm.
19	1	Thermostat
20	1	GLCD 128x64 graphing screen
Thermal and pneumatic materials		
1	½	One square meter of ceramic fiber sheet
2	1	Kilogram of refractory mortar
3	1	Smooth steel sheet Cr 20% - Ni 15% - 0.45mm - 100cm x 200cm
4	1	Pneumatic actuator with connectors No. 6 - Internal diameter 32mm - stroke 100mm - stem diameter 12mm - air consumption per cycle 1.141 L Brand: FESTO
5	1	Annealing refractory block
6	1	Valve 5/2 stable mono with solenoid drive and pilot return with No. 6 connectors. Brand: FESTO.

Source: Self Made

4. Development
4.1 Process Analysis

The analysis of the process that is carried out for the heating of the polyamide PA 6 conduits, is of great importance to find the factors and design characteristics that must be considered for the manufacture of this softening device. Operators work with BOSCH guns, they generate hot air through a fan that is inside the gun and an electrical resistance. The air that is expelled by the gun is not controlled or visualized according to the strict parameters required of the product.

The operators must use thermal gloves of security to be able to work with the pistol, since the heat that gives off has a very high temperature. Subsequently place the ducts (Figure 2.2) on the nozzle of the gun, the duct is introduced approximately 3 cm to 6 cm, since that is the distance in which the couplings and filters are assembled, then the operators freely manipulate the duct to be able to heat its diameter trying to cover the entire surface, and leave it approximately 2 to 5 seconds. Once the duct is heated it is placed in a manually operated pneumatic bench to be assembled, the mentioned procedure only depends on the skill and experience of the operator, which implies a very large margin of error in the result of the final product.

Figure 2.2 PA6 polyamide conduit

Source: (Kayser, 2018)

Figure 2.3 Measurement of temperature with NI equipment

Source: Self Made

After analyzing the process that takes place to heat and assemble the ducts, we proceeded to measure the temperature generated by the BOSCH gun, to carry out this task the tests were carried out with two teams to have reliable readings, the first of which was carried out I end up with the help of LabVIEW software and the National Instruments team, specifically the NI cDAQ-9174 chassis, (see Figure 2.4), and the NI 9219 data acquisition card with a J-type thermocouple (see Figure 2.3), shown the gun that is used to heat the ducts, this is attached to a steel base, since the guns must be fixed to avoid accidents.

The NI-9219 is designed for multipurpose testing, (National Instruments, 2018), can measure signals from sensors such as voltage meters, resistance temperature detectors (RTD), thermocouples, load cells and other triggered sensors, as well as perform bridge quarter bridge signs, etc. For the measurement of the temperature, only the first channel was used, since only one card needed to receive the temperature variable was needed, in addition to this procedure, the temperature measurement process was also performed with a thermal imaging camera (see Figure 2.5), FLIR E60 (Silva JA, Salazar P., Ponce M., & Herrera S., 2017) for the acquisition and analysis of information of non-contact thermal imaging devices and thus perform an effective calibration of the parameters in the system design (see table 2.2). The data obtained with both equipment in real time of the measurements under normal operating conditions yielded values of ± 1% error in the accuracy.

Figure 2.4 NI 9219 Card

Source: (National Instruments, 2018)

Figure 2.5 NI Cdaq-9174 chassis

Source: (National Instruments, 2018)

Figure 2.6 Camara FLIR E60

Source: (Silva J. A. , Salazar P., Ponce M., & Herrera S., 2017)

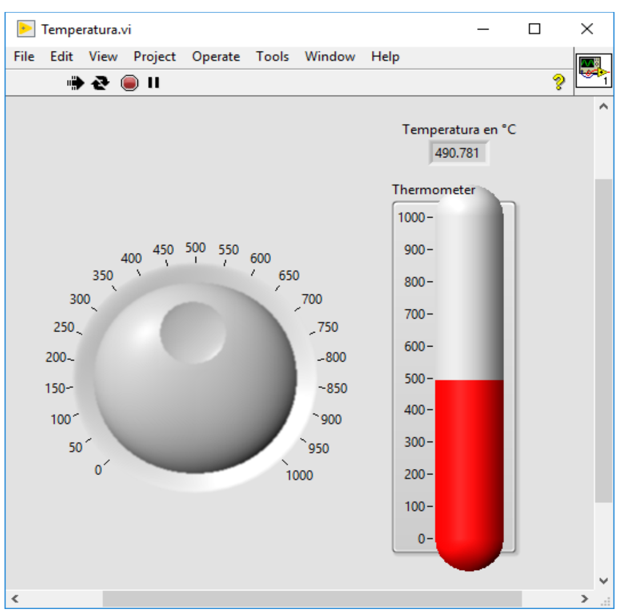
Table 2.2 Parameters for Flir

Parameters for measurement with thermal imager	Units
Emissivity	0.95
Reflected temperature	+20 °C
Distance	1 metro
RH	50%
Atmospheric temperature	+20 °C
Window temperature	0.95

Source: (Flir,2018)

With the LabVIEW 2018 software, the program was designed to visualize and acquire the temperature variable (see Figure 2.7). In the interface was incorporated a graphic and an indicator, to visualize the temperature that was generated from the gun, the results obtained showed that the temperature that was generated with the BOSCH gun was 490ºC and also the block diagram. Which indicates that the temperature obtained with the gun is not adequate to meet the quality standards needed in the process of assembly of the conduits, since it is required to have a temperature and a variable exposure time in function to the type of duct that is heating up, and that is also required to have a fixed standard of exposed duct distance at high temperature.

Figure 2.7 Heat flow through a wall



4.2. Factors and Design Characteristics

4.2.1. Exposure and softening temperature

Depending on the temperature specifications required by the duct manufacturing process, the exposure temperature of the ducts, to which it must be subjected, will depend on the dimensions of each one, which vary in diameters, thicknesses and alloys of the Polyamide PA 6 with other polymers. Based on the conduit that requires greater heating, the maximum operating temperature of 500 ° C was taken as reference, the most suitable thermal chamber for the application can be designed, denoting that the 500 ° C is the maximum operating temperature, based on design a margin of + 10% (50 ° C) is left at the maximum operating temperature. Therefore, the softening chamber can reach a maximum temperature of 550 ° C.

Another important point to analyze is the softening temperature, since for obvious reasons it can not exceed the melting temperature of the material, for the development of this project this softening temperature is 75 ° C according to procedure A ISO 75-1, (International Organization for Standardization, 2004). Among the most relevant characteristics in the design of the softening device are summarized in Table 2.3 (Inalcoa, 2018), (Sanmetal, 2018).

Table 2.3 Technical characteristics of the PA6 polyamide conduit

Mechanical characteristics	**Method / Test (DIN / ASTM)**	**Value**	**Unit**
Density	53479	1,14	g/cm^3
Stretch point elongation	53455	85	MPa
Resistance to breakage due to elongation	53455	70	%
Module of elasticity to the traction	53457	3200	MPa
Thermal characteristics	**Method / Test (DIN / ASTM)**	**Value**	**Unit**
Melting temperature	53736	220	ºC
Dynamic vitrification temperature	53736	40	ºC
Resistance to deformation	ISO 75 ISO 75	75 190	ºC ºC
Procedure A		160	ºC
Procedure B		0,23	W/ (m.K)
Temperature of use for a short time		1,7	J/ (g.K)
Specific heat conductivity capacity		7	10(-5) /k

Source: (Sanmetal, 2018)

4.2.2 Exhibithion time

Because the automotive sector manufactures different types of conduits with different geometries and alloys, the exposure time becomes a function of these. Based on the characteristics of the ducts that require higher and lower temperatures, it can be deduced that the shortest exposure time is 1 sec. and the highest 3 sec. Because you need to change the time to different values, you need to have a control whose readability is 200 msec. Having a control range of exposure time of 200 msec. to 3 sec.

4.2.3. Exposure length

The exposure length of the ducts is a standard parameter for all duct models, which is defined by the manufacturer's specifications, which in many cases is **5 cm** for all ducts.

4.2.3.1. Positioning and detection system

Due to the high temperatures that are generated inside the softening chamber, it is necessary to take into consideration the positioning system of the duct, because, if this positioning system is heated to the high temperatures of the chamber, it can burn the surface In addition, it must be ensured that when placing the duct in the heating system, the 5 cm already specified above is exposed to the duct.

4.2.4. Work area for the device

According to the dimensions of the work stations, where the softening and the assembly of the conduit takes place. The section where the softening device is intended to be placed must take care of the size and weight. The space available for mounting the camera both width, length and height is of; 20 x 80 x 40 cm respectively, see Figure 2.8 and 2.9

Figure 2.8 Available width of for the softening chamber

Source: Self Made

Figure 2.9 Available length of for the softening chamber

Source: Self Made

The maximum permissible weight for the softening chamber is 10 kg. Because it must be fastened in the structure of the work station, with this reference it has to be designed with light materials, but strong enough to operate at temperatures of 500 ° C.

4.3 Design

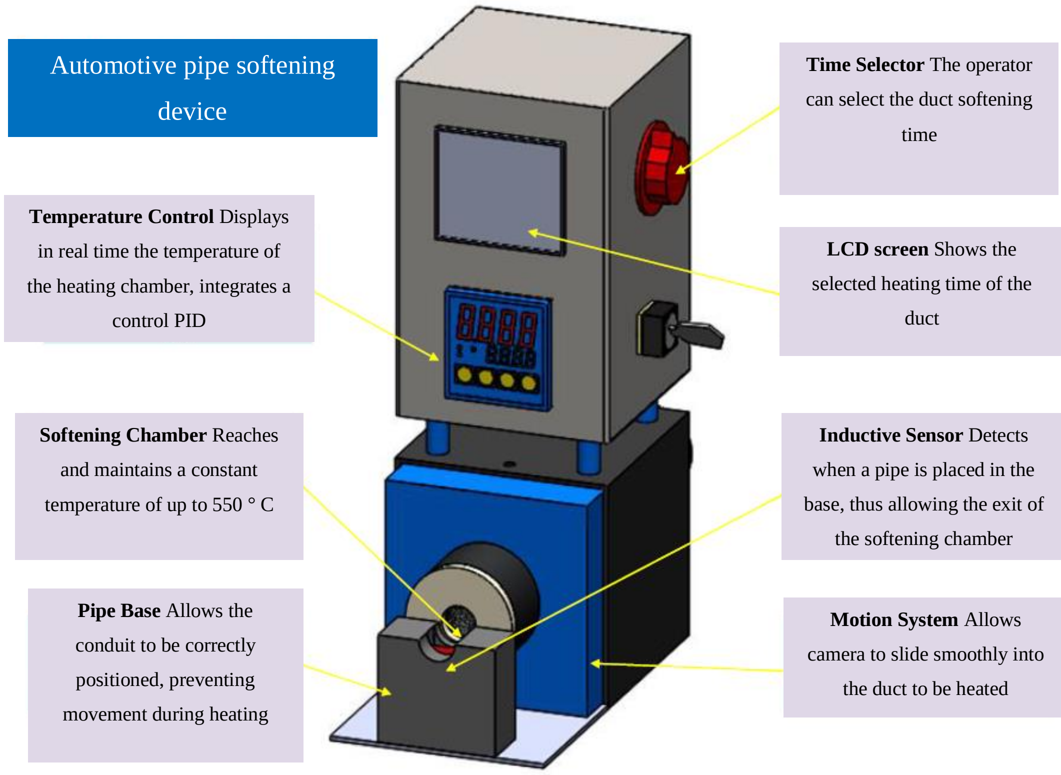
4.3.1 CAD Design Structural and Softening Chamber

4.3.1.1 CAD Design Structural

With the help of CAD design software, Solid Works, the design of the heating system was carried out to have the structural plans of the same, which has a 128x64 LCD screen to visualize the time in which the duct is exposed to heat, time selection has a readability of 200 ms and a maximum range of 3 sec. The process temperature measurement procedure was carried out in the first instance using infrared thermography (Silva JA, Salazar P., Ponce M., & Herrera S., 2017) to ensure the calibration and specify the parameters to be used in the mathematical model of the system.

It also has a PID temperature controller, which shows the temperature generated in the device and the maximum temperature that must be inside, with it we can vary the temperature we want to have in the chamber with a range from 0º to 550ºC, since the maximum temperature at which the pipes must be subjected is 500 ° C for a time of 1s to 3s, depending on the dimensions thereof. To measure the internal temperature of the chamber, a J type thermocouple was placed in the central part of the heating chamber in order to receive the temperature signal, it was ensured that the thermocouple was not close to the resistance, since in this way the signal of temperature that it would receive would be greater due to the radiation that it emits, (see Figure 2.10).

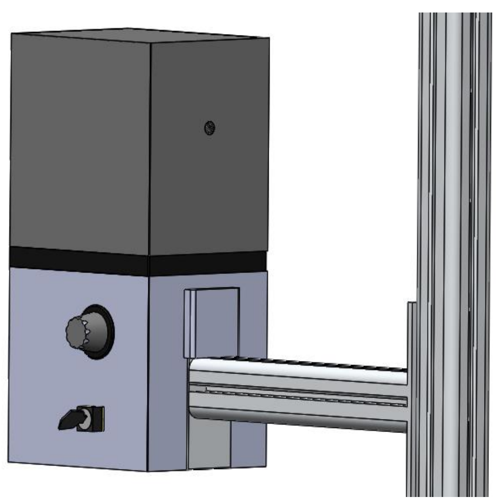
Figure 2.10 Design of Heating System in Solid Works



Source: Self Made

At the bottom of the design is the heating chamber, which has a pneumatic actuator that moves the camera 5cm towards the base where the duct is placed, this chamber is designed to generate a maximum temperature of 550ºC. The heating chamber has insulations with low conductivity coefficient, to avoid energy losses in the system and an external coating of stainless steel to avoid the least heat loss by radiation. In the back of the heating system there is a tab to be able to attach it to an arm that is at the base of the work table, this helps the equipment does not move and is a danger for operators, based on the oscillatory mechanical behavior of the pneumatic cylinder that controls the displacement of the linear movement, the analysis of the magnitude of the signal of the vibration spectrum and the phase angle was performed to ensure the minimum imbalance of the equipment while it is in operation (Silva J., Salazar P., Ponce M., & Herrera S., 2016). Figure 2.11 shows the rear view of the camera which has an entrance to attach it to an aluminum arm. In this way the camera will be fixed helping it to be manipulated in a more comfortable and safe way for operators.

Figure 2.11 Warming camera tab



Source: Self Made

Table 2.4 Heating system specifications

Specifications		
Physical	High	318 mm
	Width	170 mm
	Background	141 mm
	Weight	7000 gramos (+/- 200g)
Counters / Timers	Logical Levels	TTL
	Accountants	1
Digital I / O	Bidirectional Channels	12
	Maximum Voltage Range	0 V – 5 V
	Entry resolution	12 bits
Timing - Accountants	Shooting	Digital
	Accountants	---
Temperature 1	Maximum temperature	550° C
	Readability	1° C
Consumption Energy	Power	1000 W

Source: Self Made

4.3.1.1.1. Dimensions of the softening chamber

Once the CAD design was finished, according to the required specifications, the dimensions of the camera were designed and specified. To start the camera, the largest size of duct was taken as reference, which has 3.5 cm outside diameter, which by entering 5 cm into the chamber occupies a volume of 48.1 cm^3. Taking as margin 1.5 cm in diameter and 1 cm in depth, and considering 1 cm of thickness in the block results in a volumetric figure of 7cm x 7cm x 10cm, and as an inner chamber a cylindrical geometry of 5cm in diameter and 6cm background, giving as inner volume 117.8cm^3. The cylindrical figure of the inner chamber was taken as a consequence of the geometry of the body to be heated, because it is required to heat the duct uniformly around its diameter, and to achieve this, it is required that the heat transfer from the walls from the inner chamber to the surface of the body must meet the perpendicularity.

4.3.1.2 Design of the Softening Chamber

Returning to what was analyzed in chapter 4.1 and 4.2, it is taken as a reference in this chapter, because depending on these aspects we can start with the thermodynamic design of the softening chamber, as is the thickness of the insulation necessary to have the losses of allowable energy, in addition to determining the adequate resistance for the system, thus avoiding an excessive consumption of energy and increasing operating costs.

4.3.1.2.1 Calculation of the energy balance of the system

In any thermal design it is necessary to determine an energy balance, since in real life there are energy losses that are not thoroughly analyzed in an empirical problem. Given as a guideline, the energy balance for this thermal system is denoted by Eq. (1), (Faires, 1982).

$$Q_T = Q_s + Q_p \quad (1)$$

Where:

Q_T = *Total heat supplied to the system*
Q_s = *Heat absorbed by the body to be heated*
Q_p= *Lost heat of the system*

4.3.1.2.1.1. Calculation of heat losses (Q_P)

In the first instance, the heat losses due to the heat flow in the insulator and the environment are calculated, which can be denoted by Eq. (2).

$$Q_p = Q_k + Q_{cv} + Q_r \tag{2}$$

Donde:
Q_k = *Heat losses by conduction*
Q_{cv} = *Convective heat loss*
Q_r = *Heat losses by radiation*

4.3.1.2.1.1.1. Calculation of the coefficient of heat transfer by convection

According to the norm NOM - 009 - ENER - 1995 and NOM - 018 - ENER - 2011, (National Secretariat of Energy, 1995), the coefficient of heat transfer by convection or also denoted by the film coefficient (h_{cv}) in flat surfaces, is given by the following mathematical relationship, see Eq. (3).

$$\boldsymbol{h_{cv}} = 3.0075C\left(\frac{1.11}{T_{sup}+T_{amb}-510.44}\right)^{0.181} * \left(\frac{1.18}{(T_{sup}-T_{amb})^{-1}}\right)^{0.266} * (1 + (7.9366 * 10^{-4})(v))^{0.5} \tag{3}$$

where:
$\boldsymbol{h_{cv}}$ = *Coefficient of film by convection* $\left(\frac{W}{m^2K}\right)$
$\boldsymbol{C}$ = *Coefficient of form, 1.79 for flat surfaces and 1.016 for pipes (dimensionless)*
$\boldsymbol{T_{sup}}$ = *Assumed temperature of the outer surface of the insulation, (K)*
$\boldsymbol{T_{amb}}$ = *Ambient temperature, (K)*
$\boldsymbol{v}$ = *Wind speed* $\left(\frac{m}{h}\right)$

According to a study carried out by (Soler & Palau Ventilation Group, 2015), the wind speed scale is proportional to the force of the wind, and this scale is called the Beaufort scale, see Table 2.5 measured values at 10 m height. The value of the wind that was taken for the purposes of Beaufort scale calculations is "0"

Table 2.5 Beaufort scale

Beaufort scale	Name of the wind	Speed	
		m/s	Km/h
0	Calm	0.5	2
0	Calm	0.5	2
1	Light air	1.5	5
2	Light breeze	3	11
3	Soft breeze	6	22
4	Moderate breeze	8	30
5	Fresh breeze	11	40
6	Strong breeze	14	50
7	Moderate wind	17	60
8	Fresh wind	21	75
9	Strong wind	24	87
10	Great Wind	28	100
11	Storm	32	115
12	Hurricane	36 or more	130 or more

Sourcee: Soler & Palau Ventilation Group

Replacing the particular values to Eq. (3), we obtain:

$\boldsymbol{C}$ =*1.79*
$\boldsymbol{T_{sup}}$ =*378.15 (K)*
$\boldsymbol{T_{amb}}$ = *298.15 (K)*
$\boldsymbol{v} = 1800 \left(\frac{m}{h}\right)$

$$\boldsymbol{h_{cv}} = 3.0075(1.79)\left(\frac{1.11}{378.15+298.15-510.44}\right)^{0.181}\left(\frac{1.18}{(378.15-298.15)^{-1}}\right)^{0.266}(1 + (7.9366 * 10^{-4})(1800))^{0.5}$$

$$h_{cv} = 12.714234 \left(\frac{W}{m^2K}\right)$$

4.3.1.2.1.1.2. Calculation of heat transfer coefficient by radiation

In the same way the norm NOM - 009 - ENER - 1995 and NOM - 018 - ENER - 2011, (National Secretariat of Energy, 1995), the coefficient of heat transfer by radiation (h_r) in flat surfaces, is given by the following mathematical relationship, see Eq. (4).

$$\boldsymbol{h_r} = 0.9824 * 10^{-8} * \varepsilon * \frac{{T_{amb}}^4 - {T_{sup}}^4}{T_{amb} - T_{sup}} \tag{4}$$

Where:

$\boldsymbol{h_r}$ = *Radiation transfer coefficient* $\left(\frac{W}{m^2K}\right)$
$\boldsymbol{\varepsilon}$ = *Emissivity of the radiant surface (Adimensional)*

Taking the emissivity value of polished stainless steel ε = 0.074 and substituting the values corresponding to Eq. (4), we obtain:

$$\boldsymbol{h_r} = (0.9824)(10^{-8})(0.074)\frac{298.15^4 - 378.15^4}{298.15 - 378.15}$$

$$h_r = 0.11401\left(\frac{W}{m^2K}\right)$$

To determine the global heat transfer coefficient (h_g) and then use it to obtain the total heat losses per unit area, Eq. (5) is used.

$$h_g = h_{cv} + h_r \tag{5}$$

Substituting the corresponding values you get:

$$h_g = 12.828244\left(\frac{W}{m^2K}\right)$$

4.3.1.2.1.2. Calculation of the total heat flow lost per unit area in the system

To determine the total heat losses in the system, Fourier's Law (Kern, 2013) is used, which states that the heat flux per unit time (q) (W) passing through a flat wall is directly proportional to the area (A) (m^2) of the wall, to the temperature change (dT) (K) and to the $(k)(\frac{W}{m\,K})$, denominated thermal conductivity of the material of the wall and inversely proportional to the thickness of the wall (dx) (m), see Figure 11. The equation that relates this process is the Eq. (6).

$$dq = kA\left(-\frac{dT}{dx}\right) \tag{6}$$

Solving the differential equation is obtained Eq. (7), the sign agreement will be a function of the direction of heat flow that one assumes.

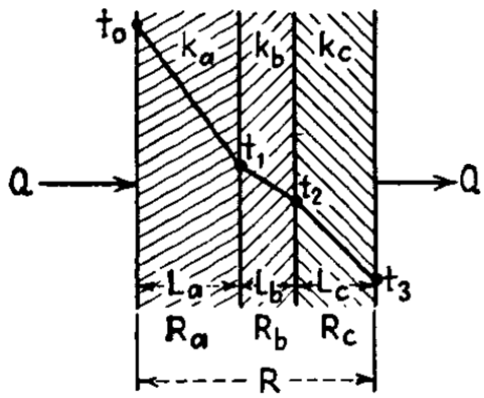
$$q = kA\frac{\Delta T}{\Delta x} \quad \rightarrow \quad q = kA\frac{T_2 - T_1}{\Delta x} \tag{7}$$

Where:

$\boldsymbol{T_2}$ = *Warmer face temperature*
$\boldsymbol{T_1}$ = *Temperature of the least hot*
$\Delta\boldsymbol{x}$ = *Wall thickness*

For the case of composite walls, the analogy of the law of ohm is used (see Figure 2.12). Where Eq. (7) is modified to Eq. (8) and the heat flow will be given per unit area **($\dot{q}$)** $(\frac{W}{m^2})$.

Figure 2.12 Heat flow through a composite wall.



Fuente: (Kern, 2013).

$$\dot{q} = \frac{q}{A} = \frac{T_0 - T_i}{\sum_{i=0}^{i} R_i} \quad \rightarrow \quad R_i = \frac{\Delta x_i}{k_i} \tag{8}$$

Where:
T_0 = *Warmer face temperature*
T_i = *Temperature of the last face*
R_i = *Thermal resistance*
k_i = *Thermal conductivity of each material of the composite wall*
Δx_i = *It is the thickness of each material of the composite wall*

For our particular case, Eq. (8) is modified to Eq. (9), this is due to the fact that, by combining heat transfers by convection and radiation, thus obtaining the global transfer coefficient, we can combine the transfer of heat by convection, radiation and conduction in a single equation thus obtaining the total heat losses per unit area of the system, (Holman, 1996).

$$\dot{q_T} = \frac{q}{A} = \frac{T_{int} - T_{amb}}{\frac{1}{h_g} + \frac{\Delta x_0}{k_0} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2}} \tag{9}$$

Where:
T_{int} = *Temperature of the inside of the wall of the softening chamber 823.15 (K)*
T_{amb} = *Ambient temperature 298.15 (K)*
h_g = *Global coefficient of heat transfer* $12.828244 \left(\frac{W}{m^2 K}\right)$
k_o = *Thermal conductivity of the refractory block* $1.04 \left(\frac{W}{m\,K}\right)$
k_1 = *Thermal conductivity of ceramic fiber* $0.12 \left(\frac{W}{m\,K}\right)$
k_2 = *Thermal conductivity of stainless steel* $15.1 \left(\frac{W}{m\,K}\right)$
Δx_0 = *Thickness of the refractory block 0.01 (m)*
Δx_1 = *Thickness of ceramic fiber 0.0508 (m)*
Δx_2 = *Thickness of ceramic fiber (0.002) (m)*

Substituting the particular values of our problem to Eq. (9) we obtain:

$$\dot{q_T} = \frac{823.15 - 298.15}{\frac{1}{12.828244} + \frac{0.01}{1.04} + \frac{0.0508}{0.12} + \frac{0.002}{15.1}} \quad \rightarrow \quad \dot{q_T} = 1027.3285 \ \frac{W}{m^2}$$

To determine the flow of heat lost q_{pT} due to the conduction, convection and radiation of the walls, multiply the $(q_T)^{\cdot}$, between the area or exterior surface of the heating chamber, which has dimensions of 0.206529 m^2, from the above you get:

$$q_{pT} = \left(1027.3285 \ \frac{W}{m^2}\right) (0.206529 \, m^2) = \mathbf{212.1740 \, W}$$

To verify if our calculations were correct, the norm NOM - 009 - ENER - 1995 and NOM - 018 - ENER - 2011, suggests to use the Eq. (10), which relates the real temperature of the exterior surface (T_{reals}) and the heat per unit area (q_T'') lost in the system with the assumed temperature (T_{sup}).

$$T_{reals} = T_{amb} + \frac{\dot{q_T}}{h_g} \tag{10}$$

If T_{reals} = T_{sup}, then the heat losses are equal to q_T'' and therefore the temperature of the isolated surface is T_{reals}, otherwise T_{reals} = T_{sup} is taken and the calculations made previously are repeated, from Eq. (3).

$$T_{reals} = 298.15 + \frac{1027.3285}{12.828244} \quad \rightarrow \quad T_{reals} = 385.05\, K$$

$$T_{reals} = 378.23.05K \;\cong\; T_{sup} = \;\; 378.15\, K \;\; \therefore \;\; T_{sup} = \; T_{reals}$$

Recalling the value of the assumed temperature and buying its value with the actual temperature of the calculated surface, no significant difference is noted, so the assumed temperature is correct and in the same way the calculations made previously.

4.3.1.2.1.3 Calculation of the heat flow provided to soften the duct

For the total calculation, Eq. (11) is used for the effective heat flow (q_{AT}) provided to heat the duct.

$$q_{AT} = q_{rT} + \; q_{cvT} \tag{11}$$

Where:
q_{rT} = *It is the flow of heat provided by radiation from the inner wall of the chamber (W)*
q_{cvT} = *It is the flow of heat by conduction due to the air staked inside the inner chamber (W)*

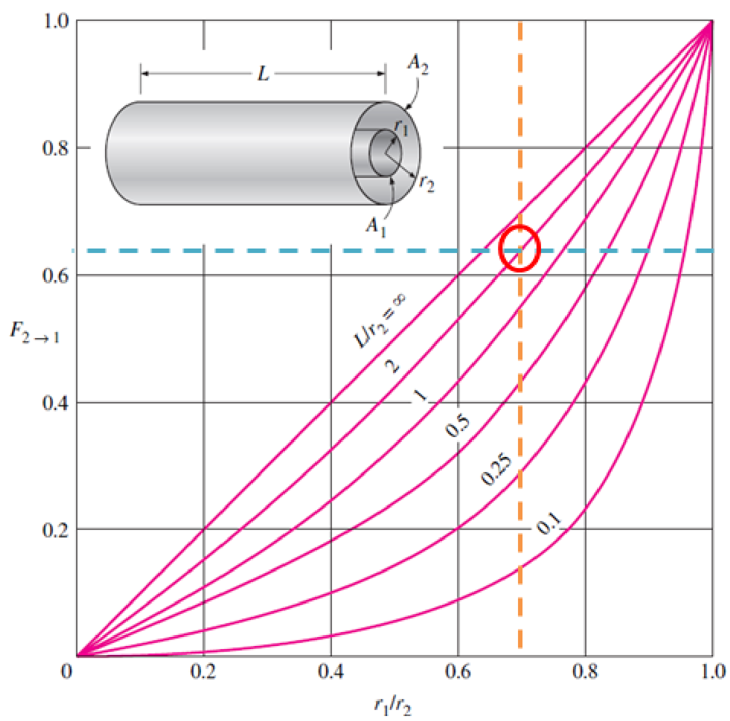
For the analysis of the total heat of heat supplied by radiation (q_{rT}), Eq. (12), (Holman, 1996), which is a particular derivation of the Stefan-Boltzmann radiation equation for surfaces, is used cylindrical concentric between them.

$$q_{rT} = \frac{\sigma({T_{int}}^4 - {T_{cd}}^4)}{\frac{1-\varepsilon_1}{\varepsilon_1 A_1} + \frac{1}{A_1 F_{12}} + \frac{1-\varepsilon_2}{\varepsilon_2 A_2}} \tag{12}$$

Where:
σ = *Constant of Stefan-Boltzmann* $5.6703 * 10^{-8} \left(\frac{W}{m^2K^4}\right)$
T_{cd} = *Initial temperature of the duct 298.15 (K)*
A_1 = *Radiating area of the camera 0.00785398 (m^2)*
A_2 = *Area of the radiation absorbing duct 0.00549778 (m^2)*
ε_1 = *Emissivity of the irradiating surface - chamber with mortar coating (0.93)*
ε_2 = *Emissivity of the absorbent-conductive surface of polyamide PA6 (0.94)*
F_{12} = *Form or vision factor for concentric cylinders*

In order to determine the form factor (F_{12}) for our particular case, the relationship given in Figure 4.1 is used, (Gengel, 2007).

Grafico 2.1 Form or vision factor for concentric cylinders



Source: Calorie and mass transfer, a practical approach, Yunus A. Cengel 2007

Where:
$\boldsymbol{L}$ = *Conduit length 0.005 (m)*
$\boldsymbol{r_1}$ = *Conduit radius 0.0175 (m)*
$\boldsymbol{r_2}$ = *Camera radio 0.025 (m)*
$\boldsymbol{r_1}/\boldsymbol{r_2}$ = *0.7 (dimensionless), denoted by the dashed orange line.*
$\boldsymbol{L}/\boldsymbol{r_2}$ = *2 (dimensionless)*
$\boldsymbol{F_{12}}$ = *Form factor ≅ **0.65**, denoted with the dashed line blue.*

Substituting the particular values in Eq. (10), we obtain:

$$q_{rT} = \frac{5.6703*10^{-8}*(823.15^{\,4}-298.15^{\,4})}{\frac{1-0.93}{0.93*0.00785398}+\frac{1}{0.00785398*0.65}+\frac{1-0.94}{0.94*\,0.00549778}} = \mathbf{117.86218\,W}$$

To determine the flow of heat by conduction due to stagnant air inside the chamber (q_rT) Eq. (6) is used, and solving the differential equation for our particular case, where we have heat exchange by conduction between cylindrical walls, (Incropera & Witt, 1999), you get:

$$q_{cvT} = \frac{2\pi L(T_{int}-T_{cd})}{\ln\frac{r_2}{r_1}} \quad (13)$$

Substituting the corresponding values you get:

$$q_{cvT} = \frac{2\pi*0.005*(823.15-298.15)}{\ln\frac{0.025}{0.0175}} = \mathbf{25.47471\,W}$$

Using Eq. (11) and replacing the values already calculated, there is a total heat flow provided to the duct:

$$q_{AT} = 117.86218 + 25.47471 = \mathbf{143.3369\,W}$$

Once calculated the total heat flow that the duct receives, we can determine if this heat flow is enough to heat the largest duct in the required time, these parameters can be consulted in chapter 4.2. To calculate the heating time of the duct with the total heat flow (q_{AT}) determined with Eq. (11), Eq. (14) is used.).

$$q_{AT} = \frac{dQ}{dt} = \rho_c V_c C_p \frac{dT}{dt} \quad (14)$$

Solving the differential equation for our particular case we obtain:

$$q_{AT} * t = \rho_c V_c C_p (T_{bl} - T_{cd}) \quad (15)$$

Where:
$\boldsymbol{t}$ = *Time used for the softening of the duct*
$\boldsymbol{\rho_c}$ = *Density of the duct to be heated, in this case PA6* $\left(1.14\ {}^{gr}/_{cm^3}\right)$
$\boldsymbol{V_c}$ = *Volume of the section of the duct to be heated (*$4.0349\ cm^3$ *)*
$\boldsymbol{C_p}$ = *Specific heat of the duct to be heated, in this case PA6* $\left(1.7\ {}^{J}/_{grK}\right)$
$\boldsymbol{T_{bl}}$ = *PA5 duct softening temperature (348.15 K)*

Clearing the time (t) of Eq. (15) and substituting the corresponding values, we have:

$$\boldsymbol{t} = \frac{1.14*4.0349*1.7*(348.15-298.15)}{143.3369} = \boldsymbol{2.7277\ seg}$$

$$\boldsymbol{t_{expuesto} = 3\ seg. \cong t = 2.7277\ seg}$$

Deducing that the calculated time (t), for practical purposes, is equal to the necessary exposed time ($t_{expuesto}$), it has an effect that the total heat flow provided to the duct, is adequate to meet the necessary characteristics of duct softening. Therefore, the flow of heat q_s supplied is double to q_{AT}, because q_{AT}, is the flow of heat that is generated every second, from the walls to the duct. From the above, the heat necessary to soften the pipe to the desired temperature and in the required time must be considered independently, therefore the heat flow q_s, is equal to:

$$q_s = 2 * 143.3369\ W = 286.6738\ W$$

4.3.1.2.2 Calculation of the total heat supplied to the system ($\boldsymbol{Q_T}$)

Taking as reference Eq. (1) and for practical defects, the total heat needed in the system, is taken as heat flow, q_T, the previous as a result of which the previous calculations are simplified determined the total heat flow of the system.

$$Q_T = Q_s + Q_p \quad \rightarrow \quad q_T = q_s + q_{pT}$$
$$q_T = 286.6738\ W + 212.1740\ W = 498.8478\ W \cong 500\ W$$
$$q_T \cong 500\ W$$

4.3.1.2.3 Calculation of resistive elements

Applying the law of electric power, Eq. (16), to calculate the power dissipated by an element that adds a certain current I is obtained

$$P = VI \quad (16)$$

Where, V is the supplied voltage and I is the current that the system consumes, as, V is equal to 127 V and the power P is equal to q_T, replacing and clearing the current value I is obtained:

$$\boldsymbol{I} = \frac{500\ W}{127\ V} = \boldsymbol{3.937\ A \cong 4\ A}$$

Applying the law of ohm and the Eq. (15), we obtain the Eq. (17), where the power that dissipates a resistance of value R and that consumes current I is obtained.

$$P = RI^2 \quad (17)$$

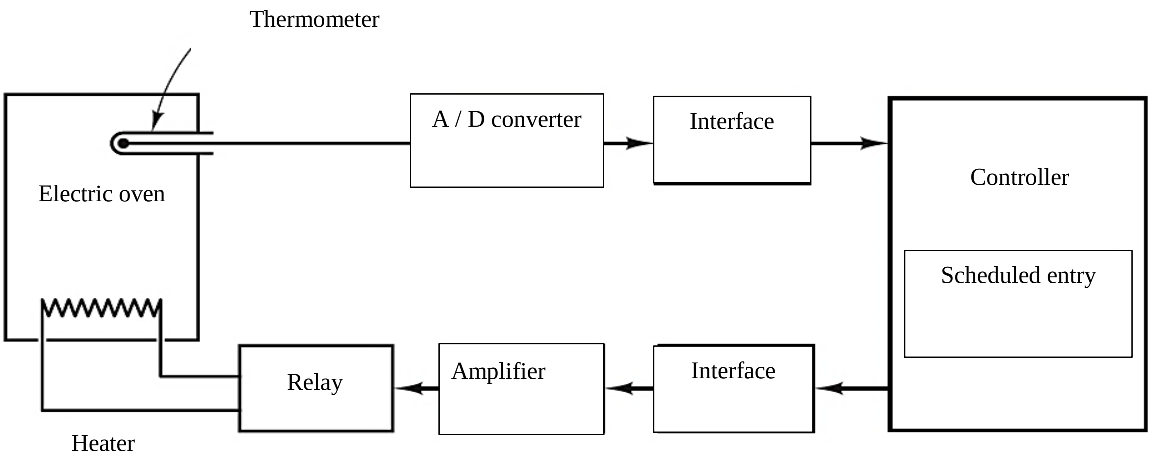
Clearing R of Eq. (17) and substituting values, we obtain the value of the resistance in Ohms that our resistance must have in order to dissipate the heat q_T.

$$\boldsymbol{R} = \sqrt{\frac{P}{I}} = \sqrt{\frac{500}{4}} = \mathbf{11.1803\ \Omega} \cong \mathbf{12\ \Omega}$$

4.3.2 Design of temperature control, time and position of the duct
4.3.2.1 Design of the temperature control system

En la figure 2.13 muestra un diagrama esquemático de lazo cerrado del control de temperatura de un horno eléctrico, (Ogata, 2010).

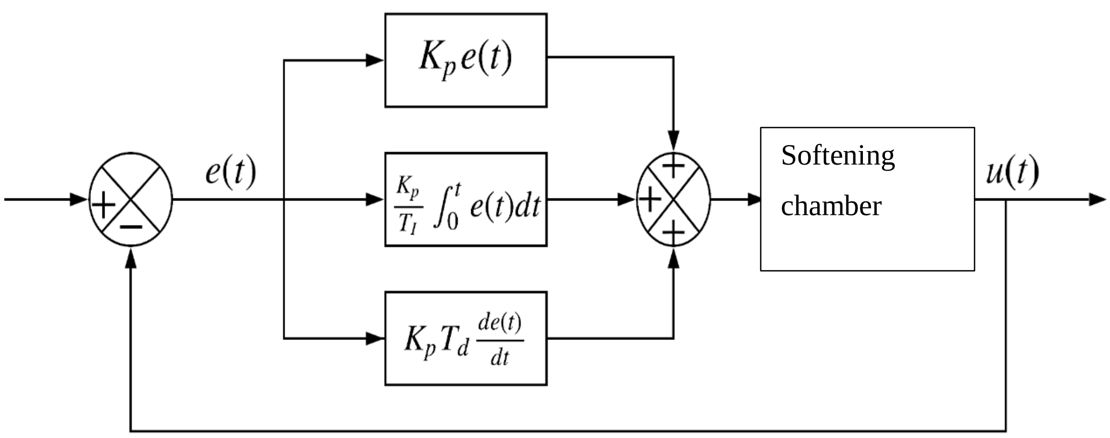
Figure 2.13 Temperature control system.



Source: (Ogata, 2010)

For our particular case, the control system that was used for the temperature control in the heating chamber, follows the same structure as in Figure 2.13, having a PID controller, whose synthesis can be seen in the block diagram shown in the figure 2.14.

Figure 2.14 Diagram of temperature PID system blocks.

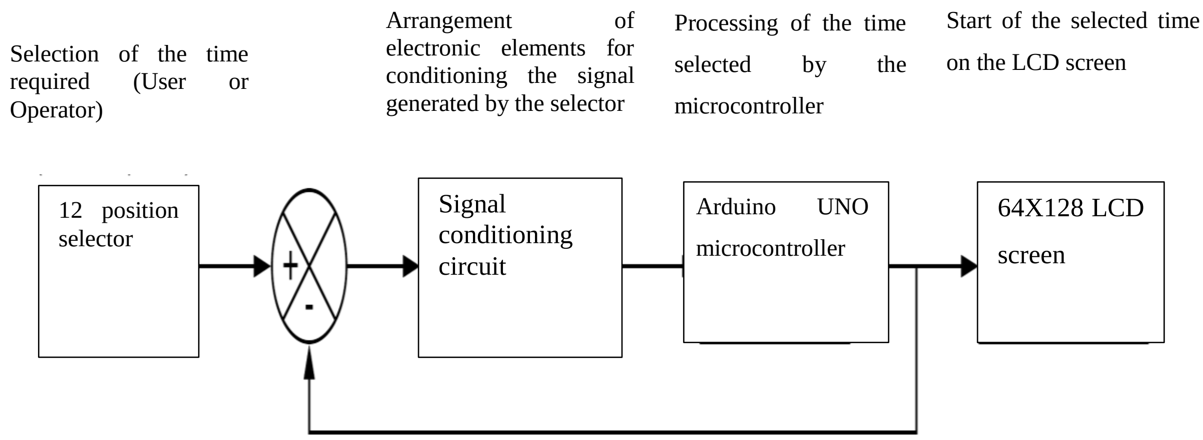


Source: (Ogata, 2010)

4.3.2.2 Design of the visualization and time control system

En función a los factores de diseño que se analizaron en el capítulo 3 y 3.1, se empleó un microcontrolador Arduino UNO, el cual nos permite seleccionar y visualizar el tiempo exposición del conducto por medio de un selector y una pantalla LCD de 64x128 pixeles. En la figure 2.15 se muestra un diagrama esquemático del funcionamiento.

Figure 2.15 Diagram de bloques del sistema de visualización.



Source: self made.

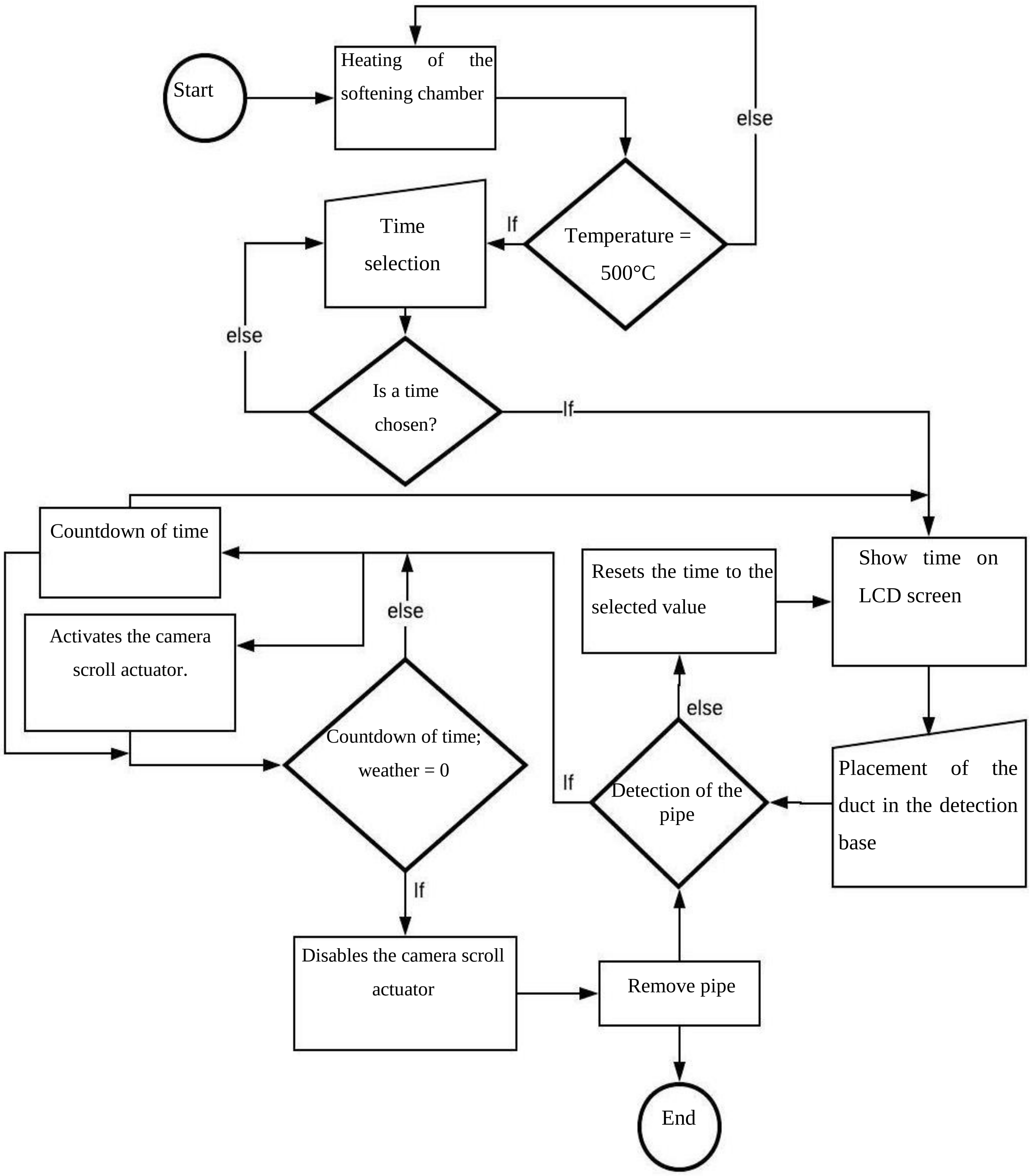
4.3.2.3 Design of the positioning and duct detection system

Returning to the design factors of chapter 4.2, it is required that this heating system has a mechanism for movement and detection of the pipeline, since, with this, it will be possible for the time counting system to detect the pipe, this is achieved due to that on the basis of detection where the duct is placed, there is an inductive sensor, thus allowing the detection of the duct and start of the heating of the duct. See figure 4.9 For the movement of the camera there is a pneumatic actuator that facilitates the movement of the heating chamber towards the pipe.

4.3.3 Control Program Design

In Figure 4.15, a flow diagram is shown where the program was designed, which was developed in the Arduino programming platform.

Figure 2.15 Diagram of flow of the designed program.



Source: Self Made

4.3.4 Selection of Materials

The selection of chose according to all the parameters and designs already analyzed in the previous chapters. You can see a list of the materials that were used for the manufacture of the softening system in the Table 2.2.

4.4 Manufacture

4.4.1 Manufacturing of the Softening System and Structure

In the design of the chamber a circle was drawn in the center of the square with a diameter of 5cm, once the hole of 5 cm was made, points were marked every 45 ° in the entire circumference. After having marked all the necessary points, with the help of a table drill and a drill for concrete, the block was drilled at each point.

After finishing the holes in the block, a nichrome resistor was placed, this was placed in a spiral around the circumference of the block, taking care that each spiral of the resistance did not have contact with each other, since when the material expands, the material expands and if there is contact of two spirals the electric current that flows would increase twice, which would cause a break in the electrical resistance. (Ver Figure 2.17 y 2.18).

Figure 2.17 Refractory block with mortar and ceramic fiber coating.

Source: Self Made

Figure 2.18 Structure of the softening system

Source: Self Made

4.4.2 Manufacturing of the Control System

For the implementation and manufacturing of the control system, a signal conditioning circuit was implemented for the inductive sensor, a position selector was placed on a side wall for different time intervals and for the 164x128 LCD screen, in addition to this circuit the necessary electronics were included to implement an Arduino UNO microcontroller, this device will have the task of acquiring and processing the signals sent by the inductive sensor and the time selector, to later process this information and send it to the LCD screen. From the above according to what was analyzed in chapter 4.3.2 and 4.3.3.

4.5 Calibrations

Once the performance tests were made and verify that the requirements are satisfactory, we proceeded to calibrate the measurements of time, temperature and distance that are required. The time required for the operation of the machine is 3s, 4s and 5s for the different types of ducts, all at a distance of 5cm. What was done to develop the appropriate calibrations was the following:

1. The temperature of 500 ° C was adjusted
2. The time was adjusted according to the type of conduit.
3. The stop of the pneumatic actuator was adjusted to be able to leave a standard length for a stroke of 5 cm.

Once the calibration of the different parameters was completed, the corresponding tests were carried out. In order to know if the calibrations are adequate, the quality department of the company provided us with samples of how the different conduits that are manufactured and assembled in the process should be, this to be able to compare them with what was obtained in this softening system.

4.6 Field Installation and Testing

The heating chamber was presented to one of the companies in the automotive sector, to start its operation and perform tests (See Figure 2.19). Once the camera was installed, tests were carried out for a period of one hour, where the operators who were in that module expressed that the method to soften and assemble the pipeline was approximately 4 to 5 sec. faster, these data were verified with a stopwatch, giving an average of 4.6 seconds, which was valid what the operators reflected, besides, they expressed that this new softening system was much more comfortable, since they only had to introduce the conduit by the mouthpiece of the camera and did not have to manipulate or make any movement with the conduit, as they did with the heat gun BOSCH. When removing the conduit, the operators observed that there was no detachment of material or excessive deformation, due to the heat that was inside the chamber, (See Figure 2.20).

Figure 2.19 Camera installation inside the Kayser facilities

Source: Self Made

Figure 2.20 Operator inserting the conduit in the chamber

Source: Self Made

5. Results

The implementation of the softening device to the assembly line obtained the following results:

- **Exposure temperature control:** as a result of implementing a PID temperature control, it was possible to manipulate this variable in a range of 0 to 500 ° C with a readability of 1 ° C, it is also possible to visualize in real time the temperature which covers with the requirements indicated by the quality department**.**

- **The exposure time:** because in this system the distribution of heat is uniform throughout the circumference of the duct, it prevents the operator from having to manipulate the duct in order to achieve complete softening. The system performs the process of softening the pipe in a time of 2 to 4 seconds, previously was done in a time of 3 to 6 seconds per conduit, which gives a total of 30 seconds for each assembly that is made with the system traditional using the BOSCH heat gun, with the new system is performed in a total of 25.71 seconds approximately in each assembly see Table 2.6**.**

- **Exposure length:** with the electronic motion control system of the softening chamber, an error of ± 3 mm was achieved in the measurements of the exposure length of the pipe.

The statistics were carried out with a sample of 140 PA6 pipe assemblies, where one out of every 20 assemblies had an error of 3% difference in the execution time of the assembly, thus giving ± 0.58 seconds of error in each assembly.

Table 2.6 Comparison in times of the conventional vs. automated system

Production system with heat gun BOSCH	Production system with softening device
Number of heated ducts in a working day of one hour an average of 120. Giving a total of 30 sec. of time used for each conduit, from the softening with the BOSH gun, to the assembly with the filter or coupling.	Number of heated ducts in a workday of an hour an average of 140. Giving a total of 25.71 sec. of time used for each conduit, from the softening with the gun, to the assembly with the filter or coupling.

Source: Self Made

6. Conclusions

The design and implementation of a control system that meets an imperative need in a manufacturing process of the automotive sector, specifically in the design of an automated PA6 pipe softening device and developed based on the Standard, has been presented in this paper. DIN 16773.

The development of the PA6 polyamide pipe softening system satisfactorily covered the following points, which were technically analyzed in depth in chapter 4.1 and 4.2.

1. The exposure temperature of the duct: PID temperature control in the range of 0 to 500 ° C.
2. The exposure time of the conduit: where the operator selects the exposure time depending on the type of pipe material with a control range of 0 to 4 sec.
3. Exposure length: in the pipe it is required to have controlled the exposure inside the softening chamber, which covers a value of 5 cm.

As it could be analyzed in the previous section (results), the proposed purpose was satisfactorily achieved by covering the critical points requested by the quality department, in addition to improving the time in which the process was carried out manually, reducing by 14.3. %, resulting in 20 more assemblies in a day of one hour. As a result of the results obtained, and the research carried out, we can say that the type of conventional procedure carried out by the automotive sector for the softening of its ducts affected the mechanical properties of the same, did not meet the required quality parameters and reduced the production of pipe assemblies with filters and couplings. As discussed in Chapter 4, the softening design that was chosen was based on DIN 16773-1, (German Institute for Standardization, 2010), using the specified parameters allowed the pipe to soften uniformly, thus avoiding crystallization of it and the excessive deformation due to heat.

Based on the above, the appropriate design of the softening chamber was the most complex point in the development of the softening system, since it required a very broad analysis about heat transfer, thermodynamic systems and properties of thermoplastics. Automotive companies are not the only sector, where this type of process is used, as a consequence of this, the application of this type of softening system is not limited to this sector, but also in systems where control is required precise heating and softening of an object, piece or product. Some of the points that are recommended to other research work related to this, is to take into account the type of material to be heated and how its mechanical properties are affected when heated, in the same way take into account the type and dimensions of the material that is going to be used for the insulation of the softening chamber, the latter as a result of what was analyzed in chapter 4.1 and 4.2, in our case in particular the dimensions of the chamber could not be adequate to isolate the heat properly As a consequence, the chamber walls are heated to 105 ° C, which is a high temperature for this type of system, but this can be sacrificed depending on the operating conditions and the installation location, this can be consulted In more detail in standard NOM-009-ENER-1995 (National Secretariat of Energy, 1995), for our case, the temperature of the walls was not a risk for the operator, because The design of the structure and movement of the duct prevents the operator from being in contact with the heating chamber.

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Chapter 3 Value chain diagnostic to formulate a portfolio of technological innovation projects in an automotive supplier

Capítulo 3 Diagnóstico de cadena de valor para formular una cartera de proyectos de innovación tecnológica en un proveedor automotriz

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Abstract

This chapter of the book documents an analysis of the current status of the value chain of an SME in the textile sector in Tlaxcala, provider of the automotive sector, for which the case study method is applied; Data collection is initially carried out on site, then an analysis is made of the information collected from which the key performance indicators (KPI's) of the manufacturing area are calculated. Finally, the Value Stream Mapping (VSM) method analyzes each of the processes of the value chain, evidencing areas of opportunity and designing strategic proposals for technological innovation and improvement, aimed at strengthening the business model of the company, as well as generate a portfolio of projects that can participate in national calls for the obtaining of economic funds.

Value Stream Mapping (VSM), Value chain diagnosis, Technological innovation, Automotive Sector

1. Introduction

The technical study in the development of a project is a fundamental part to decide the viability of this, because it must contain the essential elements related to the engineering of the project that is to be implemented, therefore it is important to apply a methodology that provides relevant information to identify the activities that give value to the processes. Therefore, the technical study is used to generate a portfolio of projects whenever according to one of its definitions it allows to propose and analyze the different technological options to produce the goods or services that are required, which also allows verifying the technical feasibility of each of them. This analysis identifies the equipment, machinery, raw materials and facilities necessary for the project and, therefore, the investment and operating costs required, as well as the working capital that is needed. (Rosales, 2005).

To identify the activities that most impact the technical study, a value chain diagnosis is applied because the value chain of an organization identifies the main activities that create value for customers and the related support activities. The chain also allows identifying the different costs incurred by an organization through the different activities that make up its production process, which is why it is an essential element to determine the cost structure of a company. Each activity in the value chain incurs costs and limits assets, in order to achieve its due analysis and consideration allow to improve the techno-economic efficiency of a company, a group of companies or a specific industrial sector. (Quintero, J., & Sánchez, J. 2006). Each activity in the value chain incurs costs and limits assets, in order to achieve its due analysis and consideration allow to improve the techno-economic efficiency of a company, a group of companies or a specific industrial sector. (Cayeros, Robles, & Soto, 2016).

Thus, the aim of the project is to justify the feasibility of proposals for Technological Innovation projects in an Automotive Supplier through value chain diagnosis. In general terms, it is to align the scope of the study with the economic and technological strategies of the company, to model a family of products to analyze the sequence of operations; collect key indicators from process flow diagrams, path and process graphs as background to in turn model the current and future VSM.

The development of proposals for technological innovation and continuous improvement from the Value Stream Mapping (VSM) of the manufacturing process of the product supplied to the automotive sector under a Lean Manufacturing approach allows to know how the production process is currently throughout of the value chain. (Nava, Tolamatl, Gallardo, & Calvario, 2016). Due to the trend of demand for the company's product in the automotive sector (statistics for the year 2013, according to Calvario) (Calvario, 2013). It is required to increase production volumes, and optimize the process. The presence of both national and foreign competition, forces a process of innovation, in order to achieve competitive advantages in quality, delivery times and satisfaction of the automotive sector.

The work plan contemplates 5 phases (Definition, Current Situation, Obtaining measurables, proposal of projects and technological innovation); with their respective actions and restrictions; which allow to clearly define the identification of areas of opportunity that may be feasible for the project portfolio; despite the fact that only an improvement proposal is carried out, and an analysis of the means and parameters of execution which are defined and supported by lean manufacturing tools for their execution and the VSM is mainly used to identify and graphically show the areas of opportunity.

The company finally evaluates the technological innovation proposals and aligns them with their development strategies. Regarding the methodology used, in Phase 1, the scopes and objectives aligned with company policies are defined. In Phase 2, information is collected and processed from the production line in order to analyze the current status of the company in its operations. In Phase 3, specific information is obtained so that in Phase 4 the value chain map is developed in the current status. Finally, in Phase 5, the projects presented by the HEI (Higher Education Institution) to the company are identified and proposed so that, this may select the most appropriate according to its priorities and technological strategy.

2. Theoretical Review

The quantification of risk in investment projects has been one of the central concerns of researchers and operators in finance, due to the growing need to respond to the regulations issued by national and international regulatory entities. (Bazzani & Cruz, 2008)

The Science and Technology Law (STL), in its article 1, (Official Gazette of the Federation, 2013) regulates the support that the Federal Government is obliged to grant, to promote, strengthen and develop scientific and technological research in the country, as well as to determine the legal, financial and administrative instruments, through the National Council of Science and Technology (Consejo Nacional de Ciencia y Tecnología) "CONACyT"; which, under the modality of the stimulus program for research and technological development and innovation, requires specific information on these projects to validate technical feasibility. Which refers to the availability of the necessary resources to carry out the objectives or goals indicated and is based on 3 basic aspects: operational, technical and economic. The feasibility study collects relevant data on the development of a project and based on this, the best decision is made. The success of a project is determined by the degree of feasibility that is presented in each of the three previous aspects.

Nowadays, the most of the public funds for the financing of technological projects, recognize as valid the structure that the standard NMX-GT-002-IMNC-2008 (Normalization, 2008) which is proposed for the formulation and planning of a technological project, so it is recommended for the companies to use this scheme to plan and monitor the projects.

But the tools under which the data are obtained to document each of the elements of the structure of the norm, are not mentioned again, nor suggested. Several authors handle technical study as a key tool to document or support projects.

The objective of the technical study is to provide both the technical information of the means of production and the structure of investments, costs and income, which will be used in the evaluation of the project (Morales C., 2010).

But once again the tools to obtain the parameters are not mentioned or suggested.

Lean manufacturing also called lean production is a work philosophy, under the approach of continuous improvement and optimization of a production or service system, by fulfillment of its objective which is the reduction of waste of all kinds, times, defective products, transportation and work by teams and people. It is not a static or radical philosophy that moves away from what is already known, rather its novelty consists of the combination of different elements, techniques, applications and improvements arising in the elaboration of the work.

Lean manufacturing has its origin in the Just in Time (JIT) production system, which was developed in the 50s by Toyota. Over the years, this philosophy has been modified and converted into the paradigm of productivity improvement systems associated with industrial excellence (Rojas & Gisbert, 2017).

Companies that work according to Lean Manufacturing principles, systematically seek to know what the customer recognizes as added value and is willing to pay for it, while eliminating those operations of the process that do not generate value.

The objective of Lean Manufacturing is to propose improvements in the processes through the analysis of the value chain, and the implementation of quality tools and macro indicators (Rueda, 2007). The OEE is included in the indicators used (Sistems OEE, 2018). This indicator measures the efficiency of industrial machinery, and is used as a key tool within the culture of continuous improvement. Its acronyms correspond to the term "Overall Equipment Effectiveness". It was used for the first time by Seiichi Nakajima, the founder of TPM: Total Productive Maintenance, as the fundamental measurement tool to know the productive performance of industrial machinery. The challenge was even greater when it created a sense of joint responsibility among machine operators and maintenance managers to work on continuous improvement and optimize Overall Equipment Effectiveness (OEE).

Another indicator that was used to balance the line and establish projects is the Takt Time (Ortiz, 2006). It is the time in which a unit of product must be obtained. It is a well-known term in manufacturing which is used to establish the time it takes to complete a unit to meet the demand.

The improvements presented by the analysis of these indicators can be seen crystallized in research projects and/or technological development and innovation. In addition to the fact that Lean Manufacturing grants the continuous improvement of a production system, the importance of using this method, and its tools, is due to the fact that it generates all the dynamics and context to develop; stages that make up a feasible project, an operational guide to guide the preparation of each of the parties; the technique and the instrument for the collection of information. In the same way, it allows establishing the conformation of a discrepancy analysis instrument and feasibility analysis. Culminating with the last two stages of a feasible project, the formulation of proposals and recommendations for a successful execution of the proposals that make up a portfolio of research projects and/or technological development and innovation with the plus of responding to the regulations emanating from national and international regulatory entities.

3. Methodology

The value chain concept of a company shows the set of activities and interlaced functions that are carried out internally. The chain begins with the supply of raw material and continues throughout the production of parts and components, manufacturing and assembly, wholesale distribution and in such a way until reaching the final user of the product or service (Quintero y Sánchez, 2006).

General Objectives

Justify the technical feasibility of proposals for Technological Innovation projects in an Automotive Supplier through value chain diagnosis.

Scope

The case covers all the areas involved in the manufacture of the products, and the proposal to identify areas of opportunity through the main use of the VSM, which is indispensable for the identification of waste, showing an overview of the current situation of the company and taking into account the importance that the client has; then, as already identified proposals, specific projects will be recommended to correct and / or improve the current situation maintained by the company.

Regarding the technical study, only the technical part will be emphasized without taking into account allusive data to the economic and operative part, as well as the justification of economic amounts related to the projects selected by the company and proposed in the CONACyT call.

The methodology used in the field followed the following structure to characterize the company:

Phases

Phase 1. Definition

a. Scope
b. Limitations.
c. Justification.

d. Objective.

Phase 2. Current situation

a. Product family.
b. Diagram of flow.
c. Layout.
d. Graphic of distances.
e. Diagram de processes.
f. Waste identification.

Phase 3. Obtención de medibles

a. Shifts by department.
b. Areas by department.
c. Cycle times by areas.
d. Quality Load Factor by area (QLF).
e. Availability index of each area.
f. Leveling of the required demand per day.
g. Inventory of raw material**.**

Phase 4. VSM Current status

a. VSM Current Status
b. Takt Time (TT).
c. Cycle Time (CT).
d. Graphic TT – CT
e. Overall Equipment Effectiveness (OEE).

Phase 5. Project proposal and technological innovation

a. Project to guarantee the uniformity of the thread.
b. Project to improve the flow of information and materials through the elimination of waste generated in the production line
c. Results report

4. Development

In Mexico, the automotive industry has developed important productive linkages with the glass, steel, iron, rubber, plastic, aluminum and textile industries (Secretaría de Economía, 2012), with which it has become an important driver of manufacturing and economic activity in the municipalities and regions where it is located (Carbajal, De Jesús, & Mejía, 2016).

The case study of the present investigation corresponds to a company in the textile sector supplier for the automotive sector located in the area of influence of the HEIs (Higher Education Institution). This company is classified within sector 313: Manufacture of textile inputs and textile finishing that groups together economic units dedicated mainly to the preparation and spinning of natural textile fibers; to the manufacture of threads and fabrics, and to the finishing and coating of textiles. To develop the project, a work plan was prepared that includes 5 phases, which were applied as follows:

Phase 1. Definition

The company needs to optimize its process, to increase the production volumes, of its most demanded product by the client, representing almost 70% of the volume of the total production. It is important to emphasize this because, due to the emergence of new competitors from both the region and foreigners, the production process must be known, to make innovation and continuous improvement, and increase the production volumes of its products, allowing to achieve advantages competitive, as well as, differentiate from the competition, making sure not to lose quality, improve delivery times and customer satisfaction.

Scope

For the elaboration of the technical analysis and the proposal of technological innovation project portfolio, the tools of Lean Manufacturing (VSM, OEE, Takt Time, CT, family of products) will be used in order to know the current situation of the company through the identification of areas of opportunity, covering all the productive spaces in the manufacture of the family of products with a vision oriented to the client.

Justification

This study will allow the company to know how its production process is really working, identify the critical points, and recommend pertinent projects to remedy the problems detected under this analysis, allowing to make its production line more efficient by increasing its productivity and competitiveness.

General Objectives

Justify the technical feasibility of proposals for Technological Innovation projects through value chain diagnosis.

Specific objectives

1. Diagnose the process of the company through the value chain.
2. Prepare portfolio of technological innovation projects.
3. Analyze technical feasibility and feasibility of technological innovation project portfolio
4. Participate with technological innovation projects in the stimulus program for technological innovation of CONACyT.

Phase 2. Current situation

The textile, yarn and finishing company has two large production areas; spinning for the manufacture of the yarns and dyeing for the finishing and dyeing of the same, has a wide variety of products, among which are mainly yarn for the automotive sector, being these widely demanded, and therefore have considerable volumes of production.

Due to the appearance of new competitors in the region, both national and foreign, the company has seen the need to be more competitive with the products it offers and to achieve this it has been forced to reduce its production costs to compensate the utility and remain in the market, making sure not to lose quality in the products and the attention of their customers.

In this way it has been chosen to make use of tools, to diagnose optimize and / or improve the resources available for the manufacture of their products. For this project the VSM is used as the main tool, in order to identify and graphically show where the main waste that reduces the productivity of the company is found, and for this it is essential to establish in the first instance a family of products that represents the essence of the business.

Product family

It is a product and its variants that pass through common equipment and similar stages of process before being delivered to the customer. The importance of product families for lean thinkers is that in the value flow maps, they are analyzed considering them as units, from the farthest stage downstream to just before being delivered to the client.

Note that product families can be defined from the perspective of any customer along an extended value stream, ranging from the last customer (the final customer) to intermediate customers within the production process (Marchwinski and Shook, 2008).

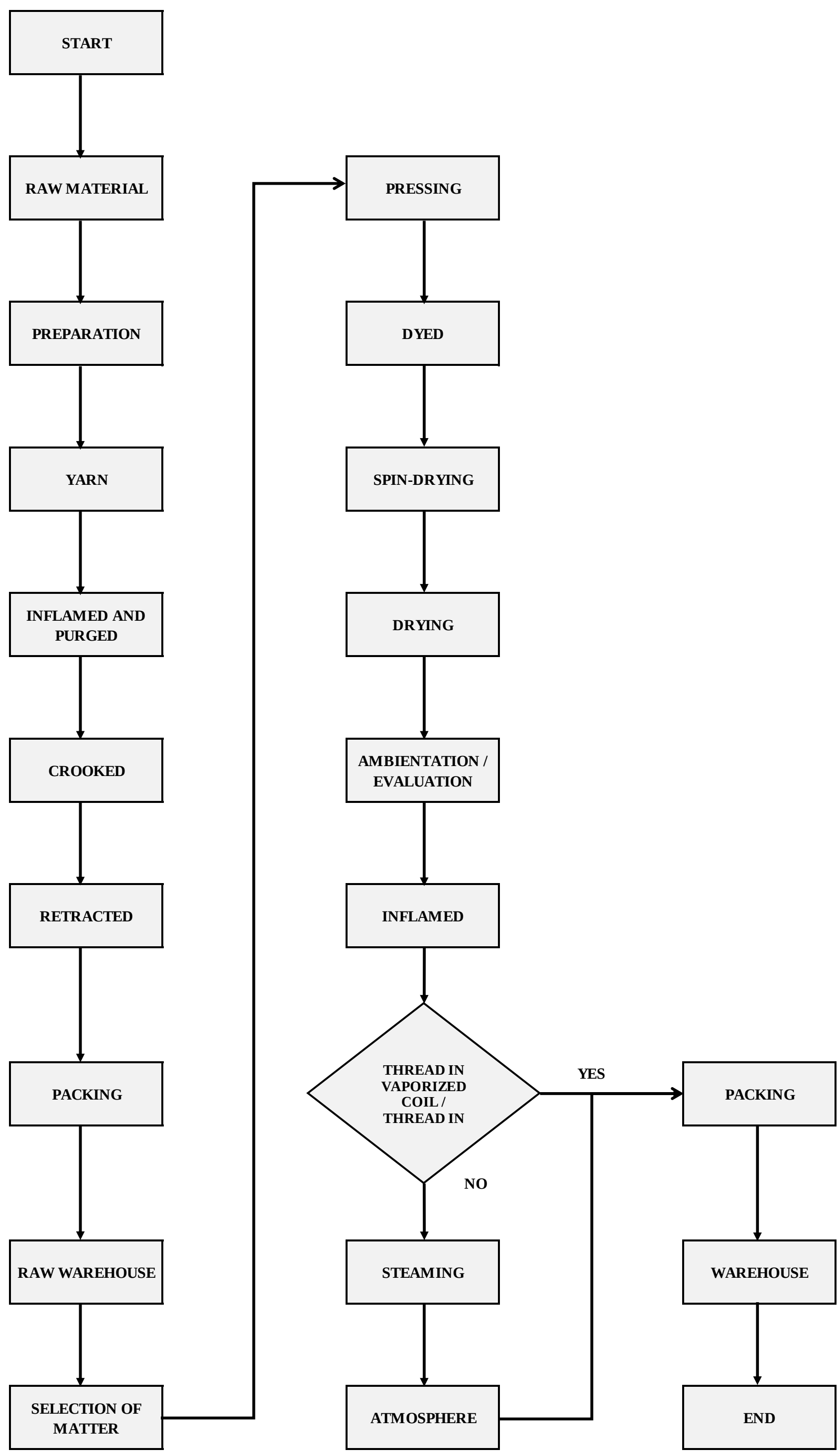
In the case of this company, there are dozens of products, 28 of which are the most commercial, but only 4 of these represent considerable volumes. 3 of these present periodicity of sale, and only 1 represents almost 70% of the volume of total production, which is why they are considered as a family of products called the parent line.

If an evaluation of production volume and manufacturing process is made, it is observed that this project will cover 92% of the production generated by the company.

Diagram of flow

A general flow diagram (figure 3.1) of the manufacture of the matrix line is elaborated in order to know the different stages of the process (Miller, Pawloski, & Standridge, 2010).

Figure 3.1 Diagram of flow of the manufacturing process



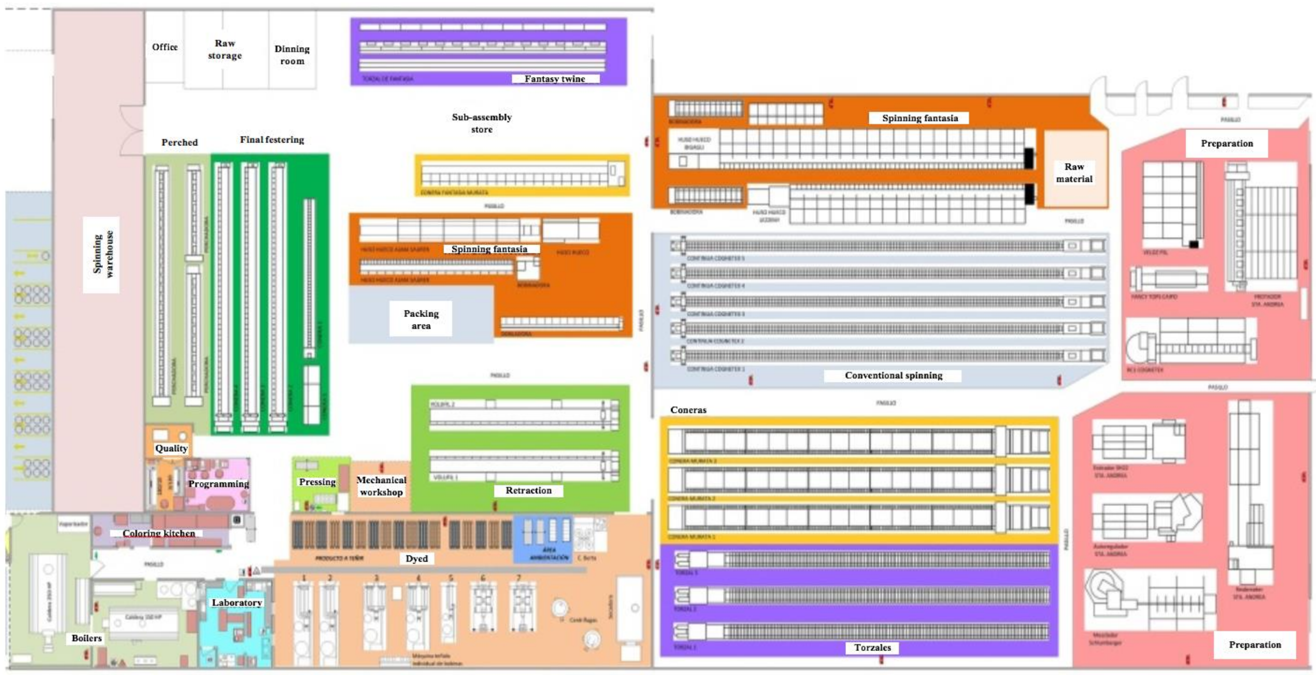
Source: Information obtained from the survey

The diagram provides an overview of the production process, since it arrives as a raw material, until it is taken to the finished product warehouse (Krajewski & Malhotra, 2013).

Layout - travel diagram

Another tool used is the route diagram (figure 3.3) which is obtained through the layout of the company (figure 3.2), where each of the areas of each production department is identified (Pérez, 2016).

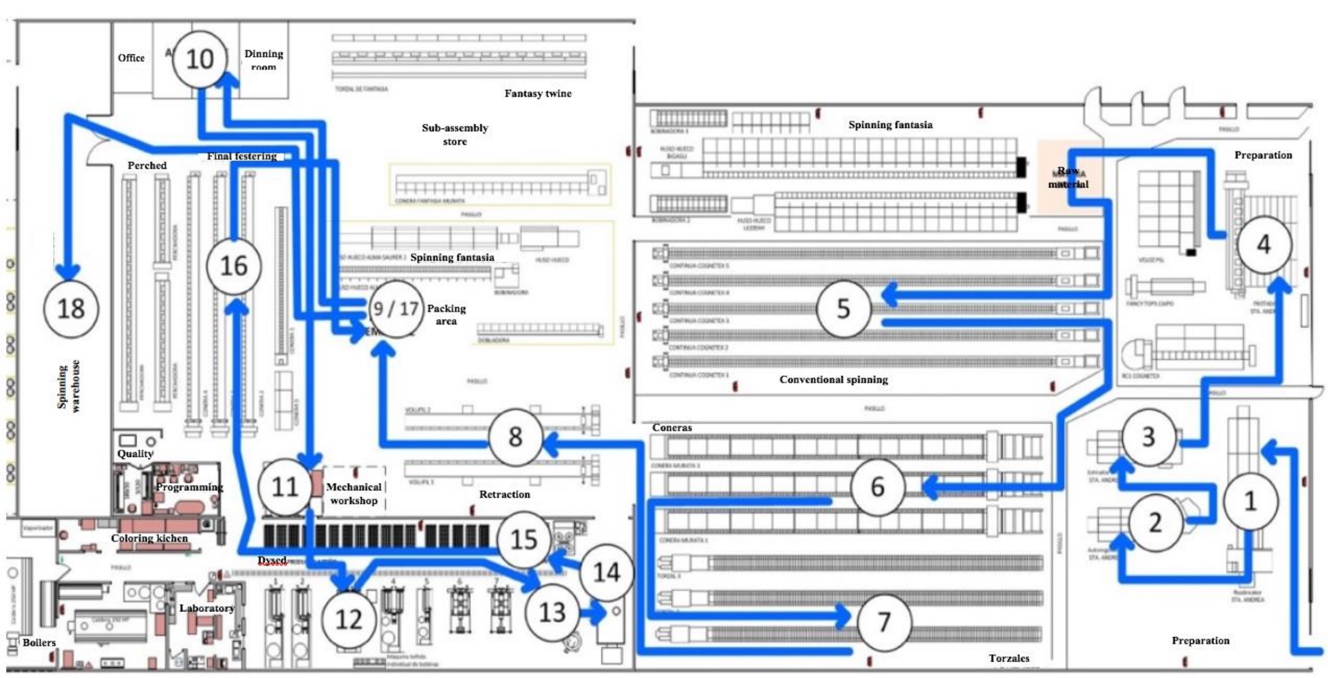
Figure 3.2 Layout of the Company



Source: Provided by the company

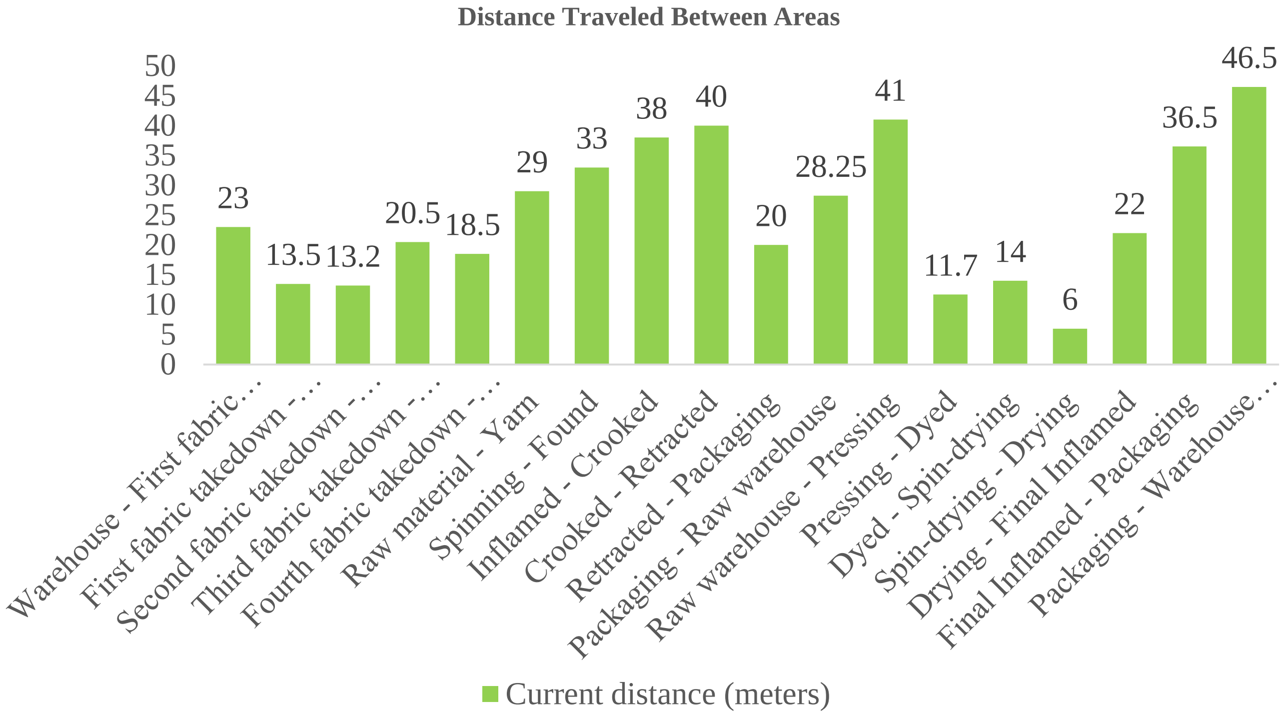
For the case of the production process of the parent line, we have the following process trajectory (figure 3.3). As can be seen, in the route diagram, the location of the machinery is not correct and shows how it was adapted the company to the changes as a result of its growth. One of the waste that takes greater relevance is the transport, and consequently the one of movement on the part of the operator, when taking or bringing material to his station of work. The distances covered by this line can be seen in graphic 3.1.

Figure 3.3 Layout with stroke of the process



Source: Information obtained in the field

Graphic 3.1 Distances traveled from the process by area



Source: Information obtained in the field

Through this information the distances traveled between each area of the production line are obtained with a total traveled distance of 454.65 meters.

Diagram of process flow

A process flow diagram is prepared to know the estimated real time of production, based on real, theoretical and historical production data, allowing to identify at the same time the different wastes that arise along the entire production line, manifesting some observations that are considered critical to devise the best plan and give the best solution (Niebel & Freivalds, 2014).

Figure 3.4 Diagram of process flow

Resumen de Actividades			
	Activity type	**Syeps No.**	**Times involved**
○	Process	15	2787.4
⇨	Transfer	18	509
□	Inspection	4	0
D	Delay	1	600
▽	Warehouse	4	0
Distance traveled: ____454.65___ Mts.			
Time value (V): 2782 No time value (NV): 1114			
VA Indexe = V / (**V+NV) =			**71%**

Details of the state method	Present / Proposed	Process	Transfer	Inspection	Delay	Warehouse	Time (sec) V	Time (sec) NV	Distance moved (meters)	Amount of lot	production	Transportation	Movements	Wait	Reworks	Warehouse	Defects	Comments
Raw material warehouse		○	⇨	□	D	▼								X				The availability of raw material, or first quality, is not always ensured.
Raw material warehouse		○	➡	□	D	▽		26	23	8 pacas		X		X			X	When there is no availability of raw material, the machines are stopped, or the machine does not work and it is sent to the second machine.
First fabric takedown		●	⇨	□	D	▽	750											They have maintenance problems and adjust the machines
Quality test		○	⇨	■	D	▽												Every time a test does not pass, the machine must be readjusted
Transport to hairstyle and fabric takedown		○	➡	□	D	▽		14	13.5	7 boats		X						
Hairstyle and fabric takedown		●	⇨	□	D	▽	750						X	X			X	Frequently the machine is misadjusted, therefore adjustments have to be made, time is lost and quality problems exist.
Quality test		○	⇨	■	D	▽												
Transportation to second fabric takedown		○	➡	□	D	▽		14	13.2	8 boats (4 per boat)			X					
Second fabric takedown		●	⇨	□	D	▽	375						X	X			X	Frequently there are faults in the machine, they are readjusted and there are lost time
Quality test		○	⇨	■	D	▽												
Transportation to third fabric takedown		○	➡	□	D	▽		23	20.5	32 boats (2 per coil)		X	X					The machine is at a considerable distance from the previous machine.
Third fabric takedown		●	⇨	□	D	▽	68.18					X	X	X		X	X	By not using quality raw material, the cycle time is raised, because the machine has to be stopped, more movements are generated when fixing the defects during the process.
Transport to raw material		○	➡	□	D	▽		20	18.5	16 coils		X						
Raw material warehouse		○	⇨	□	D	▼					X	X	X	X		X		This warehouse is not controlled, therefore the aforementioned waste is generated
Transportation to yarn		○	➡	□	D	▽		32	29	352 coils		X	X					
Yarn		●	⇨	□	D	▽	16.48				X		X	X		X	X	There are 3 machines adjusted to the process, but quality raw material is not insured, therefore there is a high defect index, and scrap, in addition to not having a good production control
Quality test		○	⇨	■	D	▽												
Transportation to Inflamed		○	➡	□	D	▽		36	33	704 taps		X						
Inflamed		●	⇨	□	D	▽	44.4						X	X			X	There are 3 machines of festering in the same capacity, although they do not work 100%, because there is no excellent maintenance
Transportation to torzal		○	➡	□	D	▽		42	38	60 cones		X	X	X				Since 80% of the racks do not work, material availability is not guaranteed for the next operation.
Crooked		●	⇨	□	D	▽	289.57					X	X	X				Frequently there are problems with torzales, they do not assure availability of matter to the next operation, they generate delays, because there is no material
Transportation to retracted		○	➡	□	D	▽		44	40	115 cones (2 per cone)		X	X	X				No material availability
Retracted		●	⇨	□	D	▽	42.42							X	X		X	There are waits for not having material, there is no good flow and when they are not properly adjusted the machines are incurred to rework
Transportation to packaging		○	➡	□	D	▽		22	20	36 moff or 36 coils		X						
Raw product packaging		●	⇨	□	D	▽		5.35					X					
Transportation to raw warehouse		○	➡	□	D	▽		34	28.25	12 cones / 14 moff		X						When urgent orders are sent to another warehouse for processing.
Raw product warehouse		○	⇨	□	D	▼						X	X			X		The warehouse is at a considerable distance taking into account the trajectory that it carries out from the previous operation to the next operation
Pressed transport		○	➡	□	D	▽		45	41	1 car			X	X				
Pressing		●	⇨	□	D	▽	17.5						X	X		X		When in moff, more adjustment movements are made, in thick threads it is possible to press manually, than in thinner threads.
Transportation to dyed		○	➡	□	D	▽		16	11.7	12 coils or 14 moff in each cane		X						There is a controlled warehouse, which feeds the dyed machines.
Dyed		○	➡	□	D	▽	210					X			X		X	The PLCs are not in good condition, and some controls or parameters no longer work, they are available only in Italian, only one operator / shift is trained to control the machines. There are problems of mixing control, maintenance, and temperature.
Drainning		○	⇨	□	◗	▽		600		12 bob or 14 moff per cane		X		X				Drained from canes
Transport to spin-drying		○	➡	□	D	▽		16	14	1 trolley cart		X		X		X		
Spin-drying		●	⇨	□	D	▽	60							X				9 minutes in Berta / 1 hour in the pot (30 minutes spin-drying and 30 minutes of stoppage). The Berta spin-drying machine will be replaced with a higher capacity one.
Transportation to dryer		○	➡	□	D	▽		8	6	120 coils / 144 moff per cart		X	X					
Drying and ambience		○	➡	□	D	▽	22.5					X		X			X	If the parameters are not good on machinery or the thread to dry has defects, when leaving this operation the consequences are seen, Even after having left the dryer should be set, to dry almost completely.
Transportation to final Inflamed		○	➡	□	D	▽		25	22	1 needle cart 2		X		X				The bars of bars, are difficult to transport because they are heavy.
Final Inflamed		●	⇨	□	D	▽	56						X					There are maintenance problems with the machines, they do not always work at the same speeds.
Transport to finished product packaging		○	➡	□	D	▽		40	36.5	1 boat		X						
Packaging finished product		●	⇨	□	D	▽	80											Pack of 12 and 15 pieces
Transportation warehouse finished product		○	➡	□	D	▽		52	46.5	1 car		X						
Finished product warehouse		○	➡	□	D	▽										X		Finished product warehouse too big.
	Total	15	18	5	1	4	2782	1114.4	454.65		** V + NV = Lead Time				3,896.40			

Source: Information obtained in the field

In the process flow diagram (figure 3.4), waste that reduces production within the plant, which in this case is 29%, was identified; if it is taken into account that the value added index is 71%, although it is important to mention that the process operations are theoretical since there are always problems of adjustment in the machinery, and in some cases it was not possible to corroborate the times because They differ too much, being these high; therefore the representative sample becomes numerous and takes time to obtain the cycles to define a standard, therefore that 29% only serves as a reference although in advance it can be said with certainty that this indicator is well above this value.

There are also several problems with the supply of raw material, since this does not arrive at the time it was requested, causing delays in production, waiting to increase the dead time of the affected stations, or when it is possible to generate inventory to meet the demand. On the other hand, maintenance problems are also evident, since there is no good management of the same, there is no preventive maintenance except in some cases where machinery is checked before starting it, although it is not always carried out.

Fase 3 Obtaining measurables

Information about the company

The company has a competitive advantage to offer a wide range of products, so it is only decided to analyze the matrix line previously selected for this purpose. Information is needed on the work days for which the company has personnel divided into three shifts, which work according to the production demand of their areas, that is to say that there are cases in which only personnel of some shift work in an area already either spinning and / or dry-cleaning (low seasons), or the whole plant works the three shifts from Monday to Sunday (high seasons). The hours of entry and exit respectively for each shift are from 7:00 a.m. to 3:00 p.m., 3:00 p.m. to 11:00 p.m. and from 11:00 p.m. to 7:00 a.m.

Information about the processes

The company has two production departments, spinning (yarn manufacturing process), and dry-cleaning (dyeing and finishing process). Table 3.1 shows each one of the departments and their respective area in charge, in total there are 10 stations for the main line, and for the production line the following order is had.

Table 3.1 Departments and areas of the manufacturing process

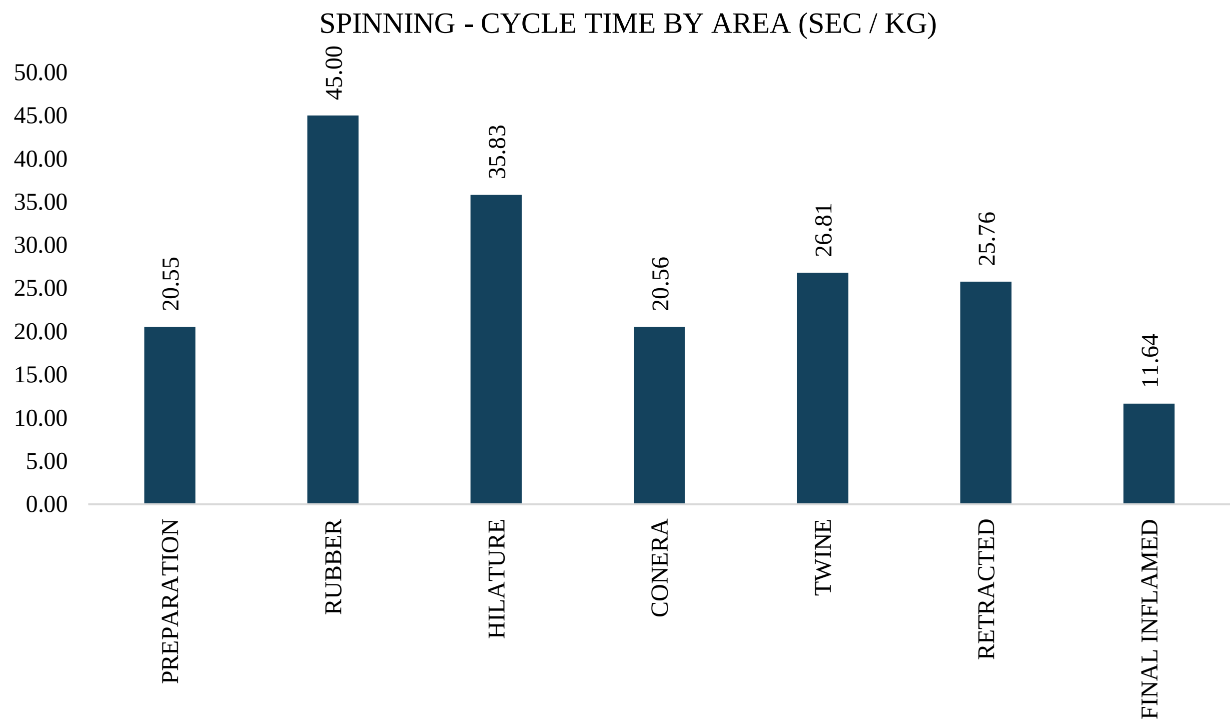
Department	Area
Spinning	Preparation (1,2,3, steps)
Spinning	Shoe
Spinning	Continuous
Spinning	Coneras
Spinning	Torzales
Spinning	Volufiles and raw packaging
Dry cleaner	Pressing
Dry cleaner	Had
Dry cleaner	Centrifuged and dried
Spinning	Reencounter and packaging

Source: Provided by the company

Spinning and dry cleaning cycle times

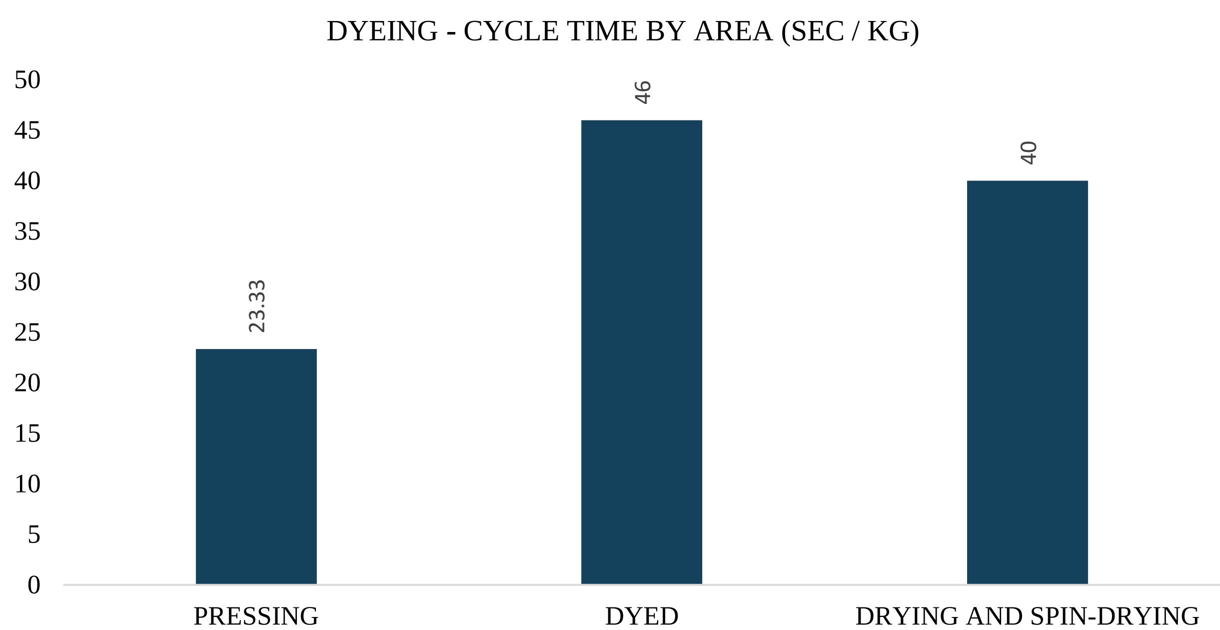
The cycle times of each of the areas were determined in order to know the manufacturing times for the matrix line, the following graphs show the cycle times in sec / kg that are needed to process one kilogram of material, in each area of spinning (graphic 3.2), and in the same way for the areas of dry-cleaning (graphic 3.3), press (pressing), Obem 1,2,4,5,7 (dyed), pot 1 and 2 (centrifuged) and boni & bulgarelli (drying).

Graphic 3.2 Spin cycle times



Source: Information obtained in the field

Graphic 3.3 Drycleaning cycle time



Source: Information obtained in the field

As in the process you have different machine capacities or you have more than one you get the real cycle time of each area, obtaining an average of all the machinery times and dividing by the amount of available machines, for the case of Different machines take the one that generated more time, given that it is the maximum speed that each area can work (Gutiérrez & De la Vara, 2013).

Determination of the quality load factor (QLF)

A sample of a week is taken into account, to collect production data, and to know how the production line really was, it should be noted that in recent months sales have declined and therefore only allowed to know the status of scrap and rework.

There is scrap concentrate and rework throughout the line which are obtained from the summary of each work station (Gutiérrez, 2014). Here you can see their respective percentage in each area and the total in the line (table 3.2).

One of the expressions for calculating the QLF is:

$$QLF = 1 + S + R \quad (1)$$

Where:
S = Scrap generated along the production line
R = Rework generated along the production line

Table 3.2 Scrap and rework indexes in the production line

Scrap Indices and Production Line Rework	
Area	**%**
Preparation	1.4%
Shoe	1.2%
Yarn	1.68%
Found	1.34%
Distorted	1.00%
Retracted and Packing	0.10%
Pressing	1.10%
Spinning and Drying	1.00%
Reencountered	1.50%
Scrap Index	10.32%
Dyeing Rework	29.41%
Q L F Process	1.3973

Source: Information obtained in the field

As the rework in dyeing is reprocessed within the line, it is considered:

Rework in dyeing equal to the inverse of the FTQ where FTQ is firts time quality for its acronym in English, then Rework in dyeing = 1 / 0.034 (considering 3.4% as quality at the first of the dyeing process) ie the rework of the dyeing department acquires a value of 29.41%. It is necessary to emphasize that the total scrap levels of 10.32% in the remaining departments and rework of 29.41% in the dyeing department are very high, giving a total quality load factor of 1.3973; waste that the company must absorb due to its low productivity. As the dyeing department was detected as an area of opportunity and could offer projects

Determination of availability

One of the most important problems in the company is the discipline to control the dead time (Kalpakjian and Schmid, 2014). In each of its areas, which did not have real and true information about the times when the machines stopped working as well as the specific causes that caused the unscheduled stoppages, however, detailed information about the volumes was available. of production as well as specific cycle times previously determined for each of the machines, so we proceeded to calculate the theoretical production volumes of each machine and compare them with the actual production volumes resulting in the difference in volume of production that the machines stopped producing for various reasons not foreseen, this difference was divided with respect to the volume of theoretical production throwing the index of dead time that each of the machines generated and the difference of 100% with respect to the time index dead determines the operational availability of each Manufacturing area (Bernstein, 2008).

There are different nomenclatures to describe the general calculation of operational availability (DO), for this reason and with the aim of avoiding controversies, it is recommended to use the following equation set out in the UNE-EN 15341 standard: 2007 (Norma, 2008).

$$D_O = \frac{Availability\ time\ achieved\ during\ the\ required\ time}{Required\ time} * 100 \quad (2)$$

Showing the results obtained in table 3.3.

Table 3.3 Availability of the areas of the production line

Production Line Availability Index	
Area	**%**
Preparation	99%
Shoe	92%
Yarn	98%
Found	94%
Distorted	99%
Retracted and Packaging	88%
Pressing	92%
Had	100%
Spinning and Drying	95%
Reencountered	97%
Online Availability Index	61.97%
Dead Time Index	38.03%

Source: Information obtained in the field

As the production process designed for the manufacture of the matrix line is a linear process and taking into account that the product of the availabilities of each area shows the availability of the system, it is observed that the production line of 100% of the available time with that account for the realization of its products only 61.97% is justified with production volume and the rest that represents 38.03% is the downtime that the line generates derived its multiple work stoppages and problems that continuously face the production process.

Determining the demand

To determine the speed at which the plant operates, we proceed to obtain historical production data for the January-June period, both for spinning and dry-cleaning, are considered in percentage terms to emphasize the production levels, taking 100% production that is greater, in the case of dry cleaning that has an average production of 41,831.12 kg per month (Table 3.4).

The level production per day of the plant is obtained, considering that they work on average 27 days a month, therefore, calculating 1549.30 kg / day.

Table 3.4 Level production data

41,831.12	Monthly production in kilos.
27	Days of production month.
1,549.30	Daily production (kg / day).
0.8	Kilograms per cone.
1,937	Cones per day.

Source: Information obtained in the field

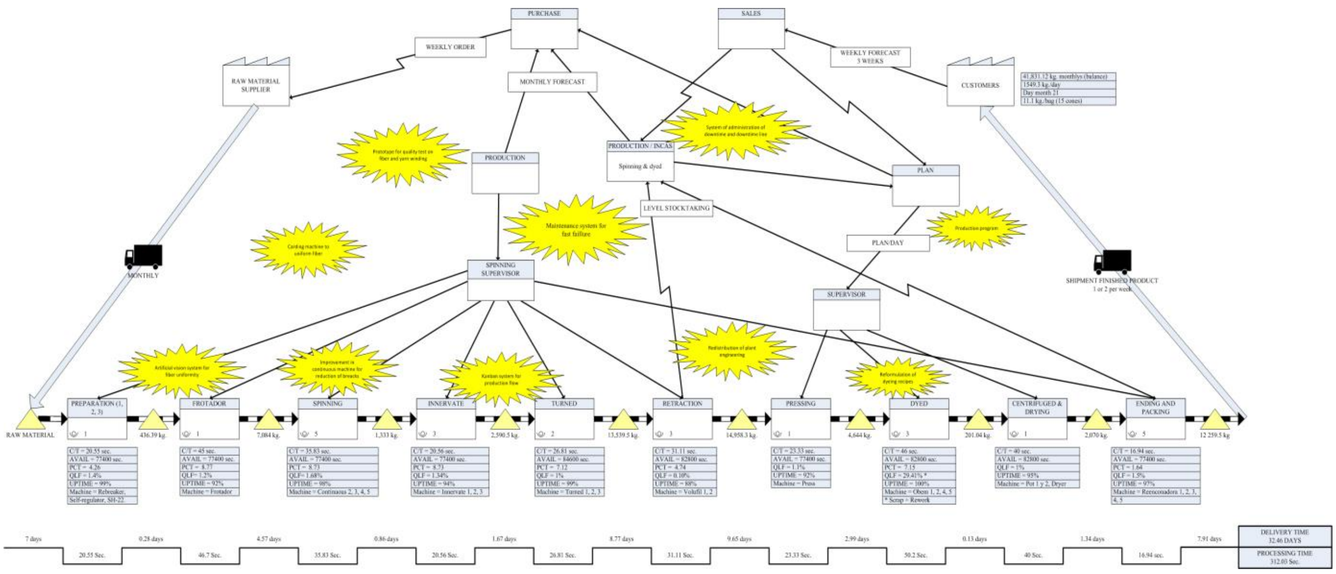
Raw material inventory

The inventory levels of each area are determined, as well as the warehouse of raw material and finished product in order to know the amount of time represented by each volume of material accumulated in each area, these inventories being the product of the planning of production and In the way in which the company manages such inventories, it should be noted that the company makes raw material requisitions every month, in which it is indicated in a disaggregated manner the one required in each week. (Valencia y Díaz, 2015).

With all this information collected and analyzed, the value chain is mapped to have a more clear vision of the way in which the company maintains its operations and how it feeds the information with each one of its respective areas (figure 3.5).

Phase 4 VSM Current Status

Figure 3.5 Current status value chain map



Source: Information obtained in the field

As can be seen in the VSM (figure 3.5), the production line involves various processes, including physical and chemical processes that allow obtaining the texture of a final thread.

The company produces in a push system, that is, the first workstation must produce to feed the next and so on to keep all other processes operating, although sometimes it is the case, where between operations if there is synchronization of time of production, but it can not be said that there is a continuous flow as such, because the parameters to ensure the flow of production are not well defined (Cuatrecasas, 2012).

It is also possible to observe information exchange between several people within the operative process, which sometimes causes confusion, incomplete information or even forgetting, since the information flows from different sides, because in addition there are not always those information channels, in Sometimes there are more ways or just the opposite, they do not happen, this channeling of information can be observed in the following VSM.

As for raw material, it is not always assured its delivery on time, there are cases in which a certain amount arrives and then another, or arrives but not another, which is also essential to start production, in this way when possible do inventory, it is done and when not, it is resorted to stopping part of the line, or in extreme cases to stop a shift.

If we mention the human resource, we do not have a record of the errors that are committed to evaluate them and put a solution or has not implemented tools to define what is the root cause of these problems.

Determination of Takt Time, PCT and OEE

From the information displayed in the VSM, the Takt Time, PCT and OEE indicators are calculated, in order to have a clearer idea of the true situation in which the company is located. Information about total time per shift is added; as starting, food, other (personnel needs) and term, table 3.5 shows the times and the calculation of Takt Time and PCT.

Table 3.5 Calculation of TT-PCT

Total requirements	1549.30	Kg/day		
	1st shift	2nd turn	3rd shift	TOTAL
Turn time (seconds)	28800	28800	28800	86400
Effective seconds				0
Start / End	600	600	600	1800
Meal	1800	1800	1800	5400
Others	600	600	600	1800
Planned dead time	0	0	0	0
Scheduled run time (sec)	25800	25800	25800	77400
Takt time = Scheduled run time / Total requirements (seg/pza)				**49.96**

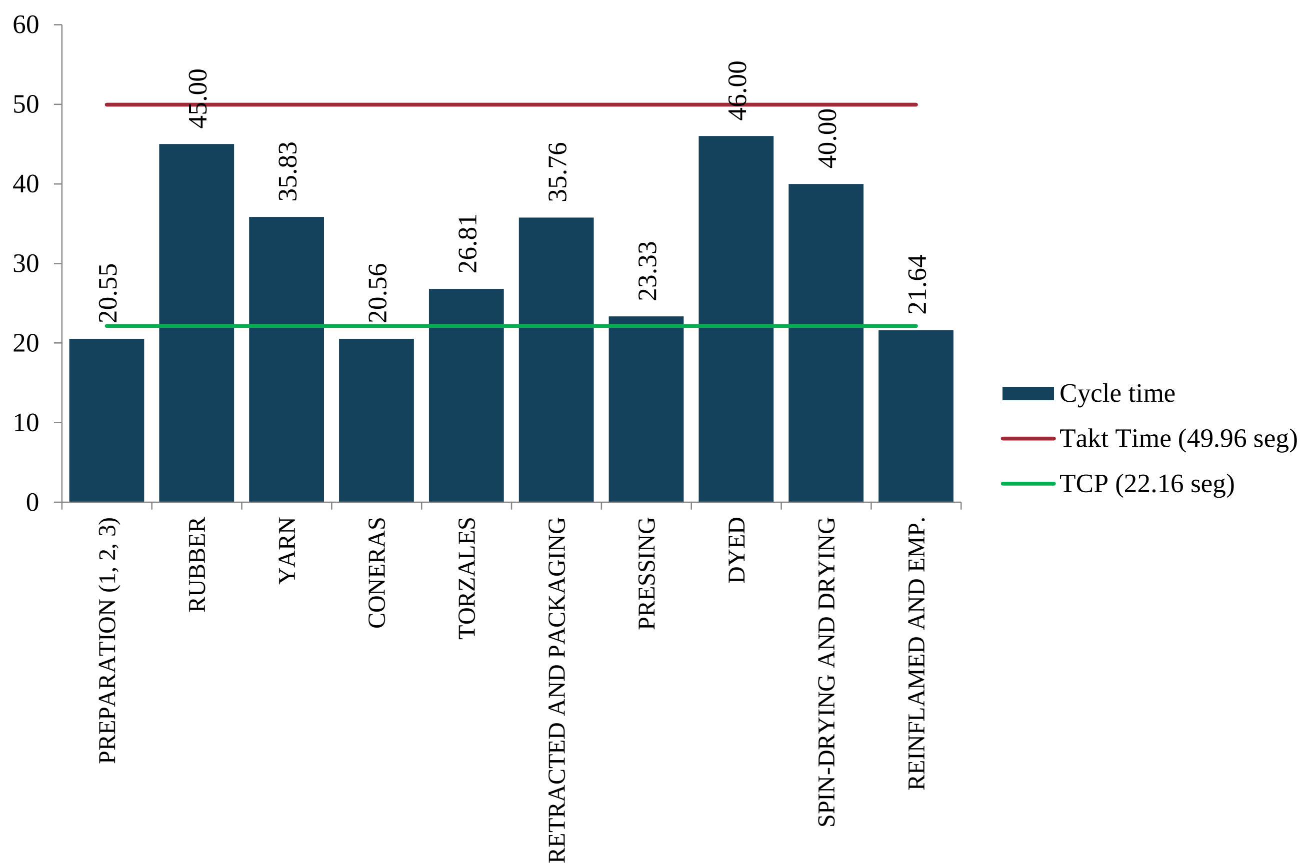
Operational availability	
Dead time (seconds)	29436
Change time (seconds)	0
Operational availability = Actual run time / scheduled run time	61.97%

Planned Cycle Time	
%scrap	10.32%
% rework	29.41%
Others:	
Quality load factor	1.397
PCT	**22.16**

Information of change times (changes, loading of material, etc.) is added. Average percentages of rework, scrap, others and average daily production, obtained from the production reports, in the same way the theoretical production is placed.

In the format there are shaded boxes of yellow and blue colors; the yellow (total requirements) is presented automatically from the leveled production, the blue ones are filled manually. Takt Time can be defined as the speed at which the customer consumes the finished product (Hobbs, 2004). Therefore, in the production line of the parent line is 49.96 sec / kg, in the same way the PCT is observed, which indicates the speed with which the line must operate to meet the demand, which is of 22.16 sec / kg. (Graph 3.4), this means that to meet the demand must be produced faster and therefore the company must assume the waste generated, otherwise if the PCT were the same as the Takt Time, it is for this reason that the company maintains high levels of inventory of both finished product and in each of its processes to cushion the delivery of customer requirements, as well as their respective delivery times.

Grafico 3.4 Comparative TT – PCT



Source: Information obtained in the field

It can also be seen that there is an availability of 61.97% on the line, which means that the company maintains more than a third of its availability as unproductive time (38.03%) derived from the continuous unscheduled stoppages it keeps in each one of its areas observing that the causes of said stoppages are mainly due to the lack of maintenance in the equipment, the bad planning for the requirement of the raw material and in some cases to the bad programming of the production to supply each one of the respective areas.

Global Effectiveness of the Equipment (OEE)

The OEE is an indicator that in percentage terms highlights how the process is, because it encompasses availability, performance and quality in the machinery used in the production line (Villaseñor, 2008). It is important to mention that this indicator must be constantly monitored and at the same time each time interval that the company considers necessary must be updated, or each time improvements or changes are made in the production line, to make sure that it has really had an best result.

In this indicator, three factors are considered:

1. Equipment availability
2. performance
3. Quality

For the first, the total productive time is considered (subtracting from the total available time the unplanned downtime such as equipment failures, supply problems, poor quality, etc.) over the total available time multiplied by one hundred, (from the working day are subtracted the planned downtimes such as start, meal, cleaning etc.).

To calculate the yield (table 3.6), the actual production of the production station or line (obtained from the productive capacity by subtracting the micro-stops, or the reduced speed) from the production capacity multiplied by one hundred is determined.

For the quality, the good production (obtained, subtracting from the real production the pieces that do not fulfill the specifications of the client either of the station or production line) on the real production multiplied by one hundred. Once the data of each one of the work stations has been obtained, the OEE of the production line is obtained (Hernández & Vizán, 2013).

Table 3.6 Calculation of the OEE of the production line.

Availability	**Seg.**	**Factor**
Total productive time	2,675,400.00	87.67%
Programmed dead time	175,800.00	
Total available time	2,851,200.00	
performance	**Kg.**	**Factor**
Real production	25,896.23	34.95%
Micropairs, reduced speed	12,484.16	
Productive capacity	38,380.39	
Quality	**Kg.**	**Factor**
Good production	25,587.85	97.62%
Rework, defective	308.39	
Real production	25,896.23	
OEE = Availability * Performance * Quality		**OEE**
		29.91%

Source: Information obtained in the field

An OEE of less than 65% in world-class companies is considered unacceptable, or of very low competitiveness; in the case of the company, there is an OEE of 29.91%, which is well below the acceptance rates, with the performance with the least competitive value, for which the company must significantly reduce all unscheduled stoppages that remain low productivity to your processes.

Fase 5 Project proposal

From the results obtained in the technical study through the VSM tools the Tack Time - PCT analysis and the calculation of the OEE we realize that the company maintains multiple problems of which the most significant are:

a. Lack of application of the maintenance program to the equipment,
b. The frequent stoppages are not programs that each of the teams present during the work days, whether due to maintenance, quality, lack of material, or processing problems.
c. The low production that is manufactured by the constant unscheduled stoppages.
d. The low quality of the raw material and the constant monitoring in the different stages of the process to guarantee the quality of the yarn
e. The lack of reliable controls that allow identifying variations in the process in order to avoid transfers of problems to subsequent processes.
f. The accumulation of materials in each of the operations generating the use of space and risks of abuse or damage to the material.
g. The lack of technology for efficient quality control.

From the previous points a portfolio of projects is proposed, exhibited in the VSM figure 5, with technical feasibility to be susceptible to be developed and implemented for the correction and / or improvement of its operations, these options allow us to eliminate one or several problems that currently they appear in their productive area.

1. Design and development of a prototype for fiber and yarn winding quality tests.
2. Development of operational availability system for the administration of downtime and line stops.
3. Design and development of carda machine to guarantee the uniformity of the fiber.
4. Development of production program system.
5. Development of artificial vision system for the detection of yarn fiber uniformity in carding process.
6. Modification of yarn guide and spindle in continuous machine for the reduction of yarn breaks.
7. Implementation of kanban for the improvement of the flow of production and decrease of inventories.
8. Redistribution of the plant engineering of the production area for the reduction of inventories and material transfers.
9. Reformulation of dyeing recipes for reducing rework.
10. Development of maintenance system and andón board for quick response to failures presented during the day.

For the selection of the technological projects to be developed and implemented in the production line, it is left to the decision of the general management and the accounting department taking into account the impact on their operations, their need and their availability to carry out investments, so which was chosen in a first line of action to improve the quality of the yarn process, even when the production that the company took and according to the OEE the quality is relatively good; To achieve this, a lot of resources were wasted, such as time in rework and line stops, and taking the experience of the production experts, it was determined that the key process to reduce unscheduled stoppages and rework is in the fiber preparation where the machines designed to make the alignment of all fiber to ensure the uniformity of these, however the machines available for this process do not have an instrument or continuous monitoring system to monitor this process, leaving this work in the decision criteria of the operator, for which the development of an artificial vision system is proposed for the detection of the uniformity of the yarn fiber in the carding process.

For the second proposal, a project was considered that would allow the elimination of other waste, such as the accumulation of materials between processes, the reduction of unscheduled stoppages, the manipulation of materials, the improvement of information channels between the different productive and administrative areas, as well as the with key indicators to facilitate decision making and speed up response times, which is why we decided to implement a kanban system with artificial vision for the acquisition of information in order to increase the added value of the resources used in the production line.

Both proposals are decided to participate to obtain funds from the program of stimuli to the research, technological development and innovation of CONACYT in the modality of INNOVAPYME being these accepted for its implementation and development for the benefit of the company.

Project 1 (Application No. 000000000199635)

Technological development of fiber filament coating by continuous torsion to ensure uniformity by Bayesian prediction.

The technological development will allow:

1. Manufacture of yarn with central core that allows to support the different fiber compositions.
2. Monitoring by artificial vision of fiber, to ensure the amount of fiber during the manufacturing process

The objective of this project is a technological development to ensure uniformity by Bayesian prediction in the manufacture of yarn, it is intended to avoid 30% of waste in manufacturing due to the lack of homogeneity of the fiber in the process given the nature of the fiber , the solution is to develop a system that allows to predict the moment where the yarn will come out with fiber variations outside the standard, there the process will stop before it becomes entangled in the cones, unlike the competitors they waste complete cones when they are detected After the manufacturing process, the evidence that this type of improvement is correct are the new machines that have been patented in Asian countries, where innovations are aimed at guaranteeing the diameter, finish, length, and shape of the yarn, as well as the composition of fiber and the effect. In such a way that these values are very close to the real values. This type of process has been the trend of the thread in the coming years globally

Scientific-technological objectives

1. Design of high-speed artificial vision system for wire monitoring with Bayesian prediction algorithms.
2. Monitor the process by Bayesian prediction.

Expected benefits

1. Obtain the automated and accurate monitoring system for the manufacture of yarn
2. Obtain a monitoring system for the critical variables of the process (diameter, shape, composition and effect).
3. Increase productivity by reducing waste by not complying with compositional characteristics.
4. Offer a better customer service that meets the quality standards NMX-A-049-1983, and MX-A-147-1970.
5. Satisfying the national market and increasing the participation in the textile industry by 7%.
6. Obtain a spinning prototype with artificial vision monitoring.
7. Involve students in the project for the realization of stays and stays.
8. Strengthen the Business-HEIs link.
9. Position the participating HEIs as an option for companies in the region that wish to carry out technological developments.
10. Increase the competitiveness of textile companies
11. Maintain and / or increase the number of jobs in the textile industry

Impacts

1. Technological development of a system for monitoring process variables and yarn winding, to increase productivity by predicting failures ensuring yarn quality and losses by winding yarns of different dimensions to those specified.
2. Generation of employment sources for the textile company of the Tlaxcala-Puebla region.
3. Increase the permanence in the market of the company when venturing into new market segments with few national competitors.
4. Participation in external markets, creating technology-based products and processes that meet international and export quality standards.

Results obtained

At the end of the project, the results obtained from the implementation of the technological development were:

1. Reduction of operating costs given that waste levels were reduced.
2. Increase in sales resulting from the reduction of waste in the company, not only decreased this index, but this production became an increase in volume to offer more production to its customers.
3. Higher profits due to the decrease of its product waste and the increase in its sales.
4. Three new products were developed since, having a greater control of their processes, their quality was benefited and the opportunity is generated to design and produce a new line of products that previously was difficult to manufacture, due to the conditions that prevailed in the company.
5. A patent is generated to protect the technological development implemented, as well as the type of processing that the company will use to manufacture the new product line.

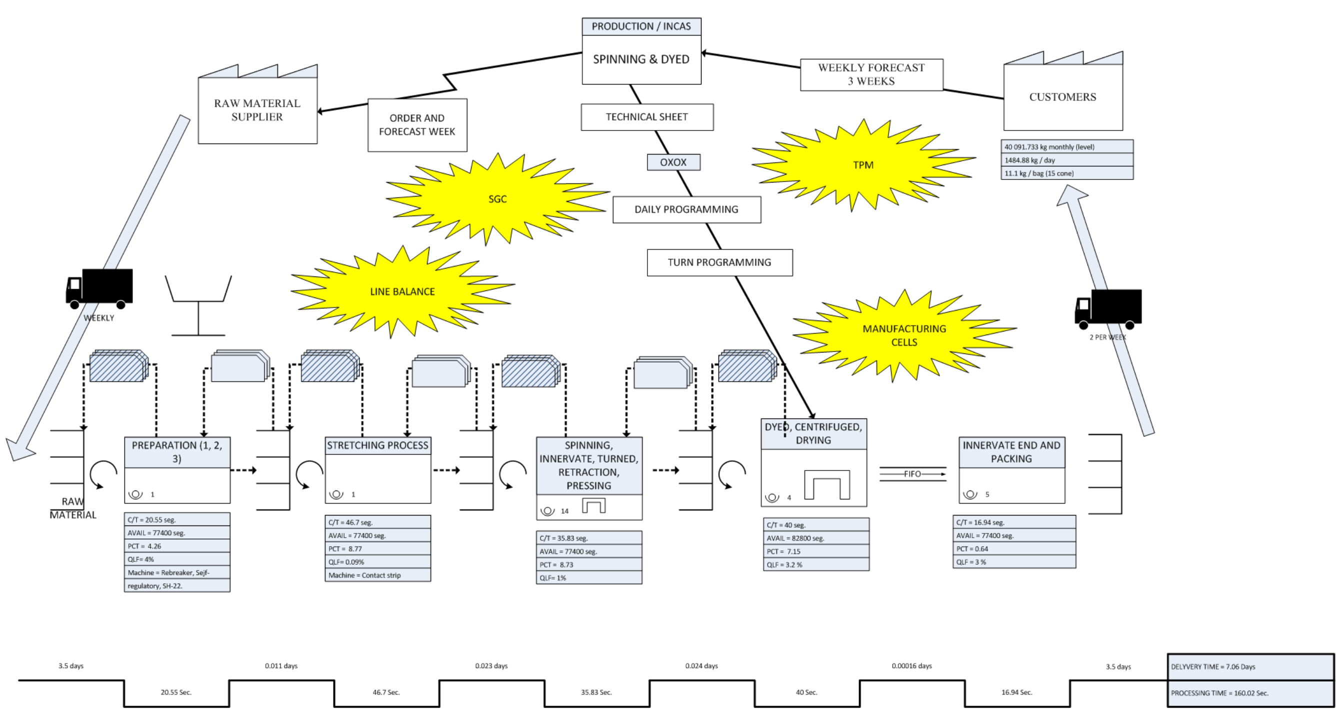
Project 2 (Application No. 000000000218755)

Kanban system with artificial vision for information acquisition in order to increase the Lean Time (added value) of the resources used in the production line under the One Piece Flow concept.

His current goal is the technological development of an automation system with a human touch called Kanban, (Socconini, 2016). Which, through the use of artificial vision cameras and a new flow of materials, will allow to control the production volume through the use of QR labels placed in the containers and sensors in conveyor belts, which will be processed and fed back by the system to project real-time results both in screens located in each thread process and in administrative areas, allowing the production plan to communicate only to the final assembly line, this line will go to the subsequent processes to extract production lots firing a chain of communication between these processes, where each will know automatically how and when to produce the parts required by the end customer avoiding the generation of isolated processes and therefore overproduction, in this way the management will be done backwards the process of complete manufacturing, resulting in the action of the required conditions significantly reducing the management work.

This technological development will allow to reduce the waste of overprocessing, scrap, response times, delivery times, inventory reduction, quality increase, and a better management of production planning (figure 3.6).

Figure 3.6 Value chain future state map

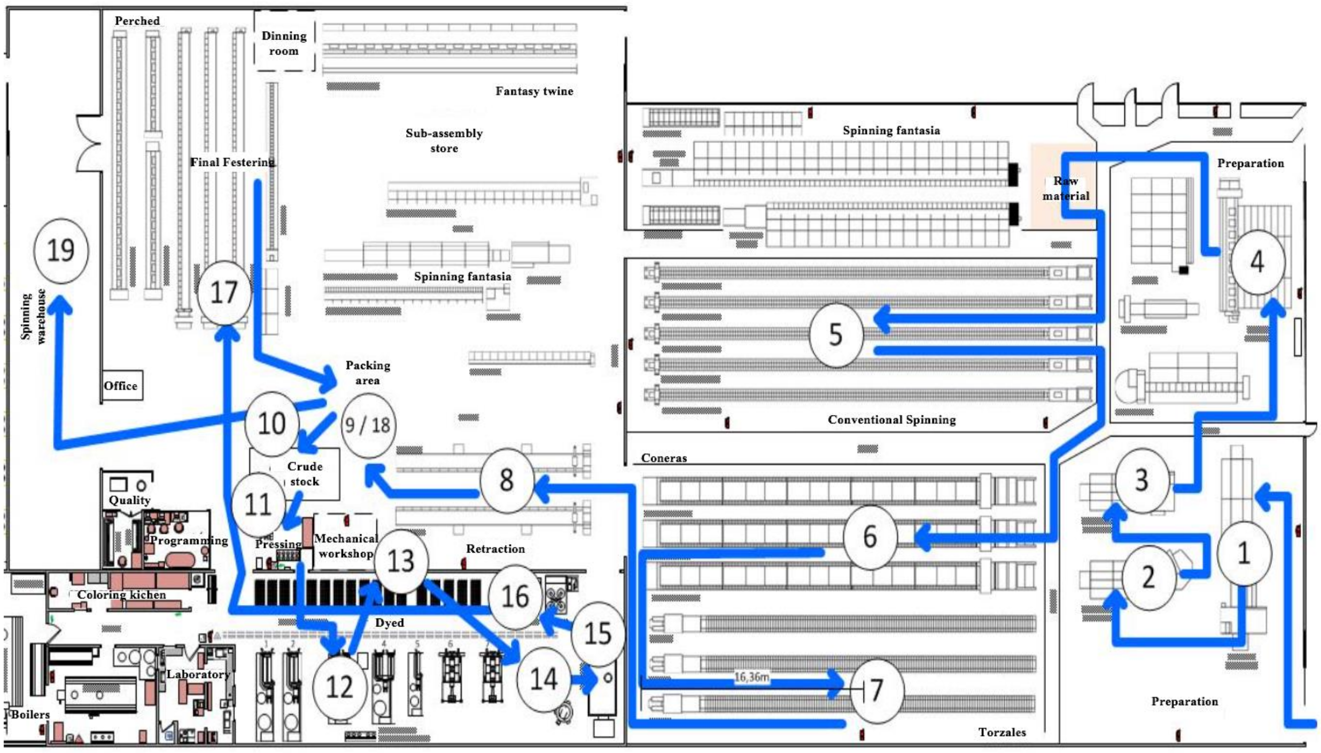


Source: Information obtained in the field

Distribution of physical spaces

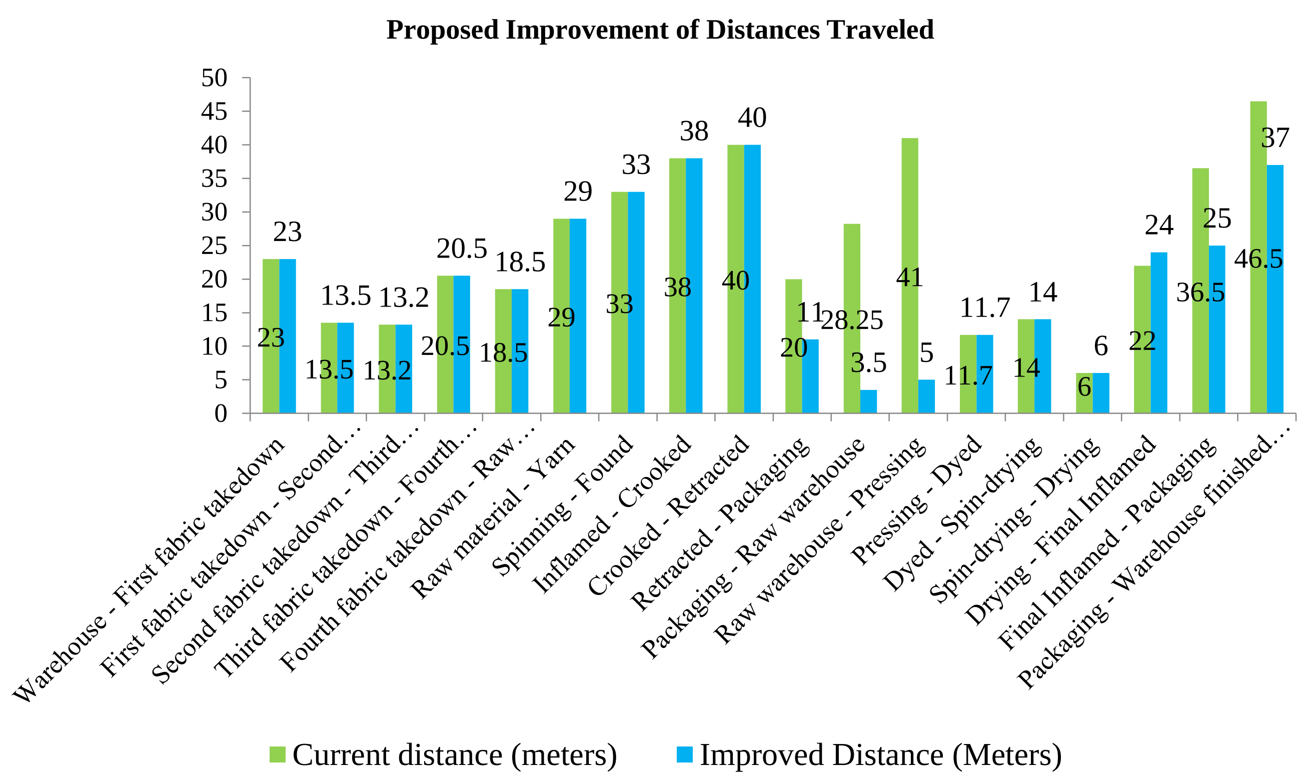
According to the route diagram of the production line (figure 3.3) deficiencies have been found that lead to the material being moved from one end to the other inside the plant, causing an increase in waste such as transportation and unnecessary movements; therefore, a redistribution of spaces is proposed to decrease the distances of transfer and therefore ensure a better flow of material. Next, the route diagram (figure 3.7) is presented, which is intended to decrease approximately 20% in distances or reduce the trajectory around 88.75 meters.

Figure 3.7 Layout with proposal of the manufacturing process



Source: Information obtained field

Grafico 3.5 Distances traveled from the process by improved area



Source: Information obtained from the survey

In graphic 3.5 the distance traveled in a before and after is observed, in blue the improvements are observed, and in green color the current distance is observed; where the decrease of distances in some areas is observed although they were not in all given that some equipment by its condition and feeding of inputs and resources is difficult to move them if it is possible to improve the distribution of some others to simplify the movements and movements of materials.

Scientific-technological objectives

1. System design by Kanban with artificial vision for process monitoring with Bayesian prediction
2. Synchronization of the process to increase the flow of production to subsequent processes
3. Monitoring the process by Bayesian prediction in real time.

Expected benefits

The Kanban system with artificial vision will be obtained for information acquisition in the thread production line which will transmit information in real time of the pacemaker process to each one of the subsequent processes through database interface visualized in screens placed in each department of work which will show the status of the preceding process in order to manufacture only the necessary parts with the necessary materials, at the time they are needed and in the quantity in which the customer is needed. With this system is expected to improve the synchronization between processes as well as improving the flow of both information and materials, while it is expected to decrease the scrap index by 30% of the current value, reduce delivery times from 32 days to 7.6 days with respect to inventory levels, this will reduce delivery times and therefore customer claims for lack of product.

Impacts

A Kanban system with artificial vision and processing of material status in the productive areas, will allow the company to move from a traditional process to a world-class manufacturing process with the use of new lean systems that will rebound, in various competitive advantages:

1. The system will allow to synchronize the yarn processes avoiding the generation of productive islands disconnected with the voice of the client, allowing him to market products with world-class processes of excellence.
2. The number of batches recovered in the dyeing area will be reduced by 10% with respect to the current value.
3. By implementing the Kanban system, a more efficient administration of resources will be obtained, especially human resources, by assigning activities that generate added value to the product.
4. When realizing the prototype of the Kanban system with artificial vision with technology of the HEIs it will be less expensive the redesigns, repair and damage updates to have local specialists.
5. The technology and the services of lean manufacturing by artificial vision can be transferred to any company in Mexico, companies of the central zone of Mexico and regional where it can be transferred without major modifications and be used for other applications and / or processes.
6. Upon entering the world-class manufacturing in Mexico, it will allow it to be the only manufacturer in Latin America with world-class processes supported by artificial vision technology and Bayesian prediction.
7. Offer a better service to the client that satisfies the quality standards (NMX-A-049-1983, and NMX-A-147-1970)
8. Satisfying the national market and increasing the industry's participation in this sector by 7%.

5. Results

Within the results obtained:

1. Although there was no implementation of the Lean Manufacturing methodology, the use of the value chain and its auxiliary tools was a trigger to identify areas of opportunity and guide the process of continuous improvement.
2. Regarding the technical feasibility and viability of the portfolio of technological innovation projects, a portfolio of 10 feasible projects is generated.

3. For the analysis of the viability of the portfolio of technological innovation projects, the technological projects to be developed and implemented in the production line are left to the decision of the general management and the accounting department, taking into account the impact on their operations, their need and your availability to carry out investments.
4. Participates with technological innovation projects in the program of incentives to technological innovation of CONACyT.
   a. Project number 5 of the project portfolio is presented in the convocation of the incentive program for research, technological development and innovation 2013 of CONACYT, in its INNOVAPYME modality supported with $ 2, 380,000. (CONACYT, 2013)
   b. The project number 7 of the project portfolio is presented in convocation of the program of stimuli to the investigation, technological development and innovation 2014 of CONACYT, in its modality of INNOVAPYME supported with $ 4, 410,000. (CONACYT, 2014)
5. Training of human resources, qualification of a student of the academic program of industrial engineering of the Polytechnic University of Tlaxcala.
6. Academic production for the academic body with registration PRODEP CA-04-UPTLAX

6. Conclusions

A company can grow as much as it has potential to face the problems that arise; In this analysis we have studied how is currently the production line of its main products (parent line), where deficiencies were found but also capabilities, which if you work on them, it is evident that there will be crucial changes that will allow development and be a leading company in the field, which will be possible only with hard work, because the benefits are not immediately tangible, it requires dedication, human potential and time, including years to see positive results.

The methodology used is considered a good practice since it supported the technical study under the CONACyT norm of the two proposed projects. The portfolios of projects under this methodology represent a business opportunity to reduce manufacturing costs to integrate world-class processes, and be benefited with economic support for the development of their projects that aim to increase the integration of national inputs and give a step to consolidate the productive chains.

Through the VSM tool, it is possible to analyze in graphic form how the value chain is, and considering the business strategy of the company; be in the possibility of establishing technological and innovation strategies that contribute to improving the competitiveness of the company.

The purpose of these proposals was on the one hand to increase the productivity of the company through the reduction of waste generated in their operational areas, improving the information flow and quality of these areas and on the other hand creating future lines of action such as deepening the value of existing processes, streamlining its administration process, reducing its deficit of specialized knowledge and promoting a global and competitive vision to face the challenges and opportunities for the company to access new markets, expand its technological base and of knowledge, and increase its production.

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Chapter 4 A case of Software automation through the use of "Robotic Process Automation" tools

Capítulo 4 Un caso de automatización de Software a través del uso de herramientas de "Robotic Process Automation"

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Abstract

The automotive industry has positioned itself in Mexico as one of the main producers and exporters, due to its access to other markets, and with prospects for high growth; facing challenges, like a very competitive environment, migration towards new technologies, and research. This chapter explores a case of software automation, using robotic process automation tools aimed at learning process flows quickly and dynamically. The product used is called RPA (Robotic Process Automation), it is a general software, developed by a company, which can be customized, or trained, by technicians of a user company, as is the case that is presented, to turn it into a virtual worker or Robot, it is able to carry out transactions, or activities to support the business in finance, purchasing or accounting. This software is based on artificial intelligence techniques. Its implementation is done through the Lean Six Sigma methodology and the use of its five-step approach (DMAIC Define, Measure, Analyze, Improve and Control) clearly defining the problem, sizing it, analyzing the possible causes, delivering the best alternative solution and controlling the results obtained, to make the solution sustainable. The aim is to show through a real example, the use of a RPA was implemented to make tasks more efficient within a massive price update process. It describes the use of a computer robot, which is the best way to solve problems in the industry by reducing time and costs due to human errors, in repetitive tasks within the information systems. The results in terms of efficiency were of 96.4% reduction in processing time of the price update, and the error rate was 0%.

Automation, Robotic Process Automation, Software Automation Tools, Lean Six Sigma, DMAIC

1. Introduction

The automotive industry is one of the main markets for the development of Mexico, because it has been consolidated as a sector that is undergoing a process of constant transformation mainly due to its design and innovation that are outstanding elements in that industry. Each year, Mexico extends its collaboration in various engineering activities, adding to the search for alternatives to examine solutions and respond to the challenges it faces around the world. This requires keeping an eye on the changes that are taking place and taking advantage of the opportunities that this industry represents, especially in Mexico..

The term "Robotics" has become a reference in this sector; it is very important to highlight the use of its tools to explain the exponential growth it is having, and the direct impact in the business field. On an existing technology, it has been able to respond to the expectations required to reduce complex processes, being able to automatically execute assigned tasks, manipulate data and drive technology towards a new way of reducing time and costs. Innovation is the main value of this technology, because it has been the vital element in the improvement of process management solutions. Understanding the automation of processes through robots, requires understanding the software that for decades have been the basis of computer science. The purpose of this chapter is to show how the use of an RPA was implemented through a real example. [1] (Robotic Process Automation) to make the tasks more efficient within a massive price update process; product based on artificial intelligence techniques, developed by a company, which allows to connect different computer systems with each other, generate information, create new databases, and execute tasks in the business world.

The real example to explain the use of RPA, consisted in the process of updating prices in an automotive company in Puebla. In this, it will be appreciated the optimization and improvement of the management through its implementation, which allowed to reach an efficiency of 96.4% in the reduction of the time of data processing, and error rate of 0%, thanks to the use of the computer robot. To have an overview of the information, we resorted to the use of the "Lean Six Sigma" methodology[2] and its five-step approach (DMAIC Defined, Measured, Analyzed, Improved and Controlled) that leads to a clear understanding of the problem, realizes the dimensioning of this, analyzes the possible causes, delivers the best solution alternative and controls the results obtained to make the solution sustainable.

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[1] and its five-step approach (DMAIC Defined, Measured, Analyzed, Improved and Controlled) that leads to a clear understanding of the problem, realizes the dimensioning of this, analyzes the possible causes, delivers the best solution and controls the results obtained make the solution sustainable (Galusha, 2017).

[2] Six sigma is a rigorous improvement methodology developed by Motorola in the 80s, whose fundamental principle is the customer focus. Use the DMAIC process and statistical methods in order to: Define the problems and situations to improve, Measure to obtain information and data, Analyze the information collected, Implement process improvements and finally, Control the processes or products in order to achieve sustained results, which in turn generates a cycle of continuous improvement (Mantilla CElis & SAnchez García, 2012).

This is a new trend that promotes the increase of productivity, the reduction of errors, and the quality of products in the digital world of every company. The process to migrate a traditional software system managed by users to an automated system through the use of RPA, is explained step by step in this chapter. Something very important to take into account before taking the first step, is that the user company must clearly define their information needs through sessions to establish objectives and determine information requirements in which all the directors participate simultaneously. the departments involved and the direct users of said information.

2. Theoretical review

2.1 Legacy Systems

Information systems are one of the main management tools in organizations, their level of complexity is related to the product or service offered, and its sophistication directly linked to the interest groups that the company has. An information system:

"It is a formal set of processes that, operating on a data collection structured according to the needs of the company, collect, prepare and selectively distribute the necessary information for the operation of said company and for the corresponding management and control activities, supporting , at least in part, the decision-making processes necessary to perform business functions of the company in accordance with its strategy" (Andreu, 1991).

In the case of "Legacy or legacy" systems, they present challenges for the managers of information systems within the companies, given that it is often necessary to maintain them due to their efficiency, usability and usability; but it is also a limitation when planning new solutions that include using the information that these systems handle. They are named like this because they represent those tools conceived decades previous to the current one, and they are the support of the central operations of many companies, but they have been relegated in time, due to their limitations (Rodríguez, 2015).

Typification of "Legacy or legacy systems"

Transactional systems: Are those, whose objective is to carry out the tasks of the support processes to give value to the organization, such as: personnel, logistics, accounting, finance, sales management, and others. Among them you can also count on ERP systems (Enterprise Resource Planning)[3] that are the integrated systems that consist of all the main modules for large organizations, mostly these systems are sold by large companies such as "People Soft" and SAP (Systems, Applications and Products)[4] , also Peruvian companies such as Novatronic, Sonda, Ofisis, all with their own scheme and to which companies have to adapt, but not the unique systems in which each one has its own forms and working models, with its own formats.
The transactional systems register the day to day of the organizations, the most common are the accounting systems (Muñoz Recuay, 2007).

Automated process systems: are used together with electronic or mechanical equipment; they are mostly made with low level languages such as "Assembler". These systems record data. As measures of time, power, production, heat, fuel level. In the case of motors, they control the operation of the machines by means of predefined and repetitive programs and may or may not store information (Muñoz Recuay, 2007).

Talking about evolution involves several aspects, from correction of failures or problems presented, the customary maintenance every so often, going through an adaptation to new needs, adding new functionalities and processes, ending with the total disposal of the whole system, that is, giving it low and / or replace it with a totally new one.

[3] ERP It is a set of tools that integrate the departments and functions of a company through a single computer system. It works with a single database, allowing different departments to share information and communicate with each other (León, 2008).
[4] SAP. It was founded in 1972 in the City of Mannheim, Germany, by former IBM employees (Claus Wellenreuther, Hans-Werner Hector, Klaus Tschira, Dietmar Hopp and Hasso Plattner) under the name of "SAP Systemanalyse, Anwendungen und Programmentwicklung". The name was taken from the division in which they worked at IBM. The SAP corporation was founded in 1972 and has developed into the fifth largest software company in the world. (RedSinergia, 2017).

On the other hand, from the beginning, SAP (Systems, Applications and Products for Data Processing) was dedicated to business applications. With collaboration with IT business executives (Information Technology)[5], and having partners around the world, SAP developed a unique way to understand the challenges encountered in implementing technology solutions for business users, developing software that can help companies integrate their business processes, helping the entire company work orderly. Today, SAP is the largest software developer for business applications in the world and the fourth largest independent software provider, in absolute terms. More than 7,500 companies (more than 15,000 installations), in more than 90 countries, chose SAP systems to control the processes of finance, manufacturing, sales, distribution and human resources, essential for their operations (Technology and IT, 2015).

With more than 1000 business processes included in the software, SAP can integrate an entire organization. With SAP it is possible to share information in real time between the different sectors of the company, suppliers and distributors, whether a company of 50 or 100,000 employees.

2.1 Automation

Industrial automation is the use of control systems, such as computers or robots, and information technologies to manage different processes and machinery in an industry to replace diverse tasks performed by a human being. Although the term mechanization is often used to refer to the simple substitution of human labor for machines, automation generally implies the integration of machines into a system of self-government (Aguirre & Rodriguez, 2017). The term automation was coined in the automotive industry around 1946 to describe the increase in the use of automatic devices and controls in mechanized production lines.

Automation can be defined as a technology related to the realization of a process through programmed commands, combined with an automatic feedback control to guarantee the correct execution of the instructions. The resulting system is capable of operating without human intervention. The development of this technology has become increasingly dependent on the use of computers and technologies related to computing. As a result, automated systems have become increasingly sophisticated and complex. Advanced systems represent a level of capacity and performance that surpasses in many ways the abilities of humans to perform the same activities (Groover, 2018). Automation technology has matured to the point where other technologies have developed from it so they have achieved recognition and a state of their own. Robotics is one of these technologies; is a specialized branch of automation in which the automatic machine possesses certain anthropomorphic or human characteristics.

2.2 Automation in the automotive industry

The digitalization and automation of services, the internet of things, robots, "cobots"[6], virtual and augmented reality, manufacturing execution systems, software for collaborative networks and the analysis of "Big data"[7]; therefore, they allow optimizing different processes inside and outside factories and making companies more efficient. The integration of these technologies brought, the already well-known concept of Industry 4.0[8], that must be developed in order not to be relegated, as a change in the traditional social order that will bring new niches of employment, because, although automation can affect the work of some sector, someone should develop new systems and robots, which means labor niches for the future.

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[5] Set of tools, processes and methodologies (such as coding / programming, data communications, data conversion, storage and retrieval, systems analysis and design, systems control) and associated teams used to collect, process and present information. In general terms, IT also includes office automation, multimedia and telecommunications (WebFinance Inc., 2018).

[6] The cobots are passive devices whose motors, of low power, could not move the robot by themselves. Your goal is to change the transmission ratio of each joint, but the operator provides all the power for movement. The control is in charge of track tracking and the operator is concerned with directing the manipulator approximately. An analogy of COBOT could be a train and its tracks (Nicolás Store, 2009).

[7] Big data It is the trend in the advancement of technology that has opened the doors to a new approach to understanding and decision making, which is used to describe enormous amounts of data (structured, unstructured and semi-structured) that would take too much time and would be very expensive to load them into a relational database for analysis. In such a way that, the concept of Big Data applies to all that information that can not be processed or analyzed using traditional processes or tools (Barranco Fragoso, 2012).

[8] Industry 4.0. it refers to a new model of organization and control of the value chain through the life cycle of the product and throughout the manufacturing systems supported and made possible by information technologies. The term industry 4.0 is widely used in Europe, although it was coined in Germany. It is also common to refer to this concept with terms such as "Smart Factory" or "Industrial Internet" (Val Román del, 2016).

The final result is that Industry 4.0 is neither a factor that drives the work nor one that destroys it, according to the Institute for the Labor Market and Occupational Research (IAB). Digitization could lead to the loss of thousands of jobs. At the same time, thousands more may arise. However, education and additional training are particularly important to cushion these displacements (Pardinas, 2016).

The automotive industry is the engine of Mexico's national economy; the next step is to develop research and innovation, because new investments will be directed towards the most technologically advanced countries, estimate representatives of the sector and researchers. After Mexico was positioned as the seventh producer and the fourth world exporter of vehicles, Fausto Cuevas, general director of the Mexican Association of the Automotive Industry (AMIA) (Executive, 2017) affirms that it is necessary to have a strong participation in research projects and innovation. Mexico is already preparing, and today there are about 30 research and development centers where the industry and local and federal governments has been given the task of seeking the link between the academy and companies, both terminally as auto parts.

The main challenge is what industries must do to remain within the framework of the industrial revolution 4.0. For example, below, some recent cases are mentioned:

"Ford Motor Company announced that it is already carrying out tests to manufacture auto parts and automotive parts in third-dimensional printers" (Notimex, 2017).

"The German Volkswagen, meanwhile, began to develop vehicles with augmented reality technology in virtual laboratories, which could revolutionize the work of automotive engineers and designers. Not to mention the advances in connectivity, so that, in about three years, all the latest model vehicles will have "WiFi on board", estimated the Telefonica Mexico's B2B Vice President, Mariano Moral." (Ejecutivo R. M., 2017).

"On the other hand, models with the On Star service of General Motors 2018 already include internet connectivity from any remote location where the vehicle is located, with the ability to connect up to seven devices on board and 15 meters range around the unity" (Vivero, 2017).

"Telefónica ventures into the automotive sector to facilitate connectivity in the Cadillac, Buick, Chevrolet and GMC models" (AN, 2017).

Robotization will have an impact on labor costs, with increases in the long term, as a result of which investments will migrate to developed countries, allowing them to develop increasingly sophisticated technological automation platforms. And if there is no reconversion to that status in the industry, there are studies that argue that, in Mexico, 51 percent of manufacturing employment would be at risk (Bensusán, Eichhortst, & Rodríguez , 2017). For Julio César Morales, director of the Engineering Division of the Universidad del Valle de México (UVM) Campus Lomas Verdes. The automotive industry in Mexico has 70% automation in its manufacturing process, for example, in a plant around 80% of the technological base, are robotic arms that collaborate from the assembly, to the painting of a vehicle. As well as programmed logistic controller technologies, integrated business management systems (SIM), an automation process reduces the level of error in the final product by 50% and increases productivity by 40% (Rosagel, 2011).

In the modern computer context refer to the automation of processes causes large oppositions. First, because it is understood as a change of execution in the way companies or businesses conduct themselves. It is clear and key that implementing automatic execution within a company is a change of great impact: technicians and professionals are not sensitized, in an initial stage, although everything changes once the true results of the execution of those processes are appreciated when they are automated.

The study of process automation, establishes that its correct analysis is directly related to the type of business or company that is being automated. If the organization manages a small amount of data it is relatively easy to manage and control information through manual execution. On the other hand, if the volume of data is significant, automation is the indicated way. Automation, is not the execution of processes in parallel.

The automation of processes is a control of data and processes that guarantees quality in the execution and availability of information, reducing errors and taking advantage of each material and human resource of the organization. In this way, programming and execution standards are set, and the logic of business is transparent for any area that is involved in corporate management. It can also be seen as the combination of four fundamental principles: mechanization, continuity of the process, automatic control; and economic, social and technological rationalization (Shimon, Y Nof, 2009).

The expansion of technological capabilities and the reduction of robot costs have increased the use of robots in new activities. The generalization of the use of robots multiplied and everything indicates that it will grow in the following years. The manufacturing industry was the traditional sector of use of robots and it still is, but it has also spread in agriculture, the construction sector for prefabricated buildings and in homes to perform dust extraction, washing clothes and crockery, as auxiliary in cleaning tasks, etc.

2.3 Robotic Process Automation (RPA)

Software robots learn powerful and dynamic process flows; In addition, they can repeat them hundreds of times. So, what exactly does RPA mean and what do these software robots do with their powerful and dynamic process flows? Basically what they do is integrate and automate a flow of data or information that connects one digital system to another (Willcoks, 2015). In simple terms, robots can reproduce the same tasks that a person performs while working with his computer. Repetitive tasks that bore the staff a lot; how to re-type what is on one screen in another or cut and paste from one application to another system, website, web portal, e-mail, etc. In many jobs it is common to consult different web platforms looking for orders, purchase orders, requests, claims and when new items appear, triggering some action in the department, in the company, in the corporate ERP, etc. Processes that, indeed, bore anyone.

The objective is not to replace, but to complement and improve. It is not about replacing the investment in existing technology in the organization. It's about filling gaps, eliminating manual tasks, improving current processes. It is about questioning how they perform things on a day-to-day basis and questioning what tasks are carried out to discover that, many of them, could be done in another way. The RPA technology offers a wide variety of applications, since in areas of work related to the tasks of "back-office" in finance, purchasing or accounting will accelerate data entry, billing management or information on the sale of products (Vector Consultoria, 2017).

2.4 Benefits of using RPA

According to T-Systems International Gmbh (2018), the reduction of costs, allows to achieve large savings directly and indirectly, up to 50%, coupled with the large increase in productivity will achieve investment returns of the order of six to seven times; increase in profitability, in terms of the process efficiency multiplied by 9, a process BPO (Business Process Operations) of insurance coverage is performed in approximately 12 minutes, however, robotic automation manages to complete the process in just 4 minutes, tripling the volume of operations; quality service, greater accuracy and better service to customers, that is, the attention span of robots is unlimited and they do not make mistakes in their calculations, thus eliminating human failure; security, regarding the alignment with the existing network security policies and access rights of the applications; specialization of the workers, referring to the employees who performed those tasks assigned to the RPA can now have a more complex occupation, contributing more value to the company; increase in sales, as a result of the efficiency and speed of the robots, the service offered to real customers is almost immediate, increasing their satisfaction (Vector Consultoria, 2017).

According to the consulting firm Deloitte (2017), the current robotization scale allows processes to be executed:

- **Specific -** technically simple and repetitive transactional tasks that are part of a larger function within the company**;**
- **Multifunctional -** similar processes that run through multiple functions in the organization. The coordination of several robots allows the optimization of current processes**;**
- **Integrals -** complete processes that require the integration of robots in all stages of the same, streamlining and optimizing their management.

The ability of organizations to adapt plays a fundamental role in their competitiveness, solvency and stability. The better the integration of your human and technological infrastructure, the greater the benefit See Figure 4.1 (Deloitte, 2017).

Figure 4.1 Deloitte Global

Fuente: Deloitte Global

The projection in the use of this technology according to Gartner (2017) for the year 2020, 85% of the data management processes will be executed without human intervention. In the same way, the following benefits of the use of automation instead of the execution of manual tasks show considerable performance indicators in several aspects: repetitive tasks are improved by 21%, error rates are reduced in the order of 21 %, improvement in the standardization of business flow processes by 19%, the reliance on multi-systems and screens to complete processes is reduced by 14% and the dependency for the execution of direct processes is reduced by 11%. There are several features of using an RPA, the first software robots are configured to perform tasks or activities with the steps in the same way as a human user, they are also trained or configured, using demonstration steps only once that you will have to execute in subsequent repetitive way, without using programming code, this means that the robots are trained by the people who actually perform the tasks.

The RPA are easy to use and require technical support for their use and once the robot is trained, it will execute the tasks without error rate. Any strategy selected to execute the tasks of the automotive consortium regarding the updating of vehicle prices is the use of RPA. Among the industries that have used the RPA of UI Path in 2017 are NASA, Oracle, Accenture, PWC, Deloitte, Sumitomo, Cognizant, among others and that have helped to save more than 650 thousand hours and project savings by 2019 of 3 million hours and 250 automated users only for the Sumitomo automotive industry, according to (UiPath, 2018).

3. Methodology

The methodology used for the implementation of the case was Lean Six Sigma through the phases like "Define, Measure, Analyze, Improve, Control" (DMAIC) in English language that mean Define, Measure, Analyze, Improve and Control.

Six Sigma is a methodology that provides tools to optimize costs, improve quality or reduce processing times for products or services. Specifically in this case focuses on the reduction of delivery times of services for updating the prices of products of the automotive industry.

To do this, the Six Sigma methodology, based on the DMAIC model, establishes the steps to be able to carry out the improvement:

- Define: Identify the problem that causes decrease in customer satisfaction, the work effort required.
- Measure: Collect information on the current performance of the process.
- Analyze: Study the process to identify the points of pain that you have, such as tasks that do not add value to the client and are not necessary, which are commonly referred to as waste.
- Improve: Corrective actions that are implemented to make the service delivery faster and improve customer satisfaction.

− Control: Validate and monitor that the improvements are sustainable and have a positive effect on service delivery times.

Some of the tools used in this case and also common within the DMAIC model in the Six Sigma methodology are the following:

Table 4.1 Correlation of DMAIC phases in relation to the Lean Six Sigma methodology

Phase	Tool	Description
Definition	Voice of the Client	Document that expresses the client's needs obtained through an interview or petition document.
Measurement	Analysis of differences Control charts	Tool used to measure the differences between the expected value (for this case, expected processing time) and the current value of the process Measures the minimum specifications required by the customer compared to the real ones
Analysis	Root cause analysis	Document that explains in a structured way the causes that cause the pain detected, in this case of study, the processing time longer than expected by the client
Improvement	Brainstorming SIPOC	Tool used among specialists to determine the best solutions to a detected problem Graphical tool that describes the steps to follow to implement the solution avoiding the use of tasks that do not add value, called waste
Control	Measuring boards	Tool to measure the efficiencies achieved before, during and after the execution of the improvement tasks

Source: Prepared based on the working documents of the project, and in accordance with the confidentiality rules of the company

The documents, boards and deliverables; they are not available for the most part in this chapter, derived from the rights that the company restricts, as well as the confidential information of the data that these entail. Each of the phases have a relevant importance to achieve the improvement of the process, however, the critical point lies in the improvement where it is essential to establish the tasks that will make the efficiencies, a reality without losing the focus of the dimensioning of the objective.

Therefore, the most used tool for the identification of these limits is the SIPOC (Suppliers, Inputs, Process, Output, Customers), which has been used since the 80s in the framework of total quality management and its use is included as a tool within the Six Sigma methodology, Lean Manufacturing, Business Process Management and Project Management Institute Project Management, which was used for the development of the definition of the project. This tool provides a quick overview of the process, in some cases, it can be too simplistic to provide better understanding and clarity of the process to be worked on, as well as to identify when and where to stop. In the mentioned case, the defined limits of entry, started from the information given by the department of finance and controlling[9] and they ended up in the information exits to the concessionaires.

This descriptive graphic tool offers a process development based on the client's needs or also called customer's voice. Highlights the need to serve internal customers to satisfy external customers. The graph identifies who receives or is affected by the outputs of the process. In this case the entries are the alterations of prices frequently maintained by the controlling department, which have to be reflected as departures in the vehicle price systems in the concessionaires; this helps to clarify the process including its specific requirements. The next step is to define the entries related to the client's requirements, to be communicated to internal and external suppliers, to drive the process from the client, there is a traceability that links the developed process with the requirements of the client fulfilled.

After analyzing and understanding suppliers, inputs, outputs and customers (including the requirements of each phase), the process is developed, identifying the steps required to convert inputs into outputs in an efficient manner of approach to the customer. SIPOC, however, simplifies the process by providing a structured approach to increase the company's knowledge of all systems, showing the interrelationships and interdependencies between the processes.

[9] Controlling it consists in verifying if everything happens in the confirmations with the adopted plans, the issued instructions and the established principles. Controlling ensures that there is an effective and efficient use of the resources of the organization to achieve the planned objectives. Controlling measures the deviation of the actual performance of the standard performance, discovers the causes of such deviations and helps take corrective action (Juneja, 2018).

Through the structure of the SIPOC method it is understood who serves whom, and the SIPOC chart can significantly improve the design of the processes (Munro, Ramu, & Zrymiak, 2015). Finally, the exposed case demonstrates the utility of software automation for the improvement of business processes, in the context of Industry 4.0.

4. Development (case study)

An automotive company of German origin, currently has implementation of SAP systems with its main modules such as finance, controlling, sales, material handling among others. However, despite the standardization of business processes through SAP, it also has many legacy systems. These legacy systems are those that do not belong to SAP and that due to their origin and seniority are still of use for this automotive company since these functionalities have not been migrated to current systems.

Legacy systems are regularly developed programs tailored through programming languages such as JAVA, .NET, PHP and others that are regularly configured by the consortium in Germany, and do not have the source code in them the different countries to make required adjustments typical of the region.

The automotive company has among one of its legacy systems that of price charges. To be able to update the sale prices, the role of the "controller"[10] you must request the installation of the system on your local computer, as well as the permissions so that your user can update the corresponding fields at prices. As part of the definition phase of the Six Sigma Methodology, information derived from the customer's requirements and pains notebook was gathered, which is called the customer's voice, in which it is indicated that this system has different update options related to the product. , of which 90% of the activities are done manually, according to the requirements notebook delivered by the client; therefore, there is a risk of generating human errors that impact the company's billing process. Likewise, said legacy system, in addition to having to be used through manual operation, that is, there are no mass loading or extraction and execution of programmed data through interfaces, nor does it have physical or digital instructions for its use, so the training must be carried out by the members of the controlling area who have the knowledge to the new collaborators of the structure.

Among the responsibilities of the users of this system are the authorization and updating of vehicle prices in Mexico once they have been approved by the vice president of finance. Other changes are those related to updates of ISAN (New Automobile Tax) and VAT (Valued Added Tax), which is considered critical in the business because they represent revenue also for the brand.

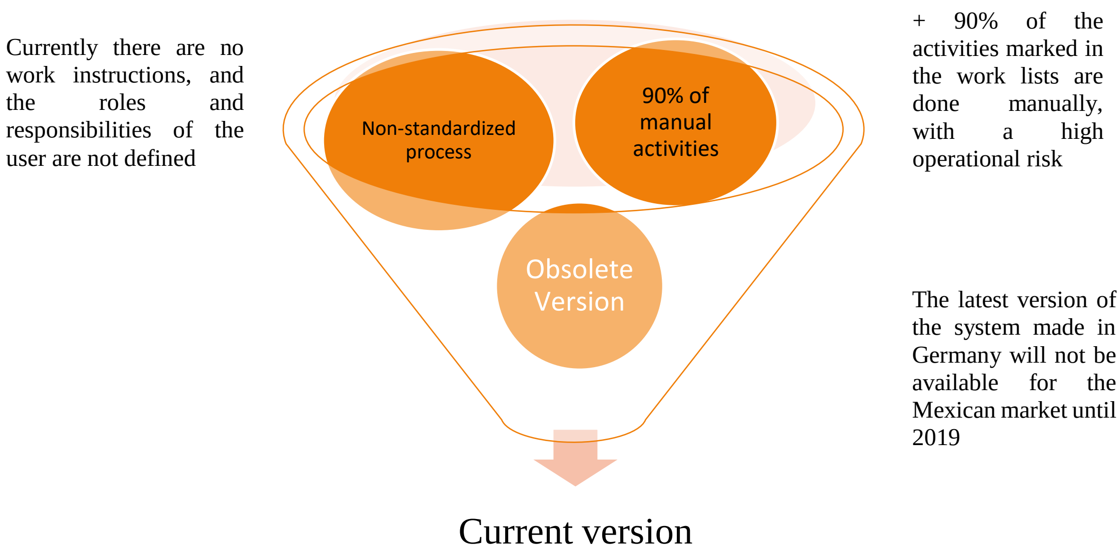
The areas involved in the process of updating vehicle prices are:

- Controlling
- Information Technology Area
- Vehicle brands

The price update, is an activity on demand that is generated whenever new prices are required for new models and versions or suffer changes on existing ones. Because these activities require 90% of manual activities, the company requires an optimization model for its better management. Some of the elements that are considered as points of opportunity for the automotive company are shown in Figure 4. 2

[10] Controller In the business field, it is the figure responsible for the design and general supervision of the management control system. At its highest level of development, that is, based on the senior management staff situation, in general, the controller is in charge of designing the different instruments that help in the management of the other executives of the company. supposed: 1. Design accounting systems (Financial Accounting - Analytical or Cost Accounting) to provide reliable, relevant information at the right time for decision making; once designed, the financial director is responsible for obtaining the financial statements (Rodriguez Martín, 2018).

Figure 4.2 Current business model



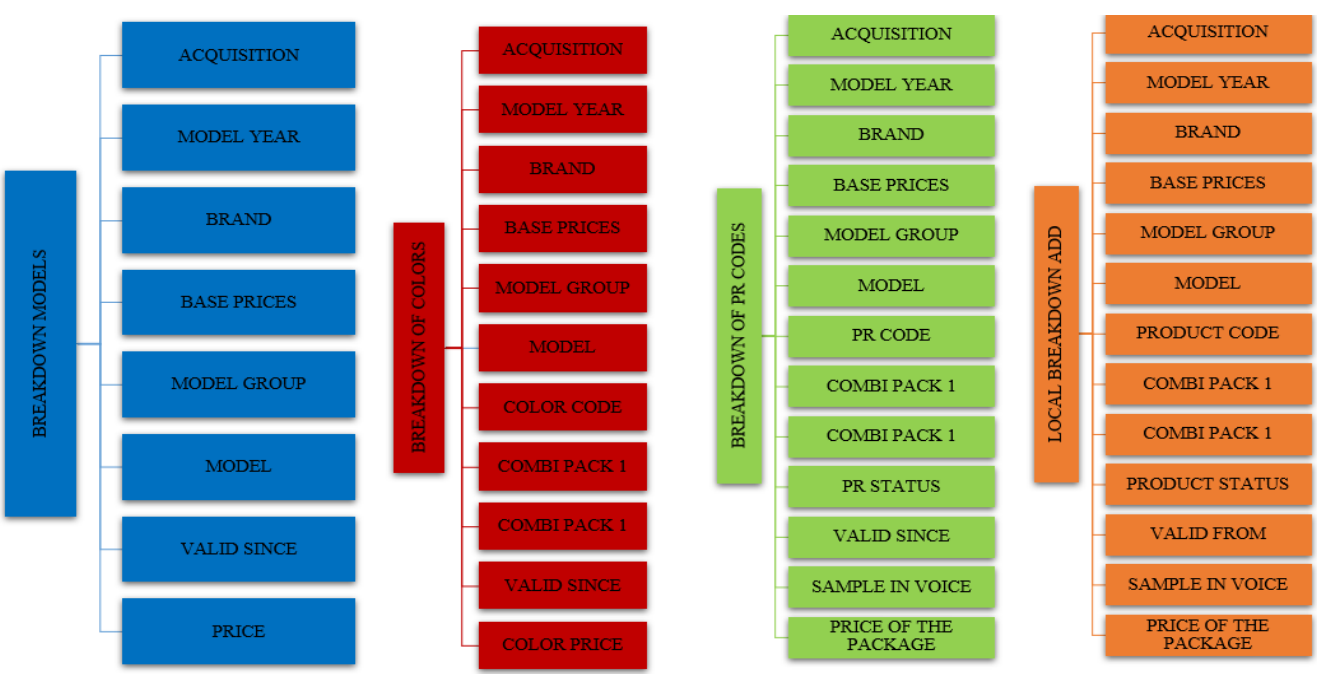
Source: Self Made with company information of the case study

Therefore, the automotive company has requested an update to the system that minimizes operational risks, the processing time of the price update and billing based on current business rules and functionalities. Each vehicle in the system has a differentiated price based on the combination of the following factors:

- Vehicle models (only to mention the current models are more than 50 among all the brands of the consortium)
- Versions (normally on average there are at least 4 versions for each model)
- Colors (with different prices)
- Special equipment (more than 20 different types of configuration)
- Taxes and local charges
- Exchange rates for export vehicles
- Price validity ranges

Therefore, there are more than a thousand combinations of vehicle models, whose prices must be updated in the legacy system in more than 90% of the process. Below is a tree diagram of the possible ways in which you can set the price of a vehicle see Figure 4.3

Figure 4.3 Tree of price configuration combinations



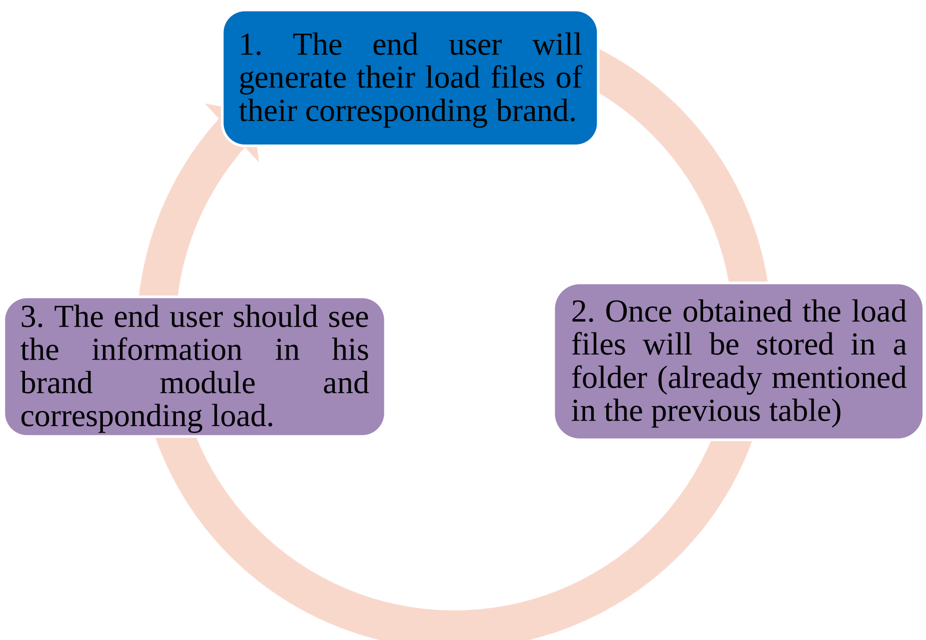
Source: Self Made with company information of the case study

Derived from the types of changes that were handled prior to 2016, the updates were made three to four times a year. However, due to the volatility of the peso against the dollar as of this same year and date, these updates are required in the consortium at least twice a month, representing at least twenty-four annual changes. This has required an increase in personnel in the IT department and controlling, exclusively to perform this task that carries a high risk to be most of the update manually. The intention that the consortium seeks, since the prices are passed through the controlling area in Excel files and captured manually in the legacy system, is that the transfer of information is done automatically without the intervention of the collaborators of IT, given that this generates an effort of around 500 hours for each update that, when carried out at least 24 times a year, represents more than 12,000 hours of human effort per year, which also have a human error rate of 2% which impacts in the financial part of the business.

As part of the measurement phase, a difference analysis was carried out to obtain the real value prior to implementation, equivalent to 500 monthly hours per update of all vehicles, which is equivalent to 30 minutes per each of them.

The value expected by the automotive company is to decrease to less than 3 minutes each update that would give as monthly time 50 hours. Likewise, to carry out the follow-up the company carried out measurements through control charts, to assess the efficiencies reached before and after the implementation. Due to the above information and derived from the long processing time specified, the analysis phase was followed through the root cause document that describes the high working times of IT collaborators for the price update, causing human error rates in around of 2% of the more than one thousand models that are updated at least twice a month, without having support automation tools to solve this task. Figure 4.4 shows the general level process of the desired solution:

Figure 4.4 Desired process



Source: Self Made with company information of the case study

The box at the top of the diagram represents the update of the Excel file that the controlling department performs and its accommodation in a folder that is on a shared route (step 1); from there they are recovered (step 2); and automatically updated in the legacy system (step 3). Given the volume of information that must be handled manually, we proceeded with the improvement phase through the technical brainstorming to find solutions and tools so that the information can be processed autonomously.

The most recommended information technology solution in this case is the use of Automated Robotic Processes or RPA for its acronym in English (Robotic Process Automation).

Selection of tool use for the creation of software robots using RPA

Identified the problem of a high manual activity in the price update, which has an impact on the increase of working hours with consequent update times and financial impacts due to human errors, it was established that the use of a computer robot is the best way to solve the problem.

This means that one or more robots will do the tasks currently performed by the IT area employees to update the prices; thus the time of these employees will be engaged in tasks of development of new systems or support of the mimes. The next step was the selection of the tool that can help the generation of software robots, for which once the ideas for improvement were established, an analysis of those that better execute the needs required by the consortium was required..

Initially, there are two types of automation tools cataloged by their function that are described below:

- **Automation tools for infrastructure work:** these are programs aimed at automating the monitoring of the current capacity of the system disks that automatically free space, also for the monitoring of the space occupied by databases, as well as the capacity of the processor . Among the most common are; Hewlett Packard, HPSA (HP Server Automation) and HPOO (HP Operations Orchestration); there are from IBM and other brands; however, they are oriented to the infrastructure rather than to the application layer of the business process, so all those that belong to the infrastructure area are discarded.
- **Application automation tools:** the automation tools for infrastructure work are vital for the proper functioning of the machine where the applications operate, but they are not sufficient to operate in the operational layer. There is another set of tools for these functions that support end users with repetitive business tasks: spreadsheets, automated emails, SAP systems automation, legacy systems, among others. In this layer are the tools that will help the company to make use of the RPA.

Within the brainstorming session, a comparison was made of the best tools that are being used as best automation practices for the management of RPA and the following were found as the main ones:

- Genexus
- UI Path

It was found that both can be used for the automation of tasks within the SAP system, as well as administrative tasks of the system, such as programming the execution of a program at a specific time, turning off the computer, enabling or disabling system components.
But specifically the facilities of Genexus (Genexus, 2018) are the following:

- Easy use for managing custom applications, which must interact with connections to or from SAP.
- Contains already available connectors to enterprise resource planning systems (ERP, for its acronym in English, Enterprise Resource Planning)
- Agile development for customized solutions within SAP

As previously mentioned, the solution required is for a legacy system and Genexus, despite being a powerful tool in the market, is more oriented to have expeditious connectivity with ERP systems, which, although it is common in the world of systems, for the requirement of this case, does not represent great help.

The UI Path tool (Uipath, 2017) has the following specific characteristics:

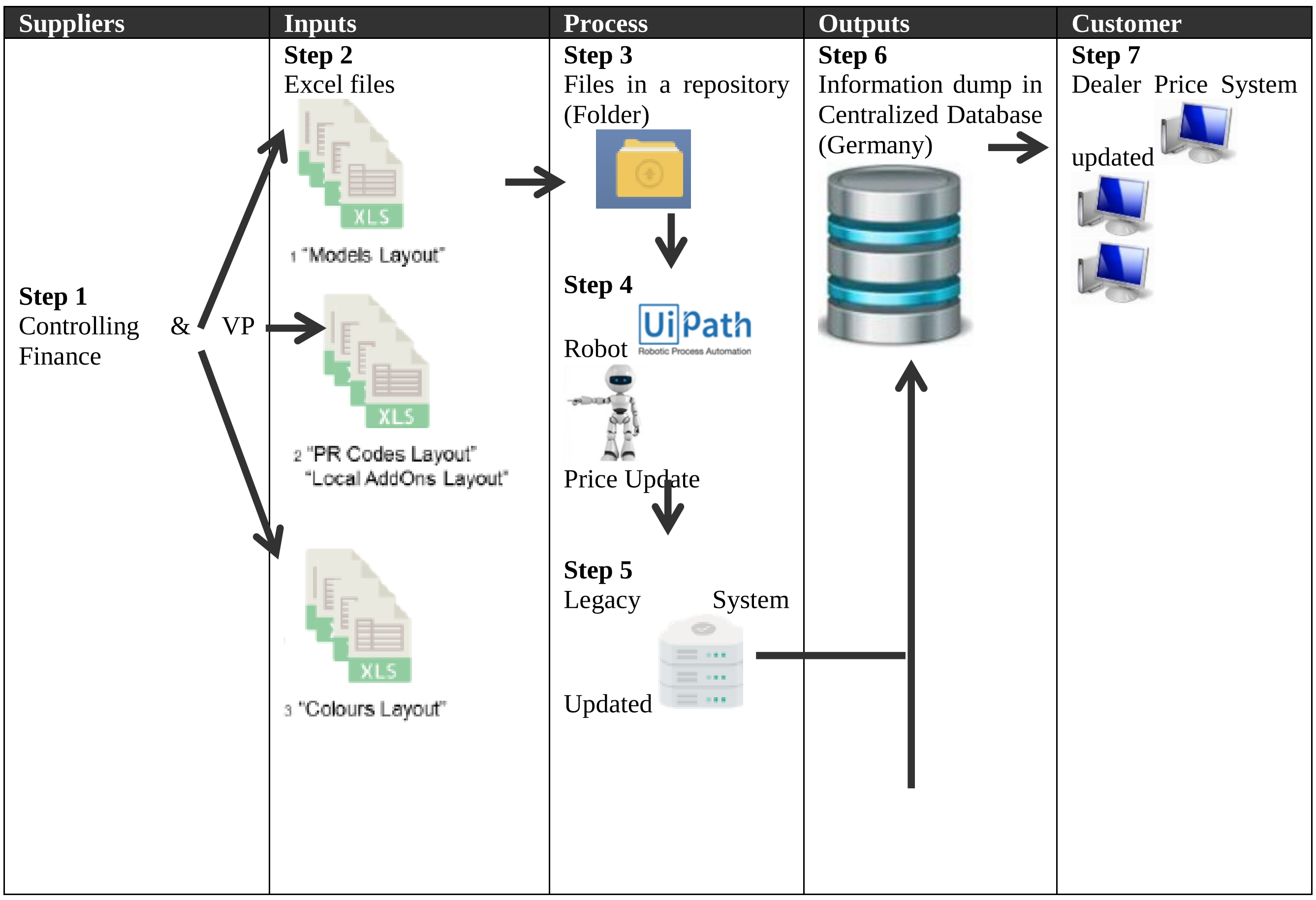
- Solution created for the RPA application
- Express execution of repetitive tasks that have similar results
- Reduction of human error rates
- Assurance of the execution of tasks 7x24 (7 days 24 hours)
- Use for tasks in SAP, legacy systems, web pages, emails and any activity that an end user performs recurrently

Due to the above, UI Path was the software tool selected at the end of the technical brainstorming session; it is the one that best adapts to the needs of the use case of the automotive consortium.

Development and proposal of solution of the use case for the price update automation

Once the scope of the proposal has been reviewed, this section details the solution that allows automation of prices per vehicle to be executed. Then; and making use of a diagram of suppliers, inputs, process, output and customers (SIPOC) still within the improvement phase, the implemented solution design is detailed, see Figure 4.5.

Figure 4.5 SIPOC of the business process of price update. New solution design. Improvement Phase



Source: Self Made with company information from the case study

Step 1. Controlling and authorization of vice-presidency of finances: As already mentioned, step one corresponds to the generation of price updates by the con trolling department. Once these have validated the new exchange rates in the market they make a dispersion of the prices, which are sent to the vice president of finance to do the validation of the same, which culminates with an official authorization.

Step 2. Excel Files: The generated Excel files, correspond among others, to the price update for the following categories, where each of the elements of the list corresponds to a file that will be the source of information that is entered into the legacy system : layout of models, brands, base price, model group, colors, equipment (for example: automatic or standard, diesel or gasoline, etc.) and special features (for example: wheel size, sunroof, etc.). The entry of these files is on demand, to the request of price changes derived from the exchange rates.

Step 3. Files in a repository (folder): When the files are generated, they are stored in a shared system folder, which prior to the incorporation of the solution, were opened by the employees of the IT department to initiate the price update of manually, which required an average annual effort of 12,000 hours, in addition to the human errors that implied financial impacts for the consortium and delays in deliveries for the new prices to the concessionaires. Under the new solution scheme, the files are saved in the same system folder, which the robot is monitoring every minute and as soon as it finds a file, it will be the trigger to start the automated work in the legacy system update.

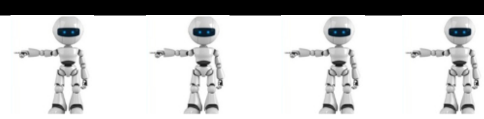
Step 4. Execution of the robot. Price update: Once one or more files are found in the system folder, an RPA orchestrator validates that there is not a robot previously executing and updating the price values in the legacy system, otherwise, the Orchestrator launches a robot, which will start with the price update. When another file is placed at the same time, the orchestrator will ensure that the update in the legacy system is not executed, but until the previous settings have been processed correctly, this in order not to generate inconsistencies in the legacy system, nor in the price update in the database. The following diagram shows the interaction between the orchestrator and the robots that run the price update in the system, see Figure 4.6.

Figure 4.6 Automation process diagram

Orchestrator

If a robot is executing the update of a file, the orchestrator guarantees that until the end of its execution, the activity of the second or subsequent robot begins.

Robots



Once a robot is called to perform the execution it starts to do the update in the Legacy system

Legacy System Update

The legacy system is updated with the new price values, based on the new and existing models, equipment, exchange rate, among other factors

Dump to Database

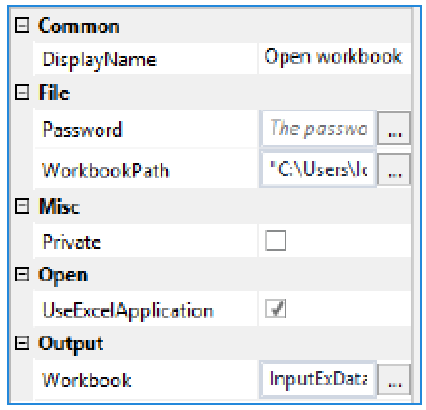
When the information is updated in the legacy system, it executes the dump of information to the database that concentrates the new prices and displays the information in the network of concessionaires

Source: self made with company information from the case study

When a robot is called by the orchestrator to execute the price update from a file placed in the common folder, the actions that are executed are as follows:

- Opening of the corresponding Excel book for which the file name must always be the same depending on the type of file to be updated, that is, depending on whether it corresponds to a file of equipment, special features, models, etc. To do this, the fixed routes where the file will be searched must be specified in the tool: The following Figure 4.7 corresponds to the configuration made in the UI Path tool

Figure 4.7 Excel File Configuration

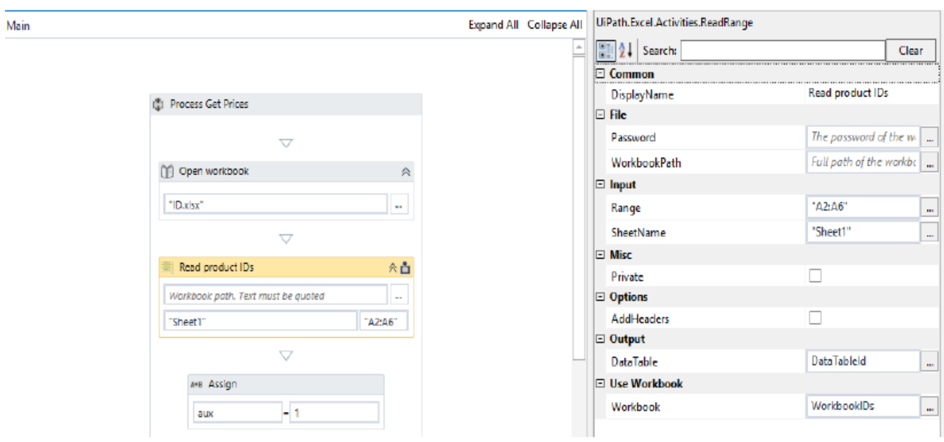


Source: Taken from the UI Path system

The special considerations to take into account are:

- Have MS Office Excel installed
- Have the folder with file sharing properties
- Visible in real time for changes
- Reading of the Excel file: The read ranges of the file are defined and the rungs of the information headers are defined.

Figure 4.8 Worksheet configuration



Source: Taken from the UI Path system

Step 5. Legacy System Updated: As the robot reads each of the records, access the legacy system by executing an identification with a specific user and password for the robot, then enter the option to update prices as shown on the system screen. See Figure 4.9.

Figure 4.9 Main menu of price update system

Source: Company information system taken

Then select the type of file that is being updated, for example, the alternative models, as shown on the screen, this being one of the options that can be modified see Figure 4.10

Figure 4.10 Model options menu

Source: Company information system taken

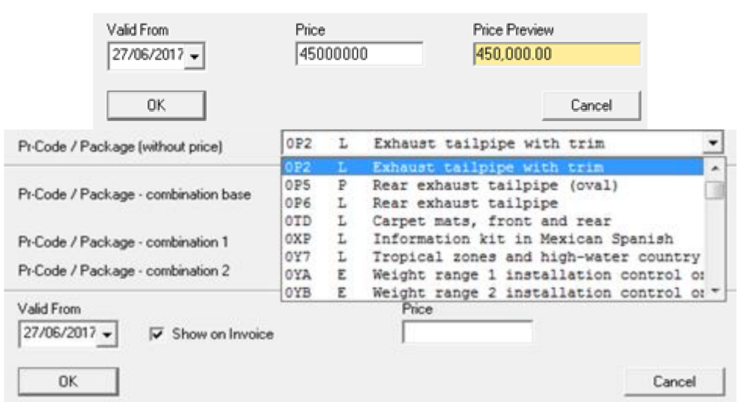
Proceed with updating the prices in the legacy system see Figure 4.11

Figure 4.11 Auto model selection

Source: Company information system taken

The robot, during its execution, begins to perform the price update, based on the special characteristics of the vehicle, see Figure 4.12.

Figure 4.12 Prices and validity of part codes



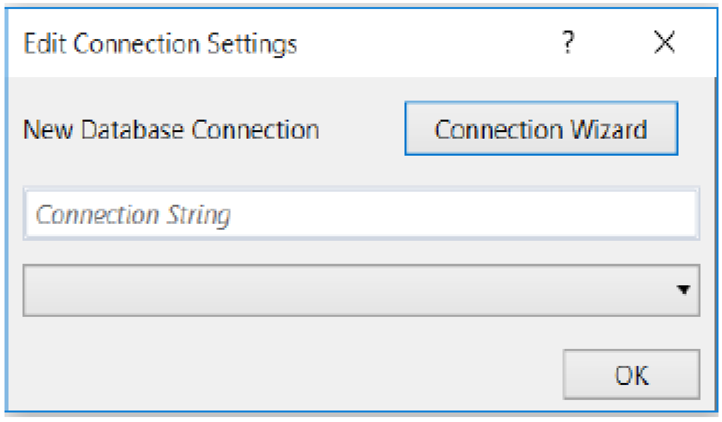
Source: Company information system taken

Step 6. Information dump in centralized database (Germany):

When the information in the system is updated by the robot, the orchestrator sends another robot to call to start updating the data in the centralized database. For this the robot executes the following functions:

- Make a connection to the database see Figure 4.13.

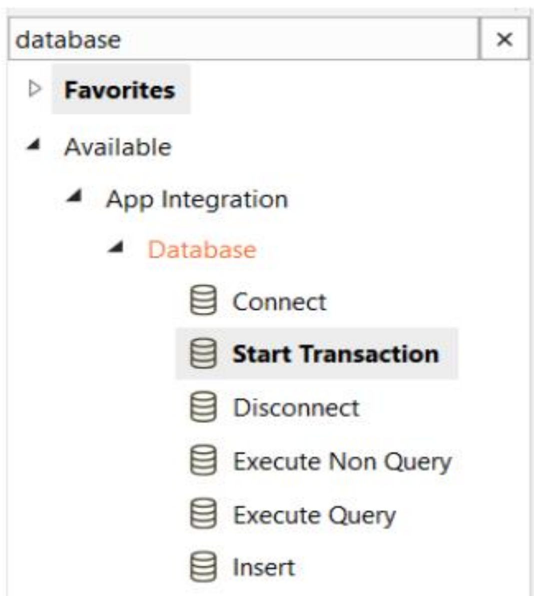
Figure 4.13 Connection to database configuration



Source: Company information system taken

- Open the connection, act on the same database and insert new information if it is a new model or update for existing models see Figure 4.14

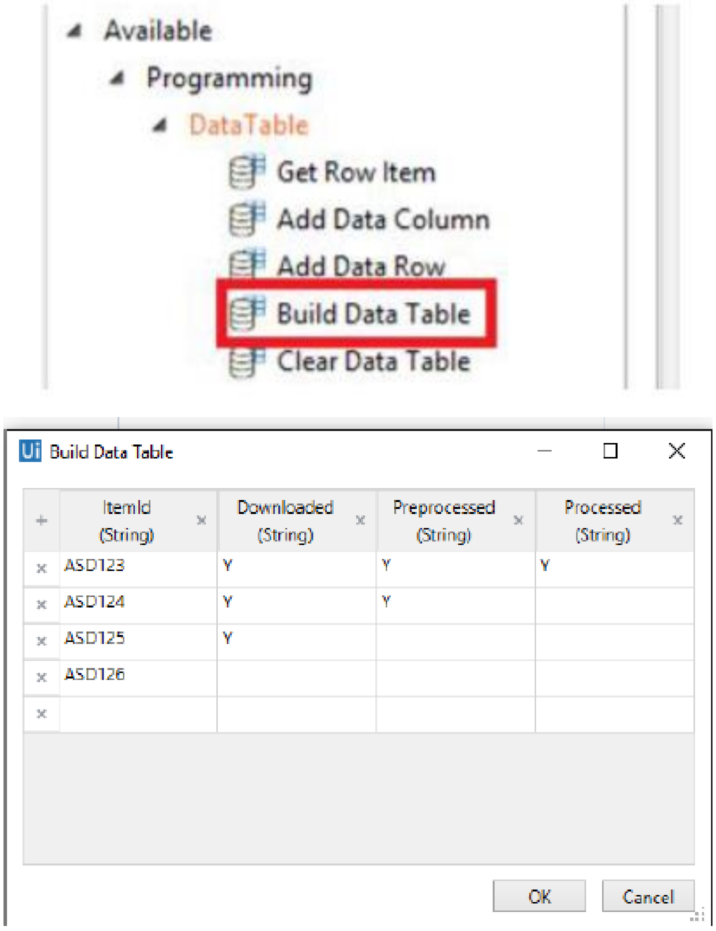
Figure 4.14 Connection to central database instance



Source: Company information system taken.

- This is done directly on the tables that have the price information see Figure 4.15.

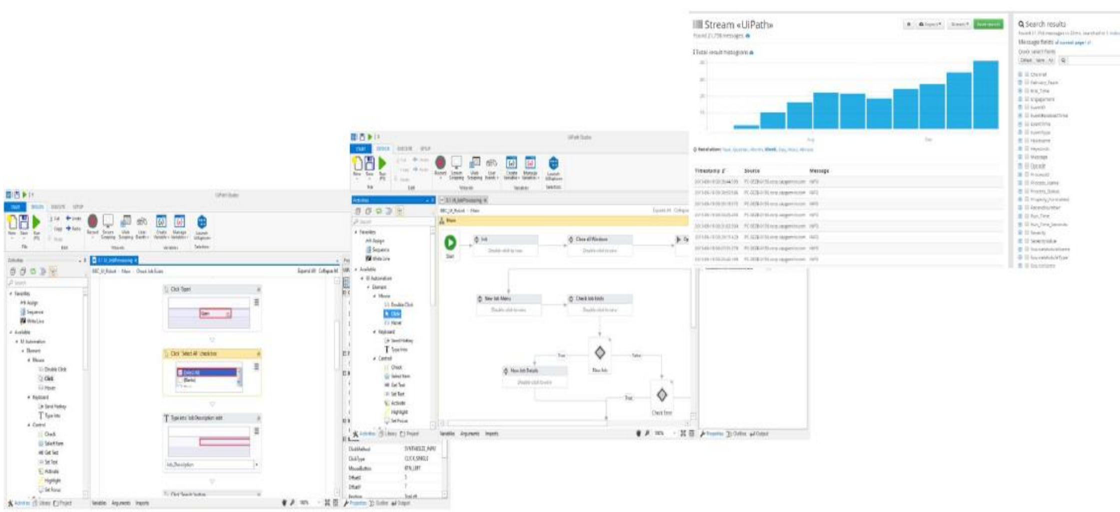
Figure 4.15 Configuration for access to tables in the database



Source: Taken from the UI Path system

The orchestrator keeps a detailed control of how many files have been updated historically, controls the flow of information so that there is no data inconsistency and guarantees the quality of the information. The following image shows a series of indicators and controls of the orchestrator; see figure 4.16.

Figure 4.16 View of the orchestrator working on the execution of robots in real time



Sourcee: UiPath Software

Step 7. Dealer Price System updated

Finally, the price system can be accessed in the view of dealers in a correct and timely manner.

Due to the new solution, and thanks to the measurement boards used by the company in the control phase, it is shown that updating the price of a vehicle after the solution is implemented, takes between 45 to 90 seconds, in addition to the error rate low to 0%. Due to the above, the annual execution times decreased from 12 thousand hours of work of the IT collaborators to less than 400 hours per execution of robot tasks autonomously, reaching the pre-established objective in the measurement phase that indicated having a time for below 500 hours and zero failures as operating error rate.

Prior to the new design of the solution, the update of a specific model through the manual activities took around 30 minutes for the updating of the different modules in the legacy system, as well as the double or triple verification to try to mitigate the risks in the entry of erroneous prices for erroneous captures, such as omission of decimal points, prices entered in wrong characteristics, taking into account that the list exceeds 500 records, and updating in a table with more than 40 columns complicates the correct visibility. All the above caused a rate of errors greater than 2%. Due to the new solution the price update of a vehicle takes between 45 to 90 seconds, plus the error rate dropped to 0%.

Below is the table of comparative summary of previous results, proposed or objectives and achieved after the implementation of the RPA:

Description	Previous	Objective	Reached
Human error rate	2% (20 for every 1000 price updates)	0%	0%
Annual processing times in hours	12000	500	400

5. Conclusions

The automotive industries, historically pioneers in the automation of the manufacturing process, have turned to see the IT departments to assess which points can apply thinner processes, and identifying repetitive tasks that can be done better and faster with the use of the automation. In this case of real study, it is shown that the parameters of decrease of error rate, and of execution times; They can be ambitious but achievable thanks to the implementation of software robots. Based on the success achieved in the automation of the price update process, IT management is analyzing other tasks where it is feasible to implement the RPA through the DMAIC methodology.

The use of RPA tools to automate IT work scenarios based on a methodology, structured for continuous improvement, such as Lean Six Sigma and its DMAIC approach; they demonstrate that defining, analyzing and weighing problems make it possible to select cases to be automated more efficiently, starting with those that generate the most problems in the chain of business processes and that will ultimately have a greater impact.

One of the main fears of those involved in a process that must be automated, is that their tasks are reduced and their work positions are at risk; however, the primary objective is contrary to this, since it means that employees focus on the strategic layer where their work is reoriented to decision making, where they can be the important differentiators of the business. Undoubtedly the implementation of RPAs, involves major challenges from the technological point of view. To achieve that the specific characteristics of the use case are reached, requires that on automation technologies there is the skill of programming to fine-tune even the smallest feature required by the business.

It is recommended that each time you want to implement an automation case, the design of the solution is validated very well, starting from a "Lean" analysis to thin the process, eliminate the tasks that do not add value, normally called waste, which minimize those that do not add value, but those that add value to the business process are necessary and finally are automated. The task of automating IT tasks requires an interdisciplinary collaboration between the owners of the process that are those who know the requirements, the software programmers that will implement the robots and a technical coordinator who is recommended to know both the tasks of the programmer and of the business process that you want to automate.

The use of price automation is the first to be developed and implemented in productive environments for the automotive company in Mexico, which leaves precedents for future cases where manual and repetitive tasks can be automated.

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Chapter 5 Logistics performance evaluation in the auto parts sector of Tlaxcala

Capítulo 5 Evaluación del desempeño logístico en el sector autopartes de Tlaxcala

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Abstract

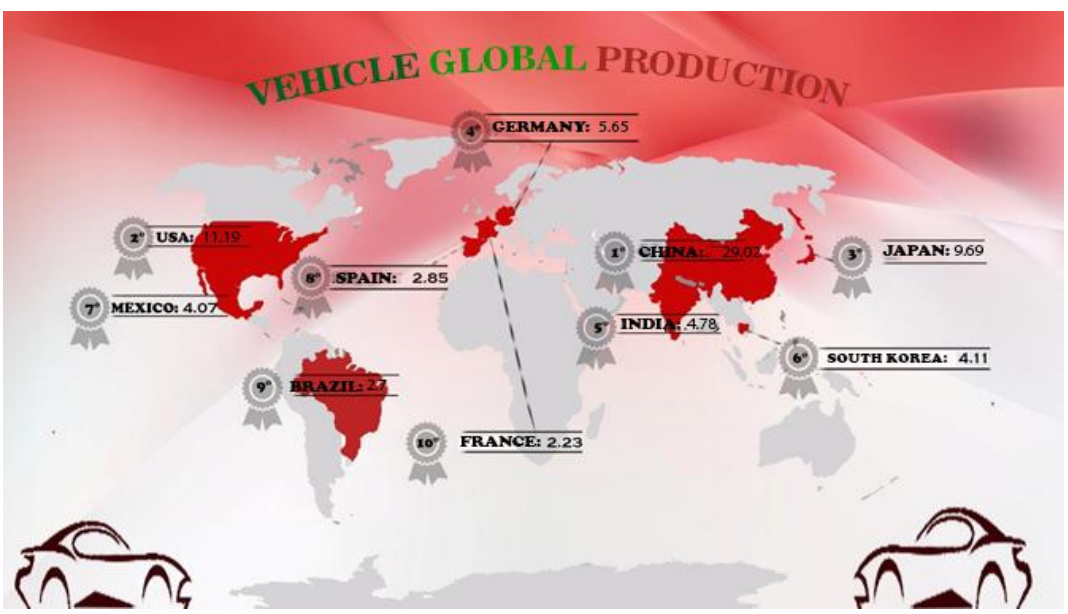
The auto parts industry in Tlaxcala has historically been influenced by the proximity of the Volkswagen plant and, currently, by the opening of the AUDI plant in San José Chiapa, Puebla. The arrival of the main global auto parts companies has driven the domestic sector to adopt the best practices of the supply chain. This has improved the competitiveness that leads to a quantum growth in exports. However, the Tlaxcala auto parts industry has to operate in a unique environment that poses challenges to the already complex automotive supply chain. In this study, we conducted an assessment of the logistics performance of the auto parts sector in the state of Tlaxcala. For its analysis, the indicators of the Logistics Performance Index were used and the variables taken into account are: Infrastructure, tracking and tracking, punctuality and performance of customs. The results within the positive factors are the strategic location of the state of Tlaxcala allows to communicate with the main markets, ports and customs of the country; 76% of cargo transport companies in the entity deliver their products within the stipulated time; 90% of cargo transportation companies in the state have a satellite monitoring system.

Automotive industry

Universally, the automotive industry has been accepted as an important driver of growth in a country's economy and is a major contributor to the global economy. The car has been described as a product based on "form and function" which implies a high level of engineering and is positioned as a fashion product (Thomas, 2013). The industry has been called "the industry of industries", since it uses products from almost all manufacturing industries (Drucker, 1946) and supports industries such as mining, steel, plastics, electronics, petrochemicals; and even companies in the financial sector. (Kearney, 2013). This industry generates 17.8% of the gross domestic product manufacturing worldwide and for the time being it continues to grow, registering an increase of 24.8% in the last decade (2007-2017). The automotive industry is of great importance, both because of the size of the companies that make it up, which have a combined production of more than two thousand billion euros per year, as well as the level of occupation of skilled labor since for the construction of more than 90 million vehicles the employment of about 9 million people directly in the manufacture of vehicles is required.

The estimates of the International Organization of Automobile Builders show that each job within the industry generates five indirect jobs. This indirect effect on employment is achieved by the complex production chain generated by car manufacturers (Oica, 2017). The global vehicle production reached 97.3 million units in 2017, grew at an average annual rate of 2.4% between 2016 to 2017. In 2017, the main automobile producing countries were China, the United States of America and Japan with the 49% of total production. For its part, Mexico ranked seventh as a manufacturer of light vehicles and its production in terms of units represented 3.9% of the world total. Figure 5.1 shows the main automobile producers in 2017.

Figure 5.1 World vehicles production



Source: Self Made. OICA data, 2018

Automotive industry in Mexico

In Mexico, the automotive industry is one of the most dynamic and competitive. The jobs, services and products that derive from it make it relevant in the national and local economy. Its contribution to the national total GDP is 3.3% and manufacturing 18%. Its exports, to more than 100 countries, represent 21.5% of the total Mexican exports, with more than 45, 000 million dollars. Generates 1.6% of national employment. In addition, it has become the main generator of foreign currency, above sectors such as electric-electronic, oil and tourism (INEGI, 2018).

In 2014 Mexico became the largest producer of automobiles in Latin America and the seventh producer worldwide, this growth has continued considering that automotive production reached 4, 068,415 cars in 2017 and is projected to be 4.8 million in 2019, according to figures of the Mexican Association of the Automotive Industry (AMIA, 2018). For years, manufacturing quality has been the outstanding characteristic of vehicles manufactured in Mexico. They are exported to the most demanding markets in the world, such as the US, Germany and even Japan, where Mexican plants have been presented as examples of quality and commitment to continuous improvement. For automobile manufacturers, the quality of the Mexican plant and labor are some of the most important factors when deciding their investment strategies, location and geographical position.

As proof of the above, in the last five years, the majority of companies manufacturing vehicles and commercial vehicles in our country and a significant number of companies producing automotive, parts and components have made large investments to expand their capacity of production, equipment, modernization and automation.

The production of automobiles reached a new historical maximum in 2017, driven by the installation of new plants in the country and a greater demand in strategic markets such as the United States and Canada. In the year 2017, according to information from the International Organization for the Construction of Automobiles, the assembly of cars broke the record of 4 million units per year, 13% more than the 3 million 600 vehicles made a year before. Figure 5.2 shows the key indicators of the Mexican automotive industry.

Figure 5.2 Key indicators of the Mexican automotive industry

Source: Self Made. Pro Mexico data, 2016

Supply chain

The supply chain covers all activities associated with the flow and transformation of goods and associated information from the raw materials phase to the end user (Ballou, 2004). It is essentially a set of connected providers and customers; where each client is in turn supplier of the next organization until the finished product reaches the end user. Increasingly, companies around the world are turning to the supply chain as the latest methodology to reduce costs, increase customer satisfaction, make better use of assets and build new revenues.

With the automotive industry constantly evolving, the supply chain can be complex. Automotive companies must reconsider their supply chain strategies in order to exploit new market opportunities, reduce costs and maintain a competitive advantage. The OEMs (OEM) operate in an environment with strong global competition, the market is more turbulent, complex and uncertain. The automotive industry offers a rapid increase in the number of models and variants that are available in the global market for customers. The segments of traditional cars such as hatchbacks, sedans, trucks and pick-ups are fragmenting the variety more and more into niches. Derivative car segments, such as minivans, roadsters, two-seat vehicles, SUVs and sports vans, are growing. This fragmentation and segmentation of vehicles results in a more complex supply chain that must be managed flexibly. The key trend in the automotive industry is the standardization of components and construction modules for common platforms. This means that the models can be adjusted to the individual requirements of the customers and the delivery schedules allow OEMs to produce multiple models (based on variable platforms), in the same manufacturing facilities.

The complexity of the automotive supply chain can be measured by the fact that a typical vehicle comprises approximately 20,000 components with approximately 1000 subassemblies or modules (Schwarz, 2008). The automotive supply chain includes many tier 1, 2 and tier 3 suppliers or manufacturers with many assembly operations and a number of dealerships. Customer demand for varied configurations and specific features increases the high level of response needed from automotive supply chains. The delivery time required by a customer is averaged from 4 to 6 weeks in the automotive industry (Meyr, 2004) and there is a definite correlation between the implementation of Supply Chain Management (SCM) practices and quality and Design conformity (Sharma, Sahay and Sardana, 2008).

Supply chain in Tlaxcala

Regarding the state of Tlaxcala, it does not have an assembly company, although the development of the sector has been strongly influenced historically by the proximity of the VW plant and its main T1 suppliers in Puebla and, currently, by the opening of the AUDI plant in San José Chiapa, Puebla, in the limits of Tlaxcala. From the point of view of the state government, the automotive industry is made up of 46 companies, of which 54% are Tier 1, 41% are Tier 2 and the remainder are Tier 3. Of these companies, 71% of the companies they export their products and the rest are for national consumption (Sedeco, 2018).

Regarding the size of the companies located in the entity, 25% are large companies, 44% are medium-sized companies, 29% are small companies and only 2% are micro-companies. The main products for original equipment manufactured in Tlaxcala are: injected plastic parts of medium and high range, such as panels and consoles, including paint or flock finish, finishes of levers, steering wheels and leather and vinyl interiors, seats, harnesses electrical and finally stamped and die-cut parts.

The contribution of the automotive sector of Tlaxcala is a little more than 8% of the national production, obtaining more than 3.5 million gross production. Despite the good level of production there is a low profit margin, considering that the automotive sector represents 2.4% of the state's employed personnel and contributes 2% of the state GDP. For its part, the manufacture of auto parts of motor vehicles, ranked 15 at the national level and represents a little more than 5% of the personnel employed in the sector at the national level (Conacyt, 2016).

However, the proximity to the assembly plants and T1s of Puebla and the connection through the north arch with assemblers located in the State of Mexico and the Bajío, has boosted the growth of the sector in the state. The Autopartes de Tlaxcala companies were created through the natural growth of the VW conglomerate; this has benefited most of the entity's auto parts companies because they present progressive technologies, high-tech production methods and close cooperation. The structure of the supply chain in Tlaxcala was adapted to meet the conditions and requirements of three different cultures of automobile producers (German, Japanese and US). The structure is composed of suppliers 1st-Level, 2nd-Level, 3rd-Level and the cooperation is complemented with other small and medium-sized companies, service providers and institutes.

Auto parts companies in Tlaxcala, in their capacity as strategic partners of car manufacturers, must be able to respond quickly to changing market demands because OEMs are giving up their responsibilities in the areas of development, supply and planning; and Tlaxcala auto parts companies must demonstrate that they can deliver the required design, quality, service and price. Figure 5.3 shows the supply chain of the automotive industry of Tlaxcala

Figure 5.3 Supply chain of the auto parts industry of Tlaxcala

Source: Self Made

The supply chain and the logistics process in the auto parts environment of Tlaxcala start from the client and end with the client. Each auto parts company in the entity is connected to other parts of the supply chain by the flow of materials in one direction, the flow of orders and money in the other direction and the flow of information in both directions. The supply chain coordination focuses on the control of the flow of materials and the flow of information between suppliers, manufacturers and customers through the processes of information exchange, communications and transmission.

The construction strategy of the assembly companies is related to the delivery of parts from the auto parts companies of the State of Tlaxcala to the assembly plant. The customer makes his request through the distributors and the specifications are communicated to the car manufacturers. Orders delivered by telephone, fax or other paper order methods can be processed as those received electronically. The information is captured in a central database and the allocation of invoices is made to determine the cost of production and the place of decision where the car will be manufactured; the nearest location of the production plant of the customer's vehicle model is indicated; Once the production plant is located, Tlaxcaltecas autoparts companies supply their components according to the just-in-time (JIT) or Just in sequence (JIS) methodology to ensure that the parts of the vehicle reach the correct point on the assembly line and at the correct time for installation in the respective body (to insert in the particular vehicle for which they are made).

Based on a scheduled production sequence planned several days in advance (or in the order in which the bodywork of the vehicles leaves the paint shop), the original equipment manufacturers ask the Tlaxcalteca Tierís to deliver the components for that match the production sequence.

The Tlaxcalteca auto parts industry can guarantee that the order of sequential delivery of these to the assemblers continues to produce components in batches, since they are stored, generally in a location near the final assembly plant. When the sequence orders come from the assemblers to the supplier, the warehouse components are simply repacked (often with the help of information-based tools) in the correct sequence and delivered quickly. Once the car is assembled, it is transported by rail, plane, ship or by tractor-truck to be delivered to the customer.

A change in any link in the chain usually creates waves of influence that propagate through the supply system. These waves of influence are demonstrated in prices (for raw materials, labor, parts and finished products), flow of materials and products (within a single installation or between facilities within the supply chain) and inventories (initial, in process, and finished product). The way in which these influences propagate through the complex system determines the dynamics of the supply chain. Supply chains of Tlaxcala autoparts companies are becoming more demand driven than driven by prediction to respond effectively in real time to the demand of car manufacturers.

Methodology

At an international level, the Logistic Performance Index (LPI) is a measurement made by the World Bank, the LPI works as a mechanism with the objective of showing and describing global trends in logistics, measuring efficiency of the supply chains of each country and how it develops in trade with other countries. The factors that the LPI takes into account are the following: Infrastructure, tracking and tracking, punctuality and customs performance. To evaluate the logistics performance of the auto parts sector of the state of Tlaxcala in its analysis, the indicators of the Logistics Performance Index were used. The methodology used for the study was mixed, in relation to the data presented in the infrastructure variables, customs performance, a documentary and descriptive research approach was used, since it is characterized by measuring or collecting information in a independent or joint on the concepts or variables, that is, its purpose is not to indicate how these relate. According to its temporal dimension it is a cross section, since the data is analyzed at a moment in time.

On the other hand, the methodology used for the punctuality, tracking and tracking indicators was descriptive. These indicators were surveyed by companies in the cargo transport sector that are strategic partners of the Tlaxcalteca auto parts industry for the distribution of their products. To identify which companies in the cargo transportation sector in the state, the Secretariat of Communications and Transportation of the State of Tlaxcala, the National Institute of Statistics and Geography and the field investigation were called upon. 58 companies were identified, of which only 21 companies have the capacity to meet the demand of auto parts companies.

It was determined to apply the measurement instrument to managers, middle managers and operators.

The 21 cargo transport companies were visited to apply the measurement instrument, obtain the information and proceed to the corresponding analysis.

A measurement instrument was designed with 10 questions, these, from the indicators of the Logistics Performance Index and the variables that are taken into account are: monitoring and tracking as well as punctuality. From the questionnaire, 5 questions focused on the tracking and tracking variable; the rest of the questions focused on the variable of punctuality in the shipments. The design of the measuring instrument consists of the following characteristics:

- Method: Likert type
- Measurement level: Ordinal
- Address of affirmations: Positive or favorable
- Measurement scale: 1. Very little, 2. Little, 3. Regular 4. A lot. 5. Too much
- Type of questions: Closed

Theoretical review

The Logistic Performance Index, or LPI for its acronym in English, is a measurement made by the World Bank in order to show and describe the global trends in Logistics. The LPI was launched for the first time in 2007 and was designed to measure the peripheral components of the supply chain, such as transportation and commercial facilitation. The LPI is responsible for measuring the efficiency of supply chains in each country and how it operates in trade with other countries (business partners). In this report, the inputs for the statistical review are obtained through surveys which are carried out to more than 1200 professionals in the logistics field around the world. The factors that the LPI takes into account are the following:

- **Customs.** Measures the speed and efficiency of the procedures and dispatch processes, in terms of speed, simplicity and predictability of the formalities of the customs control agencies.
- **Infrastructure.** Take into account the quality of the infrastructure related to trade and transport: maritime, land, rail and air as well as communications and transport information technologies. Also take into account aspects such as storage and transfer of cargo**.**
- **International deliveries.** The ease of processing shipments at competitive prices is considered**.**
- **Quality and Competence in Logistics.** It measures the competence and the quality of the logistics services of transport operators, customs agents, among others**.**
- **Tracking and Tracking.** Determines the ability to track and track shipments to the final customer. This leads to the exact location and the trajectory followed by the product from the moment it is delivered to the company that provides the service until it reaches the customer**.**
- **Puntuality.** It is related to punctuality, that is, it determines the delivery of the shipments in the established times, which is important due to the competition in the market, a delay in the shipments is not acceptable.

According to the previous points, it can be observed that the study evaluates the dimensions of the performance of the supply chain, the customs clearance, the infrastructure, quality of the service, reliability of the shipments and efficiency in the customs clearance. In a biannual period, the LPI shows the position (ranking) of the countries evaluated, the relative percentages, and the evaluation in aspects such as cargo transport, storage, and payment system among others.
In the 2016 edition, Mexico's logistics performance decreased positions in four of the six sub-indexes:

- Infrastructure from position 50 to 57.
- International shipments from position 46 to 61.
- Competition from position 47 to 48.
- Punctuality from position 46 to 68.

Some indicators showed improvement over the 2014 edition and these were:

- Customs, from position 70 to 54
- Tracking and tracking, from position 55 to 42.

The results of the indicators in this study provide quantifiable information which allows us to make better decisions and improve the logistical processes in such a way that excellence is achieved in each one of them. On the other hand, the challenge of improvement is also for logistics companies, their evolution in technologies that meet the demands of a more competitive digital market.

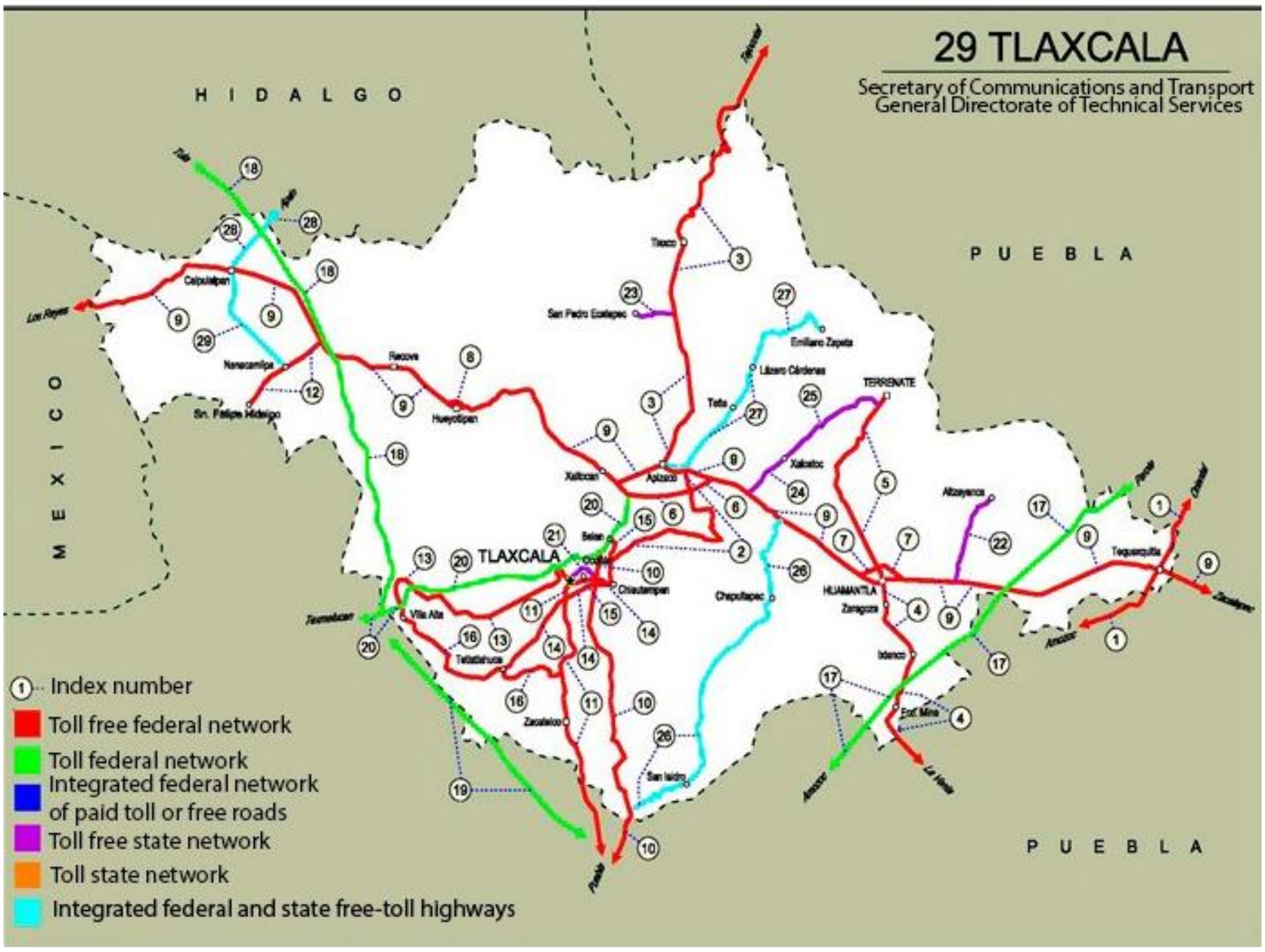
Results

Variable Infrastructure

In the automotive sector, after the manufacturing process of automobiles in the assembly plants, the distribution services consist of taking the new units to the concessionaires, borders or to the main ports of the country for shipment and start exporting. At this point, the madrina or wet nurses make 25% of the land transfer of the units without rolling to a warehouse or a loading yard.

At the state level, the strategic location of Tlaxcala makes it a compulsory transit center for different industries in its main commercial routes, it also contributes to the development of productive activity due to the ease of integration of its roads, motor transport and the potential of connectivity to other markets. Figure 5.4 shows the distribution of roads in the state prepared by the Ministry of Communications and Transportation.

Figure 5.4 Map of the State of Tlaxcala and its main land routes



Source: Road network of the State of Tlaxcala, 2012

The communication channels that Tlaxcala has, have become a fundamental factor for economic and social development, such is the case of the German company ODW Elektrikn located in the Ciudad Industrial Xicohténcatl park, where mechatronic systems are manufactured for the market automotive In this place the accesses were adapted and the road adjacent to this industrial park was expanded to four lanes under the requirements of the businessmen settled in this area (urban center 2016). It is clear that, through this type of infrastructure, the auto parts industries established in the entity contribute to the process of strengthening the Mexican automotive chain, because they have the capacity to capture and link their activities with factors that influence the increase of added value and, consequently, in the generation of innovation factors. Currently, of the total number of automotive companies installed in the entity, 26 are direct suppliers of the main carmakers worldwide, originating in Germany, Austria, Slovenia, Spain, the United States, India, Italy, Japan, Luxembourg, Switzerland, Poland, Portugal. and China (Industrial Cluster, Urban Center 2018). The State has an average of 58.46 km of roads per 100 km2 of land, the existing highway is integrated with the neighboring regions, which has generated good communication, see Table 5.1.

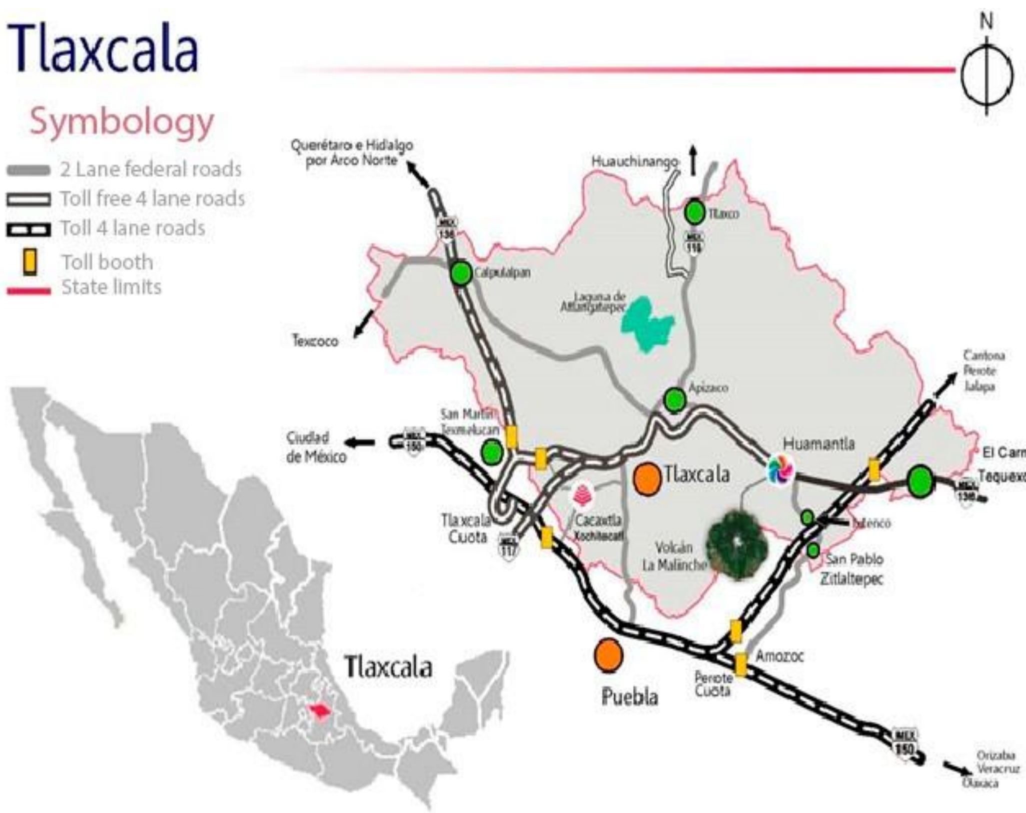
Table 5.1 Length of the highway infrastructure in the State of Tlaxcala

Road length in km							
Linear				**Equivalent**			
Total	Runner	Basic	High school	Total	Runner	Basic	High school
560.57	141.95	100.51	318.11	814.71	273.96	155.31	385.44

Source: Ministry of Communications and Transportation, 2016

In the western area, where the municipalities of Calpulalpan-Nanacamilpa are located, the Arco Norte, which connects from the southern region of Zacatelco, through the southern center of the municipality of Tlaxcala, to the western region of Calpulalpan. The northern arch is also one of the main communication routes of various states of the republic. The distribution of these roads can be seen in Figure 5.5.

Figure 5.5 Infrastructure highway in the State of Tlaxcala



Source: Economic Development Secretariat of Tlaxcala, 2016

In the northern area, there are the Apizaco Tlaxco, Tlaxco Tejocotal highways. In the southern zone is the Mexico Puebla Texcoco highway that also connects with the North arch. There is also the Tlaxcala Puebla highway and the Amozoc Perote highway. In the eastern area, Cuapiaxtla Cuacnopalan highways are located The central area of the State has federal roads of 2 and 4 lanes, likewise provided by State communication channels which give fluidity to all Tlaxcala.

Infraestructura ferroviaria

The railway infrastructure crosses the country from north to south and from east to west, connecting the main towns, ports and borders. This infrastructure is considered one of the logistical assets of greater importance because its network allows intermodal transport, where different modes of transport are combined to obtain advantages and greater efficiency. These industries have seen a solution to their national logistics problems in rail transport because they manage to mobilize large volumes of new units and auto parts for assembly or distribute them in the spare parts market..

In this context, the Mexican Association of Railways (AMF) emphasizes that the first requests of the assemblers are to have an effective connection with the railroad (Cedillo-Campos MG, García-Ortega MG, Martner-Peyrelongue, CD et. Al 2017), and that also provides efficiency and competitiveness, security, time and price. Regarding the automotive sector, the railroad transports 75% of the cars produced in the country according to the Mexican Railroad Association (Martínez, E 2016), which shows an economic interdependence between the railroad and the assembly plants established in the National territory. Currently, the company Ferromex has moved 3 million vehicles completed during the year 2017, this is 72% of the production of the assembly plants of Chrysler, Ford, General Motors, Honda, Mazda, Nissan, Toyota and Volkswagen.

As has been described so far, the links between the automotive industry and the railroad correspond to a bilateral relationship that is to say for both, the point of integration is situated in the incorporation of the railroad to the logistics needs of the automotive industry. The railway industry moves large volumes of finished vehicles and auto parts for assembly or spare parts market, have found a strong ally in rail transport to meet their needs for both national and international logistics that allows the movement of compact, medium and large vehicles towards markets in North America and the rest of the world, through the rail network.

Rail infrastructure represents one of the most important logistics assets, because it is the main element within the logistics network that facilitates the so-called intermodal transport, where several modes of transport combine their advantages to achieve greater efficiency. In Tlaxcala, the presence of small and medium-sized companies in the automotive sector has been strengthening, manufacturing plants are concentrated in three industrial cities located in Tetla, Tlaxco and Huamantla; in addition to the corridors located along the two roads that connect the State with the City of Puebla. In terms of rail infrastructure, the entity of Tlaxcala in the year 2017 had 352 km of railways which are integrated by three lines: Mexico-Veracruz, via Apizaco, which crosses the entity from west to southeast; Mexico-Veracruz, via Mena, Tlaxcala and Jalapa; and Mexico-Veracruz, via Orizaba and Córdoba that passes through the municipalities of Calpulalpan, Nanacamilpa, Sanctórum and Mariano Matamoros, see Figure 5.6.

Figure 5.6 Railway network in the State of Tlaxcala

Source: Economic Development Secretaria of Tlaxcala, 2018

Marine transport

Maritime ports for the automotive industry constitute one of its most important strategic logistics assets, given its participation in the international exchange of goods. According to statistics from the World Trade Organization (WTO, 2012), more than 80% of the merchandise marketed in the world moves by sea, with ports being the nodes that allow this exchange to operate. The port with the lowest distance to the state of Tlaxcala is Veracruz, which is located 309 km away (SCT, 2017). Table 5.2 shows the distances from Tlaxcala to the main high-altitude ports in Mexico.

Table 5.2 Distance to the main ports of height

Port	Distance in Km
Tuxpan/ Veracruz	204
Manzanillo/ Colima	934.90
Coatzacoalcos/Veracruz	502.50
Lázaro Cárdenas/ Michoacán	734.10
Dos Bocas/ Tabasco	681.30
Altamira/Tamaulipas	345
Ensenada/ Baja California	2921
Guaymas/Sonora	1871
Veracruz/ Veracruz	309
Topolobampo /Sinaloa	1548
Puerto Vallarta/ Jalisco	941

Source: Selfmade with information from the communications and transport secretariat

In relation to the State of Tlaxcala, due to its strategic location and its connections to the main high-altitude ports of Mexico, it offers privileged access to the United States and Canada and maritime connectivity to Asia, Europe and South America.

Figure 5.7 Strategic location of Tlaxcala for high altitude ports

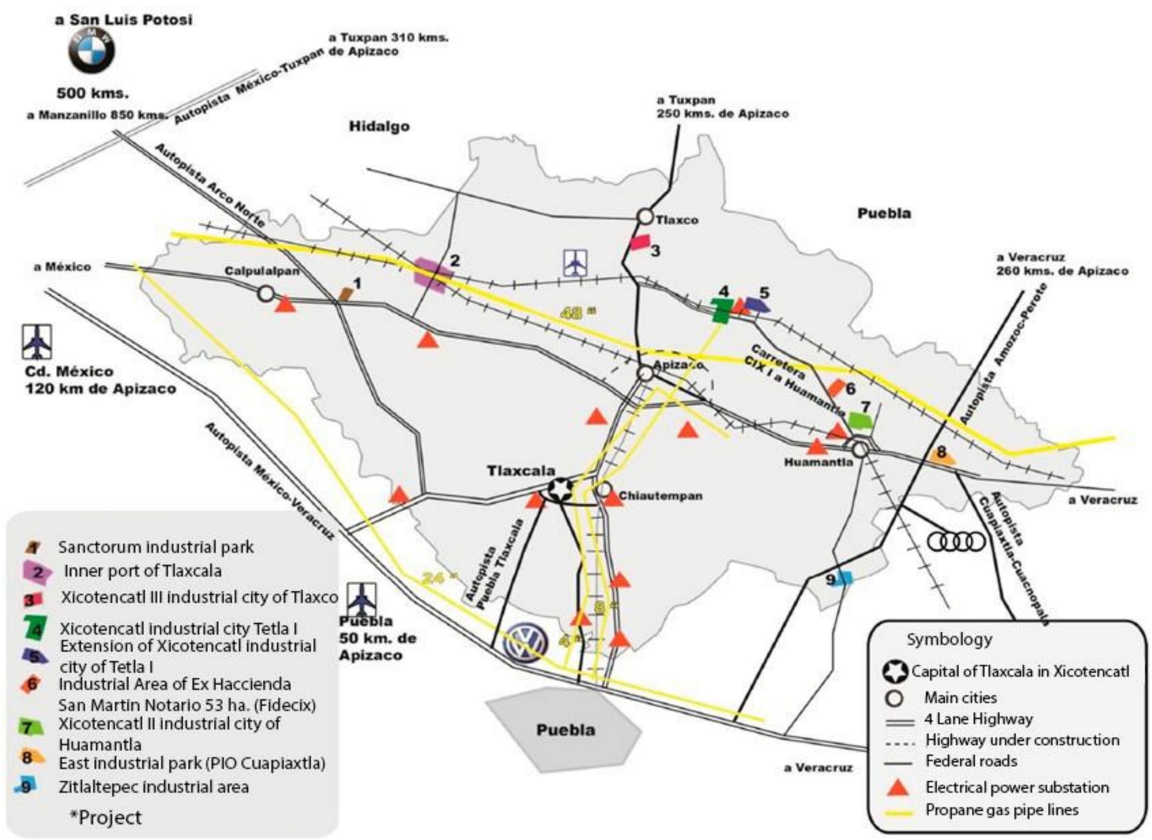
Source: Secretary of Economy Tlaxcala, 2016

The advantages of having a connection to high-altitude ports is to offer companies the ideal conditions to do business, the economic benefit being fundamental, this is achieved by making their logistics operations more efficient, reducing their costs and execution times. Figure 5.7 illustrates the geographic location of the country and the state of Tlaxcala with respect to other countries, the difference in the schedules of the main cities that trade.

Air Transport

Air transport is an innovative industry that guides economic and social progress. It connects people, countries and cultures. It provides access to global markets and generates trade and tourism. Forges ties between developed countries and developing nations. For the automotive industry one of the main factors is the adequate compliance with delivery times for its customers, so air transport plays an important role in the export or import of auto parts and products that provide to the automotive industry. In terms of airport infrastructure, the state of Tlaxcala has a national airport. However, this has only reported operations in 1994 and was only 24. Figure 5.8 shows the summary of the infrastructure that counts the state of Tlaxcala.

Figure 5.8 Productive infrastructure of the state of Tlaxcala



Source: National Institute of Statistics and Geography, 2018

Variable Customs

In Mexico, the General Administration of Customs (AGA) is an entity dependent on the Tax Administration Service (SAT) that is responsible for monitoring, monitoring and controlling the entry and exit of goods from the national territory. The customs offices are the administrative offices which are located in the borders of the country, in the same way borders are established in the littorals and important cities. The distribution of customs infrastructure in the country can be seen in Figure 5.9.

Figure 5.9 Geographic location of the customs in the Mexican Republic

Source: Customs in Mexico, RUBISA group, 2016

In the logistics operations for the supply of raw material in the manufacturing industries, it is common to import special materials from the countries of origin, together with the export of finished products (auto parts, spare parts and new vehicles) it is essential to know the distance from State to each of the customs points as shown in Table 5.3

Table 5.3 Distance to the main customs in Mexico from Tlaxcala

Location of Customs of Mexico	Distance from Tlaxcala (Km)
Northern border	
Agua Prieta, Sonora	2055
Ciudad Acuña, Coahuila	1415
Ciudad Camargo, Tamaulipas	1017
Ciudad Juárez Chihuahua	1092
Ciudad Miguel Alemán, Tamaulipas	1171
Ciudad Reynosa, Tamaulipas	932
Colombia, Nuevo León	1248
Matamoros, Tamaulipas	928
Mexicali, Baja California	3092
Naco, Sonora	2107
Nogales, Sonora	2279
Nuevo Laredo, Tamaulipas	1228
Ojinaga, Chihuahua	1613
Piedras Negras, Coahuila	1354
Puerto Palomas, Chihuahua	2014
San Luis Río Colorado, Sonora	2631
Sonoyta, Sonora	2401
Tecate, Baja California	2826
Tijuana, Baja California	2859
Southern border	
Ciudad Hidalgo, Chiapas	1094
Subteniente López, Quintana Roo	1225
Aduanas Marítimas	
Acapulco, Guerrero	478
Altamira, Tamaulipas	463
Cancún, Quintana Roo	1520
Ciudad del Carmen, Campeche	834
Coatzacoalcos, Veracruz	499
Ensenada, Baja California	3121
La Paz, Baja California Sur	1790
Guaymas, Sonora	1877
Mazatlán, Sinaloa	1123
Manzanillo,	928
Lázaro Cárdenas, Michoacán	726
Salina Cruz, Oaxaca	646
Progreso, Yucatán	1249
Dos Bocas, Tabasco	674
Veracruz,	310
Tuxpan,	253
Tampico,	435
Interior Customs	
Aeropuerto Internacional de la Ciudad de México, CDMX	118
Aguascalientes, Aguascalientes	589
Chihuahua, Chihuahua	1546
Guadalajara, Jalisco	654
Guanajuato, Guanajuato	453
México, CDMX	116
Monterrey, Nuevo León	1008
Puebla, Puebla	37.4
Querétaro, Querétaro	305
Toluca, Edo México	173
Torreón, Coahuila	1101

Source: Self Made with information from Grupo RUBISA

In the state of Tlaxcala has installed a significant number of industrial companies which require customs services motivated by the magnitude of products required for manufacturing and export of various finished products to different countries. The Official Gazette of the Federation establishes the decree establishing the interior customs office of the state of Tlaxcala, where an Internal Customs Office of the State of Tlaxcala is determined, with a location in the municipality of Atlangatepec (DOF: 25/10 / 1984). The customs services of the state of Tlaxcala are in charge of the customs of Puebla, where its territorial circumscription includes the state of Morelos. The customs sections of Cuernavaca, in the Municipality of Jiutepec, in the State of Morelos and the Hermanos Serdán International Airport, in the Municipality of Huejotzingo, in the State of Puebla, also depend on this Customs Office. This customs office is fundamental for the commercial process to all of America, Europe and the rest of the world, providing security and guaranteeing the shipment and delivery of goods and reducing the costs of international trade through the application of regulations such as:

- Study and formulate of the projects of tariffs compensatory quotas and other measures of regulation and restriction of foreign trade.
- Enforce the agreements and conventions that are celebrated in customs matters.
- Order and practice the verification of foreign trade merchandise in transport.
- Verification of the transit of vehicles of foreign origin.
- Determine foreign trade taxes and other contributions.

The proper functioning allows compliance with the provisions on foreign trade, also guarantees national security, protects the country's economy, public health, the environment by preventing the flow of dangerous or illegal goods (Customs, SAT). As expressed (Zamora-Torres, Navarro Chávez, 2015) efficiency in customs has a significant impact on the reduction of costs related to trade and the performance of commercial administration. In this sense, the use of new technologies that the Tax Administration Service grants to the customs service allows obtaining a 100% automated customs clearance, which will reduce the administration of risks.

The investment in 2016 was 8540 million pesos, an amount that covered the installation and replacement (analogous to digital) of 14,400 video surveillance cameras that will be installed at 60 checkpoints in the country's customs, reading boxes and license plates goods that pass through customs (Bulletin of prey, The Economist 2016.)

Variable International Shipments

Currently, the manufacturing companies of auto parts installed in the state of Tlaxcala require very high quality national and international shipping services, since a service of low quality has as a consequence the delivery out of time, delivery in defective form of the merchandise or product. In both cases, the above means losing the client. The courier, parcel, and cargo transportation companies that offer their services in the state to the interior of the Mexican Republic and beyond their borders have a national and international logistics capable of mobilizing shipments efficiently and cost accordingly. the dimensions of the cargo, origin and destination.

By transporting more and more products to greater distances, the optimal management of all the resources involved can not only mean better financial results, but the survival of the company itself (Dorta-González, 2013).

These shipping companies share the philosophy of providing logistical support through effective and qualified processes to ensure the safe transport of cargo, courier and parcel service, in addition to meeting deadlines for delivery. Some of the companies installed in the entity are: DHL, FedEx, Estafeta, RedPack, Multipack among others, while the cargo transport companies are: Grupo Sercomex, Logística y Distribución de Tlaxcala, S.A. de C.V, Transportes Hernández Guevara, S.A. of C.V to mention a few.

Currently, the clients of these companies evaluate the quality of the service, its added value and its availability in a timely manner. In this way, the need to make the processes efficient (Cano-Olivos, Orue-Carrasco, 2013) arises. In competitiveness, logistics innovations and supply chain management are important factors for the distribution of national and international merchandise.

In summary, the service providers in the Tlaxcala must have a local, national and international coverage, in addition they must have a document that explicitly details both national and international destinations. It can also be mentioned, the messaging service which has the telegraphic network TELECOM, which has 5 offices of the 11 that are distributed in the state.

There is also the company Continental Service of Messaging which has coverage throughout the national territory where the areas can be urban, semi-urban and rural representing approximately 7% of shipments. Other companies such as FedEx have a new operating station located in the state of Puebla, which will be functioning as a connection point for the states of Tlaxcala, Veracruz, Oaxaca and Chiapas. The infrastructure has an installation of more than 9,000 square meters, which makes it one of the largest stations in the country, also has two access ramps, six loading platforms and capacity to serve 60 routes.

Variable Traceability and Tracking

The companies involved in the manufacture, storage and distribution of the auto parts sector understand the value of tracking them from the moment they are created until they are sold. To obtain traceability in the automotive supply chain, RFID tags, sensors and smart devices are used to track and optimize the movement of materials from the suppliers to the receiving docks and during assembly. However, they carry the instrumentation even further, using it to improve visibility in all processes; For example, dealers can use smart tags not only to locate specific cars in large batches, but also to ensure that they install the correct customizations on the right vehicles.

The supply chain of the automotive industry is highly interconnected, even in complex distribution networks. Dealers can see their own inventory of parts, as well as the inventory of other distributors and distribution centers to order the parts they need from any location.

The automotive supply chain uses greater instrumentation and interconnectivity to improve products and operations, as well as to obtain consumer information. The systems and software integrated in the vehicles help the supply chain to obtain data on indicators of possible failures. This information, in turn, provides visibility into the demand for parts and services and helps the manufacturer improve quality and reduce warranty costs. For tracking and tracking in the automotive industry, outsourcing is a potential area of opportunity to reduce costs.

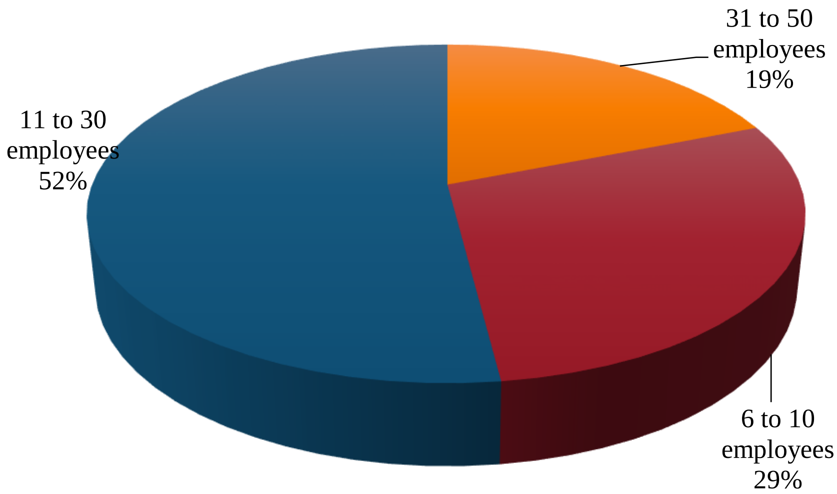
The only function of the supply chain that most automotive executives subcontract extensively is the transportation of up to 76 percent of automotive companies subcontract this service (IBM, 2009). For this reason, in the traceability and follow-up variable, the scope of the study was defined for companies in the cargo transportation sector in the state of Tlaxcala, which are the companies that carry out the distribution for the auto parts industry.

Finally, once the data is collected in the traceability and follow-up variable, we have information from 21 companies that collaborated. According to the statistical procedure determined for the handling of the data, it begins with the description of the demographic variables that were collected in a first questionnaire that was applied to the companies in question. The findings are described below.

Number of employees of Cargo Transport companies

The data arrogan that of the 21 companies established in Tlaxcala that have the capacity to send the products of the auto parts sector are mostly small companies with a range of employees between 11 to 30 which speaks of companies with a low participation in the working market. 29% of the population is composed of micro enterprises, see graphic 5.1.

Graphic 5.1 Number of employees of freight transport companies

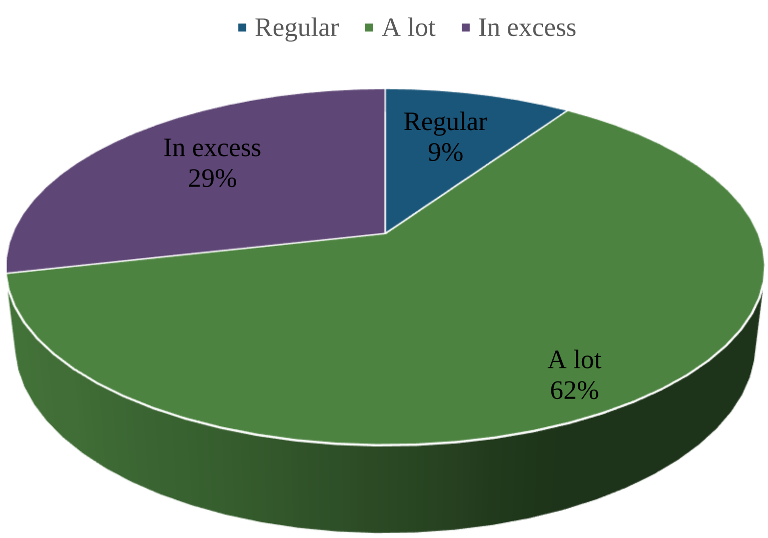


Source: Own creation

Importance of technology in logistics processes for tracking and tracking

A revealing fact in the companies of motor transport of load that have the capacity to distribute the products of sector autopartes consider in 62% that the technology in the logistical processes has a lot of importance; 29% refers to the fact that in their processes, tracking and tracking of the load units, the technology has an excess of importance and only 9% of the companies give it a regular importance.

Graphic 5.2 Importance of technology in motor transport companies

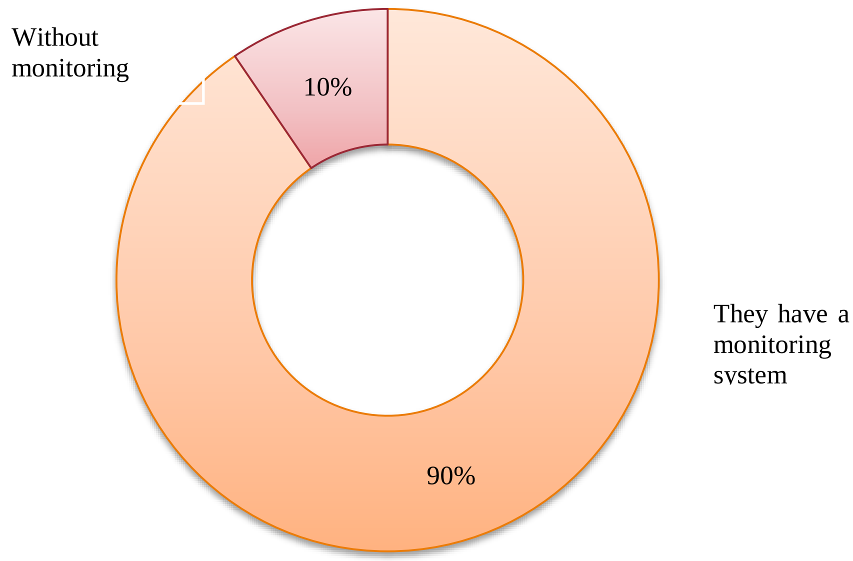


Source: Own creation

Companies that have a monitoring and tracking system

In relation to companies that have a monitoring and tracking system, 90% of freight transport companies in the state do have this system, this shows that companies in the auto parts sector can count on a reliable transport service and efficient. See graphic 5.3.

Graphic 5.3 Companies with monitoring and tracking system

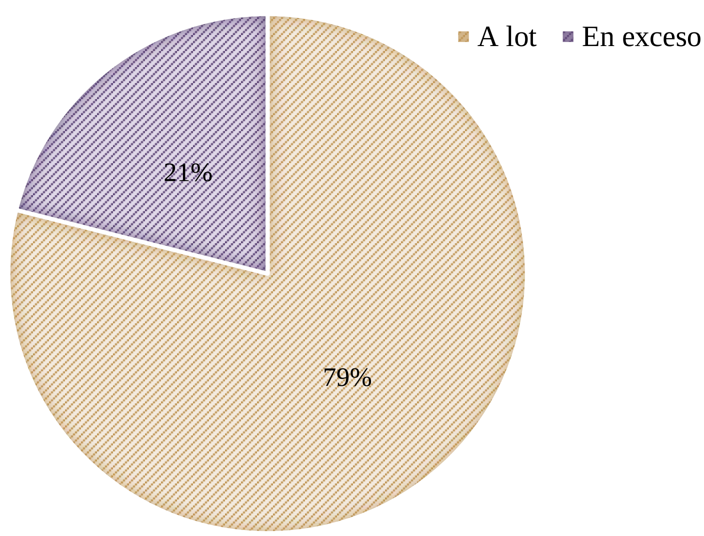


Source: Own Creation

Ability to track and monitor cargo units

Regarding the ability to track and monitor the cargo transport units, 79% of the companies state that at the time of monitoring the units they present some setbacks for their location; 21% of the rest of the companies state that the location of their units is carried out immediately and without any contracting times. See graphic 5.4.

Graphic 5.4 Ability to track and monitor when performing it sent



Source: Own Creation

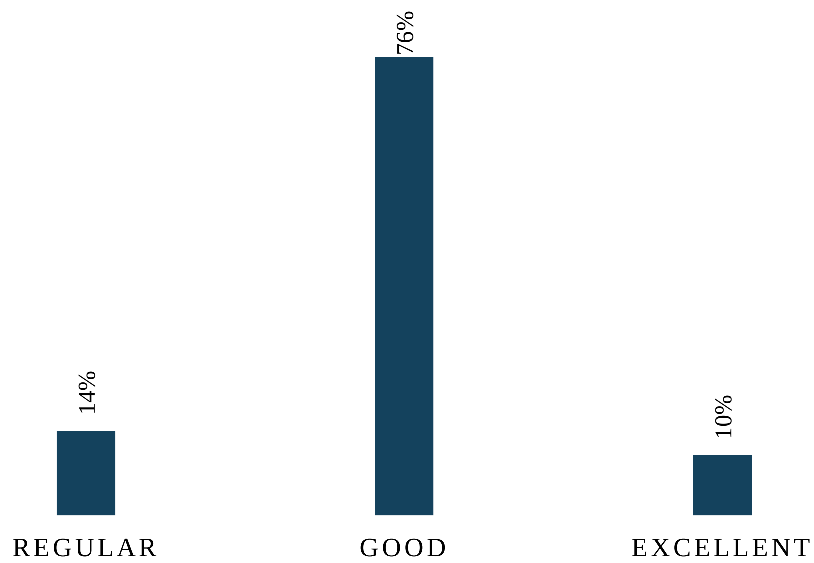
Variable Punctuality

One of the most important factors in the automotive industry is the punctuality in the delivery of the auto parts; the load must arrive on time, in optimal conditions, and without breakdowns. Accomplishing this requires a perfect recognition of the path that this load will take, and monitoring it in all that transit with the necessary quality measures so that the delivery estimates in time and form are effectively met. Regarding the survey, the data obtained in the punctuality variable are presented below:

Frequency of deliveries on time

Graphic 5.5 shows that 76% of companies consider that the delivery of their products to end customers is good, while 14% refer to it as regular and the remaining 10% is excellent. This reflects that the cargo transportation companies of the state of Tlaxcala comply with the provisions on punctuality and competitiveness for the auto parts sector.

Graphic 5.5 Delivery on time

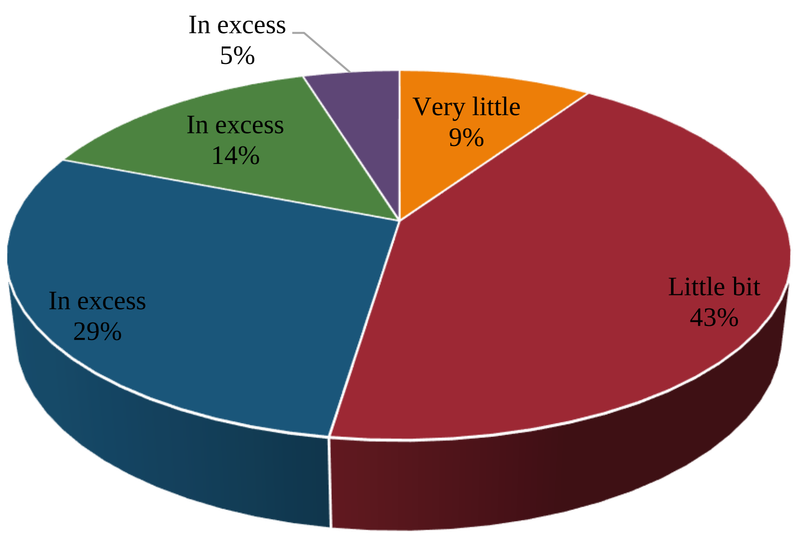


Source: Own creation

Frequency in which the delays of delivery of your product with your customers due to congestion is:

One of the reasons why orders are not delivered on time is urban congestion, 43% of the companies surveyed in the state of Tlaxcala mention that congestion affects little to the punctuality of deliveries, 29% affecting In a regular manner, only 5% refers to the fact that it affects excessively. See graphic 5.6.

Graphic 5.6 Delays due to congestion

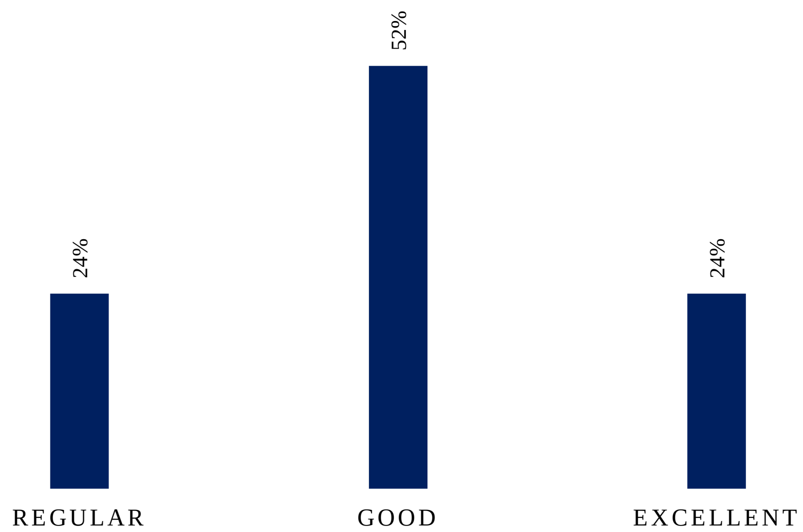


Source: Self Made

Frequency of receipt of product on time

For shipments to be made within the stipulated time it is of the utmost importance that the reception of the products in the transport companies be carried out in the planned time; With regard to this variable, 52% of the companies referred to have received good products on time, 24% consider that they are regular and the remaining 24% are excellent. See graphic 5.7.

Graphic 5.7 Reception of products on time

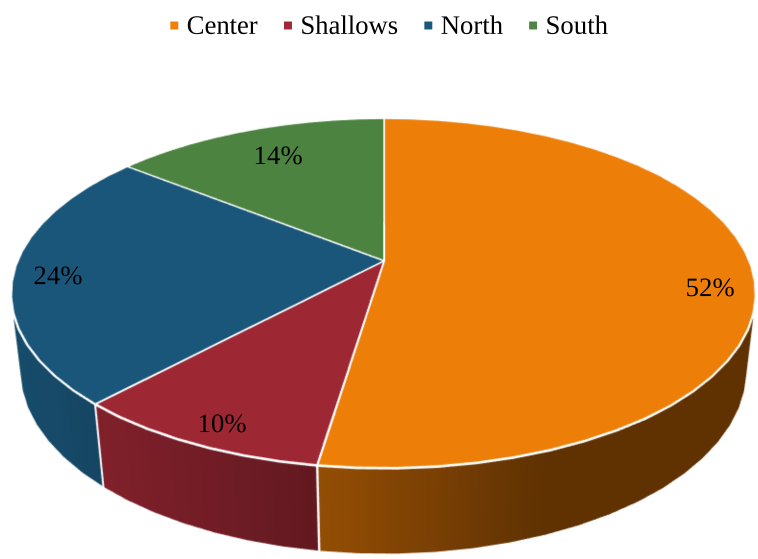


Source: Own creation

9.- When organizing shipments to areas of the country, how often do they arrive late?

Regarding the shipments with setbacks to the zones of the country, 52% of the companies make reference that the center of the country is where there is the greatest problem to deliver the products in the stipulated time, followed by 24% of the north of the country, with 14% the south and finally only 10% present problems of delays with the area of the shoal.

Graphic 5.8 Frequencies of delays to different areas of the country



Source: Own Creation

Conclusions

The strategic location of the state of Tlaxcala allows to communicate with the main markets, ports and customs of the country, which provides to the installed auto parts manufacturing companies the transfer of raw materials and finished products to the assembling companies, agencies or autoparts market. The supply chain of this industry of auto parts in the state involves the participation of a network of companies from the supply of raw materials to the delivery of the final product. Currently, these manufacturing companies move their products such as seat covers, harnesses, safety belts, airbags, automotive electronic components to states such as Puebla, San Luis Potosi, Guanajuato, Aguascalientes, as well as countries in Europe and the United States. United. To this end, the infrastructure available to the state allows access to the Bajío region through the north arch located in the western area of Tlaxcala, and to Puebla via the short route through Santa Ana Chiautempan or from the Tlaxcala bypass Puebla. Regarding exports, these can be made by sea through the Gulf of Mexico through the port of Veracruz, or by air through the international airports of Mexico City and Puebla.

The objective for the suppliers of the entity is to produce the correct pieces in the correct amount at the correct price, delivered in the right place at the right time; However, there are lags identified in the logistic performance of the entity which are mentioned as follows: there is lag in the interior port of the state, such as multimodal internal customs, airport disabled for commercial flights, there is no controlled premises, poor technology point, an infrastructure of industrial parks little strengthened, evidences the lack of technology of the companies of transport of load to realize traceability and pursuit of the automotive units.

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Chapter 6 Redesign of warehouse layout: Key piece in the supply chain

Capítulo 6 Rediseño de ubicaciones en el almacén: Pieza clave en la cadena de suministro

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Abstract

The automotive sector has become one of the most important industries, its importance lies in the social and economic effect it causes in the regions it operates. The challenge is to maintain a sufficiently flexible and coordinated supply chain among the various participants, so that changing demands, delivery times and increasingly short life cycles can be met. Hence, warehouses are vital in the supply chain and have ceased to be only the facilities that are dedicated to store materials or products, now they have become centers of service and support of the organization. An efficient warehouse has an impact on the overall performance of the supply chain, for this it must be located in the optimum place, be designed according to the necessary operations, use the appropriate equipment for handling materials, and have an information system that support inventory control. The main objectives of the design of the warehouses is to facilitate the speed and precision in the preparation of orders, as well as the efficient placement of stocks, all this to enhance the competitive advantages of the organization. Through the Systematic Layout Planning (SLP) methodology, warehouses can be configured to achieve the aforementioned objectives. In this case of study, the poor location of the materials inside the warehouse generated excessive time in the preparation of orders (picking) of materials, which clearly affected the productivity of the supply chain, so it was decided to redesign the locations of materials within the warehouse through the SLP methodology, the results that were obtained from the implementation were significant, since it was possible to reduce the picking time of materials of 67 and 69 minutes of the front and rear products to 33 and 34 minutes respectively, and as a result, online stoppages, overtime hours, costs, among others, are reduced.

Automotive industry, Supply Chain, Logistics, Warehouses, SLP

1. Introduction

The automotive industry is the most relevant sector for many economies in the world and has been a source of innovation in the design of products and manufacturing technologies. In Mexico it is one of the most competitive and dynamic economic activities since it contributes with more than 3% of gross domestic product and generates around 900,000 jobs in the country (Mexican Association of Automotive Distributors [AMDA], 2016). For this reason, many organizations that are part of the Supply Chain (CS) of the automotive industry, have adopted different methodologies to improve logistics performance. It should be noted that the supply of automotive parts in many cases is through a Just in Sequence (JIS) or Just in Time (JIT) scheme, hence the interrelation and coordination of all members of the supply chain must be the basis for generating strategic procurement (Chiang et al., 2012) and competitive advantages that contribute to achieving the objectives and achieve the success of the organization.

In particular, logistics is what manages the flow of products between points of origin and points of consumption, this involves integrating information flows, handling of materials, production, packaging and packaging, inventories, transportation, storage, among others; while the administration of the supply chain is the one that strategically coordinates the functions and activities among the companies that make up a supply chain (Li, 2014).

The objective of this case study was to redesign the locations of materials within the warehouse of one of the suppliers of the automotive industry, in order to reduce picking times and consequently minimize overtime hours. In the first part of this chapter is the literature review, which addresses the importance of the distribution of warehouses, as it is considered vital in the supply of materials, since poor distribution can increase logistics costs, delivery times and decrease the level of customer service; In the second part, the three phases of the Systematic Layout Planning (SLP) methodology are described; in the third part, the development of the case study is described, starting by analyzing the problem, finding solutions and making decisions; in the last part the results obtained and the conclusions of the work are shown.

2. Theoretical review

The automotive industry is one of the most competitive sectors in the market, but demand, flexibility, quality and agility are the critical success factors (Caridade et al., 2017), that is, supply chains change every day, change of size and configuration (MacCarthyet al., 2016), and even more coordination, control and management also become dynamic. For this reason, the supply chain of the automotive industry has been the most studied (Xie, 2014), and in general the administration of the supply chain has received special attention from academics (Ou et al., 2010).

For the importance of the coordination and integration of the supply chain is essential to compete in the globalized world, however this has been characterized by the high degree of difficulty and complexity of the multiple relationships and interactions between the members (Kamariah & Mohamed, 2009), these interactions are not only complicated by their volume and variation in processes, but also by the complexity inherent in the existing dependency between the parties in time and space (Power, 2006). Therefore, it is necessary for the organization to have strategic collaboration with all members of the supply chain, both internal and external, in order to achieve effective and efficient flows of products and services, information, money and decisions, with the objective of maximizing the value to the customers at the lowest cost and faster (Zhao et al., 2008).

Logistics plays a very important role in any company, as it is responsible for managing, managing and controlling the inventory of materials, and is also responsible for providing materials to the production processes, however there are two important factors that have to be considered in the supply system, these are the time of collection of materials and location of raw materials in the warehouse. Currently successful organizations are increasingly characterized by the ability to abandon inadequate work configurations (Raguseo et al., 2016), for this case the proper distribution of the store can mark the success (or failure) of the business (Huertas et al., 2007; Frazelle, 2002).

It should be noted that warehouses are considered a vital part (Faber et al., 2013), since they are the intermediate and critical point of the members of the supply chain (Kiefer & Novack, 1999), since they can affect several aspects of the supply chain warehouse performance such as the cost of material handling, space cost and storage capacity (Rakesh & Adil, 2015). The main functions that warehouses must fulfill are: a) Maintain the flow of materials along the supply chain, b) Consolidate products from multiple suppliers and, c) add value to the activities of collection, labeling and personalization of the product (Horta, 2016).

While it is true that the most appropriate warehouse design depends on its operational conditions and characteristics such as modularity, adaptability, movement, accessibility and flexibility (Hassan, 2002), the design of the warehouse layout is a dependent problem, since there is no better design, due to the diversity of factors that influence the operation such as access, types of racks, racks levels, among others. (Tompkins et al., 2003; Carranza et al., 2004; Bartholdi & Hackman, 2005). The layout of the warehouses must consider a dynamic flow of materials, to minimize the cost, handling, transport of stored products (Gopalakrishnan et al., 2004), to improve the use of space (De Koster et al., 2007; Gu et al., 2007); and also must provide better working conditions (Richards, 2011).

Since years ago, the problems of designing the layout have been an active field of research, Vis & Roodbergen (2011) proposed three different concepts and procedures that can be used to design the layout of the warehouse; the first as a fixed layout, which is designed for a considerable period of time; the second layout based on categories, seeks to incorporate greater flexibility in such a way that it allows to categorize the materials according to the daily information; and the third as a flexible layout, this must allow daily changes.

There is also literature that divides the problems of layout design, algorithmic and procedural into two main categories. The algorithmic approach uses numerical calculations to optimize the system design, that is, it only implies quantitative data; whereas the procedural approach can incorporate quantitative and qualitative data (Liu, 2016).

Yang (2000) believed that the procedural approach was not enough to handle the problems of multi-objective layout planning, but through some evaluation functions these problems can be solved more effectively. The systematic layout planning (SLP) proposed by Muther (1976) is a relatively simple and procedural approach tool that has been proven in several organizations.

The SLP method is used to determine an efficient layout that:

1. It is based on the analysis of a logistic relationship between blocks and operating units.
2. Use a method of factor evaluation to evaluate the proposals.
3. Obtain the optimal layout (zhou et al., 2010). The main objective of the slp is to find a layout that minimizes the transport costs of the goods, in other words locate the departments as close as possible (Van Donk & Gaalman, 2004).

Although the relationship between the characteristics of the warehouse and the cost of maintenance is understood, little work has been done to evaluate the connection that the service level has with the distribution of the warehouse (De Marco & Mangano, 2011), as the interior distribution of the warehouse is to treat a very complex logistic process, since it has to be considered from the reception of the materials, handling of loads and storage, control and management of stocks, preparation of orders and delivery of material.

A well-managed and distributed warehouse gives balance to the company, because it is able to stabilize production with demand, since it tries to synchronize manufacturing and demand and also assumes a permanent supply. Therefore, the warehouse is considered a key element in the logistics network as it serves as a regulator of the flow of materials, and also must function and fit seamlessly throughout the supply chain to achieve excellence.

3. Methodology

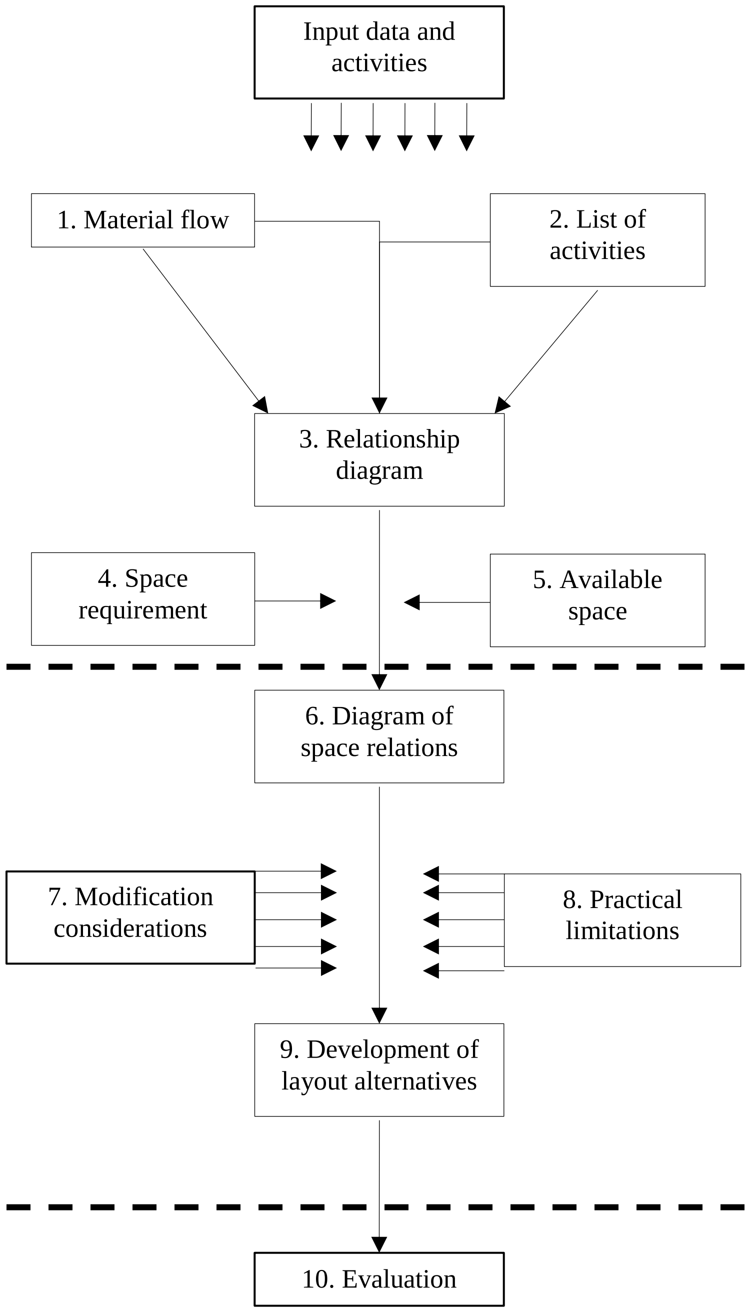
The objective of redesigning the locations of materials within the warehouse is to optimize the flow of materials, people and information (Monks, 1987). The SLP is a method widely used in companies due to accessibility (Gilbert, 2004), since it facilitates decision making in the redesign of facilities (Silva y Moreira, 2009). However, to initiate the application of this methodology it is important to identify the flows, procedures, activities and limitations of the distribution of the facilities (Trein & Amaral, 2001). According to Tortorella & Flogliato (2008), the SLP is divided into three major steps:

1. Analysis, is the collection of company data, flow and activities related to the process, resulting in the map of relationships.

2. Research, several alternatives are constructed considering the diverse characteristics and limitations.

3. Selection, the performance of the various arrangements is evaluated and the best one is chosen. This case study was developed with the methodology of the systematic layout planning (figure 6.1), it should be noted that the objective of this work is to minimize the picking time, because the excessive times have generated high labor costs extra.

Figure 6.1 Systematic Layout Planning (SLP)



Source: Self Made

3.1 Analysis of the problem

To begin the analysis, information on the current system is needed to determine the relationship between departments, as well as the space required for these and the space available. The tools that are used in this stage are described below.

a. Flow of materials: The flow of materials includes all movements of raw material, product in process and finished product. To facilitate the analysis, the process flow diagram is used, which specifies the material route along the process and a diagram from-to, to know the distance between processes.

b. Relationship of activities: Consists of preparing a table of relationship of activities, developed by Muther (1976), this measures the importance of proximity between departments or processes. For this, all the departments in the table are listed, the importance of the relationship between them is determined, a criterion is defined to assign the importance of closeness, and the relationship value is established and the reason for which said value was assigned. The relationship value is usually expressed as follows:

A: Absolutely necessary
E: Especially necessary
I: Important
O: Ordinary proximity
U: Not important
X: Undesirable
XX: Highly undesirable

All those involved in the development of the table are allowed to have an opportunity to evaluate and discuss possible changes. In the table you can see which departments have to be close to each other so that material handling is efficient (Acevedo, 2001). With the flow of materials and the table of relationship of activities a relationship diagram is drawn up. This diagram shows if there is a flow of materials between each department as well as the relationship between these.

a. Space requirements: The space required for each department or process is determined, taking into account the dimensions of the machinery, the space necessary for the operators, for the inventory in queue and the inventory in process.
b. Available space: It is important that the space available is equal to or greater than the space required, in order to continue with the development of the SLP.

3.2 Search

In this stage the locations are redesigned taking into account restrictions and modifications, through:

a. Diagram of relationship - space: In the relationship diagram, the spaces required for each department or process as well as the location are added.
b. Modifications flexibility.
c. Practical limitations They can be of space and / or resources.

3.3 Evaluation

In this last stage the proposals are evaluated, for the evaluation criteria can be taken as the adjacency compliance between departments, the form of the departments, the cost of material handling, the total distance between departments, among others.

Proximity of departments: Consists in verifying the type of adjacency that is desired and in case of fulfilling said type of adjacency in the proposal a value is assigned. For this evaluation you have to consult the activity relationship diagram where the type of adjacency appears. Once the adjacency between all the departments is verified, the score is added, the highest being a better grade. Below is the value that is applied to each type of adjacency that is met.

A = 20
E = 15
I = 10
O = 5
U = 0
X = 15
XX = 20

Geometric space: The shape of the departments determines a better functionality of the departments. The desirable form of a department is the one that most resembles the perfect square, or if it is a rectangle that is not thin. For this evaluation, the area and perimeter of each department must be calculated. Once you have these data the following formula is developed:

$$\boldsymbol{F} = \frac{p}{4\sqrt{A}} \quad (1)$$

Where:
p = perimeter
A = area
F = department shape coefficient
If $1 \leq F \leq 1.4$, The shape of the department is acceptable

Costs: The total cost for material handling and is calculated with the following formula.

$$C = \sum_{i=1}^{m} \sum_{j=1}^{m} c_{ij} f_{ij} d_{ij} \quad (2)$$

Where:
C = total cost
c_{ij} *= cost of material handling between department i and department j.*
f_{ij} *= flow of materials between department i to department j.*
d_{ij} *= distance between department i and department j.*
m = number of departments.

The desired alternative in this evaluation is the one with the lowest total cost for handling materials

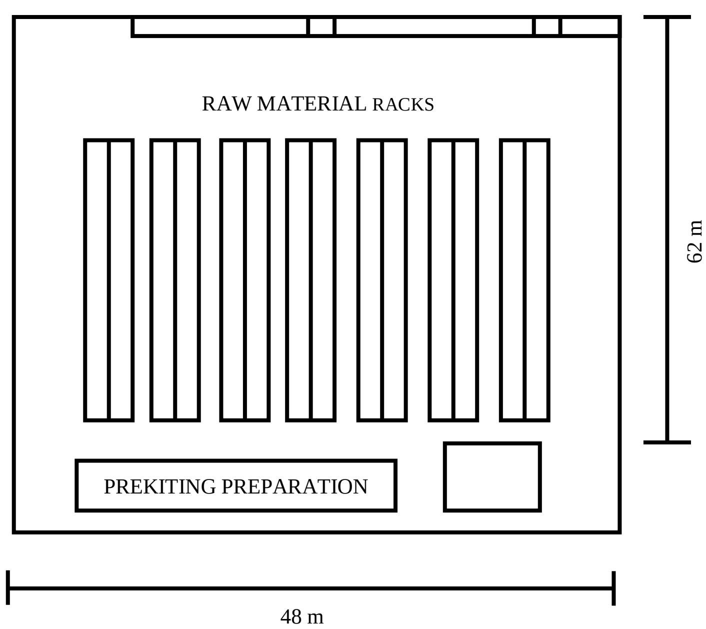
Simulation: According to Kelton (2004), simulation refers to a wide collection of methods and applications to mimic the behavior of real systems, usually on a computer with the appropriate software.

5. Development

5.1 Analysis of the problem

This study was carried out in a company that manufactures components for the automotive industry, and specifically analyzed the physical distribution of the raw material warehouse locations of the front and rear products, which has an approximate area of 3000 m^2; in this space there are 7 ramps, 15 racks of 3 levels, area of order preparation and a quality release zone (figure 6.2).

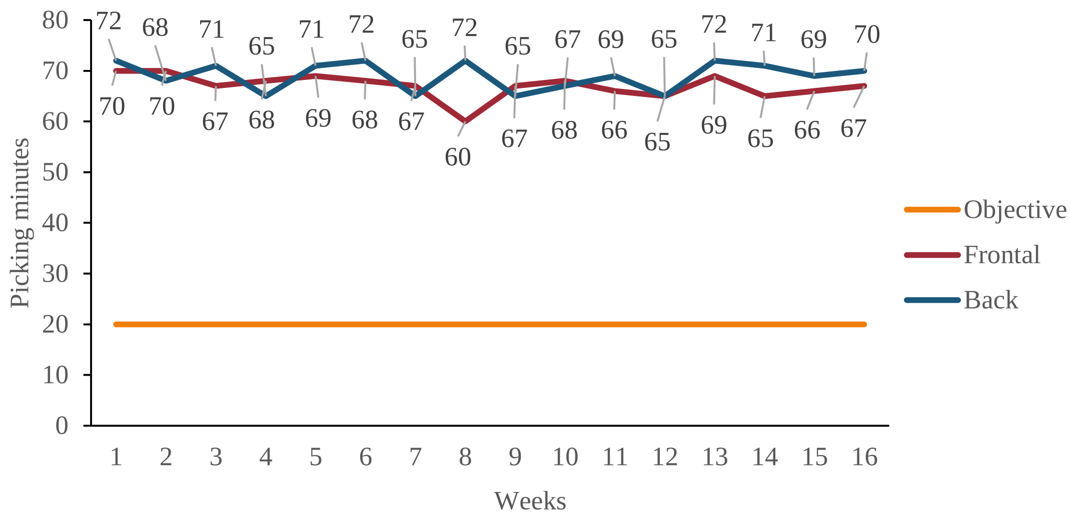
Figure 6.2 Current layout of the materials warehouse



Source: self made

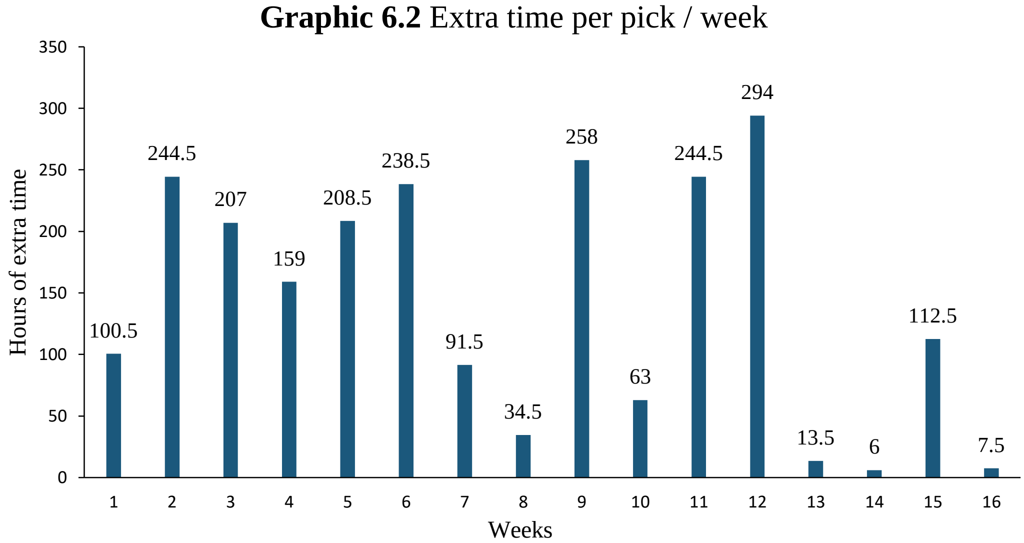
Although the physical facilities of the warehouse currently meet the basic needs in terms of space for the dimensions of inventory that are handled for the short and medium term, the distribution of the warehouse has led to the times of the total flow of the picking exceeding 20 minutes of time customer's touch (graphic 6.1), which has generated that the preparation of orders for the materials to be used for the production of front and rear products, are made in advance through extraordinary work days (Graphic 6.2) to satisfy 100% of customer requirements.

Graphic 6.1 Average picking time / week



Source: Self Made

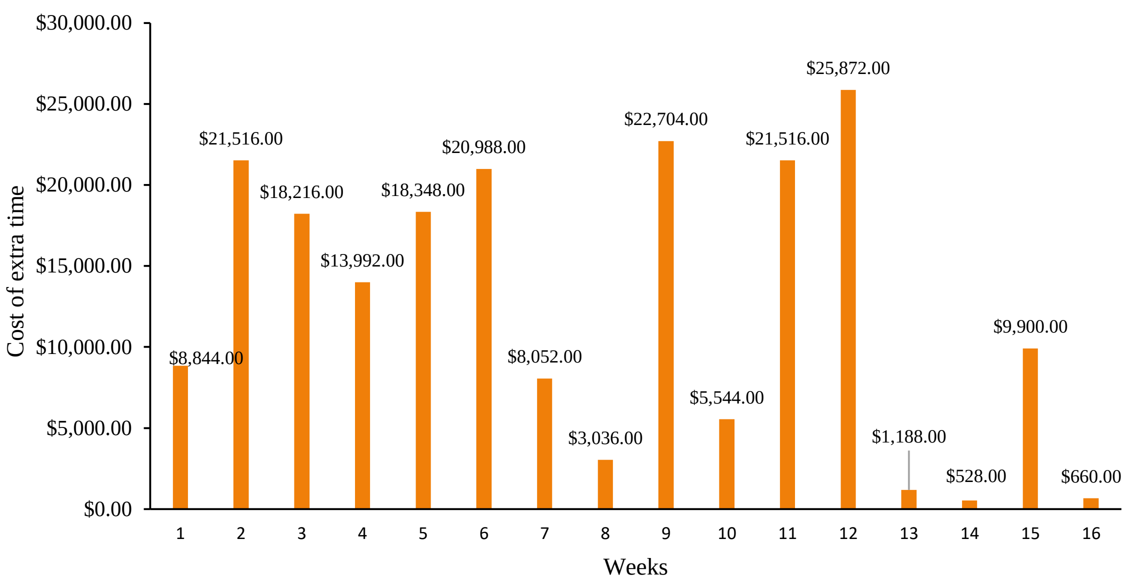
Graphic 6.2 Extra time per pick / week



Source: Self Made

This increase in hours represents a high economic impact within the company, since it is allocating non-budgeted resources for the payment of payroll for the concept of extra time (Graphic 6.3).

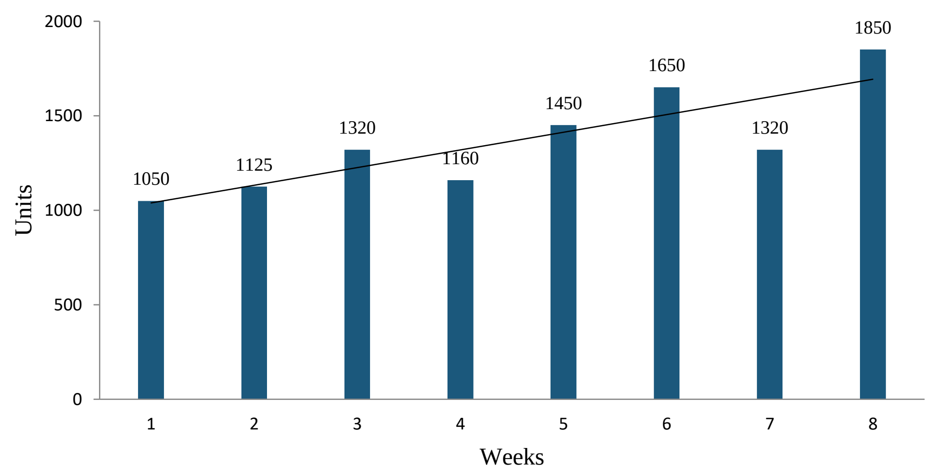
Graphic 6.3 Cost of extra time / week



Source: Self Made

From this problematic was made the analysis of the picking process times to be able to satisfy the customer demand, it was as well as it was detected that the times and movements were very high, that is, the route of the operators are a bottleneck in the operation, for this reason it is necessary to re-configure the locations of the materials of the front and front products within the warehouse through Strategic Layout Planning (SLP), in such a way that the distances traveled from the picking, take advantage of the spaces, save energy, and identify areas of opportunity that allow the organization to be channeled towards competitiveness. One of the important aspects for the sizing of a warehouse is the volume needed to protect the materials, since the total production volume of the last periods has been increasing (graph 6.4), which is why it is necessary to plan the resources for the Following periods, for this reason and under the JIT scheme, the locations of the raw materials warehouse have to be adjusted to reduce picking times, operating costs and optimize labor.

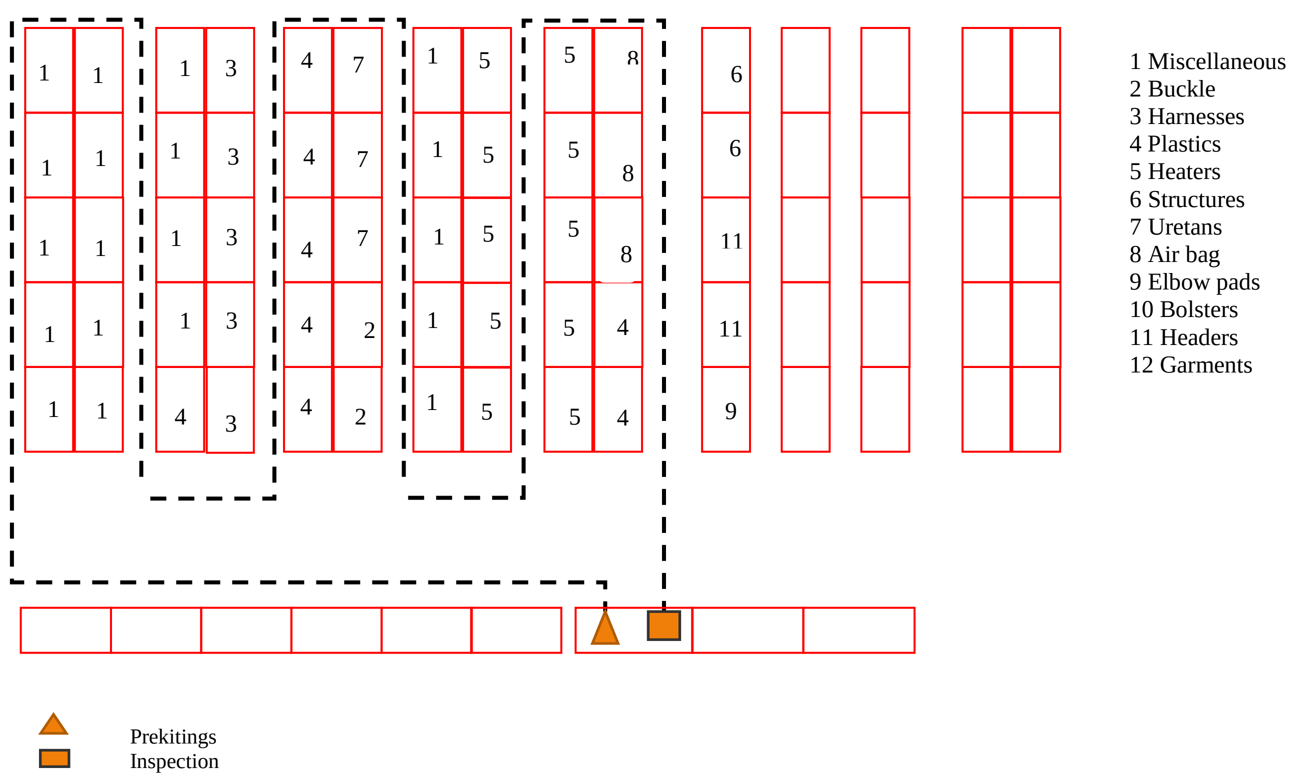
Graphic 6.4 Total production volume



Source: Self Made

That is, each flow added to the work system is one more cost that is added to the process within the raw material warehouse, the picking operations are those that have the greatest weight in the total amount of the operation, so the importance of analyzing by means of a flow chart of materials the routes and times (figure 6.3), in this the location of each of the materials is indicated, currently there are empty spaces, however it is important to relocate the materials, in such a way that the picking times be minimal. It should be noted that each location is a 3-level rack and applies to the front and rear products.

Figure 6.3 Flow chart of the raw material warehouse



Source: Self Made

In the following multiproduct diagram (figure 6.4) the times of travel for the picking of the front and rear products are observed, on average they are 67 and 69 minutes respectively, while the expected is 20 minutes, this imbalance has been compensated with extraordinary days, as already mentioned above with the explanation of graphs 6.2 and 6.3.

Figure 6.4 Multi-product diagram

Operation / material	Product			
	Frontal		Back	
Prekitings	△		△	
Miscellaneous	1	2	1	2
Vestments	12	13	12	13
Bolsters			10	4
Plastics	4	1	4	1
Harness	3	2	3	2
Plastics	4	3	4	3
Urethanes	7	2	7	2
Miscellaneous	1	3	1	3
Buckle	2	1	2	1
Heaters	5	2	5	2
Structures	6	3	6	3
Air bag	8	1	8	1
Headers	11	6	11	6
Plastics	4	8	4	8
Elbow pads			9	3
Inspection	100	20	100	15
Time (minutes)		67		69

Source: Self Made

The relational diagram was also made between each of the activities involved in the picking process (Table 6.1), this applies both to front and rear products, considering the proximity between each of the materials and the basic safety restrictions of the materials sensitive or explosive.

Table 6.1 Relational activity diagram

Activity	Importance of closeness													
0. 0. Pre-kiting														
1. Miscellaneous	E													
2. Buckle	I	I												
3. Harnesses	O	X	U											
4. Plastics	I	U	O	U										
5. Heaters	U	X	O	E	O									
6. Structures	I	U	I	O	I	O								
7. Urethanes	I	U	O	U	U	I	O							
8. Air bag	XX	X	U	A	U	O	U	U						
9. Elbow pads	O	O	O	O	I	O	I	U	I					
10. Bolsters	O	U	O	O	I	O	O	U	E	A				
11. Headers	O	U	U	O	O	U	O	U	I	E	A			
12. Garments	X	U	U	O	I	U	O	I	I	I	E	A		
13. Inspection	A	U	U	U	U	U	U	U	U	I	I	E	A	
	14. Pre-kiting	15. Miscellane	16. Buckle	17. Harness	18. Plastics	19. Heaters	20. Structures	21. Urethanes	22. Air bag	23. Elbow pads	24. Bolsters	25. Headers	26. Vestments	27. Iinspection

Nomenclature	
A:	Absolutely necessary
E:	Especially necessary
I:	Important
O:	Ordinary proximity
U:	Not important
X:	Undesirable
XX:	Highly undesirable

Source: Self Made

5.2 Search

The necessary space for each bay was determined, without forgetting the restrictions of relations and proximity allowed by type of material, it is also necessary to consider that each rack is composed of three levels, each level of 5 bays, each bay has an approximate space of 3.5 m long, by 1.5 m high. It is important to consider the number of part numbers by ABC classification, the amount contained in a standard pack of the supplier and their dimensions. Tables 6.2 and 6.3 show the spaces needed to store the materials.

Table 6.2 Spaces required for the storage of materials (Frontal)

Commodity	Frontal Units	Space m^2	Classification	Type of storage	Space in number of bays
Plastics	119	81	A	Paperboard	23.1
Vestments	109	75	A	Paperboard	21.4
Harness	49	56	B	Paperboard	16
Headers	110	75	B	Paperboard	21.4
Miscellaneous	38	26	B	Paperboard	7.4
Structures	26	17	C	Plastic	4.8
Heaters	25	17	C	Paperboard	4.8
Urethanes	26	17	C	Plastic	4.8
Air bag	15	10	C	Paperboard	2.8
Buckle	5	3	C	Plastic	0.8

Source: Self Made

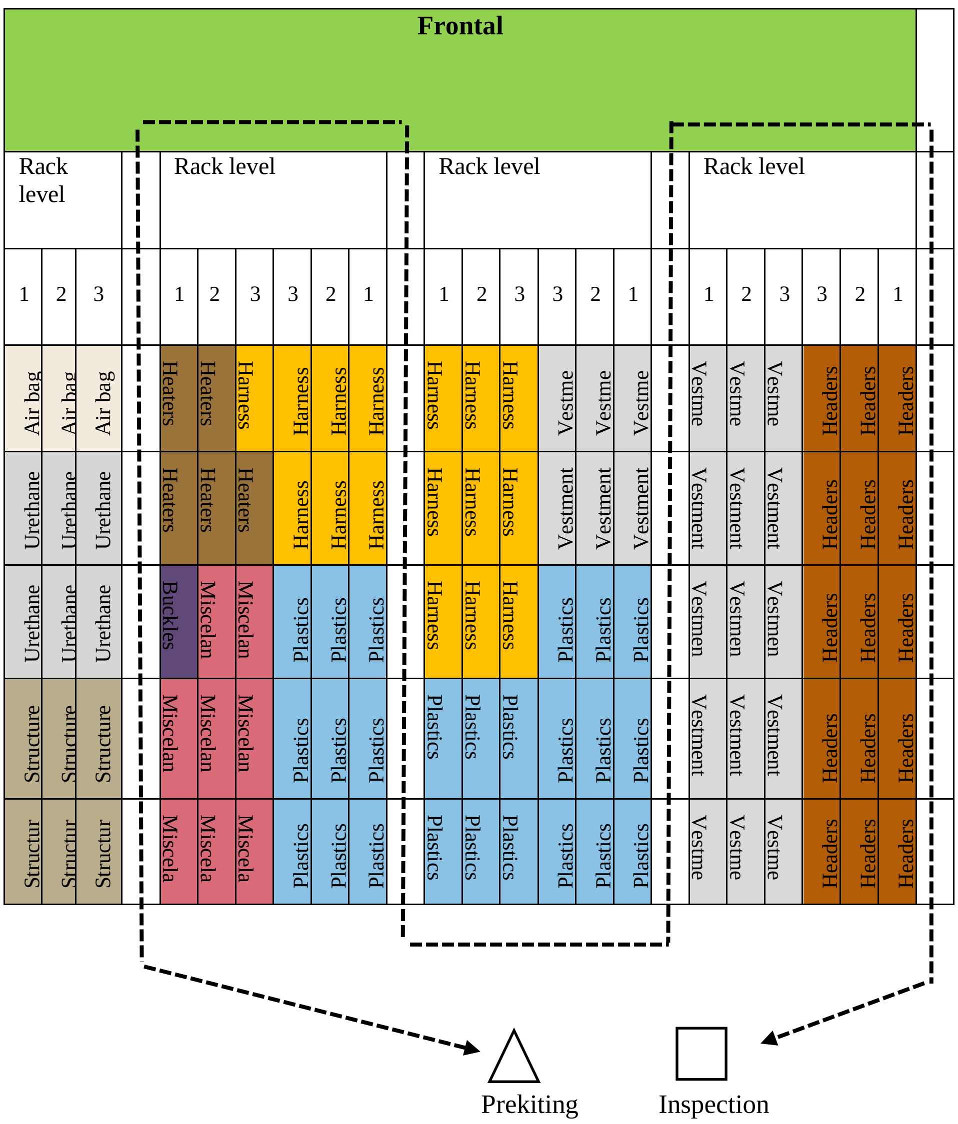
Table 6.3 Spaces required for storage of materials (Rear).

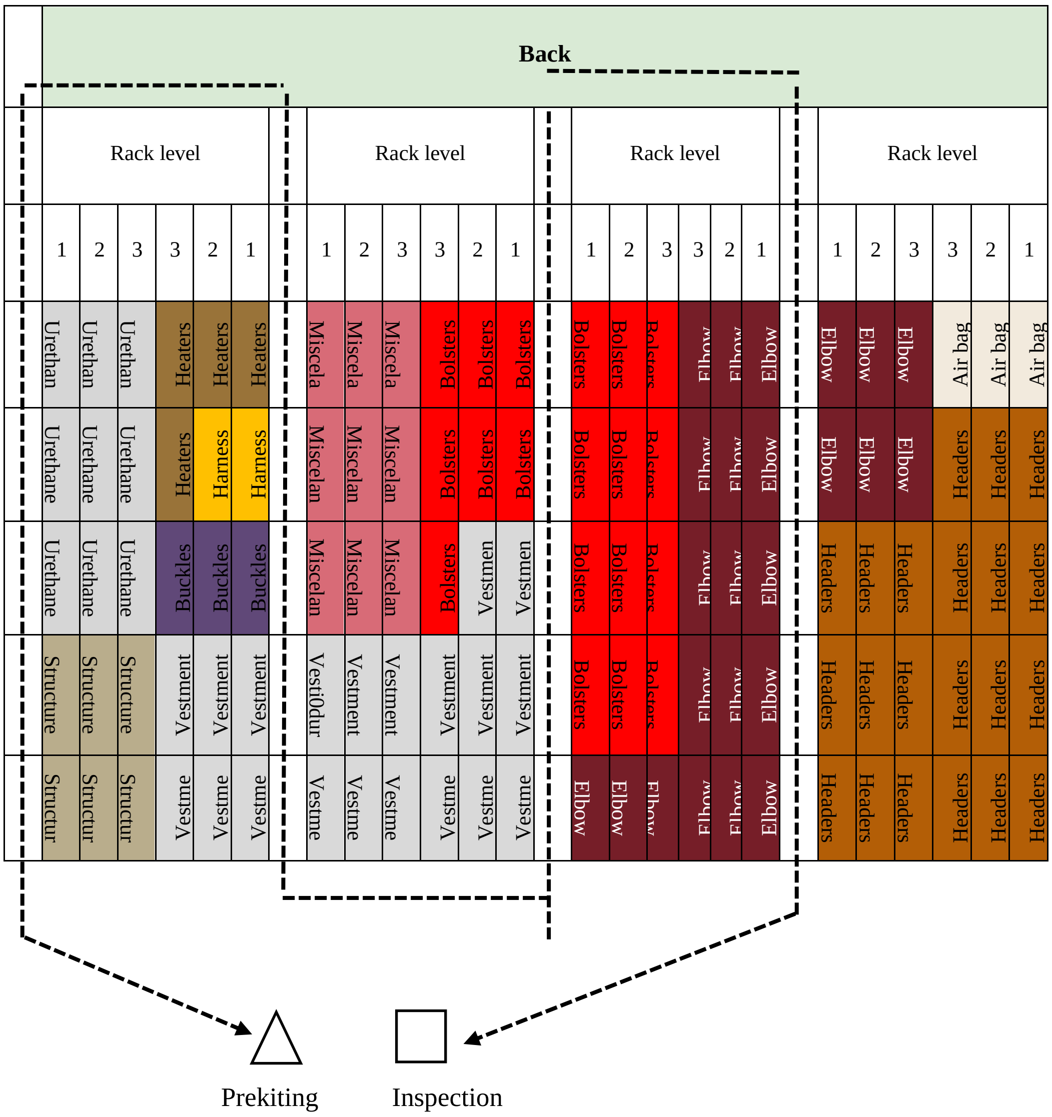
Commodity	Back Units	Space m^2	Classification	Type of storage	Space in number of bays
Vestments	102	70	A	Paperboard	20
Plastics	30	20	A	Paperboard	5.7
Bolsters	102	70	B	Paperboard	20
Elbow pads	102	70	B	Plastic	20
Headers	102	70	B	Paperboard	20
Urethanes	50	34	B	Plastic	9.7
Buckle	13	8	C	Plastic	2.2
Heaters	15	10	C	Paperboard	2.8
Structures	30	20	C	Plastic	5.7
Air bag	10	60	C	Paperboard	1.7
Harness	5	3	C	Paperboard	0.8
Miscellaneous	50	34	C	Paperboard	9.7

Source: Self Made

The general distribution of the warehouse was divided into two sub-warehouses, the left zone assigned to the materials of the front line and the right side to the materials of the rear line (figure 6.5). In this way, the spaces available for each production line are specialized.

Figure 6.5 Relocation of materials of the front and back products inside the warehouse





Source: Self Made

6. Results

The implementation of the redesign of the locations of the materials within the warehouse was carried out in a period of 2 to 3 months, mainly due to the needs of physical adjustments that imply that the operations are totally suspended, the changes were developed in three phases:

a. Classification of raw materials: Identification of racks for each part number; indicating part number, quantity of standard pack and location of the bay
b. Physical inventory: separation of nonconforming materials was made, obsolete and not corresponding to the location. This process, in addition to being a corporate requirement per semester, was essential to purge the warehouse.
c. Creation of sub-warehouses. The redesign of the material locations within the warehouse was implemented.

Once the physical reconfiguration of the warehouse was put into operation, the times of travel and operation for the picking of the products were taken. The results are shown in figure 6.6.

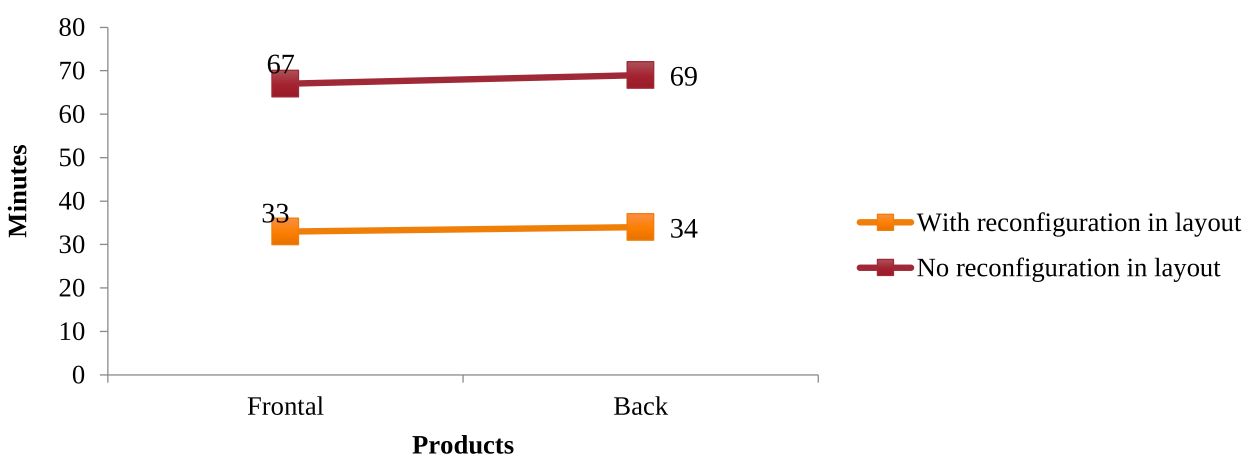
Figure 6.6 Multi-product diagram (redesign layout)

Operación/material	Producto				Operación/material
	Frontales		Traseros		
Prekitings	△		△		Prekitings
Estructuras	6	2	6	2	Estructuras
Misceláneos	1	2	7	3	Uretanos
Buckle	2	2	5	2	Calefactores
Uretanos	7	3	1	2	Misceláneos
Air bag	8	1	3	2	Arneses
Calefactores	5	2	2	2	Buckle
Arneses	3	2	12	3	Vestiduras
Plásticos	4	3	10	3	Bolsters
Vestiduras	12	3	9	3	Coderas
Cabeceras	11	3	4	3	Plásticos
			11	2	Cabeceras
			8	1	Air bag
Inspección	100	11	100	6	Inspección
Tiempo (minutos)		33		34	Tiempo (minutos)

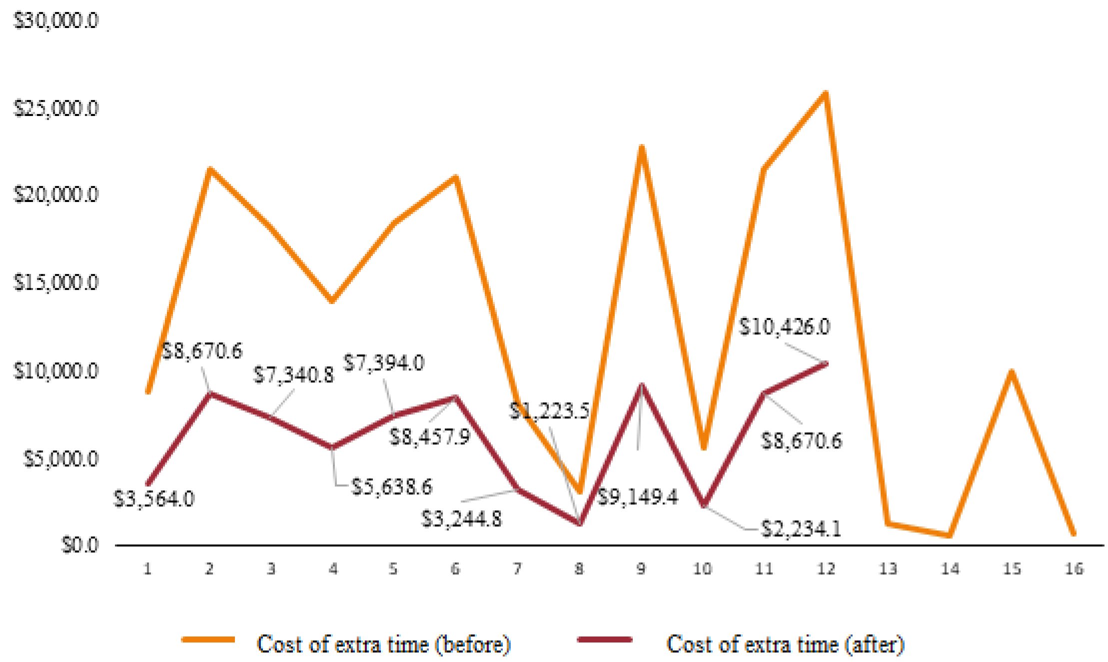
Source: Self Made

The following graph shows the comparison of prekiting times (minutes) before and after the redesign of warehouse locations. As can be seen in figure 6.6, the picking times were reduced by 51% for front products and 50% for rear products, which will be reflected in the costs of extra time (graphic 6.6).

Graphic 6.5 Comparison of results (minutes)



Graphic 6.6 Comparison of results (Costs of extra time)



Source: Self Made

8. Conclusions

The daily competitiveness in which companies are immersed leads them commonly to the idea of investing in new resources, whether human, technical, physical, etc., however, it is important to know that there are tools and methods that allow facing the problems of orderly and measurable way. The benefits of the practical integration of different tools in the analysis of data, decision making, and proposals of alternatives lead to achieving important objectives in the company, such as: increase productivity, efficiently use resources, maximize profitability, eliminate waste, among others.

One of the key pieces to plan the supply chain is to redesign the locations of the materials within the warehouses, as it optimizes the activities and generates a greater guarantee in the logistic services that the company can offer the client, for this it must be taken into account. account the strategy of inputs and outputs of the merchandise, the type of storage, the internal transport system, the frequency of rotation of the products, the level of the inventory, the guidelines of packaging and preparation of orders, among others. By taking into account these elements the operations of the warehouse will be more efficient as they will achieve faster order preparation and a decrease in errors. This translates into a better flow of materials, lower cost and greater customer service, in addition to offering workers a suitable and safe work environment.

In this case the reconfiguration of the material warehouse distribution in an automotive JIT plant through the SLP, provides the flexibility to adapt the tools to very specific and specific processes, to improve the process flows that allow to satisfy the client's demands in the agreed times, which generates competitive advantage by reducing time, distance, energy, labor, material handling and also contributes to the traceability of materials.

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Chapter 7 Economic impact of the automotive sector in the eastern region of the state of Tlaxcala

Capítulo 7 Impacto económico del sector automotriz en la región oriente del estado de Tlaxcala

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Abstract

The installation of the automotive assembly plant AUDI in 2016 and the companies that are integrated into this supply chain in the eastern region of the state of Tlaxcala, generate an economic impact, directly benefiting seven Tlaxcala municipalities. The innovative aspect of the study is the generation of a model using Bayesian networks, which allows visualizing the growth and development of the different sectors in the eastern area of Tlaxcala, taking into account the analysis of the variables: economic units, employed personnel, remunerations, investment, income and total gross product, which they infer in the economic branches of twelve sectors of commerce and services that develop activities in the municipalities of interest. This investigation allowed to know the opportune and profitable economic turns for its growth based on the determined needs.

Automotive, Economic Growth, Prediction, Bayesian Networks

1. Introduction

The economic growth of a region is linked to various factors ranging from its geographical location to the ethnic origin of its population. One of them, which depends directly on the governmental instances, is the diffusion of the industrial activity in the regions that present social and economic backwardness. In the last three decades the government of the state of Tlaxcala has adopted promotion strategies that allowed an intense process of industrialization. According to the Secretarìa de Economìa (SE, 2015), in 2014 Mexico ranked as the seventh producer of vehicles at the international level and the first place in Latin America. The production and export of light and heavy vehicles set a new historical record in the country at the end of that year. The automotive sector in Mexico is driven by the presence of vehicle assembly companies such as: BMW, Chrysler, Ford, General Motors, Honda, Mercedes-Benz, Nissan, Toyota, Volkswagen and Volvo; In total there are 24 productive complexes in the country in 14 states, in which activities ranging from assembly and armoring to the casting and stamping of components for vehicles and engines. Currently, Mexico produces more than 40 models of cars and light trucks. Most of the assembly companies in Mexico have auto parts companies that are located around their vehicle plants to meet the requirements of supply and delivery times.

At the beginning of 2012, the automotive and auto parts industry announced its plans to expand in Mexico. The government of the state of Tlaxcala considered that the establishment of this type of companies benefits the entity and forces to create poles of development in diverse sectors to cover the needs that are generated (González, 2013). The objective of the present investigation was to project the economic growth of the eastern area of the state of Tlaxcala, through analysis through Bayesian networks of the variables: economic units, employed personnel, remunerations, investment, income and total gross product, which infer in the economic branches of twelve sectors of commerce and services that develop activities in the eastern area of Tlaxcala.

The study carried out has a quantitative and correlational approach because the relationships between the variables of interest were analyzed to describe the phenomenon, the methodology is made up of eight steps: definition of the domain of the problem, identification of the variables of interest, collection and pre-processing of data, definition of the state of the variables, design of pilot networks, proposal of the network for the eastern region, validation and evaluation of the network and propagation of evidence in the network. The results of this research can be considered as a statistical basis for the elaboration of a regional development plan. The statistical data generated could also be used by investors interested in the area, to know the economic branches with the greatest potential due to the increase in the demand for services. It should be mentioned that the data was projected using the Bayes algorithm, which was trained with previous economic information from the states of Aguascalientes and Puebla, where similar automotive companies have been established.

Twelve economic branches of commercial sectors and services with greater potential in the region of study were identified, which could offer to the original settlers, profitable business options, to provoke the economic growth of the region, driven by investment capital of local origin. With the Bayes-trained algorithm, the projections of the six variables were obtained: economic units, employed personnel, remunerations, investment, income and total gross product, which are inferred in each of the sectors in the municipalities of interest.

2. Theoretical review

This section provides a vision of where the proposed approach lies within the field of knowledge in which the research is developed, exposing the concepts and theoretical applications related to economic growth, economic sectors and Bayesian networks.

Growth and economic development

Man has always been faced with satisfying his needs, which is why he discovered fire, agriculture and other forms of using the elements of nature and transforming them into the elements he requires; when living in society it became necessary to look for general models to ensure the satisfaction of their needs as well as the conditions of their coexistence (Marx & Engels, 1979). López (1967) refers that the word economy etymologically comes from the Greek and is composed of oikos that means house and nomos that means law. Which, according to the author, can be interpreted as the order and rules that are observed in the income and expenses of a household. Later economy meant the order in which things are managed.

According to Fuentes and Martínez (2001), economics is the science of choice. Study the way in which individuals decide to use scarce or limited productive resources to produce various goods and distribute them among different members of society for consumption. Taking the above definitions it can be said that the Economy is in charge of studying the allocation of scarce resources among different activities in order to obtain goods and services that are distributed among individuals for the satisfaction of their needs. The various theories of economic growth use simplifications of reality, called economic growth models, to explain their causes. These models do not refer to any particular economy. However, most of the conclusions are that the economy grows because workers have more and more instruments for their work, that workers with more knowledge are more productive and that the economy grows by the technological process; Many authors explain the economic growth with these three variables in the models that pose (Miller & Gómez, 2013).

Another determining factor is the increase of the population to know if the product or per capita income increases or not. Development is a complex phenomenon that includes improvements or economic, political, social and human changes; affecting economic structures and political and social institutions. Development can manifest itself at the economic level with the increase in GDP per capita, consumption, investment, exports, among others and social by showing a more equitable distribution of income, poverty reduction, decrease in inequality between regions, races, sex, among others. According to Heath (2012), in Mexico there is a large amount of statistics and economic indicators generated by various institutions. Some are considered first level or importance, referring to the impacts on financial markets, such as the foreign exchange market, the Stock Exchange or the money market. Others are second level, because they complement the first and can refer to indirect impacts. Finally, there are third level indicators that are of analytical and academic interest, but whose immediate impact is practically null. Most of these economic indicators come from surveys, censuses or administrative records, generally expressed in units corresponding to their value in pesos, or referred to their volume.

Economic indicators are useful for the government sector, businessmen, and even for citizens in general, because by understanding, relating and interpreting them, it is possible to forecast the economic future and anticipate changes. Since 2011, the INEGI is responsible for the calculations and dissemination of the main economic indicators of Mexico. Although you can still find all the information on the Banco de México website, INEGI publishes all the indicators in detail. The Board of Economic Indicators of INEGI provides an overview of the evolution of fundamental variables that interact in the Mexican economy, as well as other external variables that influence it. This table includes variables from the real sector and the labor market, financial variables and the so-called opinion or feeling indicators.

Sectors of economic activity

The identification and classification of different types of sectors is fundamental in the economy, since once a key sector is detected, specific policies can be used that enhance it and benefit the rest of the economy. For analytical purposes economists classify the economic activity of production into three sectors, each refers to a part of the economic activity whose elements have common characteristics, keep a unit and differ from other groups. Its division is made according to the production processes that occur within each of them.

The primary or agricultural sector is the one that obtains the product of its activities directly from nature, without any process of transformation. Within this sector are agriculture, livestock, forestry, hunting and fishing. Mining and oil extraction, which are considered part of the industrial sector, are not included in this sector.

On the other hand, the secondary or industrial sector includes all economic activities related to the industrial transformation of food and other types of goods or merchandise, which are used as a basis for the manufacture of new products. This sector can sub divided in two: industrial extractive and industrial transformation. Finally, the tertiary or service sector includes all those activities that do not produce a commodity per se, but are necessary for the functioning of the economy and contribute to the formation of national income and the national product of a country. This sector is dedicated to providing services to people and companies, so that they can devote more time to their central work, without having to take care of other tasks.

Given its close relationship with productive activity, the development of services to production must be analyzed in relation to the evolution of the organization of contemporary production, and more specifically to the growing internationalization and the development of new information technologies.

According to Hernández (2013), it is possible to affirm that the services sector is more closely related to the aggregate economy than the secondary sector, not only because of its relative contribution to GDP, but also because of the magnitude of the long-term elasticity it exhibits. In that sense, it can also be said that the activities of trade, real estate services and transportation are at least as relevant to the economy as manufacturing and construction.

The North American Industrial Classification System (NAICS) is a regional classifier because it is essential that in a free trade zone there are truly compatible economic classifiers, this implies that both its construction and its updating are done in coordination with the United States and Canada. The versions published since 1997 respond to the trilateral five-year update agreement of the SCIAN taken by the national statistical agencies of Mexico, the United States and Canada to prevent the classifier from becoming obsolete, adapting it to the changing circumstances of constantly changing economies.

SCIAN is composed of twenty activity sectors; five sectors are essentially producers of goods and fifteen are fully service providers. The hierarchical structure of the SCIAN is made up of five levels of aggregation: sector (the most aggregated level), subsector, branch, sub-branch and activity class (the most disaggregated level). The first four levels constitute the trinational classifier, which is common among the three countries, and the last level, that of the activity class, was reserved so that each country could make a greater breakdown according to its national statistical requirements.

Bayesian networks

A Bayesian network is a directed acyclic graph in which each node represents a random variable that has a conditional probability function associated with it. The structure of the Bayesian network provides information on the relations of dependency and conditional independence existing between the variables. Bayesian networks (also known as probabilistic causal networks, causal networks, Bayesian expert systems, belief networks, probabilistic expert systems or influence diagrams) are statistical tools that represent a set of associated uncertainties based on conditional independence relationships that they are established between them (Santiesteban, 2012).

One of the most important advantages of Bayesian networks is that the structure of the associated graph determines the dependence and independence relationships between the variables, so that it is possible to discover, without the need for numerical calculations, which variables are relevant for another variable of interest.

Sometimes, Bayesian networks are called causal networks when the arcs that connect the nodes can be interpreted as the representation of direct causal relationships. Experts are often able to relate causes and effects in a way that reveals inherent conditional independencies that are representable through a Bayesian network (Nilsson, 2001).

A Bayesian network is used to model a domain that contains uncertainty in some way. This uncertainty may be due to an imperfect understanding of the domain, an incomplete knowledge of the state of the domain at the moment in which a determined task must be carried out, a randomness in the mechanisms that govern the behavior of the domain or a combination of these. These models can have diverse applications, for classification, prediction, diagnosis, among others; and they are widely used in fields such as medicine, education, marketing and social sciences. According to Sucar (2015), Bayesian networks are a graphical representation of dependencies for probabilistic reasoning, in which the nodes represent random variables and the arcs represent direct dependency relations between the variables.

For Huete (1998) Bayesian networks constitute one of the most powerful tools in the design of probabilistic expert systems. From a graphic point of view, a Bayesian network is an Acyclical Directed Graph, where the nodes represent the variables of a problem and which allows to represent knowledge from two points of view:

- Qualitative: expressing the relationships of dependence and independence between the variables. Graphically, they are represented by the presence of connections or paths between the variables.

- Quantitative: expressing the strength of relationships of relevance or dependence. Allows you to represent the uncertainty that you have about the occurrence of events.

Bayesian networks represent an acyclic structure of dependence between random variables for probabilistic reasoning. Each variable is characterized by its corresponding states, which can be defined by numerical values, intervals, qualitative estimates or Boolean functions. The relationships between variables are established in terms of probabilistic dependence. To each variable corresponds a table of conditioned probability, which presents the probability distribution of said variable in each of its states, given the states of its parent variables. The conditional probability information can be obtained from different sources: direct measurements, mathematical models and expert opinion (Koski, 2009) . To make predictions with a Bayesian network, it is required to build a model. A model can be learned from the data, manually constructed or a mixture of both. Prediction is the process of calculating a probability distribution on one or more variables whose values you want to know, given the information (evidence) that you have about some other variables. These can be:

- Discrete variables. For a discrete variable D with 3 states {Low, Medium, High} a prediction will be of the form [0.1, 0.3, 0.6]. That is to say. The probability of belonging to each state. The task of predicting a discrete variable is often referred to as Classification in line with other approaches.

- Continuous variables. For a continuous variable C, a prediction will contain both a Mean and a Variance. The task of predicting a continuous variable is often referred to as linear regression with other statistical approaches.

- Input and output variables. The variables to be predicted are known as output variables, while the variables whose information is used to make the predictions are known as input variables.

In Statistics, input variables are often referred to as predictor, explanatory, or independent variables, while output variables are often referred to as response variables or dependents. Bayesian networks deal strictly with inputs and outputs. This is because any variable in the graph can be an entry or exit or even both. You can even predict the joint probability of an exit and a lack of entry. However, describing the variables in terms of their functions as inputs or outputs remains a useful concept.

BayesN tool

The BayesN tool is designed with two main parts, one of them is a graphical interface where the user can enter the database to be processed, generate and modify the network, and generate complete conditional probability tables, adding arcs (relationships) between the variables under study and is based on techniques known as knowledge discovery in databases. Which is designed with two main parts: The graphic interface where the user can enter the database to be processed, generate and modify the network, and complete the conditional probability tables.

The other is an inference engine that performs the calculations and obtains the conclusions from the information provided in the database. For this uncertainty is propagated, with which its conclusions will be conditioned to such propagation. BayesN was developed by Jiménez (2003) which is based on the previous work of Cruz (1997) both from the Universidad Veracruzana.

3. Methodology

This research has a quantitative approach, during its execution a data collection was carried out to determine the variables of interest that characterize the phenomenon to be observed, and based on the numerical measurement and the statistical analysis, patterns of behavior of the study variables were established. In addition, it is correlated and applied, that is, the relationships between the variables of interest were analyzed to describe a phenomenon. It is non-experimental because the variables were not manipulated; descriptive because it seeks to specify the properties, characteristics and profiles of the observed phenomenon; and synchronous because it was carried out in a given period of time.

4. Development

The eight steps that make up the methodological proposal of this research are: define the domain of the problem, identification of variables, collection and pre-processing of data, definition of the state of the variables, design of pilot networks, validation and evaluation of the network, construction of the network for prediction and propagation of evidence in the network.

1. The domain of the problem

It is important to study the domain to have the maximum degree of knowledge and understanding about the problem to model. This will require having experts in the area, who should be sufficiently interested and motivated for the collaboration to have good results. This will require having experts in the area, who should be sufficiently interested and motivated for the collaboration to have good results.

2. Identification of the variables of interest

In this stage, each of the variables (see table 7.1) that will be used in the network, its role in the network and its origin are defined. It is also necessary to define what variables will be called objective and what variables will be called of intervention. It is important to focus only on those variables that are of interest in the current problem. For this, it helps to ask questions of the type:

- What is the situation that arises?
- What possible causes can explain this situation?
- What other factors can make the situation happen, or prevent it from happening?
- What evidence is available to support these causes, situations and factors?

There are variables that can be grouped into classes. If the problem is addressed with these classes in mind, the modeling process is easier.

Table 7.1 Types of variables according to their role in the network

Type of variable	Short description
Objective	They model objects of interest. Not directly observable.
Observations	They model the way to measure objective variables. They can be observed directly.
Factor	They model phenomena that affect other variables of the model.
Promoter Inhibitor Required Preventive	The affected variable is more likely when they are present. The affected variable is less likely when they are present. If it does not take action, the affected variable does not occur. If it goes into action, the affected variable does not occur.
Auxiliaries	Used for convenience (to simplify the model)

Source: Millán (2005)

There were two classes of economic and population variables. The economic variables are: sector, total gross production (PBT), economic units (EU), employed personnel (personnel), remunerations (remuneration), total investment (investment), income from the supply of goods and services (income), investment in manufacture of the automotive industry (inv_auto).

In the opinion of experts in Economics, these variables can describe the economic dynamics that develop within the region under study in the twelve sectors of economic activity of trade and services. The population variables are: population density (Density) and Occupation.

3. Data collection and pre-processing

In this phase, we first explored several options of computer tools, such as Hugin Lite software, Weka, the BayesN algorithm, Bayes Server, where the latter two were the ones with the most previous knowledge (training phase of the network), and then use them to obtain the projections of the statistical data of each study variable with reference to the various economic sectors established. For the design of the pilot networks, the economic and population variables were determined and trained with data from the Ministry of Economy (SE) and the National Institute of Statistics and Geography (INEGI) for the years 2004, 2009 and 2014, of the states of Aguascalientes, Puebla and Tlaxcala, these entities were considered because they have in common established companies of the automotive sector.

For the classification of economic units INEGI makes use of the Industrial Classification System of North America, Mexico 2013 (SCIAN), a classifier that offers the double possibility of forming and grouping the data according to the characteristics of the Mexican economy, and at the same time compare it with statistics from Canada and the United States of America, countries that also use this classifier.

For the purposes of this research, only data from 12 service and commerce sectors were used. Namely: 43 Wholesale trade, 46 Retail trade, 48-49 Transport, mail and storage, 51 Information in mass media, 53 Real estate and rental services of movable and intangible assets, 54 Professional, scientific and technical services, 56 Business support services and waste management, and remediation services, 61 Educational services, 62 Health and social work services, 71 Cultural and sports entertainment services, and other recreational services, 72 Temporary accommodation services and food and beverage preparation, 81 Other services except government activities.

Another important source of information were the experts in economics, whose opinions were gathered through personal interviews, with an official of the Tlaxcala Delegation of the Ministry of Economy, with an INEGI official and with a teacher-researcher from the School of Tlaxcala. In order to contrast the statistical results of the analysis with the reality perceived by the inhabitants of the region, surveys were also conducted to owners or employees of the economic units of the twelve sectors of commerce and services in the municipalities of interest.

The database of the INEGI page was obtained in an Excel file format, the data was pre-processed to adapt them to TXT files, which are the extensions that BayesN can interpret, which is an algorithm programmed in Java tests of conditional independence adding arcs (relations) between the variables under study and is based on techniques known as discovery of knowledge in databases. In order to compare the behavior of the variables of interest in regions where the Automotive Industry is in a degree of maturity, data were obtained from three municipalities of Aguascalientes, six municipalities of Puebla and seven from the Oriente Region of Tlaxcala: Atltzayanca, Cuapiaxtla, El Carmen Tequexquitla, Huamantla, Ixtenco, Terrenate and Ziltlaltepec.

The database of the research is formed by 1833 (see table 7.2) records that cover the economic and population data of sixteen municipalities and twelve economic activity sectors of the three states of the Mexican Republic that were chosen, said states were considered because they installed automotive plants and there were already economic growth results which could be compared with the projections.

Table 7.2 Records by year and state

	2004	2009	2014	Total
Aguascalientes	170	177	186	533
Puebla	265	316	351	932
Tlaxcala	107	122	139	368
Total	542	615	676	1833

Source: self made (2016)

4. Definition of the state of the variables

Each variable will have different states (see table 7.3) that can be represented as intervals, absolute values, categories or binaries. The BayesNAIVE algorithm, which consists in the generation of Bayesian networks based on the training of the Bayesian network with existing data for the prediction of future scenarios based on the Bayes algorithm, was chosen because other researchers had already made successful projections with this software it uses discrete variables and the INEGI databases have numerical attributes, so it was necessary to transform them into qualitative attributes.

A normalization technique was used that transforms the range of values to a certain interval (normally [0,1]). This technique is useful because distance-based learning algorithms will be applied so that all the attributes are in the same range.

Table 7.3 States of the variables

<table>
<tr><th>Variable</th><th>States</th></tr>
<tr><td>Sector</td><td>Trade: Retail sector
M commerce: wholesale trade sector
Services: twelve service sectors</td></tr>
<tr><td>Occupation</td><td>Low: less than or equal to 15%
Medium: less than or equal to 30%
High: greater than or equal to 31%</td></tr>
<tr><td>Density</td><td>Low
Medium
High</td></tr>
<tr><td>Inv_Auto</td><td rowspan="7">Very low: less than or equal to 0.15
Low: less than or equal to 0.30
Medium: less than or equal to 0.65
Height: less than or equal to 0.80
Very high: greater than or equal to 0.81</td></tr>
<tr><td>EU</td></tr>
<tr><td>Personal</td></tr>
<tr><td>Remunerate</td></tr>
<tr><td>Investment</td></tr>
<tr><td>Income</td></tr>
<tr><td>PBT</td></tr>
</table>

Source: Self Made (2016)

5. Design of pilot networks

Defined the set of variables and their states, the records were used to generate 9 networks that describe the relationships between the variables for the three states: Aguascalientes, Puebla and Tlaxcala in three different moments of time corresponding to the last three Economic Censuses published by INEGI in 2004, 2009 and 2014. Table 7.4 summarizes the 55 relationships that the algorithm found in the different data groups that were used to form the nine networks that describe economic activity in the twelve sectors of commerce and services chosen for this research in the sixteen municipalities of the states of Aguascalientes, Puebla and Tlaxcala that were used as reference for the manufacturing activity of the Automotive Industry.

Table 7.4 Summary of the relationships found in the networks

Arcos detectados	Aguascalientes			Puebla			Tlaxcala			Total
	2004	2009	2014	2004	2009	2014	2004	2009	2014	
EU - Staff		X	X		X	X	X	X	X	7
Remunerate - PBT		X	X	X	X	X		X	X	7
Sector - Density	X			X		X			X	4
Inv_Auto - Occupation		X	X		X	X				4
Personal - Remuneration		X	X	X		X				4
Sector - Occupation						X		X	X	3
Occupation - Density						X		X	X	3
Occupation - Sector		X	X		X					3
Personal - Income					X			X	X	3
Sector - Revenue			X			X				2
Inversion - Revenue	X	X								2
Income - Investment				X	X					2
Income - Remuneration								X	X	2
Density - Income						X				1
Density - Occupation					X					1
Density - EU			X							1
Density - Sector					X					1
Personal - Investment	X									1
Remunerate - Staff	X									1
Investment - Staff				X						1
Inversion - Remunera					X					1
Income - PBT	X									1
Total	5	6	7	5	9	9	1	6	7	55

Source: Self Made (2016)

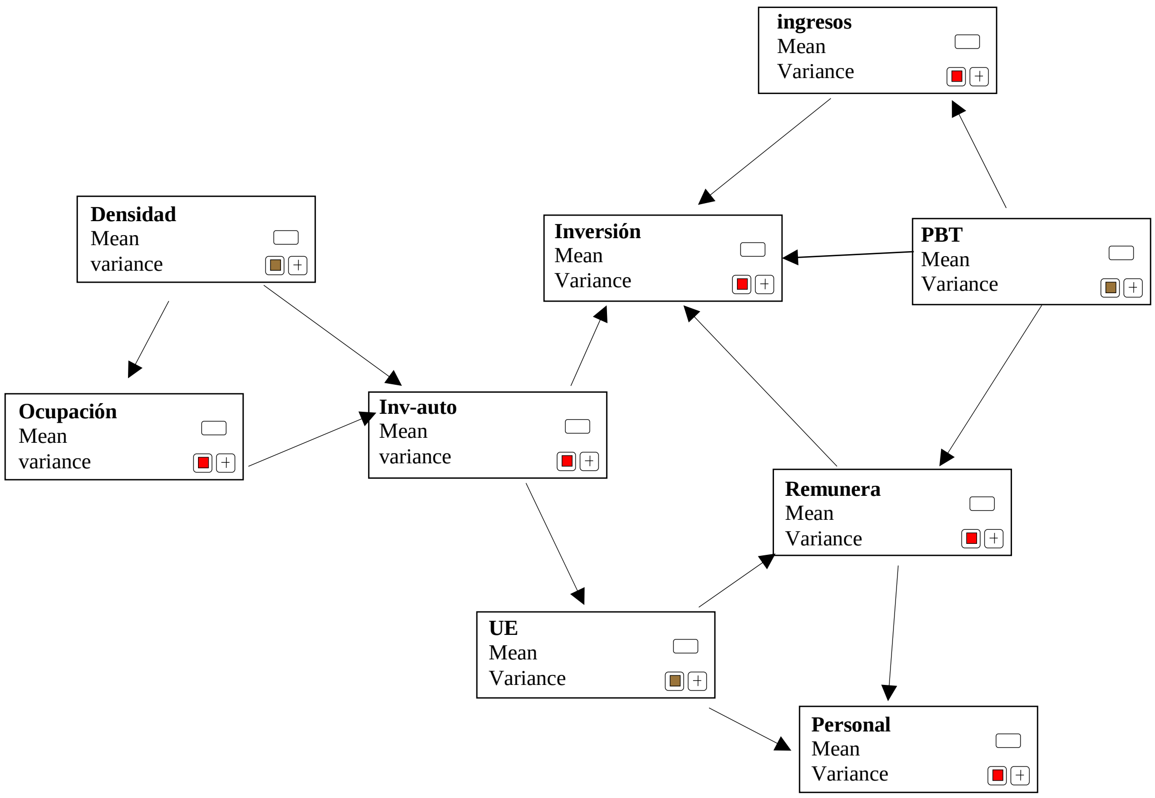
The behavior of the networks increased the relationships and the information is more sensitive to the number of records as they were accumulated from one census to another. The two most repeated relationships are: UE - Personal and Remunerations - PBT, for which they were considered in the construction of the network for the prediction of the variables of interest.

6. Proposal of the network for the Oriente Region

Given the analysis of the projections of the previously applied networks, we proceeded to consult the valuable opinion of the human experts, who validated them and proposed a network that was able to predict the behavior of each of the variables of interest. The network was built on the Bayes Server software, which is a tool for modeling Bayesian networks. This software is from an English company that specializes in the development of intelligent systems based on artificial intelligence, machine learning and data science.

The main window of Bayes Server is that it has the six menus that allow the user to manage files, build a network, make queries, load data, analyze the data and manage the views of the windows, which accepts continuous variables, so that the data of the records were loaded with the original values of the information source in an Excel file. To construct the Network for the Oriente Region, nine nodes were created with the names of the variables that were analyzed. The next step was to add the arcs between the nodes through the algorithm for structural learning that uses conditional independence tests to determine the structure of the network; for this learning, the records of Aguascalientes and Puebla were loaded into the network. For the 2014 census, nodes were added and deleted with the information in the summary table, taking into account the validation of the human experts from where the necessary variables were determined. The result was the network shown in Figure 7.1 (it should be mentioned that this figure is automatically generated by the Bayes Server software).

Figure 7.1 Proposal: Network for the Oriente Region



Source: Bayes Server (2016)

Then, the parametric learning is executed, that is to say, that each node is assigned statistical parameters with the help of an algorithm of trees. Since the data is continuous instead of calculating probability tables, each node is adjusted to a Normal Distribution function. This learning was done in Bayes Server loading the data to Tlaxcala in the 2014 census.

7. Validation and evaluation of the network

In this stage, the results obtained are verified, which must be reviewed and contrasted, since there may be discrepancies that require a modification of the network to adjust it to the analyzed case of study. It is convenient that the validation and the evaluation are carried out with the experts in the subject for congruence of the results. The information was validated with data from the 2004, 2009 and 2014 censuses, which coincide with the results obtained by the Bayes Server software, this instrument being valid for future projections.

8. Propagation of evidence in the network

Once the network was built and trained, a consultation was made for each year to be projected taking as available evidence the Density of Population (Density), the Investment in Automotive Manufacturing (Inv_Auto) and the Percentage of Occupation by Sector of Economic Activity (Occupation). Values were determined from the experts' considerations and the natural growth of the populations and the economy.

This process is known as propagation, a probability propagation algorithm uses the independence relations implicit in the Bayesian network structure to calculate the probabilities of each of the nodes given the available evidence. Thus, taking into account the values of those variables determined by the previous networks and the propagation of them, these were determined for the projection of the following three economic censuses: 2019, 2024 and 2029; the evidence to propagate in a network is shown in the following table.

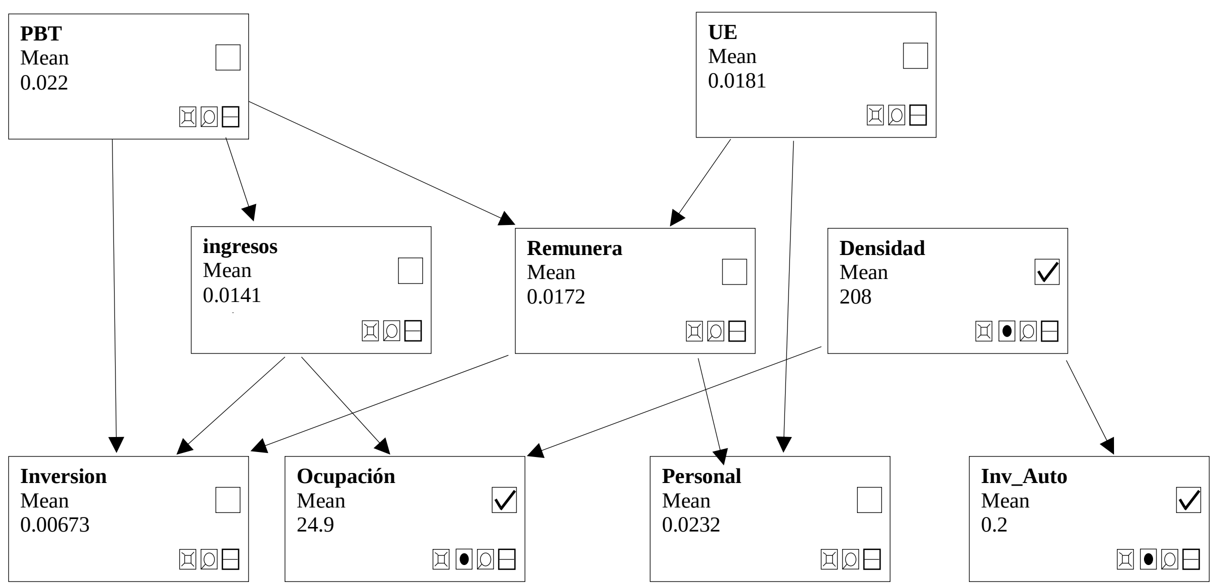
Table 7.5 Evidence to spread the network

Year	Occupation (%)	Commerce Services (%)	Density of population (inhabitants)	Investment in automotive industry (%)
2014	11.88	22.55	175.84	0.01
2019	13.46	24.86	207.52	0.20
2024	15.98	27.35	249.02	0.30
2029	17.53	30.96	288.87	0.35

Source: Self Made (2016)

The steps in the tool to carry out the propagation of the evidence are presented with the following figures that were taken from the screens of the application. Figure 7.2 shows the load of evidence in the network, generated by the Bayes Server software.

Figure 7.2 Loading of evidence on the Net for the Oriente Region



Source: Results generated through Bayes Server software (2016)

After the load, a query is made so that the tool calculates the projected values for each dependent variable. Table 7.6 shows an example of one of the eleven queries of each of the study variables: economic units, employed personnel, salaries, investment, income and total gross product.

Table 7.6 Result of the consultation to the network

A	B	C	D	E	F	G
Case_ID	Predict(UE)	Predict(Personal)	Predict(Remunera)	Predict(Ingresos)	Predict(Inversion)	Predict(PBT)
1	0	0.008727	0.026272	0.022568	0.010501	0.008364
2	0	0.008727	0.026272	0.022568	0.010501	0.008771
3	0.056288	0.05753	0.013704	0.022568	0.012599	0.017002
4	0	0.008727	0.026272	0.022568	0.010501	0.007172
5	0.007916	0.01559	0.024505	0.022568	0.010796	0.007904
6	0.003518	0.011777	0.025486	0.022568	0.010632	0.007252
7	0	0.008727	0.026272	0.022568	0.010501	0.007458
8	0.002639	0.011015	0.025683	0.022568	0.010599	0.007817
9	0.003518	0.011777	0.025486	0.022568	0.010632	0.007402
10	0.001759	0.010252	0.025879	0.022568	0.010567	0.007173
11	0.001759	0.010252	0.025879	0.022568	0.010567	0.007541

Source: Bayes Server (2016)

5. Results

The results obtained by the network that was generated are presented in numerical and percentage tabular form for each of the six study variables, where the economic impact of each sector in the eastern region of the state of Tlaxcala can be observed when companies are established of the automotive sector.

Current situation of the Oriente Region

Based on data from the 2014 Economic Census in the seven Tlaxcala municipalities of Atltzayanca, Cuapiaxtla, El Carmen Tequexquitla, Huamantla, Ixtenco, Terrenate and Zitlaltepec, which make up the Oriente Region of Tlaxcala there are 4546 economic units that carry out their activities in the twelve tertiary sectors that were chosen to be analyzed. As can be seen in Table 7.7, the largest percentage share refers to Retail Trade, which represents about 2/3 of Economic Units (EU) and Employed Personnel; in Investment and Revenue represents 3/4 parts; finally in Remuneration and Total Gross Production (PBT) a little more than half. The behavior of this sector in the region under study is similar to that of the state of Tlaxcala, where the Retail Trade EU represents 53% and the national where it is 50% of the total EU.

Table 7.7 Variables by Sector of economic activity, Oriente Region 2014.

Economic sector	% UE	% Personal Occupied	% Remuneration	% Investment	% Incomes	% PBT
Retail trade	65.4	61.4	52.2	77.6	71.8	56.4
Accommodation, food and beverages	8.9	9.6	5.8	3.3	3.7	11.6
Other services	14.7	12.6	9.0	6.8	3.2	10.4
Wholesale	0.9	1.9	8.8	0.3	16.9	7.6
Educational services	0.7	4.3	12.2	0.9	1.4	4.6
Health and social assistance services	2.5	3.7	6.3	5.7	1.3	4.2
services professionals, scientists and technicals	0.9	1.4	3.0	0.6	0.7	2.2
Support for business	2.7	2.2	1.1	1.9	0.4	1.2
Recreational, cultural and sporting services	1.5	1.2	0.8	2.0	0.3	0.9
Real estate services	1.5	1.4	0.2	0.9	0.1	0.3
Information in mass media	0.2	0.2	0.2	0.0	0.1	0.3
Transportation, mail and storage	0.1	0.1	0.3	0.0	0.0	0.1
Total	4.54	9.413	98.753	27.430	86.98	74.44

Source: Self Made based on Economic Census 2014 (2017)

Economic Units (EU). The number of UEs established by sector in the Eastern Region of the state of Tlaxcala will have growths (against previous census, see table 7.8) of 8.8% in 2019, 10.8% in 2024 and 6.9% in 2029. What in the most positive scenario would lead to to an accumulated growth of 90.8% based on 2004 and of 28.8% on 2014, date of the last census publication.

Table 7.8 Economic Units by sector, base year 2014.

	Historical			Projection					
Sector	2004	2009	2014	2019	%	2024	%	2029	%
Retail trade	2,220	2,714	2,972	3,212	8.1	3,554	19.6	3,813	28.3
Other services	427	547	667	730	9.4	800	19.9	837	25.5
Accommodation, food and beverages	178	324	404	447	10.6	510	26.2	552	36.6
Support for business	36	110	121	132	9.1	145	19.8	158	30.6
Health and social assistance services	57	66	114	133	16.7	145	27.2	148	29.8
Wholesale	28	65	41	45	9.8	50	22.0	55	34.1
Recreation, cultural and sports	3	55	69	78	13.0	87	26.1	94	36.2
Real estate services	15	39	70	74	5.7	84	20.0	90	28.6
Services professionals, scientists and technicals	33	41	41	48	17.1	53	29.3	56	36.6
Educational services	27	25	34	38	11.8	42	23.5	45	32.4
Transportation, mail and storage	71		40	40	0.0	43	7.5	45	12.5
Information in mass media			11	11	0.0	12	9.1	12	9.1
Total	3,095	3,986	4,584	4,988	8.8	5,525	20.5	5,905	28.8

Source: Self Made (2017)

Busy Staff This variable includes all the people who worked during the reference period, depending contractually or not on the economic unit, subject to their direction and control.

Table 7.9 shows the expected figures for the twelve sectors of economic activity, these figures are expressed in number of people, and in percentage form, where the other services sector is the one with the highest projected growth with 36.3%.

Table 7.9 Employed Person by sector, base year 2014.

	Historical					Projection			
Sector	2004	2009	2014	2019	%	2024	%	2029	%
Retail trade	3,551	5,736	5,780	6,537	5.6	7,199	17.9	7,740	24.2
Other services	582	1,153	1,188	1,281	12.3	1,442	27.9	1,518	36.3
Accommodation, food and beverages	359	858	905	956	12.6	1,067	23.0	1,124	26.7
Support for business	231	328	404	448	7.8	519	21.4	545	27.8
Health and social assistance services	92	155	352	385	10.9	447	28.5	471	34.9
Wholesale	150	262	179	201	13.1	229	24.6	244	33.9
Recreation, cultural and sports	56	209	208	231	9.4	266	27.0	271	33.8
Real estate services	71	126	129	143	6.4	153	16.4	156	25.5
Services professionals, scientists and technicals	22	108	135	152	11.1	166	27.9	171	30.3
Educational services	3	91	110	117	10.9	128	18.6	138	20.9
Transportation, mail and storage	134		5	5	5.6	5	11.1	5	16.7
Information in mass media			18	19	0.0	20	0.0	21	0.0
Total	5,251	9,026	9,413	10,475	11.3	11,641	23.7	12,404	31.8

Source: Self Made (2017)

Remuneration to the personnel. Are all payments and normal and extraordinary contributions, in cash and kind, before any deduction, to compensate the work of personnel dependent on the company name, in the form of wages and salaries, social benefits and utilities distributed to staff. Includes: employer contributions to social security schemes, payment made to licensed personnel and temporary permission. Excludes payments for liquidations or indemnities, payments to third parties for the supply of employed personnel; payments exclusively for commissions for those personnel who did not receive a base salary; fee payments for professional services contracted infrequently. The expected behavior of this variable is represented in thousands of annual pesos (table 7.10), where the transport, mail and storage sector has a projected higher growth of 44.5% with respect to the rest.

Table 7.10 Remuneration by sector, base year 2014.

	Historical					Projection			
Sector	2004	2009	2014	2019	%	2024	%	2029	%
Retail trade	31,780	40,491	51,559	58,223	12.9	64,887	25.9	69,033	33.9
Other services	6,699	1,366	12,030	13,341	10.9	15,076	25.3	15,844	31.7
Accommodation, food and beverages	5,450	6,141	8,726	9,686	11.0	10,596	21.4	10,946	25.4
Support for business	1,926	5,071	8,893	10,067	13.2	11,282	26.9	12,205	37.2
Health and social assistance services	2,145	4,941	5,758	6,138	6.6	6,801	18.1	6,917	20.1
Wholesale	1,126	2,725	6,258	6,802	8.7	7,632	22.0	8,220	31.4
Recreation, cultural and sports	603	1,809	2,978	3,279	10.1	3,505	17.7	3,736	25.5
Real estate services	1,977	-	306	353	15.2	408	33.2	442	44.5
Services professionals, scientists and technicals	152	805	1,101	1,204	9.4	1,383	25.6	1,423	29.2
Educational services	52	915	155	168	8.5	192	24.0	207	33.4
Transportation, mail and storage	18	174	776	845	8.9	925	19.2	980	26.3
Information in mass media	-	-	213	238	11.7	256	20.4	282	32.5
Total	51,928	74,438	98,753	110,345		122,944		130,235	

Source: Self Made (2017)

Income from the supply of goods and services. It is the amount obtained by the economic unit during the reference period, for all those activities of production of goods, commercialization of goods and provision of services. Includes: the value of the goods and services transferred to other economic units of the same company, plus all expenditures or taxes charged to the buyer. Excludes: financial income, subsidies, fees, contributions and sale of fixed assets. Table 7.11 shows the expected figures in thousands of pesos per year and the sector with the greatest projection is information in mass media, with 39.9%.

Table 7.11 Income projection by sector, base year 2014

	Historical					Projection			
Sector	2004	2009	2014	2019	%	2024	%	2029	%
Retail trade	769,353	1,074,037	1,342,335	1,526,790	13.7	1,685,941	25.6	1,806,837	34.6
Wholesale	88,080	184,609	316,813	333,921	5.4	376,329	18.8	388,748	22.7
Accommodation, food and beverages	25,294	57,855	69,081	79,029	14.4	90,725	31.3	95,261	37.9
Other services	23,786	44,226	60,330	66,016	9.4	73,020	21.0	75,909	25.8
Educational services	14,689	21,871	26,562	30,653	15.4	32,982	24.2	35,456	33.5
Health and social assistance services	6,551	10,157	24,225	26,744	10.4	30,756	27.0	31,187	28.7
Professionals, scientists and technicians	5,068	5,669	12,746	14,594	14.5	16,973	33.2	17,329	36.0
Support for business	2,353	8,510	7,178	8,047	12.1	8,795	22.5	9,630	34.2
Postal transport and storage	15,946	-	783	856	9.3	921	17.6	951	21.5
Real estate services	1,078	5,426	2,658	2,958	11.3	3,381	27.2	3,507	31.9
Cultural and sports entertainment	134	2,295	5,516	6,200	12.4	6,820	23.6	7,502	36.0
Information in mass media	-	-	1,753	1,934	10.3	2,251	28.4	2,453	39.9
Total	952,332	1,414,655	1,869,980	2,097,741	12.2	2,328,893	24.5	2,474,770	32.3

Source: Self Made (2017)

Investment. It is the increase in assets, inputs and products that the economic units experienced during the reference year. It is obtained by adding to the Gross Formation of Fixed Capital the variation of Stocks, table 7.12 shows the expected figures for this variable, where the sectors Wholesale trade projects a greater growth of 43.1% with respect to the others, and the one of Postal and storage transports, begins to have economic movement with the projections from the year 2019.

Table 7.12 Investment projection by sector, base year 2014

	Historical					Projection			
Sector	2004	2009	2014	2019	%	2024	%	2029	%
Retail trade	17,985	32,935	21,273	23,477	10.4	26,018	22.3	28,155	32.4
Wholesale	3,336	287	911	1,034	13.5	1,168	28.3	1,199	31.6
Accommodation, food and beverages	541	647	1,861	2,087	12.1	2,399	28.9	2,491	33.8
Other services	621	1,844	78	90	15.8	105	34.8	112	43.1
Educational services	233	222	1,573	1,809	15.0	2,046	30.1	2,199	39.8
Health and social assistance services	494	630	530	561	5.8	652	23.0	708	33.6
Professionals, scientists and technicians	554	37	245	278	13.6	313	27.7	324	32.4
Support for business	182	310	260	288	10.8	336	29.1	357	37.5
Postal transport and storage	5	142	540	621	15.0	699	29.5	711	31.7
Real estate services	277	130	153	173	12.9	194	26.8	205	34.3
Cultural and sports entertainment	55	-	-	30		31		41	
Information in mass media	-	-	6	7	9.6	8	25.6	8	33.8
Total	24,283	37,184	27,430	30,425	11.0	33,938	23.8	36,470	33.1

Source: Self Made (2017)

Total Gross Production. It is the value of all goods and services produced or marketed by the economic unit as a result of the exercise of its activities, including the value of the products produced; the gross margin of commercialization; the executed works; income from the provision of services, as well as the rental of machinery and equipment, and other movable and immovable property; the value of fixed assets produced for own use, among others. Includes: the variation of inventories of products in process. Goods and services are valued at the producer's price.

The Total Gross Production variable will behave like the data displayed in table 7.13 and where the sector with the greatest economic projection is Cultural and Sports Recreation, with 48.2%.

Table 7.13 Total Gross Production by sector, base year 2014

	Histórico					Proyección			
Sector	2004	2009	2014	2019	%	2024	%	2029	%
Retail trade	189,844	280,291	323,726	360,630	11.4	392,004	21.1	410,036	26.7
Wholesale	25,004	56,641	66,791	79,548	19.1	88,377	32.3	90,498	35.5
Accommodation, food and beverages	23,403	42,184	59,673	66,416	11.3	75,116	25.9	79,097	32.6
Other services	42,585	29,671	43,644	49,274	12.9	54,595	25.1	56,887	30.3
Educational services	14,694	21,871	26,562	28,979	9.1	32,456	22.2	34,435	29.6
Health and social assistance services	6,627	10,155	24,168	28,518	18.0	31,426	30.0	32,305	33.7
Professionals, scientists and technicians	5,000	5,663	12,411	14,260	14.9	16,042	29.3	17,453	40.6
Support for business	2,236	8,218	7,127	8,160	14.5	9,384	31.7	9,637	35.2
Postal transport and storage	15,928	-	783	843	7.7	900	14.9	987	26.1
Real estate services	1,086	5,412	2,654	3,105	17.0	3,514	32.4	3,812	43.6
Cultural and sports entertainment	134	2,178	5,155	6,160	19.5	7,188	39.4	7,640	48.2
Information in mass media	-	-	1,748	1,924	10.1	2,151	23.1	2,312	32.3
Total	326,541	462,284	574,442	647,817	12.8	713,153	24.1	745,099	29.7

Source: Self Made (2017)

Conclusions

The purpose of the investigation was to project economic growth in the Eastern Region of the state of Tlaxcala, due to the installation of an automotive assembly plant, through the generation of Bayesian networks, allowing to identify the economic branches with the greatest growth potential. Having tested the projections of the Bayes Server Software with the real data in the States where companies of the automotive industry had already been installed and compare that the growth was similar, the instrument could be validated and trained with data from the State of Tlaxcala. For the development of the research, the behavior of six variables (Economic Units, Employed Personnel, Remuneration, Investment, Income and Total Gross Product) of the economic branches of twelve sectors of commerce and services that carry out activities in the seven municipalities of interest.

It should be noted that the figures presented in the Economic Survey Report are estimates made based on data from the original electronic sources of INEGI, and were calculated by statistical methods for research purposes, so they should not be considered as information from the original source. In the period of the investigation, there was no commercial and service infrastructure in the Oriente region of Tlaxcala that would support the demand caused by the increase in the flow of people involved in the installation of an automotive assembly plant, but by capitalizing on the opportunity for the inhabitants of the surrounding municipalities, this physical and economic infrastructure could provide the population that Sedatu is projecting in almost 200 thousand inhabitants by the year 2030.

The economic growth of the Eastern Region of the state of Tlaxcala was projected, using the Bayes Theorem tool and statistical inference to determine the dependence between them. The economic branches that have ample growth potential in the years 2019, 2014 and 2029, derived from the data processing of the Bayesian Network, were presented in the various tables corresponding to each study variable. As a summary of this information, table 7.14 is presented, where this information is presented.

Table 7.14 Economic sectors with greater projection for the year 2029

Economic sector	Variable	% Projected for 2029
Accommodation, food and drink	Economic Units (EU)	36.6
Services professionals, scientists and technicals	Economic Units (EU)	36.6
Other services	Busy Staff	36.3
Transportation, mail and storage	Remuneration	44.5
Wholesale	Investment	43.1
Information in mass media	Income	39.9
Recreation, cultural and sports	Total Gross Production (PBT)	48.2

Source: Self Made (2017) based on the projection of the Bayesian network

We can observe in the projection for the year 2029 the variables such as economic units, employed personnel, remuneration, investment, income and total gross production show significant growth. If we analyze the growth of the other states that served as a guide for the analysis where automotive companies had settled, we can highlight that there was also an important growth of the companies related to the automotive industry, in this way we can conclude that in the State of Tlaxcala it is inferred that there will also be an economic development.

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Capítulo 8 Design and development of a prototype production line with automated control mechanisms

Chapter 8 Diseño y desarrollo de una línea de producción prototipo con mecanismos de control automatizados

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Abstract

Improving the production process is a must in many factories that want to be competitive in the automotive industry, therefore it is important to invest in new machinery and structures to do this activity even there is in Mexico a model of linking that enables to work industry and Universities, and this is the case that it presents in this work in order to design and manufacture of a prototype production line with automated control mechanisms. This work is supported by the using the Finite Element Method in order to validate the design stage.

Design, prototype, mechanism.

1. Introduction

The use of the correct amount of material in any mechanical structure or device is very important in the cost and manufacture of it that include the time and energy needed for this last issue, therefore it is necessary to design this kind of products in an effective way, this starts with the analysis of the function of the part to implement in the process in this case. In order to have a well design product, it can be used the module of the Finite Element Analysis that is included in a CAD software, at first to calculate the stresses and deformations that will be produced by the forces applied to the parts and then if necessary optimizing the cross sections that depend on the thickness of the piece.

So this job focuses in the analysis of the stresses produced by the loads applied to a prototype production line that is integrated by supports, rails, tubes, plates, reinforcements. On the other hand it presents the methodology to select the motors and devices to automate the prototype production line. This job is important because the reliability of the product function can be made through this kind of analysis and in this way the cost must be the adequate for it. The conventional stress calculations of structures subjected to loads are very complicated to do, and the selection of several items in a production line is an information that is available to the experienced people in the industry world.

Therefore, this project means to be a reference how to make the design and development of mechanical components and the establishing of a methodology of selecting items in an electromechanical product. The main problem to solve is the transportation of flocked pieces, from the beginning of the process passing through the application of flock in a furnace, and finally delivering them to the next process. Taking into account, the time to cool these products, so it has to set a speed that controls this variable, by electrical motors in order to accomplish the production rate.

The hypothesis is that the design of automated mechanisms must be assessed, by means of the Finite Element Method in order to assure that the whole transportation of the flocked pieces will not fail because of the lack of material of the components. On the other hand, the cost of the prototype line will not be excessive due to the specification of more material than the necessary.

This chapter integrates a theoretical revisión, the methodology, the case study breakdown in: modeling of prototype line structure components, simulation of stresses and deformations, optimizing of cross sections, virtual subassembly of prototype line, Making of drawings, manufacture of prototype line parts, final assembly, selection of electrical components, results and conclusions.

2. Theoretical Revision

Several authors have considered that Archimedes used a method similar to the finite element to determine the volume of some solids. Although he calculated areas, lengths and volumes of geometric objects, dividing them into simpler ones and then adding up his contributions, the concept of variational approximation is nowhere to be seen. The relationship with the definition of MEF is very poor. It can be argued that the measurement of the volume (area, length) of an object is a scalar function of its geometry. Changing "measured" by energy and "objects" by elements in the previous lines, the description is close to that established by the MEF "the energy of the system is equal to the sum of the energy of each element". However, Archimedes needed derivative definitions to perform his energy calculations and Calculus was not invented until 20 centuries later.

In 1941, Hrenikoff presented a solution for elastic problems using the "frame work method". In an article published in 1943, Courant used polynomial interpolation by parts on triangular sub-regions to model torsional problems. The basic ideas of the finite element method originated in the structural analysis of aircraft. In the 1950-1962 period, Turner working for Boeing formulates and perfects the Direct Stiffness Method. Turner and other researchers obtained stiffness matrices for trusses, beams and other elements and presented their results in 1956. Clough was the first to coin and use the term finite element in 1960. In the early 1960s, engineers used the method to obtain approximate solutions in problems of stress analysis, fluid flow, heat transfer and other areas. A book by Argyris, published in 1955, on energy theorems and matrix methods, cemented additional methods in finite element studies. The first book on finite elements by Zienkiewicz and Cheng was published in 1967. At the end of the 1960s and the beginning of the following decade, finite element analysis was applied to non-linear problems and large deformations.

Technological advances, together with capital and labor factors, have been seen for some time as essential for economic growth. Consistent with this broad and generally accepted belief, governments of developed or developing countries have allocated resources for research and technological development, with diverse results. Since the end of the war of 1939-1945, fears have frequently been expressed about the future of human society under the pressure of technological progress. It is said that it was an executive of the Ford Motor Company who coined the word "automation" (automation, automatic synthesis and mechanization) at the beginning of the 1950s, in Figure 8.1 the application of mechanics and in the Figure 8.2 the use of computational mechanics for the modeling of solids and structures, are shown.

Figure 8.1 Application of mechanics

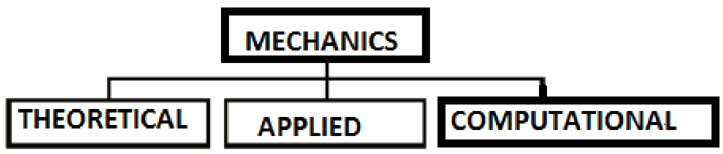
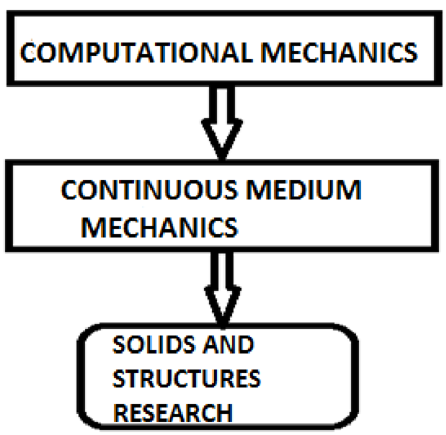


Figure 8.2 Divisions of computational mechanics



The global recession, has created unemployment in all industrial countries in different proportions, has tended to mask the unemployment generated by technological advances. But union leaders are more than aware of the erosion of the jobs of their affiliates in certain sectors of industry, as in the graphic arts of the United Kingdom, the struggle to introduce the "new technology" in Fleet street It has lasted for years, to the point that the proposed technology is far from being new. The composition and printing of English newspapers is carried out with facilities and machinery almost a century old, in terms of design. The new technology, which uses composition by computer, photography and offset printing, is a much shorter process, with less margin of error, easier to correct, silent (except web-offset presses), as it is a technology more refined, because the editing and advertising texts could be typed directly by editors and journalists, using screens in which their composition is visually controlled. [Andrew, 1981].

The problems of the design of mechanical elements have a design approach to systems engineering following a typical design process. The preliminary, intermediate and final design is made after an identification of the design problem, within that process a sequence of tasks such as synthesis, analysis, prototyping and evaluation was completed. An example is a design idea that selected five initial design concepts and became the final system after the evaluations and modifications. The results of the tests showed that the designed machine can be easily integrated. The weight and manufacturing cost for the design were reduced to a minimum, to facilitate the application of this equipment designed to replace human work by providing high performance, for highly automated and modern factories. [Yucheng, 2017].

For the development of computational models that present underlying ideas of a computer program that takes as input a scheme of a mechanical or hydraulic energy transmission system, more specifications and a utility function, and returns predefined catalog numbers for optimal selection of the components that implement the design. Unlike programs for designing individual components or systems, this program provides the designer with a high level "language" to compose new designs. Then he performs some of the detailed design processes for him. The process of "compiling" or transforming a description from high to low level is based on a formalization of quantitative inferences about sets of artifacts and operating conditions organized hierarchically. This allows the compilation of the design without the exhaustive enumeration of alternatives. [Ward, 2008].

Research has shown that during the conceptual design, designers continuously seek potential design results, which consist of problems, solutions and evaluation criteria, in different design spaces. Both quality and quantity design results are affected by various factors, such as the design method used, the capacity of the participating designers and the design problems used. Works are presented using the understanding of the search for design spaces, developing methods to evaluate the effects of various factors, such as individual capacity, the method of creativity used and the problems solved, in the quality and quantity of design results. Design experiments are used to empirically identify the effects of these factors on the design results. We observe that, compared to the capacity of the participating designers and the problem used, the design methods strongly influence the design results. In addition, it is possible to predict the influences of the designers on the design results by understanding the profiles generating solutions of the designers in other experiments. [Sakar, 2014].

Variability of Design Methods

Every year, both researchers and professionals continue to design different methods to solve increasingly complex design problems. This wealth of design methods is both a blessing and a curse: on the one hand, having a broader set of methods deepens our toolkit for problem solving, which allows us to find better solutions; On the other hand, the variety of options quickly becomes overwhelming. For example, the largest current database lists more than 300 different design methods [Roschuni, 2011]: a conservative estimate that easily exceeds any designer's ability to learn or even search manually.

The solution to many design problems involves two steps: the designer (1) creates a configuration by making choices of components and (2) selects values for the parameters associated with the components in that configuration. For example, in car design a configuration decision may be to use disc brakes and a single turbocharger. Consequently, the parametric values to choose include the radius of the disk and the entrance area of the turbo. The mathematical models used to represent such problems and to evaluate the chosen alternatives tend to be large, non-linear and involve discrete and continuous variables. Since, in general, a single design algorithm will not suffice to solve such problems, the currently available computer tools are generally limited to a small range of problems or parts of major problems. We believe that a computing environment that allows flexible access to a diverse set of tools can help designers quickly generate high-quality solutions for a wide range of problems. [Ramaswamy, 1993].

In the last three decades, various computational, cognitive and innovative approaches have been developed to advance in the fields of artificial intelligence and knowledge-based design systems. The diverse investigations develop the systems of generative design in the literature. They present a framework of a generative design system with several examples of real design. Finally, the document examines the future direction for the advancement of the generative design.

A generative design system supports the generation and exploration of a large number of alternative design solutions, using automatic transformation algorithms. It maintains a consistent style of all the solutions explored, but with design characteristics and variables. It can also include an evaluation mechanism in the generative process for the system to look for potentially optimal design solutions. [Jia, 2017]. Dealing with this abundance of methods raises several questions: what makes the methods similar and how do you classify them effectively? How are methods applied in different situations and what differences help designers decide which method to apply? How should designers address new methods not used? Previous attempts to answer these questions have meticulously reviewed collections of methods or case studies of design (summaries of a particular design problem along with methods used by the designer) to discover why some methods work in some contexts, but not in others [Broadbent, 1969, 1979] [Jones, 1992] [Margolin, 1996]. While these types of studies provide a valuable basis, they necessarily cover only a small part of the design methods: scaling that type of analysis to the large number of current methods requires a prohibitive effort.

In the area of automotive engineering, different studies are carried out focused on the solution of problems in different areas, an example that was carried out to reduce the aerodynamic drag, evaluates the performance of the aerodynamic resistance devices of the lower part of the body in function of the real shape of a sedan type vehicle. A covert air dam was applied under the side flap as aerodynamic drag reduction devices on the underside of the body. In addition, the effects of interactions based on the combination of aerodynamic drag reduction devices were investigated. A commercial sedan type vehicle was selected as a reference model and its shape was modeled in detail. The aerodynamic drag was analyzed by computational fluid dynamics at a general road speed of 120 km / h. The simple aggregation of the effects of the aerodynamic drag reduction by the individual device did not provide the precise performance of the combined aerodynamic drag reduction devices. An additional aerodynamic drag reduction of 2.1% was obtained on average in comparison with the reduction in resistance of the expected advance, which was due to the synergy effect of the combination, this performed by computational simulation systems. [Junho, 2017].

Another example was made in production processes such as high-strength leaf springs, which consists of shearing, punching, heat treatment, hot cambering, shot peening, scraging and later speed, load and durability tests were carried out. . The processing of the raw material plays a vital role in achieving life with the required fatigue. The objective of determining the effects of material processing and the design parameter on the fatigue life of leaf springs is paramount. The processing parameters of the material considered are the decarburization of the surface and the scraping effort, while the design parameter considered is the inclination of the individual sheet. Partial and complete surface decarburization is determined during lamination and its effect on the fatigue life is predicted. The effect of searing tension on the life of fatigue is also determined. An ideal range of burning effort is proposed for the improvement of the fatigue life. A suitable leaf inclination is proposed for the individual sheets. Modeling is applied for the determination of the effect of the assembly tensions due to the inclination of the individual blade in the fatigue life. [Arora, 2015].

Every year, design professionals and researchers develop new methods to solve problems. This increasingly large collection of methods causes a problem for novice designers: how do you choose which design methods to use for a given problem? Experienced designers can provide case studies that document what methods they used, but studying these cases to infer the appropriate methods for a new problem is inefficient. It is determined that knowing which methods occur frequently together allows you to recommend design methods more effectively than just using the description text of the problem itself. In addition, it is demonstrated that the automatic grouping of the methods that frequently occur in a conglomerate spectral form replicates the groupings provided by humans with 92% accuracy. Leveraging existing case studies, recommendation algorithms can help novice designers navigate efficiently in the growing range of design methods, leading to a more effective product design. [Mark, 2014].

Technological advances focus on design processes that are very useful in the preliminary development stage through the effective support of simulations. This type of design processes based on simulation are effective in the development of mechanical and process drives among others. Based on multiple test results, they show performance improvements that include low friction and vibration, improved durability and profitable parts design, compared to conventional processes. These studies propose an integrated approach to preliminary design.

The approach involves structural and dynamic analysis. The studies summarize the dynamic and structural analyzes, as well as the topological optimization to describe a process to obtain optimal results. [Jung, 2017]. When studying mechanical parts are taken into account as engineering components often exhibit unavoidable local stress concentrations due to steps, notches or other geometric discontinuities. Such stress concentration sites under service load can drastically reduce the operating life of a structure. To preserve structural integrity, it is essential to understand the stress-strain responses in the critical areas of failure (notches). When carrying out finite element analysis, elastic stresses and finite-thickness plate deformations containing notches on the opposite U-shaped side with different notch configurations are systematically investigated. The plate is subject to uniaxial tension. For the analysis of a plate, the finite element analysis (FEA) is used, this shows that even if the plate is in an elastic state, the stress and strain concentration factors are different. It is also shown that the effect of Poisson's ratio is significant in the weakest point concentration factor. The accuracy of finite element results is verified with analytical solutions available in the literature. [Khatawate, 2016].

The elements of machines on the market today have been designed and implemented for many decades. Research is carried out to carry out the optimization of the design. A reports are shown on the directions of the conceptual evolution of the traditional design components and the feasibility of their significant improvements. The role of the "axiom of ideality" and of the prevailing tendencies of the evolution of engineering systems in the creation of novel concepts is emphasized. Descriptions of new concepts of gear and power transmission couplings, key connections, vibration isolators, cantilever design components characterized by high performance parameters are presented, all modeled in a computational way and using the numerical or finite element methods They give certainty to the new designs. [Rivin, 2008].

A good option for mechanical design studies is the development of widely applicable formulations to investigate the propagation of designs in mechanisms. Here the analytical criteria are presented in terms of the variations of the articulation position vectors and the orientation matrices for the plane and spatial mechanisms. Mechanisms are represented using graph theory and closed loops are converted to a tree-like structure by cutting together and introducing new constraints. The Jacobian matrix in the Cartesian space is transformed into the space of joint coordinates. Two cases are considered: a pair of bodies that remain connected by a joint after cutting the additional joints and a pair of bodies are disconnected after cutting the joints. Using this method, a designer has the ability to study the propagated effect of changing a design variable. The presented formulation is validated through a numerical example of a McPherson strut suspension system. The system is analyzed and an assembled configuration is calculated after a design change. [Zou. 2007].

The Finite Element

The finite element method is a numerical method for the resolution of differential equations, it is based on dividing the body, on which are defined certain integral equations that characterize the physical behavior of a certain problem. The set of finite elements forms a partition of the domain, also called discretization. Within each element a series of representative points called nodes are distinguished. The set of interconnected nodes is known as mesh. The calculations are made on a mesh or discretization created from the domain with mesh generating programs.

The set of relationships between the value of a given variable between the nodes can be written as a system of linear (or linearized) equations, the matrix of said system of equations is called the system's stiffness matrix. The number of equations of said system is proportional to the number of nodes. Typically, the finite element method is computationally programmed to calculate the field of displacements and, subsequently, through kinematic and constitutive relationships, the deformations and stresses respectively, when dealing with a problem of deformable solids mechanics or more generally a problem of mechanics of the continuous medium. The numerical solution of partial differential equations is an indispensable tool in much of modern science and engineering.

However, the development and successful application of advanced solvers with partial derivative equations presents complex problems and requires the combination of diverse skills in mathematics, scientific computation and low level code optimization, which rarely is that level of expert presented in a single guy For the finite element method, a skill set is required that includes at least the knowledge of the system that is simulated, the analysis of the resulting partial derivatives, the numerical analysis to create appropriate discretizations, mesh generation, graph theory to create data structures in these meshes, the analysis and implementation of linear and non-linear solvers, parallel algorithms, vectorization and optimization of loop nests under memory restrictions. [Florian, 2016].

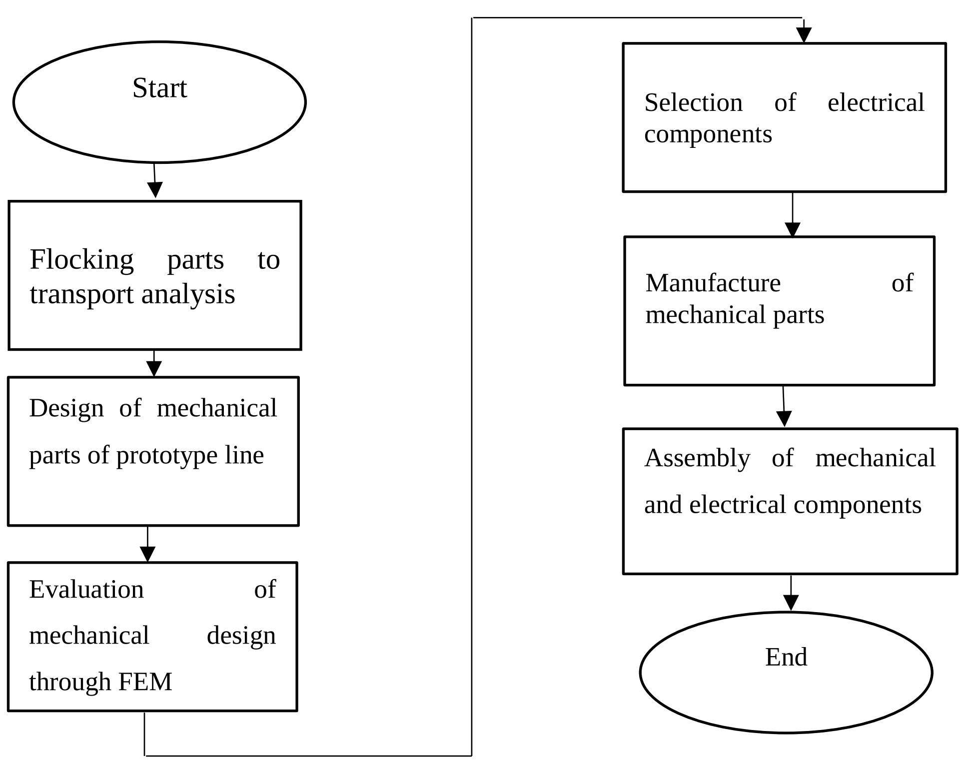
When modeling with finite element is analyzed the possibility of replacing the gray iron, traditionally used for the production of relevant parts in machines, with ductile iron or vermicular iron. Experimental computational tests are performed to determine the mechanical behavior of ductile and vermicular irons with respect to tensile, fatigue and fracture loads, and microstructures were also analyzed. The results show that ductile or vermicular cast iron in parts and components of machine tools could provide additional rigidity and strength with respect to gray iron. A balanced use of these alternative irons would make the most of each specific property (such as strength, hardness, weight, etc.). [Fragassa, 2016].

In the design and manufacture of mechanical devices, there are parameters whose values are determined by the manufacturing process in response to errors introduced in the manufacturing or operating environment of the device. These parameters are called adjustment parameters and are different from the design parameters for which the designer selects values as part of the design process. Studies show that by introducing adjustment parameters in the design methods of: optimization, Taguchi method and imprecision method (Wood and Antonsson, 1989). Including adjustment parameters in the design process can result in designs that are more tolerant of variational noise. [Otto, 2008]

3. Methodology

The variables that handles in the Project were the load that corresponds to the weight of each piece of the flocked parts. Another variable is the speed that must be specified to move the pieces from the beginning to the end of the flocking processes these are the main variables that must be taken into account to design the automated mechanisms and the selection of the electrical components.
In Figure 8.3 observes the process diagram to accomplish this methodology.

Figure 8.3 Methodology to design and develop of prototype line



Source: Own Elaboration

Another way to do this project is to design the mechanical components without taking into account an assessment of them, which represents a risk from the safety point of view or it can be expensive from the costs issue due to excess of material. The value that this project adds is the optimization of the mechanical parts, but the rest of the components are important to mention because all of them integrate the prototype line.

In Table 8.1 shows the comparison between the methodology used in this work and the regular methodology.

Table 8.1 Comparison between two methodologies for design of mechanical components

Methodology	Advantages	Disadvantages
Using of FEM to evaluate mechanical components	FEM is useful to optimize mechanical parts through several criteria that assures the structural function.	When using FEM requires a CAD/CAE license that is expensive.
Using of experience to specify mechanical components	No need for CAD/CAE license.	Uncertainty about structural specification

Source: Own Elaboration

3.4. Case Study

At first, it receives information from the production department according to the needs of a prototype line that includes:

- Length of the line
- Space of the facility
- Maximum production rate

This information analyzes and the drawings of the mechanical components are made, these components are:

- Poles
- Brackets
- Supports
- Rails
- Chains
- Plates
- Reinforcements
- Tubes
- Angles

3.4.1 Modeling of prototype line structure components

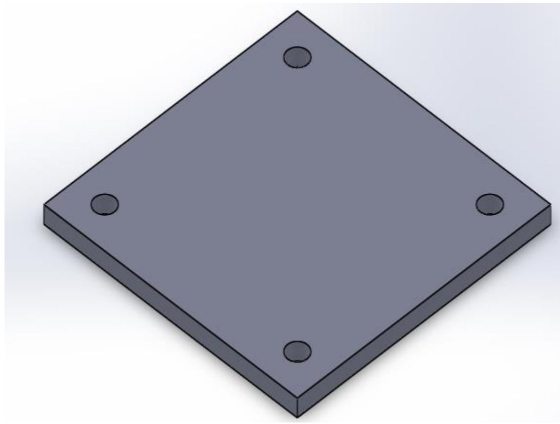
All of these parts draw in a CAD/CAE software and they show in figures 8.4 to 8.9. There are mandatory dimensions in every part, and calculated dimensions. The difference between both types are summarized in table 8.2

Table 8.2 Differences between mandatory and calculated dimensions

Mandatory dimensions	Calculated dimensions	Differences
Length of process	Thickness of parts	A mandatory dimension is the dimension that cannot be changed because of the function of the part, and the calculated dimensions can be optimized for better use of material.
Height of prototype	Length of pieces	

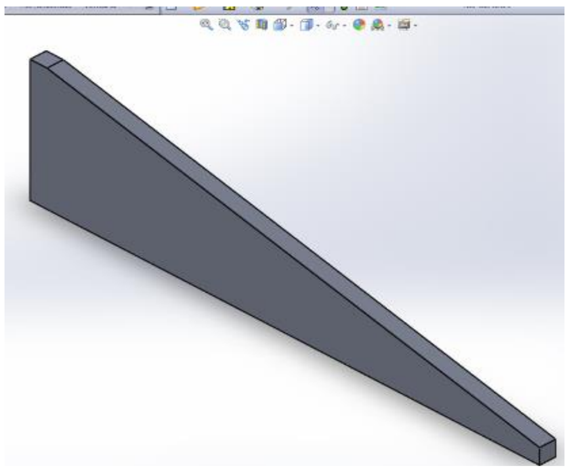
Based on these concepts of mandatory and calculated dimensions, it draws the parts of the prototype line. The mechanical parts of the prototype line integrate a structure, therefore, it specifies a structural steel when designing these components, and in this case the best option due to its economical price is A36 steel. For the structural components like tubing, it specifies a square profile, also selects the size of the chain that carries out the flocking parts to move from the beginning of the process until the next process that is the inspection of the part by quality staff.

Figure 8.4 Base plate



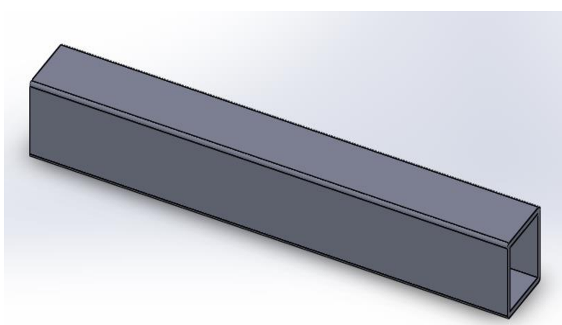
Source: Own Elaboration

Figure 8.5 Reinforcement



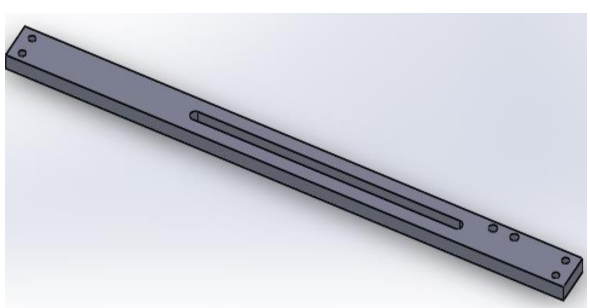
Source: Own Elaboration

Figure 8.6 Square tube



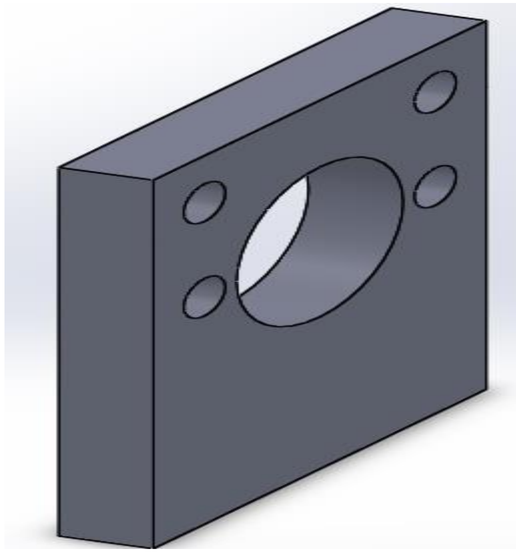
Source: Own Elaboration

Figure 8.7 Rail support



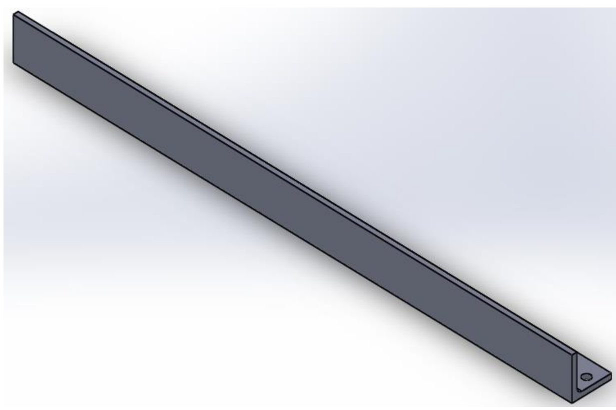
Source: Own Elaboration

Figure 8.8 Reinforcement plate



Source: Own Elaboration

Figure 8.9 Rail angle



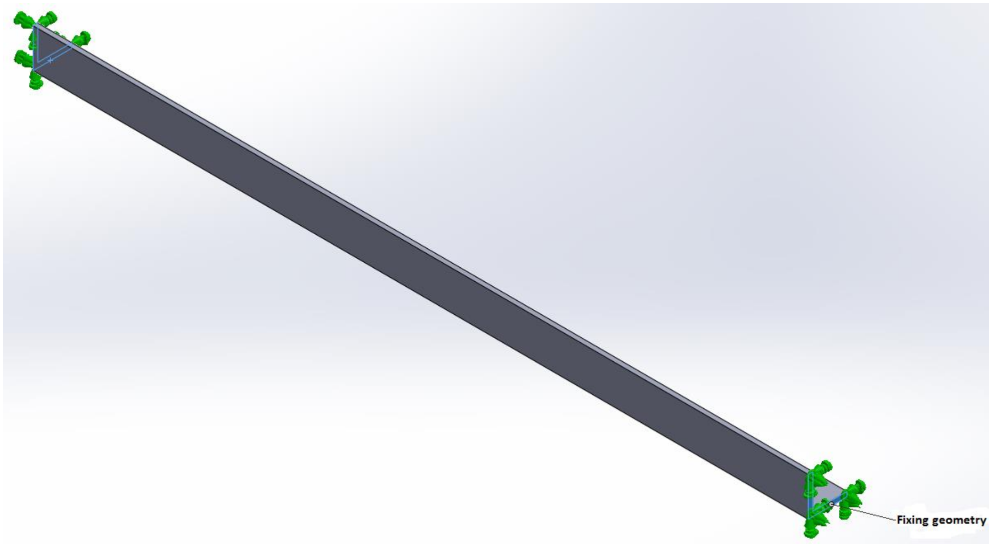
Source: Own Elaboration

After modeling the parts of the prototype line in a CAD software, they can be simulated by in the CAE software.

3.4.2 Simulation of stresses and deformations

In order to have a better idea about how the structural components of the prototype line work regarding the loads which apply to it. In this case the loads are the weight of each piece of plastic that arrives at the start of the prototype line. Another case is the supporting of components like the electrical motor that is part of the structure. When doing the simulation of stresses and deformations, it is necessary to define the references like the supports of each part and establish the direction, type and magnitude of the load. The first step is defining the geometry of the fixing that supports the part, it shows in Figure 8.10.

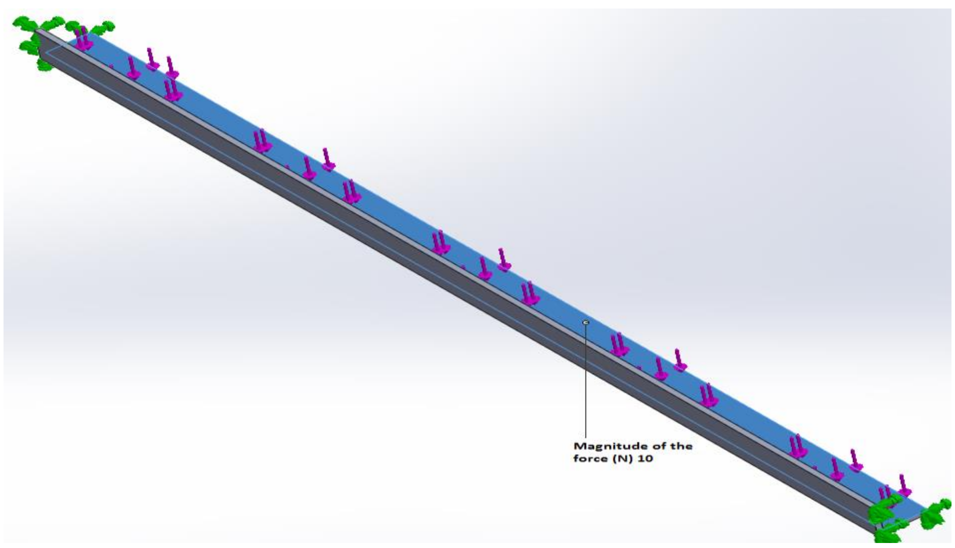
Figure 8.10 Fixing geometry of the part



Source: Own Elaboration

After this step is necessary to determine the load, in this case a force that is applied to the component, in Figure 8.11 observes this.

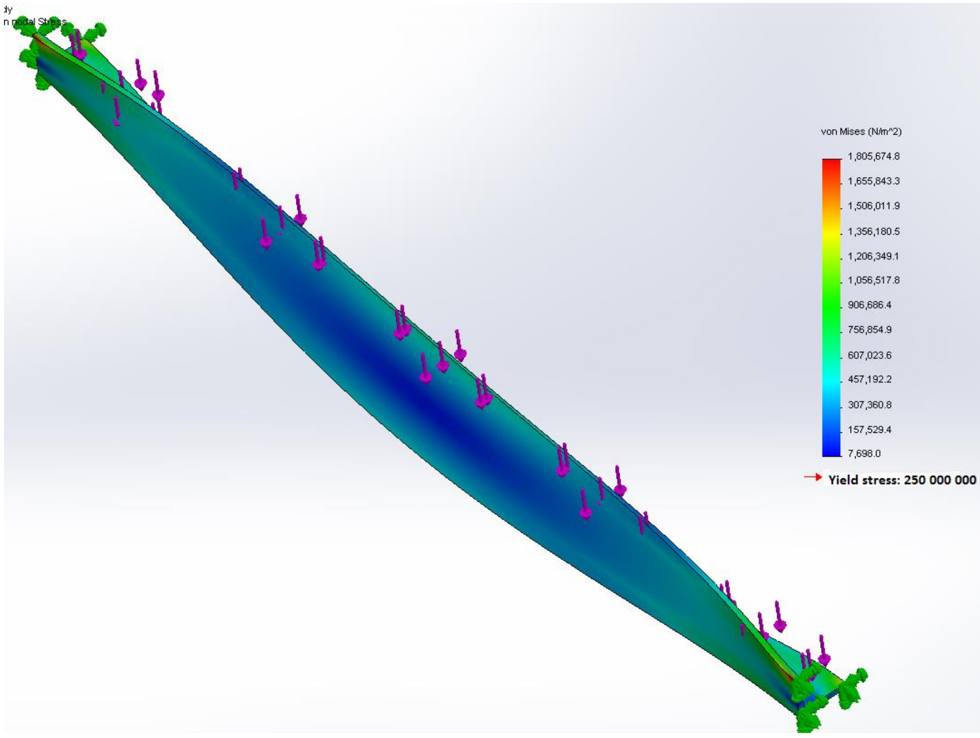
Figure 8.11 Determination of direction and magnitude of the force applied



Source: Own Elaboration

In the CAE software defines the material of the part in order to take into account the properties of it, such as elastic module, Poisson coefficient, shear module, density, yield stress, ultimate stress that the CAE software requires to calculate the stresses and deformations. Then it executes the simulation and gets the results that shows in figure 8.12

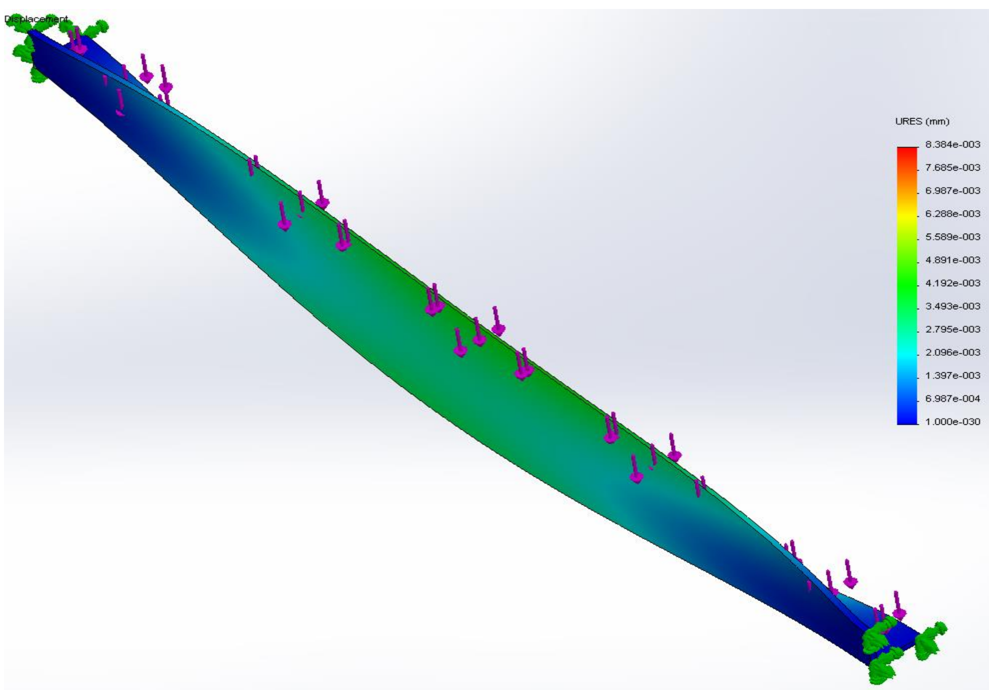
Figure 8.12 Stress results



Source: Own Elaboration

Then it also runs the deformation simulation to identify the maximum value, this shows in figure 8.13.

Figure 8.13 Simulation of deformation



Source: Own Elaboration

This steps are necessary to do because it can compare the maximum values of stress and deformation and compare them

3.4.3 Analyzing of stresses and deformations

Once the stresses and deformations are displayed in the CAE software, it proceeds to analyze them in order to determine if an optimization is required.

A criterion to take into account to determine the rightness of the design is the safety factor that in many engineering applications must be from 1.25 to 3 for ductile material like the ASTM A36 is. On the other hand, the maximum deformation is a reference about the behavior of the material under load, the criterion for this case is the stiffness that the component needs to have to accomplish its function in the structure.

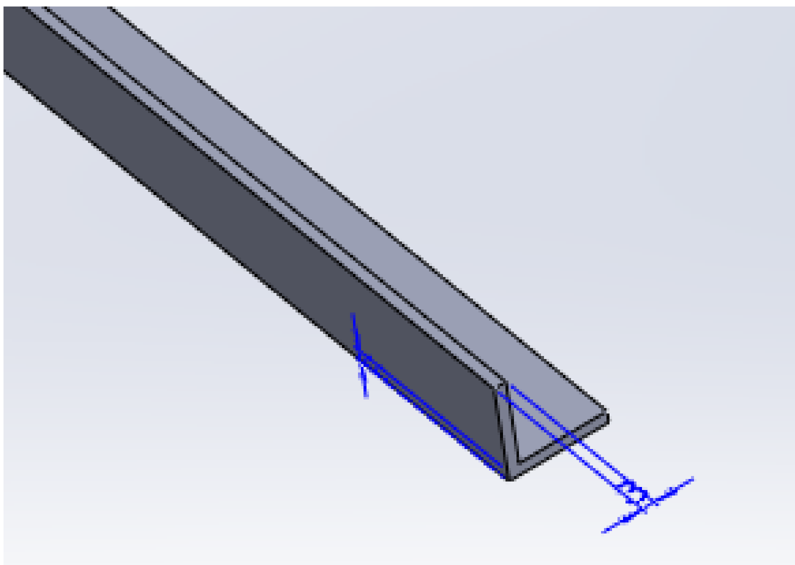
Based on these criteria, it has to determine if the cross section of the material is appropriate or not. If it is appropriate then goes on to design the next components, if it is not right the cross section, it runs an optimization to make it right.

3.4.4 Optimization of cross sections

When running the optimization process, it is necessary to define the thickness as the variable to optimize, this shows in Figure 8.14, and select one criterion that in this case the criteria available are:

- Safety factor
- Maximum displacement
- Maximum stress

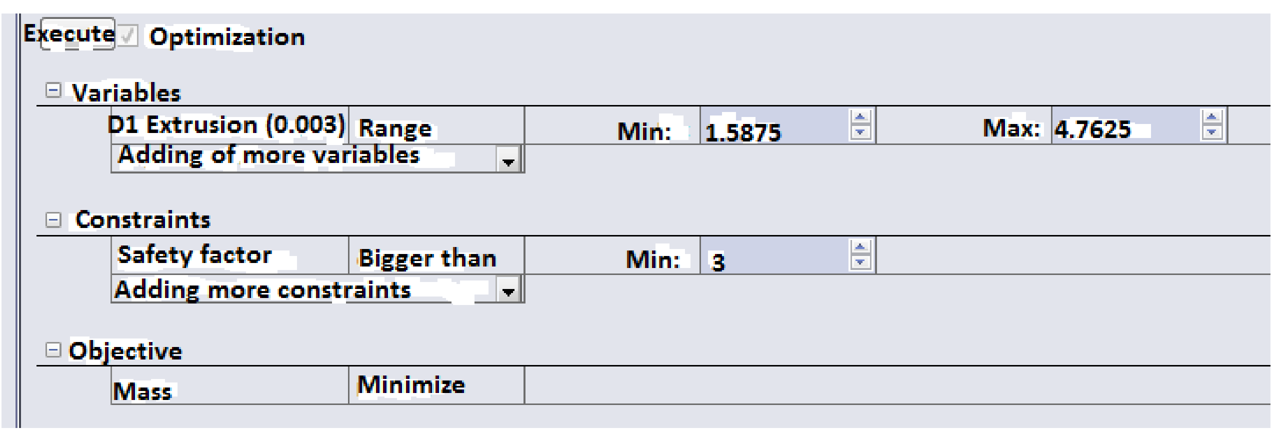
Figure 8.14 Selection of thickness to optimize.



Source: Own Elaboration

The criterion selected in this case is the safety factor and it can use a range of thicknesses that are useful, in order to range properly, it takes into account the thicknesses available in the trade issue. In Figure 8.15 shows the variable to optimize, the range of thickness, the constraint and the objective that is to minimize the mass.

Figure 8.15 Parameters needed to run optimization.



Source: Own Elaboration

Once run the optimization, it is possible to see the results, in this case the parameters of Figure 8.15 generated a reduction in thickness by a half, reduced the safety factor a 26% and the same value for the mass was reduced, this shows in Figure 8.16 As it can see this procedure helps use the material in a better way, so the costs due to this variable can lower and it obtains a design that accomplishes the same function.

Figure 8.16 Optimization results

Optimization results

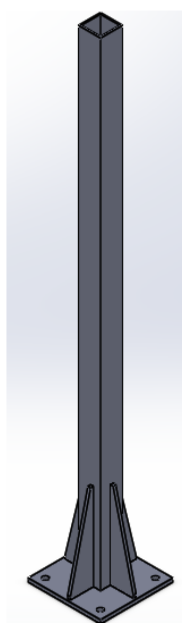
	Initial	Optimum
D1 Extrusion (0.0015)	3 mm	1.5 mm
Safety factor	138	102
Mass	0.55 kg	0.42 kg

Source: Own Elaboration

3.4.5 Virtual subassembly of prototype line

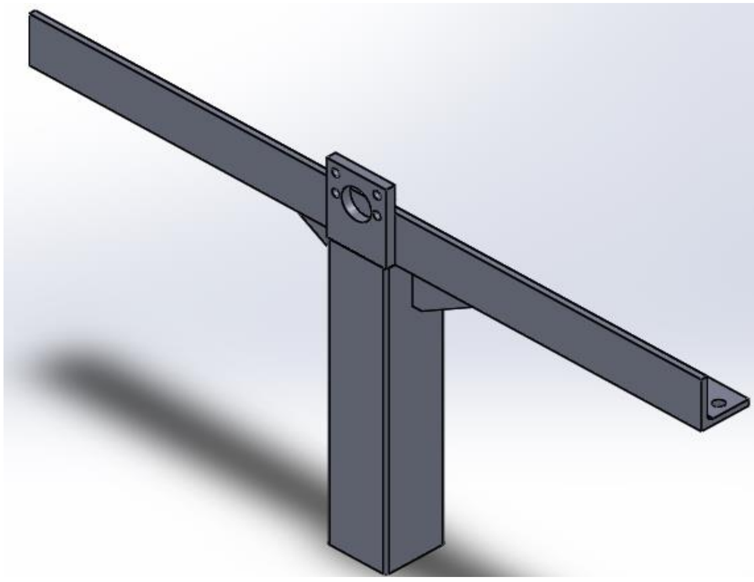
When all of the optimizations are done, it proceeds to make the virtual subassembly, Figures 8.17 to 8.21 show some of these components, these virtual assemblies are just a sample of all that integrate the prototype line.

Figure 8.17 Base-pole subassembly



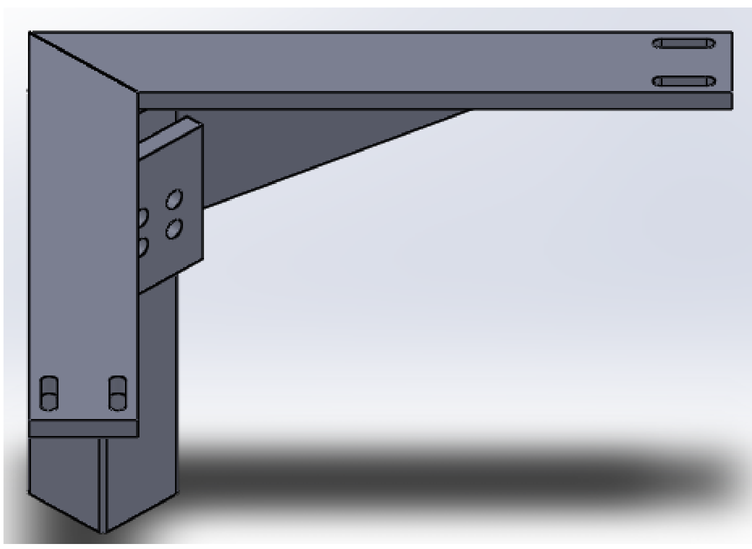
Source: Own Elaboration

Figure 8.18 Support with reinforcements subassembly



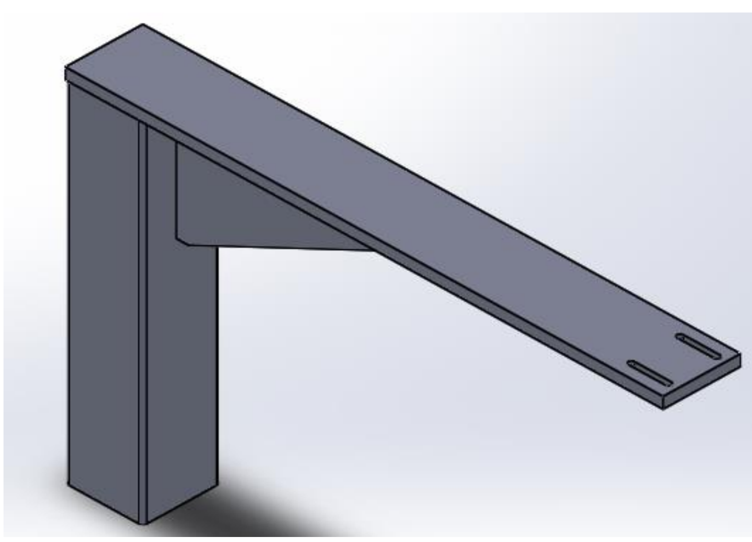
Source: Own elaboration

Figure 8.19 Change of direction support subassembly



Source: Own Elaboration

Figure 8.20 Chain support subassembly

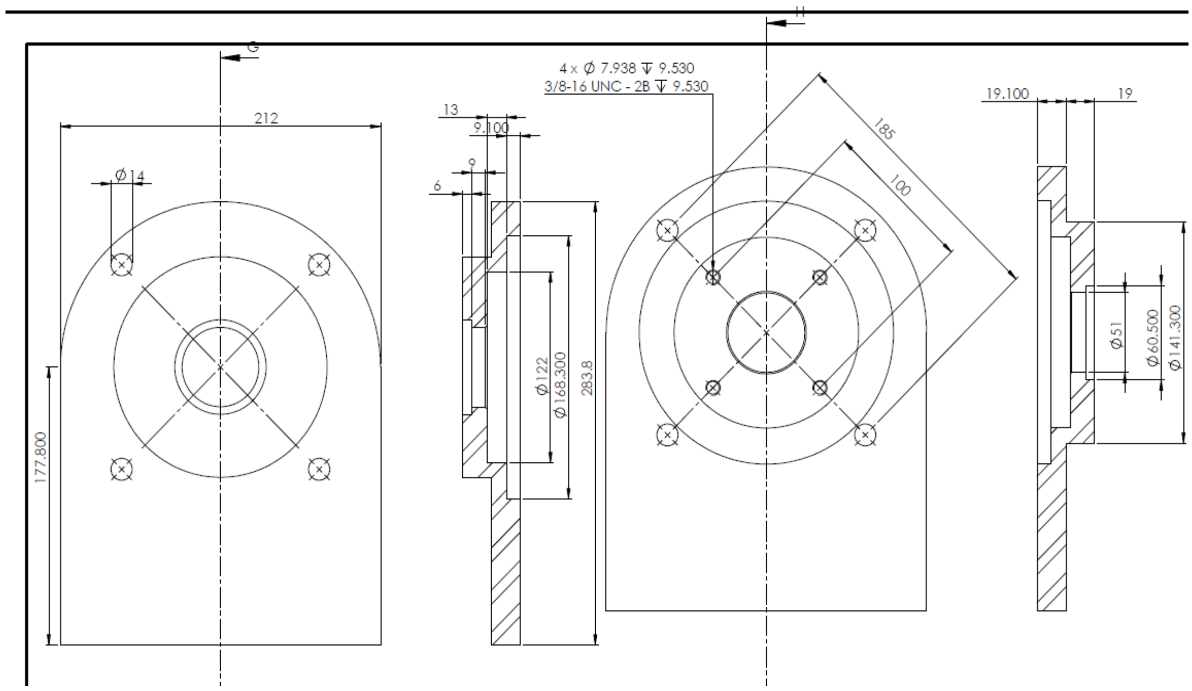


Source: Own Elaboration

3.4.6 Make of drawings

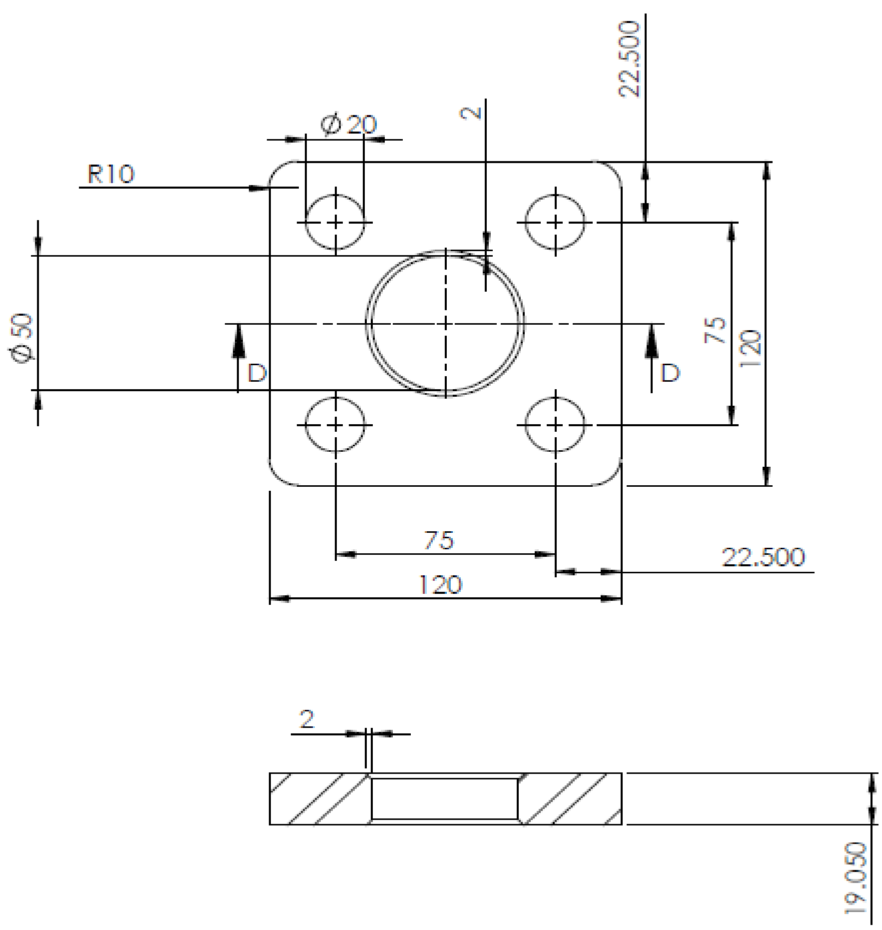
In this stage it proceed to specify the final dimensions according to the analyzing and optimization stages. Then all of the components of the prototype line are defined by technical specifications in order to manufacture each of them. Some of the drawings are presented in Figures 8.21 and 8.22

Figure 8.21 Blueprint of base plate



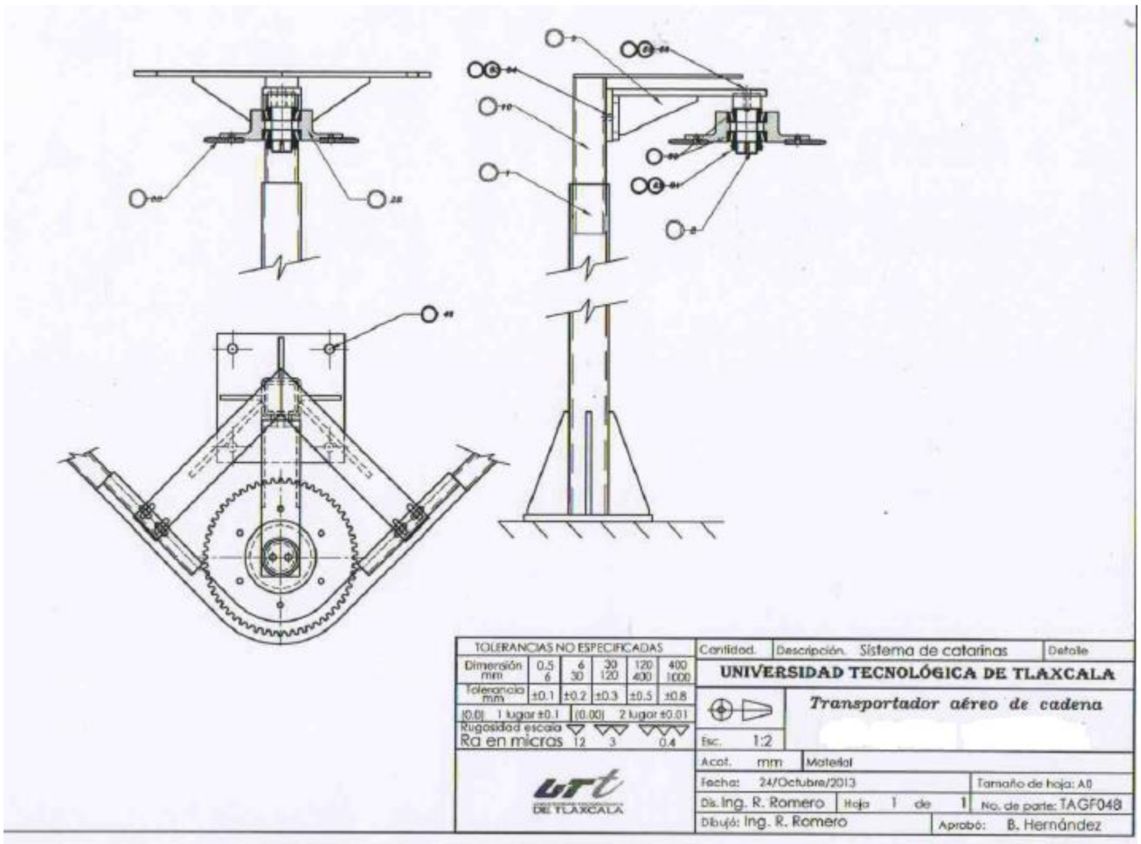
Source: Own Elaboration

Figure 8. 22 Blueprint of lower plate



Source: Own Elaboration

Figure 8.23 Assembly drawing of tension system



Source: Own Elaboration

The technical specifications include:

- Dimensions
- Geometrical and Dimensional Tolerances
- Roughness
- Material
- Refererences
- Section cuts

All of these specifications meet the requirements to assure a correct assembly of the prototype line.

3.4.7 Manufacture of prototype line parts

When all of the drawings were done, it used the information contained in them to manufacture all the prototype line components. The processes that were necessary to accomplish were:

- Cutting
- Welding
- Drilling
- Threading
- Assembly

3.4.8 Final assembly

When the prototype line components were manufactured, it assembled all of them to build it. In figures 8.23 to 8.26 show some aspects of the final prototype line.

Figure 8.23 Side view of rail

Source: Own Elaboration

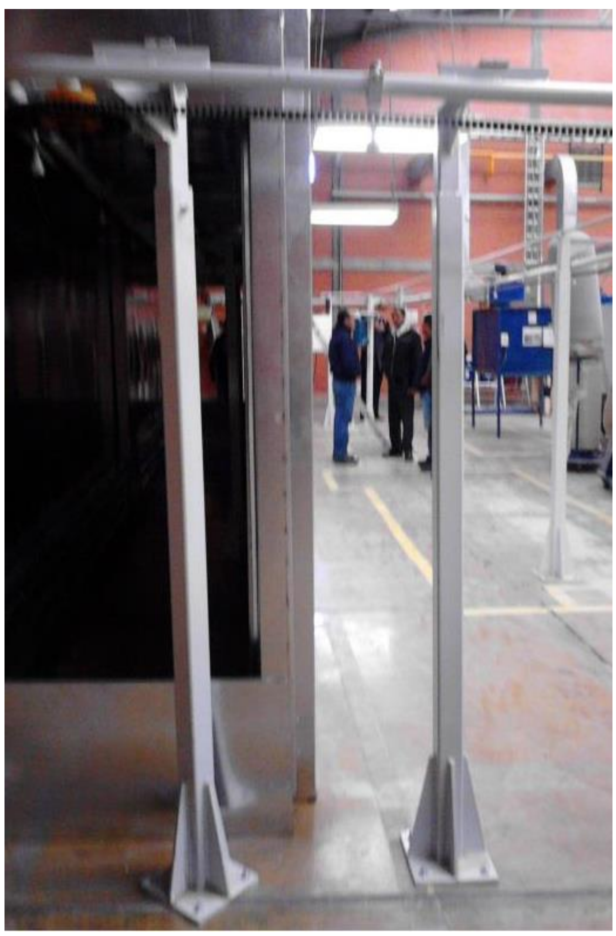
Figure 8.24 Gear motor

Source: Own Elaboration

Figure 8.25 Tension system

Source: Own elaboration

Figure 8.26 Front of prototype line



Source: Own Elaboration

4. Results

The prototype line works as it was designed and now it is possible to run batches of flocked parts in this equipment in order to test some new parts before they enter into the production of the company and in this to assure that the quality and quantity of this product will be according to the Master Production Schedule.On the other hand the participation of professors and students in this project was useful to apply theory issues in design and manufacture works, so it was a meaningful experience to everybody who made some drawing and selections of components.

5. Acknowledgment

We thank to the directive staff of Universidad Tecnológica de Tlaxcala for allowing to work in this project.

6. Conclusions

The work that develop Enterprises and Universities is a good way of achieving projects to innovate products and processes that can impact in cost reduction of structures keeping the security of the equipments that are developed.

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Chapter 9 Design and implementation of a comprehensive program for innovation in training processes in an automotive company

Capítulo 9 Diseño e implementación de un programa integral para la innovación en los procesos de capacitación en una empresa automotriz

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Introduction

Abstract

The work presents the implementation of a comprehensive training project (PIC), for an automotive industry company (EAP), which was designed and developed by academic staff of the Industrial Processes and Operations (IPOI) of the Universidad Tecnológica de Huejotzingo (UTH). These results come from the implementation of the project executed during two years of work between company and University, the previous stages were: 1). Identification and development of labor competencies for the operating personnel of a CNC[11] and improvement of the individual work role, and 2). Evaluation of operational personnel through the design and application of evaluation instruments by competencies.

The study is qualitative, exploratory and descriptive, since in the third stage the case described for this work was developed; the results achieved were, courses designed and taught, trained personnel and the hours of training, which allowed to prepare the operators of the EAP according to their needs. The innovation in the UTH was directly reflected in the methodology designed by the participating academics in the project, who gained experience in the teaching-learning processes for the industry. For the EAP, the innovation was carried out for the training process with the implementation of the PIC, which once approved was given in two phases: in the first one, all the personnel who were working in the plant participated and in the second, the personnel in the process of being recruited, in such a way that approval is currently required to be part of the EAP.

Comprehensive Plan, Training, Labor Competencies

Problem

On the part of the UTH a working group of four IPOI career researchers was integrated, who were responsible for carrying out the visits to the company (on which the case study was made), to carry out the analysis of the Training needs, on the other hand, those responsible for the project on the part of the company expressed the importance of having technical staff with the level of competencies appropriate to each of their jobs, in addition to problem solving and decision making during the development of their work. The above has as its final objective that in the long term the company has technicians certified by labor competences in the operation of machines and management of the production process in its different areas.

However, to achieve this, in a first stage the job competencies of the jobs were identified, so a pilot study of the model change in a CNC grinding machine was carried out in Perez, De Ita, Velázquez and Fernández (2016), the results achieved are described and an approximation of the integral training plan was proposed. During stage 2, Perez, Merino, Ordaz and Tlapale (2017) described the results achieved with the proposal of the evaluation instruments developed and applied to technical personnel, taking into account the different levels of competence defined and validated by the company, as well as as the integral training plan endorsed during this stage. Derived from the results of the previous projects, the UTH developed the PIC, according to the needs of the specific labor competencies of the company. Case study.

It should be considered that the processes in each area are different, however the competencies that technicians must possess coincide in most of the jobs, which is why this project describes the process for the design, development and execution of a plan that integrates the training for technical personnel of the EAP.To carry out the development of the PIC, a General objective and four specific objectives were established, which were the areas on which the research.

General Objective

Design a PIC by means of the application of a diagnosis of needs to the different areas of the company, for innovation in the training processes in the EAP.

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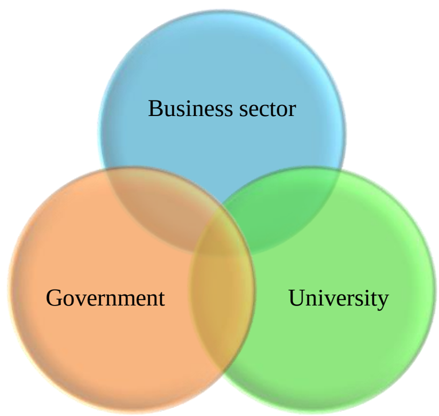
[11] CNC: computerized numeric control

Particular objectives

- Perform the diagnosis to detect training needs for technical personnel.
- Integra a team of work on the part of the UTH.
- Design the training courses that make up the training plan.
- Implement the training program.

The case study developed is important, because like all Technological Universities in the country, the UTH is based on the triple helix model, which implies the search of the link between disciplines and knowledge, where the university It has a strategic role and is the basis for generating relations between the company and government, as shown in Figure 9.1.

Figure 9.1 Triple helix model



Source: Own Development, from Etkowiz and Leydesforff, 2000

The triple helix model assumes that higher education has to respond appropriately to the nature of the work it does in the face of the new contexts presented by the globalization of markets, as well as the transfer of knowledge and technologies between countries (Etkowiz y Leydesforff, 2000).

Most universities are training professionals, although there is little interaction and linkage with the needs that the labor market requires; but in the particular case of the Technological Universities (UT's), these are born linked to the productive sector, therefore, one of its tasks is to seek the approach with the companies, where it is allowed to transfer the knowledge generated in the university to the practical field, through the development of projects that directly impact the company, but that in turn bring professional and economic benefits to the University.

Therefore, the training program that was worked for the EAP takes special relevance for the UTH, because it is presented as a case where tacitly meets the established by the model of the triple helix, but also with the mission and vision of the university, due to the fact that a close collaboration relationship arose between the company and institution where the University, can develop a scaffolding for the application of knowledge from the experience of teachers to transfer them to the company, and for its part, the company was involved in improving its processes as a form of innovation in the training programs for operating personnel, eliminating old practices in favor of continuous improvement.

Theoretical Framework

For the purposes of the research, a literature review was conducted that provided the theoretical basis for conceptualizing business innovation, labor competencies and methodologies for the development of business training programs, as well as tools to improve and control the process. What facilitated the direction in the design of the comprehensive training plan.

Innovation concept

Del Rey and Laviña (2008, p.23) from Oslo (2005), take up the concept of innovation of an organization as "the introduction of a new organizational method in the practices, the organization, the workplace or the company's external relations".

Coronado, Oropeza and Rico (2005), mention that in the theory of the solution of problems of inventiveness (TRIZ, for its acronym in Russian), five levels of innovation are defined:

- Level 1: Standard call, there is a simple solution to a conventional problem that anyone close to the situation can solve.
- Level 2: An existing systems and processes are improvements, for the solution to the problems apply known methods and principles within the industry, however the level of knowledge is more specialized than the previous level.
- Level 3: It is an invention by methods known outside the industry. Solutions are found more in science than in technology.
- Level 4. It is an innovation that requires a change of paradigm to create a system or technological process and the solution requires a new principle to perform the primary functions of the system.
- Level 5: These are scientific discoveries and pioneering inventions of a new system or process. The problem and solution are outside the limits of the science of the moment. Additionally it is about improvements in the practices of the organization.

For the case study of the EAP, the innovation focuses on level two, since it is an improvement to the process with a level of knowledge that is not of competence in the company and therefore required specialized knowledge in engineering issues, professional education and business training.

Approaches to the concept of competences

In relation to Ramírez (2012, p.85), "competences are a set of knowledge, skills and attitudes that are in constant change that are transferable and developed based on experience and that allow the individual to react, manage and act with relevance in complex and contextualized situations". However, this concept is quite general when you want to land in other fields as it happens when you must make your transfer to the workplace, because in relation to the skills that a person must have in a specific professional field whatever it may be; industrial, commercial or service there are many demands on different aspects, both individually and personally as well as socially and professionally, so it is very important to identify the specific competences of the area that is going to be addressed. For the particular case that concerns us, the competences should be studied from what is required in the workplace, in this sense in Mexico, both the Mexican Institute of competitiveness (IMCO), and the National Council for Standardization and Certification (CONOCER)), refer to the competencies that individuals must possess for the development of specific activities.

The CONOCER (2009) defines a competence as the productive capacity of an individual, who is defined and measured in terms of performance in a specific work context, not only knowledge, skills, abilities and attitudes; these are necessary but not sufficient by themselves for effective performance. The standard of competence: are the knowledge, skills, skills and attitudes required for a person to perform any productive, social or government activity, with a high performance level, defined by the sectors themselves.

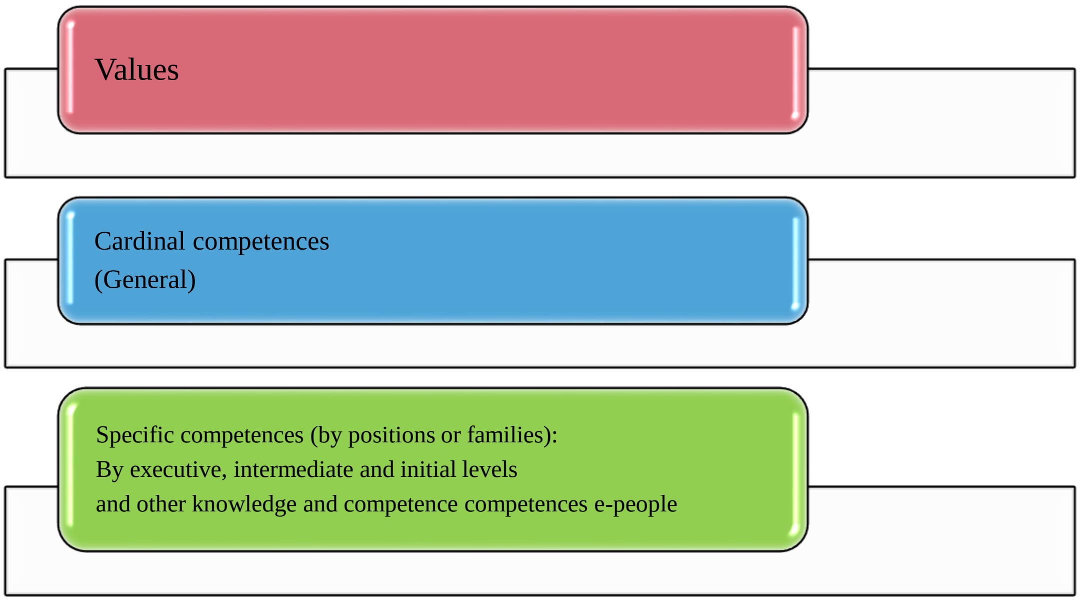
In the Mexican model, the competence issue is recent, in other latitudes, the term has a history of several decades, mainly in countries such as England, the United States, Germany, and Australia, the competences appear related in the first instance to the productive processes in companies, particularly in the technological field where the development of knowledge has been very accelerated, therefore the need to train personnel on a continuous basis, regardless of previous degree, diploma or work experience, was presented. (Huerta, Pérez y Castellanos, 2000, en Rodríguez, 2006).

The professional competences according to Flores (2007, in Echeverría, 2002), mention that they are the sum of four components; the subjects know (technical competence), know how to do (methodological competence), know how to be (personal competence) and know how to be (participative competence).

For the International Labor Office on the development of human resources and training, competences include: knowledge, professional skills and technical expertise that are applied and mastered in a given context (Vargas, 2004).

But, at present, it is necessary to develop specific competences in any area of knowledge, considering the specific function as it happens in the case of technical competences, see figure 9.2.

Figure 9.2 Specific competences



Source: Adapted from Alles, 2005

Therefore according to Alles (2005, p.161) "each company according to its reality and considering its own mission and vision can describe their competences and their respective levels, in the way that best represents the feeling and the needs of that particular organization". For purposes of the EAP in which the project was developed once the diagnosis was concluded, the specific technical competences were defined as follows:

The Generic Competence is defined as "Managing the online production of CNC grinding, ensuring the quality of the process and the product in the set-up and operation to contribute to the competitiveness of the company" (Pérez, et al 2016, p.), likewise, two learning units were defined:

1. Execute the change of model based on the technical specifications of the process and product, to reduce the variation in production, as well as comply with the production plan.
2. Conduct series production according to the production plan to meet customer's volume and specifications.[12]

In order to develop competences, it is important that companies provide personnel with the necessary means and information to achieve this, so one way to carry it out is through training. Which, viewed from different authors, can be defined as: "One of the key functions of the management and development of personnel in organizations, and therefore must operate in an integrated manner with the rest of the functions of this system. The above means both disciplines must be understood as a whole, in which the different functions -including training- interact to improve the performance of people and the efficiency of the organization" (Guglielmetti, p. 9 en Hidalgo y Jara, 1998).

[12] The process to carry out the development of the specific technical competences in the EAP of the case that is presented, is described in its entirety in the research entitled "Study of the change of machine model (Diskus) of the pilot project of certification in competences to the technicians of an autoparts company, "published in the ECORFAN Journal of Technology and Innovation, Bolivia, March 2016. Vol III. No.6 P. 46-59.

Another author mentions that "It consists of a planned activity based on real needs of a company or organization and oriented towards a change in the knowledge, skills and attitudes of the collaborator" (Silíceo, 2004, p.25). For Dessler (2001, p.49), "Training refers to the methods used to provide new and current employees with the skills they need to perform their job"

The Secretariat of Labor and Social Welfare (STPS), in Mexico, defines training as the detailed description of a set of instruction-learning activities structured in such a way that they lead to reaching a series of previously defined objectives (STPS, 2008). In relation to the provisions of the STPS, for the design of training courses should be considered: the writing of objectives, structuring of content, instructional activities, selection of teaching resources and evaluation. From the theoretical review of training concepts, you get the guidelines that companies must follow to implement a training program.

Business training: According to the concepts reviewed, the ones that most closely approximate the work carried out in the EAP are those proposed by Alles (2005) and Dessler (2001), from which the adaptation was made to carry out the design of the project. PIC for the EAP. Dessler (2001), proposes five steps in the process of training and development. Figure 9.3 summarizes the execution process for the development of the PIC for the study company, which was taken as a reference by the academics participating in the project.

Figure 9.3 Training process

Analysis	• Identify specific skills needed to develop the work • Analyze skills and needs • Develop measurable knowledge and performance objectives
Construction design	• Development of the content of the program: (Activity notebook, development of topics, activities,)
Validation	• To eliminate training defects • Present to a small group
Apply the training program	• Practical training and programmed learning
Evaluation and follow-up	• To determine the success or failure of the program

Source: Adapted from Dessler, (2001)

Based on the theoretical review, the purposes of the research, the characteristics of the company, and of course with the participation of the professors of the IPOI career, the courses were developed adhering to topics such as: teamwork, general knowledge of the product and process, as well as those focused on the management of technical documentation, so it is important to make a theoretical review of them, it is important to highlight that the definition of the courses[13] arise from the results presented in Pérez, et al., (2016) and Pérez et al., (2017).

[13] The development of the courses is a work that was published in its entirety in the article entitled "Desing of evaluation instruments by competences for operative personnel of an autparts Company" published in Journals-Marcoenomics and Monetary economy, ECORFAN, Taiwan, July-December 2017 Vol I. No.6, P. 10-17., And in the article "Study of the change of model of machine (Diskus) of the pilot project of certification in competitions to the technicians of a company of autopartes", published in the Journal of technology and innovation ECORFAN, Bolivia, March 2016. Vol III. No.6 P. 46-59.

Theoretical support of product knowledge and process

To understand the type of courses focused on knowledge of the product and process, part of the concept of productivity is defined as "the ability to generate results using certain resources. It is increased by maximizing results and / or optimizing resources "(Gutiérrez and De La Vara, 2009, p.7). Therefore, it is important to know the critical and variable characteristics of the product and process to be controlled, as well as the causes of variation, which, according to Besterfield (2009), mentions that variation is present in every process due to the combination of factors such as equipment, material, work method, environment, as well as by the operator; who carries out quality inspections and their criteria may vary slightly from one to the other despite having quality standards.

Therefore, it is important to know the critical and variable characteristics of the product and process to be controlled, as well as the causes of variation, which, according to Besterfield (2009), mentions that variation is present in every process due to the combination of factors such as equipment, material, work method, environment, as well as by the operator; who carries out quality inspections and their criteria may vary slightly from one to the other despite having quality standards. The above is related to a good administration of operations and according to Krajewski (2008), two principles must be considered: The first refers to the fact that each of the areas of an organization, including the design and operations of the processes, are part of the value chain and problems of quality, technology and personnel must be solved. The second principle considers that each part of an organization has its own identity; which must be connected with the operations.

Theoretical support for the handling of technical documentation

For purposes of the second group of courses that is aimed at the management of technical documentation, based on the principles proposed by Krajewski (2008), some of the Core Tools were considered, such as the AMEF (Analysis of the mode and effect of process failure).), which allows to find the potential failure modes of the product and the process before they are produced and avoid economic losses (Alcalaide, Diego and Artacho, 2006).

Another important tool that must be understood to ensure compliance with the required quality specifications is the management of the control plans that can be applied to a group of products, which allows a dimensional description, measurement methods, materials, and tests of the function that must occur during the construction of the prototype and production process (Thisse, 2014). Having described the above, it is important that technicians identify the tolerances of the product to be manufactured, which, according to Gieseck and Frederick (2006), is defined as the total amount that a specific dimension can vary, since greater precision implies a high cost, it is advisable to define the most adequate tolerance that allows the satisfactory functioning of the part to be produced, assigning the one in which two corresponding parts can be adjusted to each other.

This allows to control the flow of production, through the management of technical documentation in the company, allowing to ensure the continuous flow of materials to produce products in its different variants: model, color, size, own specifications of each client, so that it is important to exercise control in batches as they go through the different processes (Riggs, 2010). Regarding the inventory management Villaseñor and Galindo (2007), explain that the identification of raw material inventory allows to reduce their levels and facilitates the management thereof, so the efficient handling of travel cards is of utmost importance, Platas and Valencia (2014), consider the traveling card as an instruction label also called Kanban according to the Japanese word, it contains information that serves as a work order, allows information to be given to the production area about what is going to be produced , in what quantity and the handling of materials to be mobilized. For the efficient management of the technical documentation of companies, they use information systems such as SAP and ERP, which allows the management of information and processes concentrated in different modules (Regalado, 2016).

Theoretical support for social competences

Finally, for the development of social competences, the analysis of theories of teamwork, high performance teams (HPT) and emotional intelligence is made. Katzenbach and Smith (2006) consider that an HPT is one in which a small group of members who are highly committed to each other, with well-defined functions, possess characteristics and skills necessary to achieve objectives.

Therefore, it is important to develop teaching-learning methods that allow reaching the social competences of the personnel involved. Additionally, the commitment and participation of senior executives is necessary, since it contributes to EARs achieving the goals defined by the organization. For Blanchard, Randolph and Grazier (2006), these teams must develop high levels of trust between them, clarify limits to create freedom of action responsibly and develop self-management skills for decision making. Regarding emotional intelligence from the point of view of Goleman (2008), highlights the self-control, enthusiasm, empathy, perseverance and self-motivation as part of a genetic baggage that can be part of the person, but other times can be molded and modified during life. Evidence supported by abundant research shows that emotional skills are susceptible to be learned and perfected throughout life if they use the appropriate methods. Bradberry and Greaves (2012), emphasize that emotional intelligence requires effective communication between the rational and emotional brain, is something that is in each of us, is intangible and influences the way we manage our behavior, as well as overcome complexities social and make decisions that allow positive results.

Methodology

The study presented is considered qualitative according to Denzin and Lincoln:

> *"Qualitative research is an activity that locates the observer in the world. It consists of a set of interpretative practices that make the world visible. These practices transform the world, turn it into a series of representations, which include field notes, interviews, conversations, photographs, registers and memories. At this level, qualitative research implies an interpretative and naturalistic approach to the world. This means that qualitative researchers study things in their natural context, trying to make sense or interpret phenomena according to the meanings that people give them." (Denzin y Lincoln, 2005, p.3).*

The study is considered exploratory and descriptive because it was carried out through a diagnosis of the needs of the EAP, through semi-structured interviews, as well as competency assessments designed and applied to the technical staff during stage 2 of the project and whose results were presented in Pérez et al., (2017). This allowed the identification and description of the needs for the development of specific competences by knowledge areas and the identification of courses to be carried out. However, in stage 3 and with the previous results of the projects presented in Pérez et al., (2016) and Pérez et al., (2017), the company managers approved the types of courses to be carried out with the priority themes , the hours required in each of them, where the EPIO academics presented the final proposal, classifying them as administrative and technical within the PIC, so for purposes of this case study in table 9.1 the categories defined are shown.

Table 9.1 Definition of training categories

Objective of study	Training categories	Description	Classification
Design a comprehensive training program through a needs assessment that allows innovation to this key process for the EAP.	Course definition	Grouping of knowledge according to the competences that technicians must possess.	− Type of courses − Average hour per course
	Course design	It refers to the specialist in the area that intervened in the development of each course.	− Number of IPOI teachers who participated. − Average hours for the design and development of the course.
	Administrative courses	It is related to the courses designed to achieve the specific social competences established by the company	− Number. of administrative courses
	Operative courses	It refers to technical competences in the management of production processes	− Number of technical documentation management courses − Number of general knowledge courses

Source: Self Made, 2018

Regarding the development of the case study, the techniques used for the collection of information were:

- Direct observation: for the identification of the production processes in the areas of columns, machining and pressing, since observation was necessary to verify the execution of the tasks.
- Unstructured interview with technicians, heads of area and the head of human resources in the EAP.
- Evaluations to the technical personnel of the machining area; which allowed to evaluate the level of competence through the evaluation instruments by competences.

The instruments used in the case of observation were: field notes, video recording and technical documentation provided by the company. For the unstructured interview, direct questions were asked to the technical and managerial staff. For the evaluation of competences, the instruments used were: checklists, rubrics, technical knowledge exams, observation guides. Table 9.2 summarizes the techniques and instruments used.

Table 9.2 Techniques and instruments of the study

Technique	Instruments	Participating	personnel Purpose
Direct observation	Field notes, video recording Technical documentation of the company	Technical staff	Identify and validate the execution of the production process.
Unstructured interview	Direct questions	Technical staff, heads of area, head of Human Resources.	Collect information on the management of technical documentation on the floor.
Staff evaluations	Checklists, rubrics, technical knowledge exams and observation guides.	Technical staff	To identify the level of competence in the execution and management of the production process.

Source: Self Made from Palella and Martins 2006

Population and sample

To determine the training needs of the study population; all the technicians of the EAP were considered, for purposes of presenting this case study the sample includes only the courses designed and applied by teachers in the area of Engineering in Processes and Industrial Operations (EPIO).

To determine the training needs of the study population; all the technicians of the EAP were considered, for purposes of presenting this case study the sample includes only the courses designed and applied by the teachers of the area of Engineering in Processes and Industrial Operations (EPIO).

Materials: technical documentation, videos, recordings of the interviews.

Development of the study case

This section describes the stages that were carried out for the PIC.

Stages of the process for the design of the comprehensive training program

Based on the diagnosis made with the techniques and instruments used in Pérez et al., (2017), as well as those applied in table 9.2, they allowed to set the pattern for the design of the PIC. Table 9.3 summarizes the stages developed by the UTH for the execution of the project based on Dessler's proposal (2001).

Table 9.3 Process for the design of the comprehensive training plan

Stages of the process of a training program (Dessler)	Stages of the training program process by UTH	Description
1. Analysis of training needs	a. Diagnosis and analysis of training needs	It was made from the following instruments: • Competency matrix defined in CNC grinding machine. • Evaluation of the competencies to develop measurable knowledge and performance objectives. • Presentation and approval of the proposal of the training plan before the company.
2. Construction design	b. Recruitment by UTH to design courses by area of expertise: (EPIO Mechanics (MEC) and Project Management (GP))	Approved comprehensive training plan Identify the specialist areas of UTH personnel for course design.
	c. Course design	Attending specifications of the company and the STPS.
3. Approval	d. Feedback and approval	Carried out by those responsible for the project in the company, and according to the needs by production area.
4. Apply training program	f. Programming courses during the authorized training period (dates, level, teachers)	Execution of the training program in 2016-2017
5. Evaluation and follow-up	h. Evaluation of each course, instructors and service provided	For each completed course the evaluation of the services to the client was carried out

Source: Self Made, 2018

Process for the design, development and application of the PIC: specific case of EPIO

The following describes the process for the design of the PIC, in which the teachers and researchers of the UTH EPIO race participated specifically.

1. Analysis of training needs

From the results in Pérez et. al., (2016) of the matrix of technical competences for the execution and release of the CNC grinding machine production process, the process for designing the technical competence matrix was explained, it was possible to identify the training needs. With the results of stage 1, evaluation tools were designed and applied for technical knowledge, management of technical documentation for the preparation and / or execution of the production process, release of the product, among others; these results were explained extensively in Pérez et al., (2017). Based on the knowledge that the technicians of the EAP had to possess and once the training needs were identified, knowledge and performance objectives were set to begin with the design corresponding to the training courses.

Derived from the training proposal corresponding to stage 2 in which 18 courses were presented, a review was made that allowed the managers of the different areas of production of the AEP to make the decision of the courses that would be developed and taught. by teachers, as well as the hours needed for training and the depth of the topics, with at the end being 13 courses for the PIC, summarized in table 9.4. However, due to confidentiality issues, the contents of each of these are not emphasized.

Table 9.4 Definition of courses and hours

No.	Course	Training hours per course	No.	Course	Training hours per course
1	Product knowledge	3	8	Measurement systems	10
2	Civil liability and critical characteristics	4	9	Problem solving	8
3	Control of nonconforming product	3	10	Management of quality systems TS 16949	8
4	Technical documentation	4	11	Industrial Security	12
5	Material handling	6	12	Interpretation of plans	
6	Statistical control of the process	10	13	High performance teams 1 and 2	12
7	Interpretation of plans	8			

Source: Self Made, 2018

2. Construction design

Recruitment by UTH to design courses by area of expertise: At this stage it was identified personnel UTH different careers: Industrial Processes and Operations (EPIO), Mechanical, Project Management and Administration, whose expertise and knowledge would contribute to the development of each course. Therefore, a matrix of instructors was integrated, indicating: names and area of the personnel to develop each course, the topic, the hours of duration of the course and the number of groups that would be trained in the first stage. Course design: The work methodology was very similar for the design of all the courses. So in this stage it was necessary that the company provide each responsible for the technical documentation of the processes. Table 9.5 summarizes the content considered general of the courses designed by the EPIO career.

Table 9.5 Content of training courses

Elements of the integral plan training courses	**Development of training program**	**Activities carried out by UTH**	**Example**
	Analysis of the course for specific design by area of knowledge.	The information was collected through unstructured interviews with the operating personnel, heads of areas, use of data recording formats, photography and videos of the process.	*Material tracking: handling of travel cards, contingency actions, data recording in the SAP system, among others.*
	Objective	Definidos por cada curso en colaboración con el personal de la EAP	Identify process materials for identification and control in inventory differences
	Content structuring	According to the skills and attitudes to acquire per course.	Traceability Contingency actions among others
	Instructional activities	Realized by the instructor and participants: dialogue-discussion, expository, role play.	Playful activities that allowed to identify the importance of the correct identification of materials.
	Selection of resources	According to the course, videos, practical activities, role plays are presented.	Design of the training manual, instructor's guide, Power point of each course.
	Performance tests per course	For all the courses designed a knowledge evaluation (Questionnaire) and in some cases observation guide.	Evaluation questionnaire with topics of each topic developed during the course.
	References	The necessary for each course by area of knowledge.	The necessary for each course by area of knowledge.

Source: Self Made. 2018

3. Feedback and approval

During the development of each of the courses, feedback meetings were held with the heads of the areas responsible for production of the EAP, who approved the topics addressed in each course and provided information on each of the processes involved, in such a way that the training allowed to cover their specific needs to the production areas. Apply the PIC: Since the validation of the comprehensive training plan in June 2016, the implementation of the plan began in August for all the technical staff of the EAP, which was carried out in stages:

- Stage 1: Called refresh or feedback to consolidate the knowledge of active technical staff. Approximately 340 people.
- Stage 2: This process is known as Onboarding, and staff were included in the selection process, who once they approved all the courses could end up with the hiring.

4. Evaluation

In each of the training services provided to the EAP, the UTH conducted a customer satisfaction survey that was conducted by the course participants. Table 9.6 shows the criteria used for the evaluation at the end of each of the services provided.

Table 9.6 Criteria evaluation of the satisfaction survey

Instructor	Content of the course and activity dynamics
Met the established schedule	The content of the participant's manual corresponds to the objectives of the course.
Clarified the objectives of the course from the beginning	
The order of the subjects provided in the manual followed	The participant manual facilitated the understanding of the topics
Demonstrated mastery of the issues	
Adequately used audiovisual resources.	The facilitator did exercise to fix and review concepts during the activity
Demonstrated ability to help me understand the issues	
He kept my interest and my desire to learn	Audiovisual resources facilitated the understanding of the themes
He answered my doubts with clarity and precision	
Demonstrated courtesy, impartiality and respect	
Generated participation and commitment	
He used practical examples related to the Company.	
Application	**Logistics and services**
This course helped me improve the knowledge required in my job	The arrangement of the room was comfortable for the activity
This course helped me improve the skills required in my job (If applicable)	Audiovisual resources worked correctly
I feel able to apply what I learned in my job	The coffee service and / or refreshments and / or lunch arrived in appropriate time and quality
I would recommend this course to other people	He received sufficient and timely information before attending the activity (time, place, topic, etc.)
Opinions and suggestions	
Evaluation level: 1 = Nothing, 2 = Little, 3 = Partially, 4 = Completely, 5 = Exceeded expectations	

Source: UTH. 2016

The results of the evaluations to the courses are shown in the results section in graphs 9.6 and 9.7. The follow-up actions to the PIC have not yet been evaluated, since at the date these results are presented, it is still applied for the new staff to the EAP.

Results

The results of the diagnosis of training needs was published in Pérez et. al., (2016 and 2017), both articles describe the competencies to be developed and the first approaches to the PIC for the EAP. What is shown for purposes of this final work are:

a. The integration of the work team part of the career of EPIO
b. The courses designed
c. The evaluation of the service provided with the implementation of the PIC.

Table 1 previously described that the grouping of the courses was classified as administrative and operational, finally approving a total of thirteen for their design, which account for 92 hours of training that each of the EAP technicians must receive and distributed on average between six and twelve hours per designed course and that are part of the PIC.

Table 9.7 Classification and total of courses designed by the UTH races

Classification of courses	Central topics	Number of courses designed	Career responsable	No. of courses
Administrative	Teamwork.	2	EPIO	1
			Psychopedagogical area	1
Operative	Decision making.	5	EPIO	4
			Metal Mechanics (MEC)	1
	General knowledge of the product and process	6	EPIO	4
			IPA (Engineering in Food Processes)	1
			Metal Mechanics (MEC)	1
Total courses				13

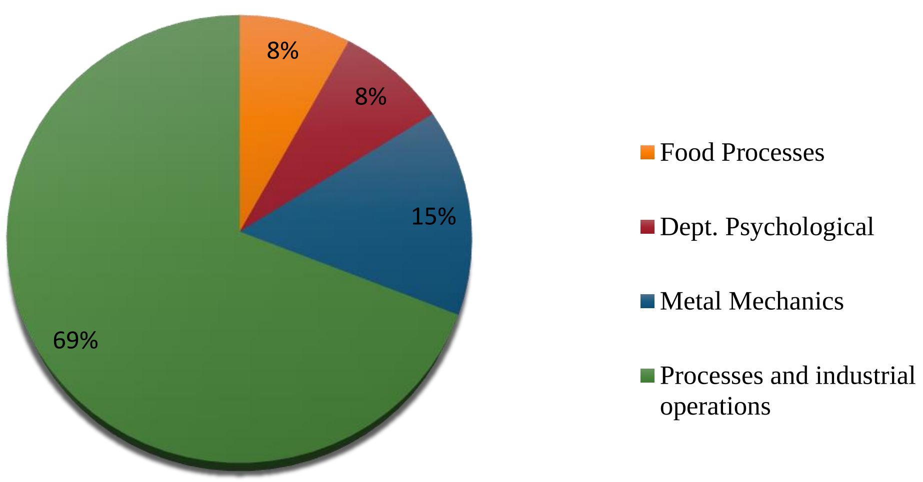
Source: Self Made, 2018

Table 9.7 summarizes the classification of the type of courses designed in total, of which 9 corresponds to the work done by the teachers of the EPIO career from the detection of needs, the career was responsible for designing an administrative course and 8 operations, corresponding to the handling of the technical documentation of the processes and general knowledge.

Design of the construction of the PIC

For this stage, the competences that the UTH researchers had to participate in the design of the PIC courses were considered. Regarding the career of EPIO, the selected personnel has experience in the industry, with the competences that the EPIO race demands, as well as those of teamwork, problem solving, responsibility, activity, among others. This was because it required working in the field to collect information to facilitate work for the development of the PIC. With reference to table 9.5, Graph 9.1 shows the percentage of courses designed by the participating UTH races.

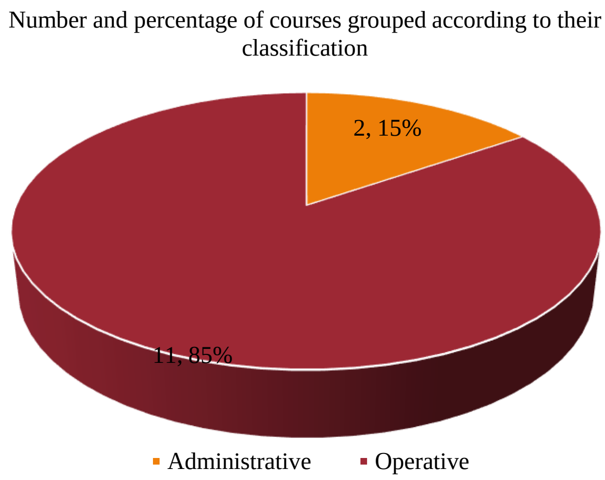
Graphic 9.1 Percentage of courses designed by career



Source: Self Made. 2018

With regard to the grouping of courses; 2 administrative offices were designed, corresponding to 15% of the total and 11 operatives for the management of technical documentation and general knowledge, representing 85%. The above confirms the importance of the proper management of documents for the management of the production process and that must be understood by all company personnel.

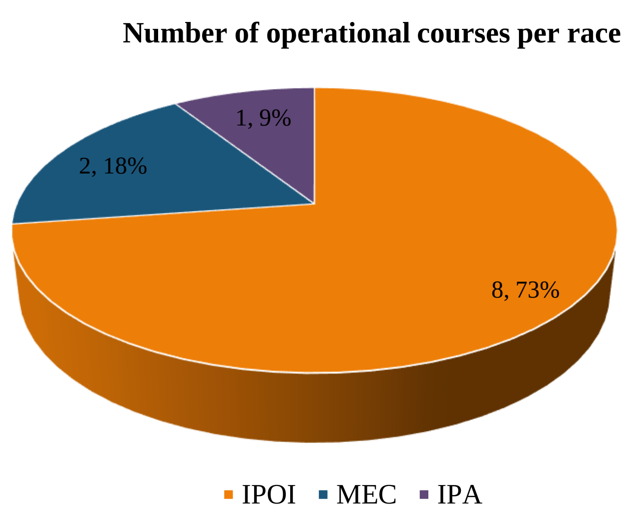
Graphic 9.2 Number and percentage of courses designed grouped by classification



Source: Self Made, 2018

With regard to the career of EPIO in Graphic 9.3, there is a higher percentage of participation for the design of the operational courses, with 8 courses designed, which represents 73% of the total participation with respect to Food process careers and Metal Mechanics. This is due to the fact that the EPIO teachers who collaborated in the project have professional training in the areas of Industrial Engineering, Industrial Mechanics, Electronics and Electricity. So their areas of knowledge are directly related to the production processes in the EAP.

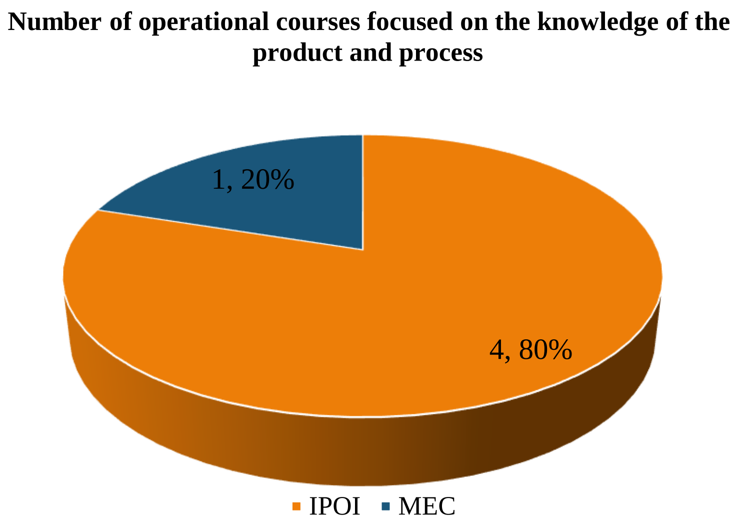
Graphic 9.3 Percentage of operational courses



Source: Self Made, 2018.

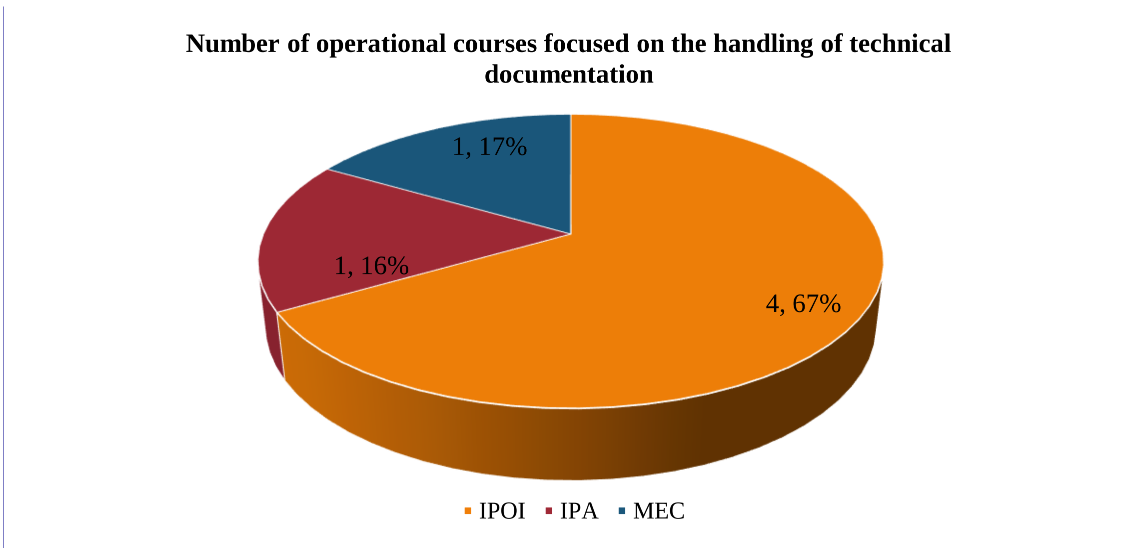
Finally, graphs 9.4 and 9.5 represent the number of operational courses for the management of technical documentation and general knowledge. Figure 9.4 again identifies that the participation of the EPIO career is 80% with 4 courses designed for the knowledge of the product and the process. Of the 6 courses designed for the management of the technical documentation of the company, the researchers of the career of EPIO carried out 4, which represents 67% of participation. It should be noted that for the design it was necessary to carry out field work in the company, since it was necessary to know the entire production process, as well as the management of technical documents of the EAP, and that are necessary to ensure that the products comply with the quality specifications, allowing the courses to be effective for the technical personnel participating in each of the trainings that would take place.

Graphic 9.4 Operational courses on product and process knowledge



Source: Self Made 2018

Graphic 9.5 Number of operational courses for handling technical documentation



Source: self made. 2018

Finally, for each of the courses designed for each of the races, the corresponding final products were delivered: Training manual, presentation in Power point of the course, instructor's guide, list of materials for the execution of the course; as it is the case of armored games, board games, instruction sheets of the activities to be developed by the participants, theoretical evaluations of the course, among other resources necessary to develop the PIC in a practical and effective way.

Approval

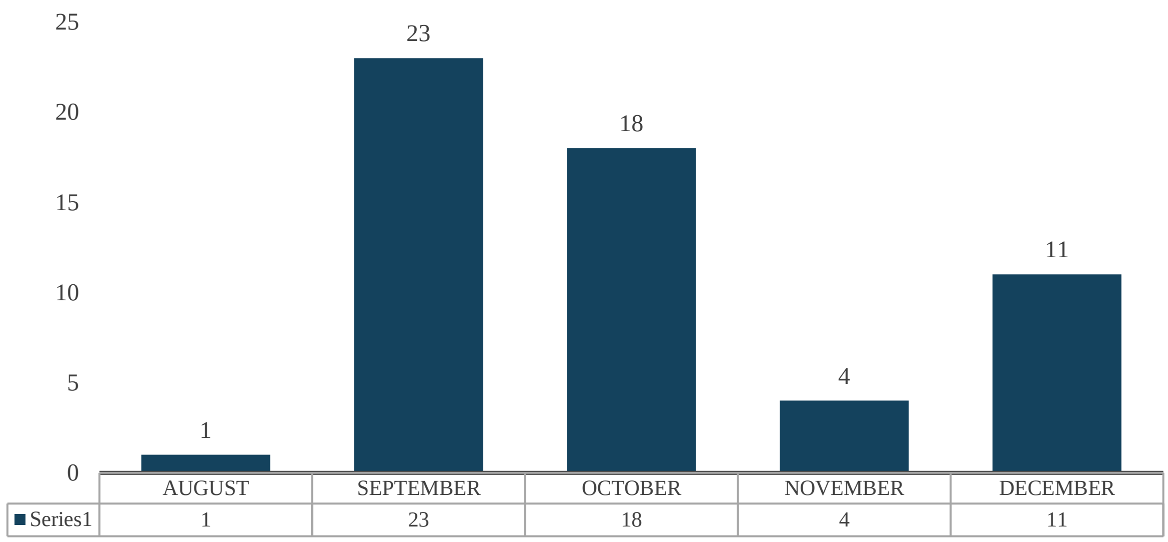
For the release of the content of each of the courses that make up the PIC, the teachers invested between 8 and 12 total hours for the project managers in the EAP to endorse them. The process consisted of scheduling visits to the EAP with the heads of the production areas involved so that the UTH researchers could explain the methodology of the courses, the thematic content, the teaching resources and the technical documents of the EAP to be managed in the training sessions, as well as the evaluation instruments were congruent with the objectives set for each of the courses.

The feedback sessions made it possible to clarify and share the necessary information among UTH researchers and those responsible in the company to strengthen the contents of each of the PIC courses to meet specific needs by production area. Once each PIC course was approved, the corresponding steps were taken between the Company and the University to carry out administrative procedures such as: confidentiality agreements, training scheduling, as well as payments to the University and when the agreements were concluded, the implementation of the PIC.

Application of the comprehensive training plan

The final stage began as of August 2016. Graphs 9.6 and 9.7 summarize the number of courses that were taught by the EPIO course, the number of services provided with the courses designed was 57 and during In 2017, 52 were taught, generating a total of 109 training courses given to operational personnel during the years 2016 and 2017 according to the needs of the company.

Graphic 9.6 Number of courses taught by EPIO in 2016

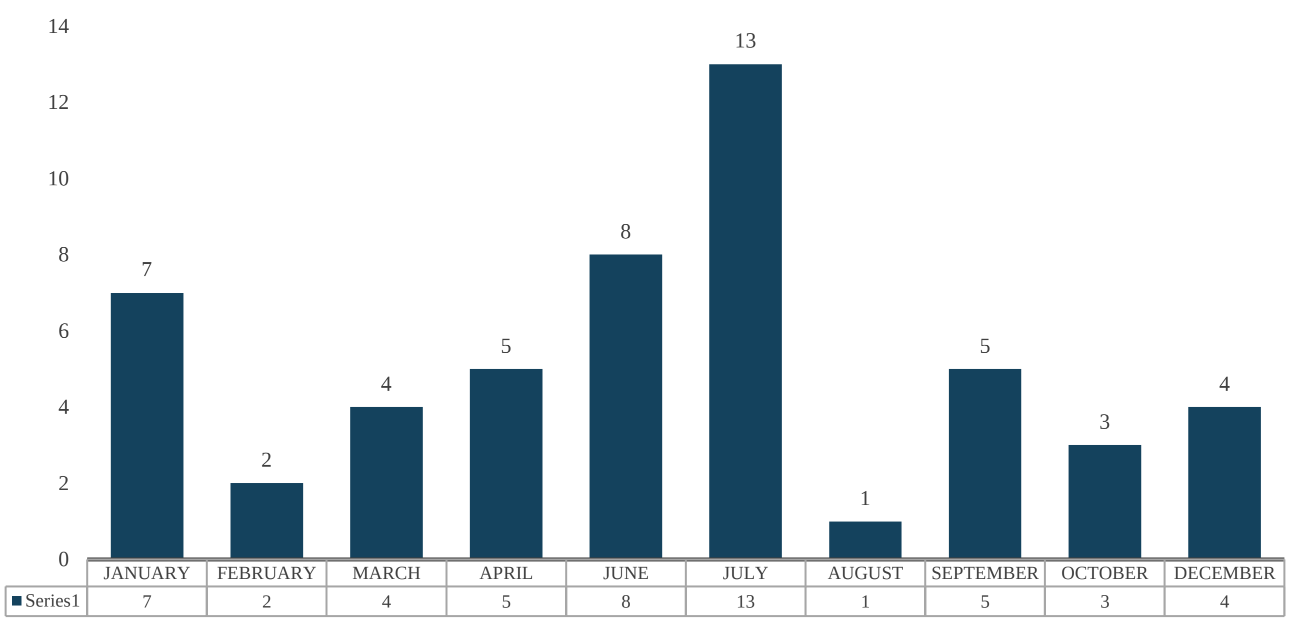


Source: Self Made. 2018

According to Graphic 9.7, the largest number of courses was given in September to cover the needs of the company according to the topics of the operational and administrative courses.

Graphic 9.7 shows the courses given by the EPIO race for 2017, corresponding to a total of 52. It should be mentioned that in the delivery of the training did not necessarily participate all the teachers who designed the course. So it was of great importance the design of the instructor's guide, whose objective was that regardless of who made it, another instructor could take charge of the delivery of the course.

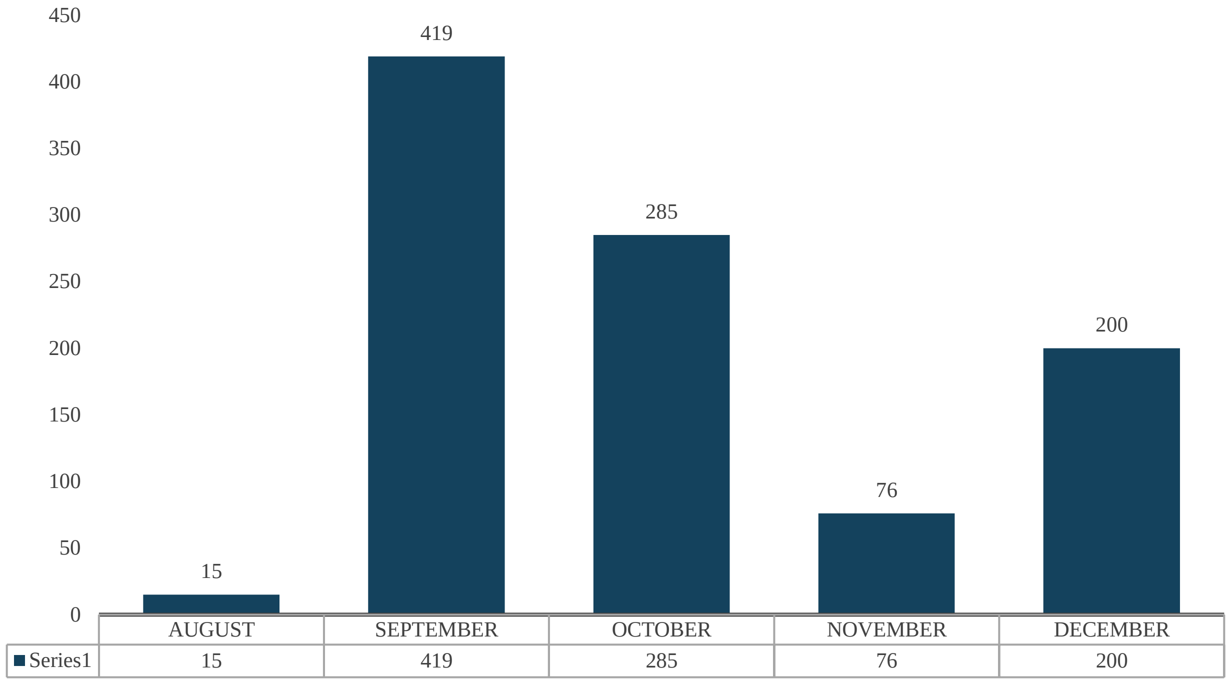
Graphic 9.7 Number of courses taught by EPIO in 2017



Source: Self Made. 2018

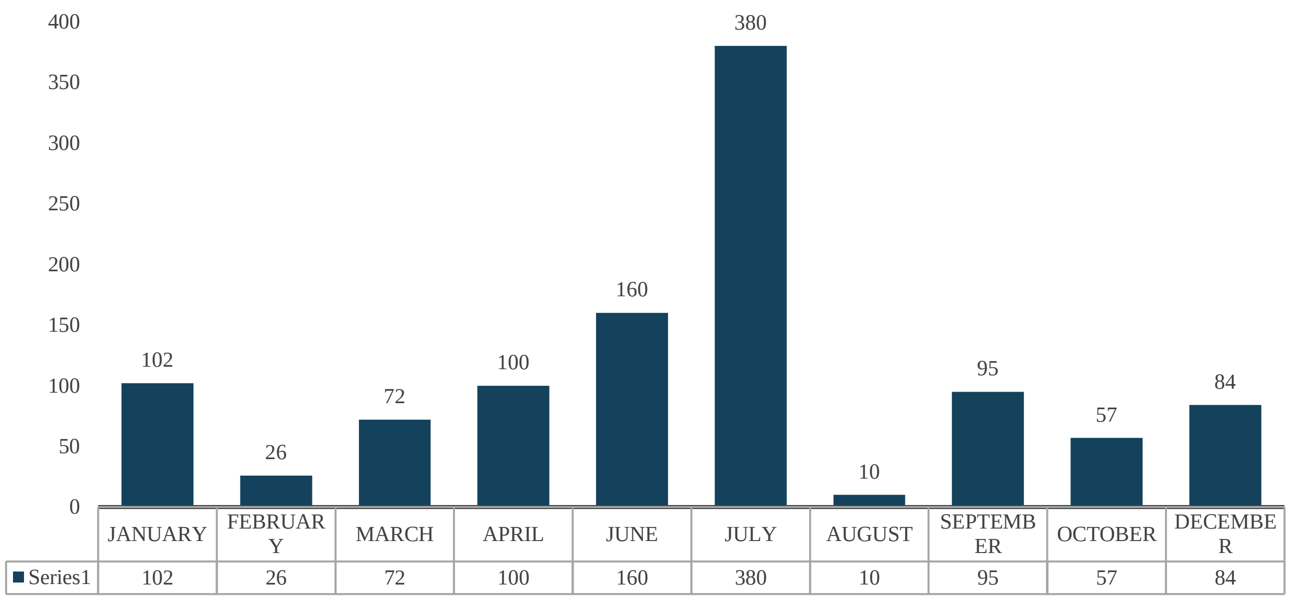
Figures 9.8 and 9.9 identify the number of participants trained for the EPIO race during 2016, totaling 995 participants and in 2017 1086 participants. It should be clarified that within these values in the same technician took different courses, however the topics treated were different.

Graphic 9.8 Number of participants trained in the various courses in 2016



Source: Self Made. 2018

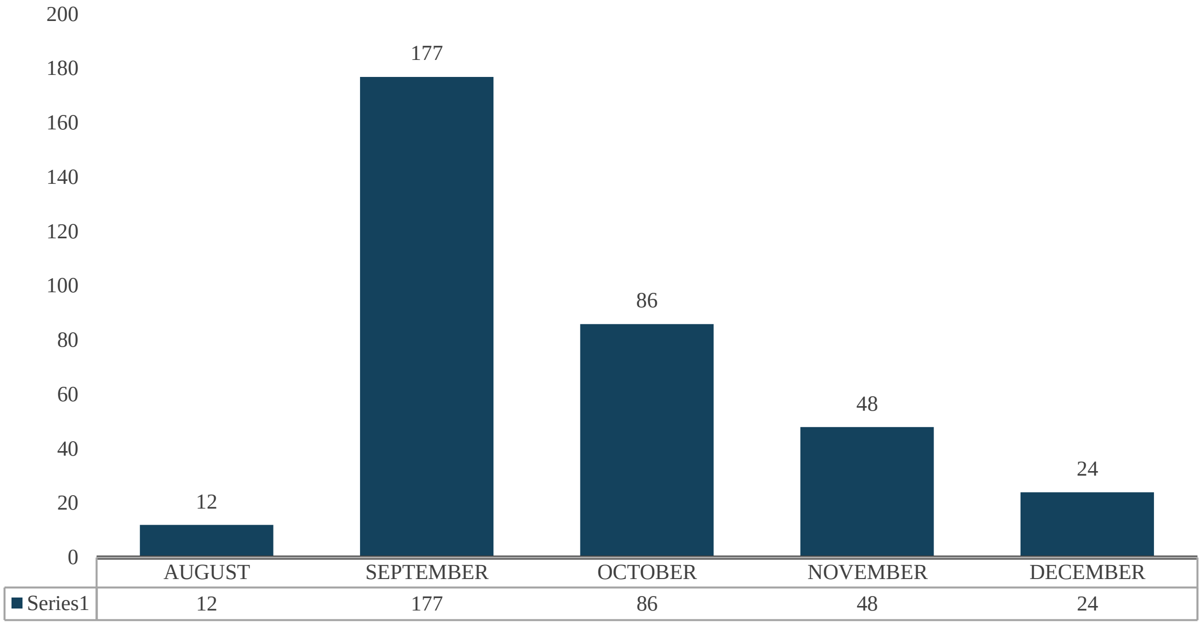
Graphic 9.9 Number of participants trained in the various courses in 2017



Source: Self Made. 2018

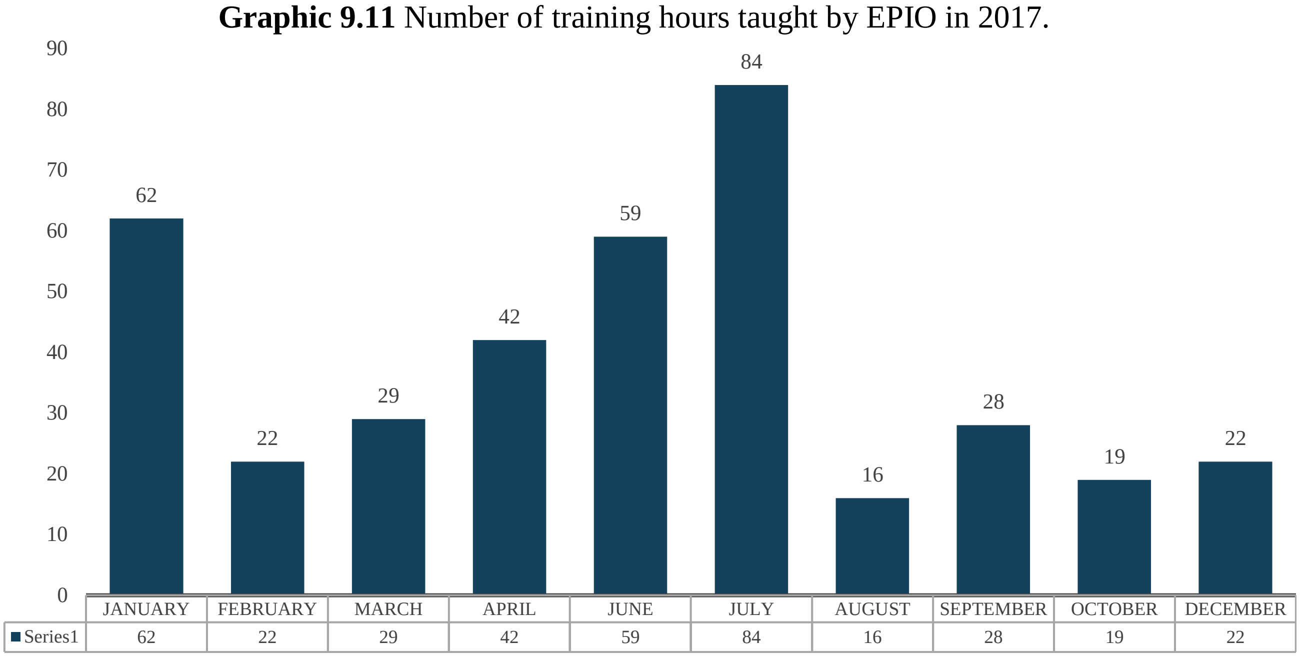
Graphs 9.10 and 9.11 represent the number of training hours in 2016 and 2017 respectively, which were invested in the technical staff among the administrative courses, such as the operational ones, corresponding to a total of 1086. The above represents an indication of the commitment of the company to maintain quality standards through the training of the operating personnel.

Graphic 9.10 Number of training hours given by EPIO in 2016



Source: Self Made. 2018

Graphic 9.11 Number of training hours taught by EPIO in 2017.

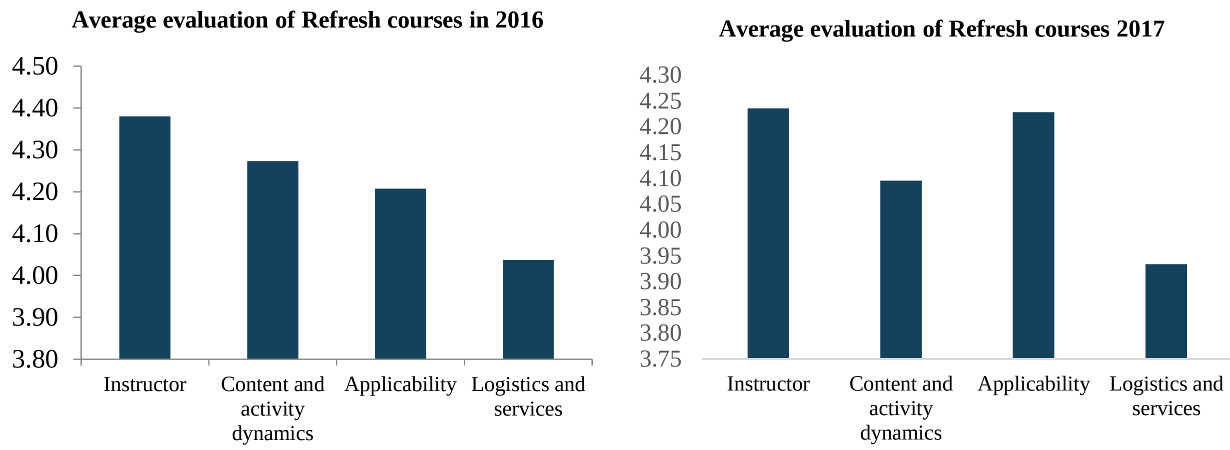


Source: Self Made. 2018

Evaluation of service satisfaction

For each course that was taught, the University evaluated the satisfaction of the service provided with the formats of the Quality Management System of the UTH. Previously in table 6 the evaluation criteria were described, in graph 9.12 the results of the refresher courses of 2016 and 2017 of the satisfaction surveys of the service carried out by the technicians of the EAP are summarized, who have between two and more of ten years working in the plant. In the graphs, there are evaluations with improvement trends above 4.20 points for the instructor, content and activity dynamics, as well as for the field of applicability, however, logistics has the lowest score. It is worth mentioning that this aspect corresponded to the EAP, since this type of courses were held in its facilities and the scheduling of dates, participating personnel, schedules and cafeteria services correspond to the needs of the EAP.

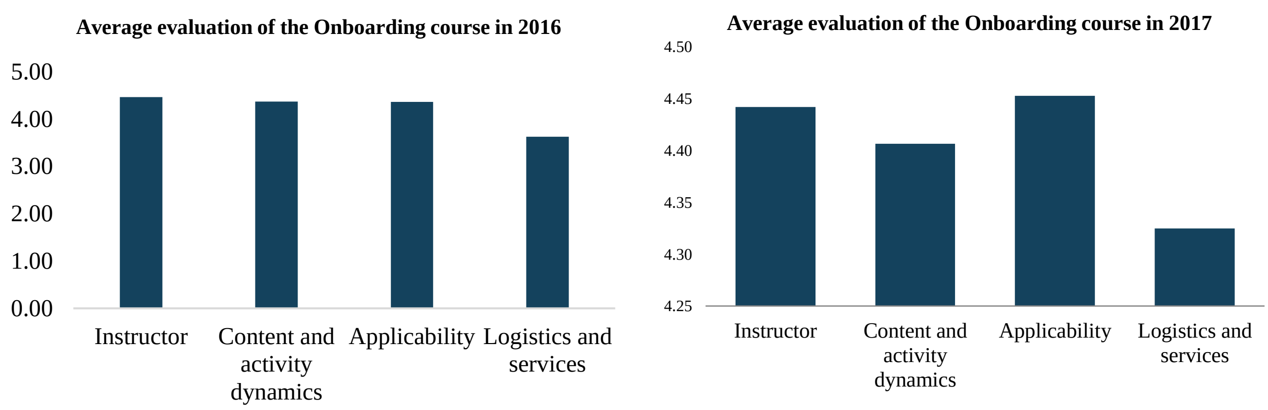
Graphic 9.12 Average evaluations of technical courses 2016-2017



Source: Self Made from documents of the UTH SGC. 2016- 2017

Graphic 9.13 presents results for 2016 and 2017 for the onboarding course, which was given to new entrants to the EAP, which was held at the UTH facilities. The logistics again have the lowest evaluations, however the comments for this item in general are; the recommendations to improve the cafeteria service. In the results of graphs 9.12 and 9.13, trends similar to those obtained in the evaluations obtained for training services provided are identified.

Graphic 9.13 Evaluation of onboarding courses 2016-2017



Source: Self Made from documents of the UTH SGC. 2016-2017

Due to time management issues and the processes inherent to collaboration agreements between the company and the university, the measurement of the impact on the application of the PIC in productivity has not been possible due to the need for prior work of agreements that benefit both parties, and being a study of great importance should be done in the near future and hand in hand with those responsible for the project. So the presentation of results will be done in another report. However, it is worth mentioning that as of the date these results are presented in 2018, the application of the PIC for the new personnel continues. Likewise, adjustments have been made to the original PIC according to the production plans in the EAP and for situations beyond the University.

Conclusions

In relation to what was established in the objectives of the research, by means of the diagnosis the training needs for the EAP were identified, the results showed the guidelines that set the pattern to carry out the development of the PIC, allowing to define what type of courses would develop, specific topics to deal with, effective hours for each course, suitable personnel for the design, development and teaching.

An important finding for the UTH was the contact with the EAP, which resulted in a strong link between the university and the productive sector, demonstrating that universities can also be directly involved in strengthening the area of knowledge and transfer of technology in companies, allowing an approach and link between both, where the main purpose is win-win. That in addition, encourage updating in the practical field of teachers, so that in turn, they propose innovations in the plans and study programs under which they are governed, so that at a certain moment they are susceptible to be modified, and individually enrich your professional practice and personal growth.

For companies that opt for training as a means to increase productivity, the benefit is greater, because the personnel update is guaranteed according to what the company needs. When this type of link is made, companies are able to access programs to obtain extraordinary financial resources from CONACYT, from the state or federal government that promote the growth of companies, as long as they involve universities and the benefits are materialized in direct actions of improvement for the company.

The final product that the UTH designed, approved and delivered to the company was the Comprehensive Training Plan, which was officially implemented in the EAP. Although at the beginning of its elaboration it was thought to develop it for the internal personnel of the same, in the end it was also extended to the personnel that was in recruitment, it is necessary to clarify that this does not imply that the candidate is integrated to the company, but still you are required to participate in the training program. Therefore, the PIC to date remains in operation hand in hand with the teachers of the UTH, who are responsible for delivering the courses, which has allowed the incorporation of new teachers, thereby expanding the training of the same for his entry into the UTH-EAP project. From the experience that was had in the planning of the diagnosis, design, delivery and implementation of the PIC, it is important to take into account the following considerations:

In relation to teachers:

- They must be up-to-date in the professional competencies required by the work environment, especially those related to the area of influence where the UTH is located.
- Have certifications as trainers in the industrial and business field.
- Develop skills to provide training to groups in specific areas, according to the needs required by companies.
- Improve the link for the development of stays in the productive sector, to strengthen technical skills and identify the needs of the industry.
- It is, was and continues to be an excellent opportunity to involve students in the participation of projects that allow applying the knowledge acquired in their educational process at the university.

In relation to the university:

- Maintain the search for opportunities for the development of projects that link and benefit the UTH-EAP.
- Opportunities were opened for students to enter to make their professional stays in the company, and some were even hired.
- Through the process of linking the UTH, you must carry out the search of projects with organizations of different turns, where the students, teachers and company are involved, considering the benefits for both.

In order for the project to remain in force, a recommendation is to suggest continuity in the work with the EAP, to carry out an investigation where the impact of the PIC can be known from its implementation to date. Which would allow to validate the objectives that the company raised in the medium and long term. Make improvements, as well as the search of areas of opportunity for the continuity of projects between the UTH and the AEP.

Acknowledgement

A special recognition to the executives of the company, who showed interest, bridling all the support and facilities for the development of the project, as well as to all those involved by the UTH, who participated actively, demonstrating professionalism, dedication and commitment, which proved the importance of establishing links that lead to establish lasting relationships between business and university.

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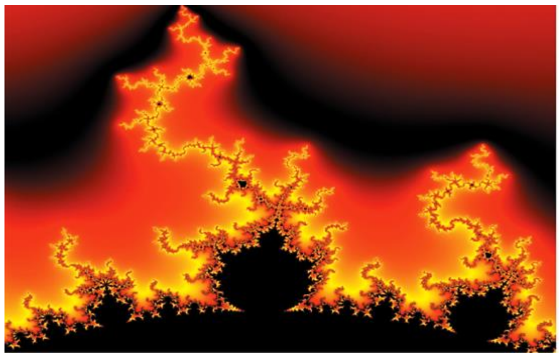

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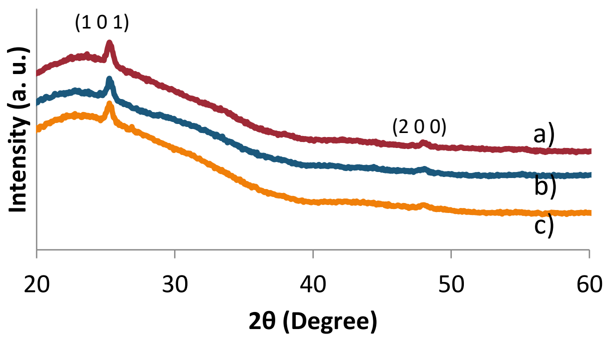

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