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IMPLEMENTATION OF AUTONOMOUS MAINTENANCE IN A FUNCTIONAL TEST AREA USING SIX SIGMA'S DMAIC METHODOLOGY: A LITERATURE REVIEW

IMPLEMENTATION OF AUTONOMOUS MAINTENANCE IN A FUNCTIONAL TEST AREA USING SIX SIGMA'S DMAIC METHODOLOGY: A LITERATURE REVIEW

Esparza Contreras Irving Andrés[1] , Valles Chávez Adán[2] , Poblano Ojinaga Eduardo Rafael[3] , Pinto Santos Jorge Adolfo[4] , Gómez Zepeda Perla Ivette[5]

[1] National Technological Institute of Mexico /Technological Institute of Ciudad Juárez,irving.aec@gmail.com , https://orcid.org/0009-0004-9132-8526;
[2] National Technological[Institute]of Mexico /Technological Institute of Ciudad Juárez,adan.vc@cdjuarez.tecnm.mx , https://orcid.org/0000-0002-6559-0123;
[3] National Technological[Institute]of Mexico /Technological Institute of Ciudad Juárez,eduardo.po@cdjuarez.tecnm.mx , https://orcid.org/0000-0003-3482-7252;
[4] National Technological Institute of Mexico/Technological Institute of Ciudad Juárez,jorge.ps@cdjuarez.tecnm.mx , https://orcid.org/0000-0001-9614-2764;
[5] National Technological[Institute]of Mexico /Technological Institute of Ciudad Juárez,perla.gz@cdjuarez.tecnm.mx , https://orcid.org/0000-0002-1767-5982

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Abstract -- This research, entitled "Implementation of Autonomous Maintenance in a functional test area using the Six Sigma DMAIC methodology: Literature Review," aims to identify and analyze existing information on Autonomous Maintenance to acquire knowledge and observe the correlation between the different variables involved in this research, which are industrial maintenance, downtime, Total Productive Maintenance (TPM), Six Sigma, and the Define, Measure, Analyze, Improve, and Control (DMAIC) methodology.
The methodology used is a systematic review (scientific articles, indexed journals, books) where a comparative technique was used to compile the most relevant information on the use of industrial maintenance, downtime, TPM, Six Sigma, and the DMAIC methodology in manufacturing industries, which made it possible to establish the necessary steps for the creation of the Literature Review. The importance of understanding industrial maintenance was identified, including the types that exist, their advantages and disadvantages, what downtime is and its classifications, the DMAIC methodology, and how Autonomous Maintenance is a pillar of TPM.
By gaining a deeper understanding of each of the variables in the research, it was possible to observe the correlation that exists between each and every one of them. The authors also mention the importance of establishing a good work team to carry out all the necessary steps for the implementation and continuity of Autonomous Maintenance in the company so that this project is not forgotten and can demonstrate all the benefits where it will be applied.
In conclusion, the literature review carried out facilitated a better understanding of all our variables in the research, how they influence and correlate with each other.

Keywords: DMAIC, Six Sigma, Downtime, TPM.

Abstract -- This research, entitled "Implementation of Autonomous Maintenance in a Functional Test Area Using the Six Sigma DMAIC Methodology: Literature Review," aims to identify and analyze existing information on Autonomous Maintenance to gain knowledge and observe the correlation between the different variables involved in this research, which are industrial maintenance, downtime, Total Productive Maintenance (TPM), Six Sigma, and the Define, Measure, Analyze, Improve, Control (DMAIC) methodology.
The methodology used is a systematic review (scientific articles, indexed journals, books) that uses a comparative technique to compile the most relevant information on industrial maintenance, downtime, TPM, Six Sigma, and the DMAIC methodology used in manufacturing industries. This allowed for the establishment of the necessary steps for the creation of the Literature Review. The importance of understanding what industrial maintenance is, including the types that exist, their advantages and disadvantages, downtime and its classifications, the DMAIC methodology, and how Autonomous Maintenance is a pillar of TPM was identified.
By gaining a deeper understanding of each of the research variables, it was possible to observe the correlation

between each of them. The authors also mention the importance of establishing a strong team responsible for carrying out all the necessary steps for the implementation and continuity of Autonomous Maintenance in the company so that this project does not fall by the wayside and can demonstrate all the benefits wherever it will be applied.
In conclusion, we can say that the literature review conducted allowed us to learn more about all our research variables, including how they influence and correlate with each other.

Key words – DMAIC, Six Sigma, Dead Time, TPM.

INTRODUCTION

Currently, there is insufficient information correlating Autonomous Maintenance, which is one of the pillars of Total Productive Maintenance (TPM), downtime, and the Define, Measure, Analyze, Improve, and Control (DMAIC) methodology in a single study. Therefore, this research will review articles that correlate at least two of these topics in order to combine them into a whole that can assist in the main research on which this literature review is based.

As you know, most companies seek to reduce downtime in their different production areas by relying on different methodologies such as Six Sigma, Lean, and Kanban, to name a few.

This article will provide a more in-depth look at all of their variables, as well as what the authors mention is necessary to be able to apply them either individually or jointly. As always, there will be authors who agree on how they should be applied and others who disagree.

We will learn about the types of maintenance, the different types of downtime that exist, the DMAIC methodology, and what is needed to apply Autonomous Maintenance, a pillar of TPM, in a manufacturing company.

Once this knowledge has been acquired, the following objective will be pursued:

General Objective

Conduct a literature review on how TPM, Six Sigma, downtime, and industrial maintenance influence and correlate with each other in the manufacturing industry, explaining the importance of autonomous maintenance in the manufacturing industry.

Justification

This literature review is conducted for the purpose of supporting the operations that will be used in a master's project that aims to reduce downtime by applying Autonomous Maintenance, one of the pillars of Total Productive Maintenance, through the Six Sigma methodology, with a view to implementing this practice in the company's various final testing areas in the future.

DEVELOPMENT

The type of research applied in this article is documentary and correlational, using the following instruments: a review of books, scientific journals, and previous works showing how Autonomous Maintenance, a pillar of TPM, is applied in the manufacturing industry using Six Sigma through the DMIAC methodology.

Methodology

We began by searching for information related to the variables established in the master's project that will serve as the basis for this article: "Implementation of Autonomous Maintenance in a functional testing area using the Six Sigma DMAIC methodology." The variables are: Downtime as the dependent variable, Corrective Maintenance Time, and Waiting Time as independent variables.

These were explored in various search engines such as Google Scholar, Mendeley, Redalyc Scientific Information System, and Latindex. Other terms were also involved with these variables, such as six sigma, DMAIC, TPM, and Industrial Maintenance, which were our keywords for searching in the search engines.

This set of terms and methods makes it easier to appreciate the correlation between the variables, avoiding confusion and clarifying the objective of the research.

The search process was carried out as follows:

1. Keywords related to the project's objective were selected.

2. We chose to read the abstract and conclusions of each article found, and if the keywords were found, we proceeded to read the entire article.

3. The article was downloaded and named as an "APA citation."

4. The information corresponding to each cited article was extracted.

Table 1 shows in more detail the search for information on our keywords related to the manufacturing industry:

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***Table 1**. Search Data.*

Keywords	Search Engine	Number Found	Relation to Objective
Six Sigma DMAIC Methodology, Downtime, Industrial Maintenance, Total Productive Maintenance	Google Scholar	380	18
Six Sigma DMAIC Methodology, Downtime, Industrial Maintenance, Total Productive Maintenance	Mendeley	21	0
Six Sigma DMAIC Methodology, Downtime, Industrial Maintenance, Total Productive Maintenance Maintenance	Redalyc	970	2
Six Sigma DMAIC Methodology, Downtime, Industrial Maintenance, Total Productive Maintenance	Books	3	3

***Source**: Table with keyword results from different search engines (Own creation, 2025).*

Once it has been established that articles, books, and magazines meet the requirements being sought, we will proceed to learn more about the concepts of the variables in order to gain a better understanding of how they are applied in the manufacturing industry.

In order to implement Autonomous Maintenance, it is necessary to understand the different types of maintenance that exist and why this type of maintenance was chosen for this area of production.

It is understood that industrial maintenance refers to all the techniques used to keep equipment and facilities in operation for as long as possible, ensuring their availability and maximum performance [1].

Maintenance types differ from each other in the specific tasks performed within each one [2]:

● Corrective Maintenance: This consists of correcting defects that arise during the operation of the equipment.

● Preventive Maintenance: This allows equipment to work without problems by checking it and replacing parts necessary for proper operation, even if no faults are present.

● Predictive Maintenance: This allows the condition and operation of the equipment to be known and reported at all times by monitoring certain variables.

● Zero Hours Maintenance (Overhaul): This involves scheduled inspections where all elements subject to wear and tear are replaced or repaired. The aim is to ensure that the equipment will function for a long time, leaving it almost as good as new.

● RCM Maintenance: This is based on the study of the equipment, the analysis of failure modes, and the application of statistical and detection techniques. It can be said to be a purely technological maintenance philosophy.

● Maintenance in Use: This is the basic maintenance of any equipment that is carried out by the users themselves. It consists of a series of basic tasks such as data collection, visual inspections, cleaning, lubrication, etc., for which no technical training is required, only a brief training session. This type of maintenance is the basis of Total Productive Maintenance.

Downtime is a period during which equipment is out of operation due to a failure or because it is undergoing maintenance.

As indicated in the article: "Preventive Maintenance Definitions" [3], there are different types, including:

●Downtime due to failures: These are caused by equipment defects that require some kind of repair.

●Downtime due to setup and adjustment: This is caused by changes in operating circumstances, such as starting a production run, beginning a new shift, changing molds or tools, warming up and adjusting machines.

●Downtime due to minor stoppages: These are caused by machine interruptions, jamming, or waiting time. In this type of loss, the equipment is not damaged.

●Downtime due to speed: This is caused by a reduction in operating speed, as higher speeds often lead to quality defects and minor stoppages.

●Downtime due to Quality Defects and Rework: These are products that are out of specification or defective, produced during normal operations. These products must be reworked or discarded.

Losses consist of the work required to fix the defect or the cost of wasted material.

●Downtime due to performance: This is caused by wasted or unused materials and is exemplified by the amount of materials returned or discarded.

Six Sigma is a term coined by Motorola engineer Bill Smith in the 1980s. This is how the company named its proposal for a radical reduction in product defects. It then experienced a new surge in popularity at the end of the 20th century when it was applied by General Electric throughout its organization, both in manufacturing and services, achieving spectacular results [4].

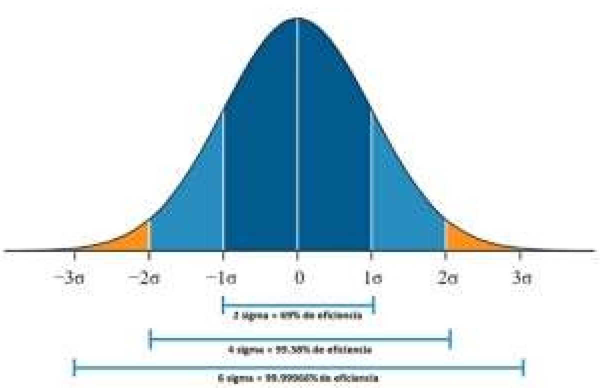
González Cordero [5] mentions that Six Sigma evolved from a simple quality indicator to become a general strategy for accelerating improvements and achieving unprecedented levels of performance by focusing on critical customer characteristics and identifying and eliminating the causes of errors to achieve zero defects in processes.

Dávila et al. [6] agree: "Due to today's global competition, companies seek to improve their processes by focusing on quality for their customers."

Pulido and De la Vara [7] define Six Sigma as "a customer-focused strategy for continuous business improvement that seeks to find and eliminate the causes of errors, defects, and delays in processes."

At its most basic level, the goal of 6σ, which gives it its name, is to achieve Six Sigma quality processes, i.e., at their optimal level, a maximum value of 3.4 defects per million units produced (3.4 DPMO) or, in other words, to guarantee 99.99966% efficiency, Figure 1.

Figure 1. *Sigma graph.*



Source. *Graph showing the relationship between the sigma level and efficiency (Novazen Consulting Solutions, 2024) [14].*

This goal is to be achieved through a vigorous improvement program, designed and driven by an organization's senior management, in which 6σ projects are developed throughout the organization with the aim of achieving improvements and eliminating defects and delays in products, processes, and transactions.

Sung H. Park [8] mentions that "Six Sigma has become very popular around the world because it is a new quality management strategy that can replace Total Quality Control (TQC), Total Quality Management (TQM), and others."

Several authors, such as Navarro, De Mast, Mason et al. [9, 10, 11], agree that "Six Sigma is seen as a statistical, scientific, and systematic system where the essence of Six Sigma is the integration of four elements (customer, process, workforce, and strategy)." Ricardo Aguirre [12] mentions that through researching different Six Sigma methods, he found the following answer: "Apart from those that are not actually a method, but rather sets of good behavioral recommendations, the equivalents are essentially equivalent."

Vidal et al. [13] agree with several authors that "achieving the objectives of Six Sigma requires time and commitment from all members of the company, as the process is costly but the results are very favorable."

The use of the Six Sigma management and organization technique in companies leads to a series of benefits or advantages that are very relevant to the company's results [14]:

● Defects, errors, or failures are reduced to a value close to zero (overall efficiency of 99.99966%). This will have a strong positive impact on the income statement.

● The savings achieved through its implementation represent a huge amount compared to the costs of implementing this methodology.

● Waste and processes without added value are eliminated, promoting those that do add value.

● Maximum customer satisfaction is achieved, thereby securing the loyalty of the company's market niche and ensuring sales.

● It helps to regain market share, make more reliable forecasts, and reduce the rate of product returns by customers.

● It is a methodology that can be applied to companies in any field, not only those in the manufacturing sector, but also in the service sector.

• Processes (both productive and non-productive) are improved and optimized, resulting in a standardized methodology that is common to all members of the company.

• The implementation of Six Sigma generates returns on investment large enough to absorb the initial costs of implementation within a timeframe that is acceptable to the vast majority of companies.

Montgomery, D. [15] discusses the DMAIC methodology, explaining that it is a 5-step procedure used to successfully implement projects related to solving quality and process problems. Pérez Domínguez, P. and Vega Morales
V. [16, 17] mention that each step in the methodology focuses on obtaining the best possible results to minimize the possibility of error.

The steps of the DMAIC methodology are shown in Figure 2.

***Figure 2**. DMAIC cycle.*

***Source.** Figure showing the steps of the DMAIC methodology (Corral V., 2023) [31].*

And they are defined as [18]:

I. Define: The objective of the Define step of DMAIC is to identify the project opportunity and verify or validate that it represents legitimate potential for advancement.

II. Measure: The purpose of the Measure step is to evaluate and understand the current state of the process. This involves collecting data on quality, cost, and performance/cycle time measures.

III. Analyze: In the Analyze step, the goal is to use the data from the Measure step to begin determining cause-and-effect relationships in the process and understand the different sources of variability. It is important to separate sources of variability into common causes and assignable causes.

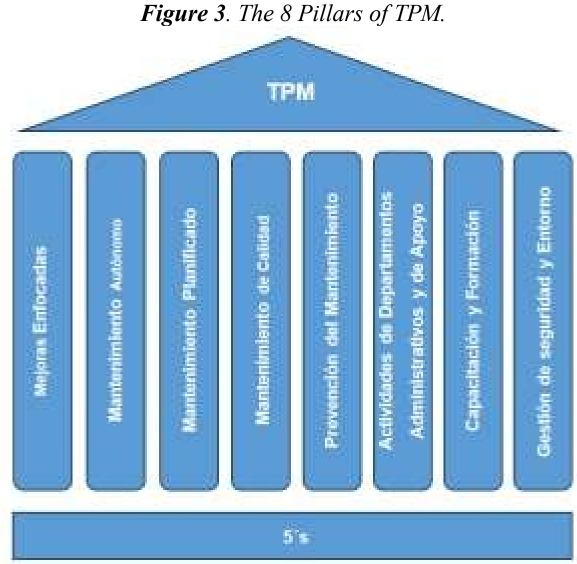
IV. Improve: In the Improve step, the team uses creative thinking about specific changes that can be made to the process and other things that can be done to have the desired impact on process performance.

V. Control: The objectives of the Control step are to complete all remaining work on the project and deliver the improved process to the project owner along with a process control plan and other procedures necessary to ensure that the project gains are institutionalized.

TPM originated in Japan (Japan Institute of Plant Maintenance) as an initiative to eliminate major equipment losses and to be able to adjust to increasingly tight demand (Just In Time). The main efficiency losses that cause the most problems are as follows: Losses due to breakdowns, losses due to machine set-up, losses due to quality defects, and losses due to start-up. Proper implementation of this method requires raising staff awareness of the need to adopt both control and monitoring tasks for machines to ensure they function perfectly. Another objective is for operators themselves to be able to resolve minor problems [19].

The methodology and the 8 pillars of TPM originated in Japan, as did some agile methodologies and the 5S method. More specifically, it emerged at a Toyota electronics subsidiary, Nippon Denso Co., where the 8 principles on which this working method is based [20] were established, as shown in Figure 3.

***Figure 3**. The 8 Pillars of TPM.*



***Source**. Figure of the pillars and basis for developing TPM (Own elaboration, 2025).*

The 8 pillars are defined as [20]:

1) Focused Improvements or Kobetsu Kaizen, the first of the 8 pillars of TPM, is based on finding opportunities for improvement by reducing or eliminating waste. It involves continuous improvement, trying to get to the root of problems in order to create more efficient processes with fewer losses. It allows factors for improvement to be identified and new solutions to be found.

2) Autonomous Maintenance or Jishu Hozen, focused on operators being responsible for performing daily maintenance tasks on the equipment they work with. Cleaning, tidying, inspection, minor repairs, etc. All of this improves the operation of the machinery, reducing broken parts and safety accidents.

3) Planned Maintenance, the third pillar of TPM, is based on properly planning regular maintenance according to the needs of each machine. The goal is to reduce breakdowns, manufacturing defects, waste, accidents, and pollution to zero. All of this reduces maintenance costs and time, as well as eliminating failures.

4) Quality Maintenance or Hinshitsu Hozen consists of identifying the different causes of manufacturing defects. Problems with machinery, materials, methodology, or operating personnel. Any detail can reduce production quality. The goal is to integrate all the details to solve the problem quickly.

5) Preventive Maintenance, the fifth pillar of TPM, consists of investigating which new machines can be used to improve production. If necessary, processes will be redesigned to increase productivity. The integration of new machinery will be carried out through theoretical evaluation, testing, FAT tests, and finally commissioning.

6) Administrative and Support Department Activities: The pillars of TPM must also be applied to administrative processes, with the aim of achieving balance in all areas of the business. The goal is to improve the efficiency of administrative processes, company management, or any other activity that has an effect on production.

7) Training and Education: Another of the pillars of TPM is based on the proper instruction of workers. Increasing employee knowledge through training, for example, allows for an increase in the long-term value of the company. This must be versatile and in accordance with the needs of both the organization and the employee.

8) Safety and Environment Management, the last of the pillars of TPM, focuses on building an environment that reduces the risk of accidents for operators. It is essential to find safe solutions that improve production times without jeopardizing the health of employees. The environment and pollution must also be taken into account.

The pillars of TPM offer a large number of advantages to organizations that decide to implement it in their factories. The most notable are [20]:

• Reducing unplanned maintenance
• Avoiding unexpected production stoppages
• Improving production quality
• Reducing maintenance costs
• Increasing worker efficiency
• Prevent wasted resources
• Reduce workplace accidents
• Improve employee performance
• Reduce production costs
• Increase profitability

DISCUSSION AND ANALYSIS OF RESULTS

Here you will find the views of several authors who helped us understand and apply the variables in our research.

Portal and Salazar [21] mention that each organization must develop a TPM program tailored to its own requirements, so that the development of TPM involves innovation, continuous improvement, and the maintenance and surpassing of standards.

According to López, A. [22], Total Productive Maintenance is one of the fundamental systems for achieving total efficiency, where the ultimate goal is to achieve a set of productive equipment, machinery, and facilities and a reduction in the necessary investments in them.

Galarza and Ondina [23] point out that a TPM program is normally carried out in four clearly differentiated phases, each with its own objectives: preparation, introduction, implementation, and stabilization.

Alfaro et al. [24] state that the increase in the automation of equipment adapted to new technologies requires the involvement of all technical departments in companies; therefore, new procedures and different perspectives with regard to maintenance must be taken into account; in other words, companies need to find a suitable methodology to create a corporate culture with the aim of achieving maximum overall efficiency from their equipment.

Canahua, N. [25] mentions that publications on TPM agree that this methodology has a participatory work philosophy, whose objective is to maximize the effectiveness of machinery and equipment by eliminating errors, defects, and other negative phenomena.

Arrascue and Cabrera [26] conclude that the objective of TPM is to eliminate all forms of time wasted associated with stoppages in the production system due to machine breakdowns, which invariably have a direct impact on process performance. Salinas Manrique [27] defines TPM as being aimed at developing change within the organization that generates greater productivity for the company.

Condezo López [28] states that we live in such a competitive world that companies seek continuous improvement by reducing operating times and increasing productivity. The TPM method is essential to avoid becoming obsolete in these times. According to Brotons et al. [19], TPM is a maintenance management system that focuses on staff involvement to eliminate any losses due to malfunctions or breakdowns.

Huamanchumo and Perez [29] mention that companies seek to optimize the use of machines, which requires that they be available for the production process. Therefore, they implement maintenance methods such as TMP, which is a support tool focused on continuous preventive planning for maintenance with upward improvements. In their literature review, they conclude that the use of TPM is a necessary business tool that fulfills the execution of objectives in the maintenance process that improve equipment availability, obtaining positive results for manufacturing companies.

Rojas Bravo [30] presents in his work a systematic review of the scientific literature on TPM in the period 2015-2020, showing how this methodology helps to raise the level of efficiency in a manufacturing plant, improves the reliability of equipment, raises product quality, and also helps to instill a culture of continuous improvement in all personnel. He concludes that the TPM methodology does have an impact on increasing OEE in industrial companies.

CONCLUSIONS

This article compiles the most relevant information on the use of industrial maintenance, downtime, TPM, Six Sigma, and the DMAIC methodology in the manufacturing industry. This observation revealed the correlation between all these methodologies and the importance of having a good team in charge of taking all the necessary steps for the implementation and continuity of Autonomous Maintenance , significantly reducing downtime, which is one of the goals of any manufacturing company. I agree with Arrascue and Cabrera [26] that the objective of TPM is to eliminate all forms of time wasted associated with stoppages in the production system due to machine breakdowns.

As can be seen from the literature review, having a good understanding of the variables and how they correlate with TPM is essential for successfully implementing Autonomous Maintenance within a company. It has significant advantages and benefits, the most notable of which, of course, is the reduction in downtime, which will ultimately be beneficial for the company where it is applied. Of course, for this to happen, it is necessary to have the support of the entire team involved in order to implement and maintain it.

Based on all the information gathered, I realized the need to unify the existing methodologies into a single one, using those steps that, although similar to each other, generate greater benefits in their implementation. To this end, I seek to create a methodology that can be implemented in a comprehensive and systematic manner, thus avoiding the nullification of some of the methodologies described here.

Thanks to the experience gained working in the manufacturing industry, I have seen firsthand the importance of avoiding work overload for operators, who regularly reject the implementation of new procedures. Therefore, I will seek, through a second approach, to address the implementation of the new global methodology in the best possible way, making them feel like an integral part of the project.

Future lines of research aim to develop the implementation of the Six Sigma methodology in the organization and analyze the economic and productive impact that would be achieved with this research. On the other hand, it will be interesting to analyze the application of predictive maintenance and reliability-based maintenance as alternatives to continue improving the organization's processes.

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Contribution Roles Table

Role	Author(s)
Conceptualization	Esparza Contreras Irving Andrés (main), Valles Chávez Adán (supporting)
Data curation	Poblano Ojinaga Eduardo Rafael
Methodology	Valles Chávez Adán (equal), Pinto Santos Jorge Adolfo (co-author)
Project Management	Pinto Santos Jorge Adolfo
Resources	Esparza Contreras Irving Andrés (principal), Valles Chávez Adán (supporting)
Software	Esparza Contreras Irving Andrés
Supervision	Valles Chávez Adán
Validation	Poblano Ojinaga Eduardo Rafael
Visualization	Pinto Santos Jorge Adolfo
Editorial	Esparza Contreras Irving Andrés (principal), Valles Chávez Adán (supporting)
Writing - Draft preparation	Esparza Contreras Irving Andrés (main), Gómez Zepeda Perla Ivette (supporting)
Writing - Review and editing	Pinto Santos Jorge Adolfo (same), Gómez Zepeda Perla Ivette (co-author)