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## Presentation of the Content

In *Issue 26*, is presented an article *Perception study on low-cost electric vehicles for urban mobility in Mexico*, by Soto-Hernández, Ana María, Rodríguez-Zapata, J. F. Franklin, Reyes-García, Brenda Lizeth and Maldonado-Soto, Otilia Georgina, with adscription at Tecnológico Nacional de México, in the next article *Competitiveness of Mexican avocado exports to the United States based on external macroeconomic variables: a multiple linear regression approach for the period 2012–2024*, by Hernández Salas, José Esteban, Ortega Montes, Fabiola Iveth, Macías-López, María Guadalupe and Domínguez-Acosta, Héctor Hugo, with adscription at Universidad Autónoma de Chihuahua, in the next section *Innovation in total quality management: strategy for operational improvement in the real estate sector*, by Guillermo-Chuc, Giselle, Quijano-García, Román, Alcocer-Martínez, Fidel, Patron-Cortes, Roger Manuel, with adscription at Universidad Autónoma de Campeche and Universidad Autónoma de Yucatán, in the next section *Resource optimization through the use of fiscal, financial, and administrative control strategies in SMEs*, by Aguilar-Pérez, Esmeralda, Soto-Rivas, Soledad and Hernández-Hernández, María Elena, with adscription at Tecnológico Nacional de México – Campus San Martín Texmelucan, in the next section *Critical Factors for the Successful Performance of TPM*, by Castillo-Salcido, Paola Fernanda, Aguilar-Duarte, Gladys Melissa, Castillo-Pérez, Martha Lina and Carrillo-Carballa, Sergio Jesús, with adscription at Universidad Tecnológica de Chihuahua, in the next section *Implementation of a safety monitoring and control system in warehouse operations: a case study in the beverage industry using the lean six Sigma DMAIC methodology*, by Moroyoqui-Espinoza, Paulina Michelle, Bueno-Solano, Alfredo, Vega-Telles, Ernesto Alonso and Acosta-Quintana, María Paz Guadalupe, with adscription at Instituto Tecnológico de Sonora, in the next section *Student perceptions of Microsoft Teams as a collaborative learning environment in higher education*, by Torres-Díaz, Anel Jacaranda, Esparza-Mendoza, Francisco Javier and Quiroz Aguilar, Jesús Alejandro, with adscription at Universidad Autónoma de Nuevo León.





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
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
## Perception study on low-cost electric vehicles for urban mobility in Mexico





### Estudio de percepción sobre autos eléctricos de bajo costo para movilidad urbana en México

Soto-Hernández, Ana María \*<sup>a</sup>, Rodríguez-Zapata, J. F. Franklin<sup>b</sup>, Reyes-García, Brenda Lizeth<sup>c</sup> and Maldonado-Soto, Otilia Georgina<sup>d</sup>

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#### Resumen

#### Abstract

The Mexican low-cost electric vehicle market is experiencing substantial growth. Consumer adoption is driven by potential operational savings. The Mexican government has established a project called Olinia, with the goal of producing low-cost electric vehicles for urban mobility, with a proposed price from 4,800 USD to 8,000 USD, targeting a potentially large and underserved segment. An exploratory study of the market in 2025 was conducted with a sample of 148 users in the most populated areas of Mexico to identify their perceptions and preferences. Surveys identified the main purchasing objections as the lack of charging infrastructure and the high initial cost, although many consumers expressed interest in the environmental benefits and fuel savings.

El mercado mexicano de vehículos eléctricos de bajo costo está experimentando un crecimiento sustancial. La adopción por parte de los consumidores es impulsada por los ahorros operativos potenciales. El gobierno de México ha establecido un proyecto denominado Olinia, con la meta de producir vehículos eléctricos de bajo costo para movilidad urbana, con un precio propuesto de 4,800 USD a 8,000 USD, enfocado a un segmento potencialmente grande y desatendido. Se realizó un estudio exploratorio del mercado en 2025, con una muestra de 148 usuarios en las zonas más pobladas de México, para identificar sus percepciones y preferencias. A través de encuestas, se identificó que la principal objeción de compra es la falta de infraestructura de carga y el costo inicial elevado, aunque muchos consumidores mostraron interés en los beneficios ambientales y el ahorro en combustible.



Electromobility, Urban Mobility, Low-Cost Electric Vehicle



Electromovilidad, Movilidad urbana, Vehículos de bajo costo

Area: Advocacy and attention to national problems

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## Introduction

The objective of this study is to identify the perceptions of urban transport users in Mexico's major metropolitan areas regarding low-cost electric vehicles, based on the government's electromobility project.

A comprehensive review has been conducted on the state of the domestic market for electric vehicles, reports and recommendations from various Mexican governmental and non-governmental entities, some of which are carried out in collaboration with international organizations. These elements contribute to the planning of a comprehensive ecosystem that allows for the adoption of technologies with a lower carbon footprint.

Here we present exploratory field research conducted using a specially designed questionnaire. It was administered via social media to a non-statistical sample of adults located in different urban areas with high mobility in Mexico.

The results of this study allow us to propose hypotheses for extensive research on the subject, which contributes to the Olinia government project for urban electromobility in Mexico.

The first section presents the findings on the supply of low-cost electric vehicles in Mexico. Given that it is a small market that has only evolved in the last decade, there are virtually no studies on customer experience after purchase.

The following section presents the features of the research methodology and design, including the characteristics of the questionnaire used and the reasons for selecting the metropolitan areas established as the subject of study.

The results section shows the demographic characteristics of the respondents and the different findings for the questions asked, based on descriptive and qualitative analysis of the words mentioned in the open-ended questions.

Finally, we share some conclusions that we consider to be important findings for the Olinia project. They also serve as basic inputs for the extensive research currently underway.

## 1. Background

Talking about electric vehicles for personal mobility in Mexico may seem like a fad, but we should also remember the light rail, metros and even trams from the Porfirian era of the 19th century, not only in what is now Mexico City [Comunicaciones, n.d.], but also in Tampico [Reyes & Saldaña, 2020], for example.

As for non-mass electric vehicles, during the second half of the 19th century, the first cars for personal use powered by rechargeable batteries appeared in Europe [Iberdrola, n.d.], but their high cost limited their accessibility. However, with the arrival of Ford's internal combustion engine and mass production, the final cost was reduced, and with the discovery of large oil reserves, electric mobility became marginal [BBVA, 2024].

In Mexico, as in Europe, the same path was followed until the arrival of Tesla and the realisation that the largest emitter of greenhouse gases was transport [Sánchez Vela, et al., 2020].

Coupled with environmental conflicts in Mexico City, there have been public initiatives and programs to incorporate electric vehicles for personal use, as well as in taxi fleets, for example.

The range of electric cars in Mexico has diversified over the last 10 years [De Luna, 2024b], from the iconic Tesla to Chinese-made cars such as BYD and Korean Kia [The Logistics World, 2024], but also including Nissan Leaf and other high-end models such as Volvo and Audi. Special mention should be made of the Zacua vehicle, produced by a Mexican company using traditional methods, whose first generation of two models, with 100 numbered units, has now sold out [Zacua, 2025].

The range of electric cars also includes hybrids [HEVs and PHEVs] and other variants, which is why only those with battery motors are known as EVs. The variants are shown in Table 1. [AMIA, 2022].

**Box 1****Table 1**

Types of electric vehicles and other technologies

Type	Meaning	Energy source	Main features
HEV	Hybrid Electric Vehicle	ICE and an electric motor without plugging in.	No external recharge. Fuel saving, low exhaust emissions and improved fuel economy. Available in the Mexican market
PHEV	Plug-in Hybrid Electric Vehicle	ICE and electric motor with external rechargeable battery.	Rechargeable in the electrical system. If the battery is low, it operates as an HEV. Low exhaust emissions and improved fuel economy. Available in the Mexican market.
EV or BEV	Battery Electric Vehicle	Electric motor with rechargeable battery.	Fully recharges via mains electricity or chargers. Zero carbon emissions. Available in the Mexican market.
FCEV	Fuel Cell Electric Vehicle	Hydrogen-powered electric motor	Generates electricity from hydrogen. Zero carbon emissions. Not available in the Mexican market.

Source: Owned based on [AMIA, 2022]

Among all of them, sales had not exceeded 5% in 2022 [Sánchez, Fabela, Vázquez, & Hernández, 2022; Hermosillo, 2023]. However, although users overwhelmingly seek electric vehicle options [Moreno, 2024], when it comes to making a purchase decision, they choose hybrids due to concerns about range, uncertainty about maintenance, the environmental disposal of the battery, and its resale price [De la Torre, 2025a; De la Torre, 2025b; De Luna, 2024a].

In 2023, 44% of consumers intended to purchase a new electric or hybrid car [Soulé, 2024], and by 2024, this figure had grown to 49% [González, 2024], representing a significant relative increase.

However, sales growth remains conservative, given the global trend towards electromobility associated with the reduction of greenhouse gases. An initial assessment of the possible causes includes the high cost of EVs, the location of a battery charging area or lack thereof, and the lack of consistent support.

This is despite China's emergence with several vehicles [Valladolid, 2024; IEA, 2025; Floty, 2025] and placing its products through non-traditional means such as department stores or online commerce [Deloitte, 2025], but also by negotiating with recognized European brands and buying factories in Latin America [Sengupta, 2025].

By 2024, the entities where electric or hybrid vehicles were most purchased were Mexico City, the State of Mexico, Nuevo León, and Jalisco, leaving the rest of the country far behind [INEGI, 2024]. Population concentrations around Mexico's most important economic areas are moving in that direction, in conjunction with support policies that are not fully known.

However, the charging infrastructure for vehicles that require it makes range a very important factor in the purchase decision, even above price [Audisio, 2023]. The term range anxiety has even been coined to describe driver concern due to the limited driving distance of an EV and the lack of convenient charging stations; this is heightened among users who live in flats or houses without access to overnight charging or those who must make long-distance trips [McKinsey & Company, 2025].

In 2025, the Mexican federal government announced the initiative of the first national automaker with a portfolio of low-cost mini electric vehicles for urban use called Olinia. The announcement mentions zero greenhouse gas emissions, quiet cars to reduce environmental impact in that regard as well, and low operating costs in maintenance and energy [Islas, 2025].

Although not widely known, there are also studies by the Mexican Automotive Industry Association to create an ecosystem that promotes electromobility [AMIA, 2023].

A great challenge in this regard is the battery, mainly due to the components, but also the current global geopolitical situation due to tensions between economic blocs.

China has an advantage because the vast majority of the battery supply chain is in its hands [Ziady, 2023; MarketsandMarkets, 2024]. However, concerns remain about the development of alternatives such as the hydrogen engine mentioned above, due to the projected demand and estimated reserves of materials, which are not easy to extract [Díaz, 2023]. The Olinia project aims to achieve national production of mini electric vehicles costing up to 7,000 USD [Mobility Portal Latinoamérica, 2025], with an aggressive strategy to reach specific niche markets such as the population with lower economic resources, but in cities with urban mobility problems.

To this end, it is essential to generate confidence in the products, ensure that their perceived value is in line with their cost, make effective use of government support, and position the brand with its own seal within the competitive market dominated by China.

It is important to emphasize that Olinia's portfolio does not only include vehicles for personal and family use. It also includes vehicles for passenger transport or neighborhood mobility, such as those that provide this extra service, whether it be transport between co-workers, taxi services or platform services.

How many higher education students have temporary jobs that involve transporting people or goods? [Islas, 2025; Buendía & Márquez, 2024]. In this area of opportunity, which is the delivery of goods in the last mile of the journey, it would be possible to go beyond cars and include motorcycles and bicycles or light cargo vehicles [Studer Noguez, Contreras, & Rubio, 2024].

Last Mile delivery has grown alongside e-commerce and has generated technological needs to meet customer requirements [XCargo, 2024]. It represents between 40% and 53% of the total shipping cost, which has led to new business models and the emergence and development of micro-logistics companies for large distributors such as Uber Eats [The Logistics World, 2025], Mercado Libre, and Amazon [Ravelo, 2023], among many others, including national ones.

For all these purposes, the proposed price point for Olinia [Barragán, 2025] targets a potentially large and underserved segment of metropolitan areas with very specific urban mobility needs. The regulatory environment currently offers some incentives [ICCT/GIZ/C40Cities/CAME, 2024], but infrastructure development, although progressing, lags vehicle sales growth [AMIA, 2023; Jiménez Vera, 2024].

The EV market in Mexico, below the 27,000 USD threshold, consists mainly of Chinese brands offering compact vehicles suitable for urban environments. This study only presents cars, leaving aside pick-up trucks, although there are some within the established price limit. Although the market offering is evolving rapidly, the models and brands available in Mexico are presented in Table 2.

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## Box 2

Table 2

Low-cost electric vehicles in Mexico in 2025

Brand/Models/Cost [USD]	Comments
SEV E-Wan Cross E-Tus SUV Friday From 16,100	The first model is the cheapest on the Mexican market. SEV is an importer and sources EVs from the Chinese brand Dayun. [Islas, 2025; Alto Nivel, 2024; De Luna, 2024b]
JAC E10X E10X Cargo E30X From 19,200	A pioneering Chinese brand in Mexico with local assembly operations. Other models are used for transporting goods. E10X is a popular hatchback. [De Luna, 2024b; Grupo Farrera, 2024; JAC, 2025a; JAC, 2025b]
BYD Dolphin Mini Dolphin From 19,330	Popular hatchback. Chinese brand with an assembly plant in Brazil. World leader in battery technology. [Sengupta, 2025; Islas, 2025; De Luna, 2024b; Grupo Farrera, 2024]
Renault Kwid E-Tech From 19,200	Small SUV/hatchback. It leverages the established brand, but the vehicle is produced with investment in China. [De Luna, 2024; Expansión, 2024]
MG MG4 Style From 24,700	Brand with British roots, now owned by the Chinese company SAIC, with a strong presence in Mexico. The model is a hatchback. [De Luna, 2024b; Herrera, 2024]
GWM ORA 03 From 26,900	Premium base hatchback. Chinese brand with an assembly plant in Brazil and a global research and development network. [Sengupta, 2025; De Luna, 2024b; Grupo Farrera, 2024; GWM, 2025]

According to their use, the EVs mentioned in Table 2 can be classified as: urban personal mobility, passenger transport, and last-mile cargo/delivery, which are described below.

**Urban personal mobility.** Mainly hatchback or minivan cars in the A/B segment, according to the European car classification.

The A segment refers to mini-compacts with a length of up to 3.7 m and a weight of less than one tonne. The B segment consists of small compacts up to 4.30 m in length [AUTOHERO, 2025]. Therefore, this classification would include all the smaller models of the brands, such as E-Wan Cross, E10X, Dolphin Mini, Kwid E-Tech, MG4 Style, Ora 03 Premium. The focus is on affordability, maneuverability in the city and basic travel needs. Olinia's personal model fits here, but at a lower price point.

**Passenger transport.** The requirements established by the platforms for this service involve models with a minimum of four doors and a capacity of four people, in addition to the driver. A low total cost of operation, a minimum value, and a guarantee of being in very good condition are desirable [DiDi, 2025]. Models such as the JAC E10X or BYD Dolphin could be candidates. VEMO, an electric car rental company for platform transfers, uses EVs available in Mexico such as the BYD Dolphin Mini [VEMO, 2025]. Olinia's passenger model should specifically consider these aspects.

**Last Mile Cargo/Delivery.** JAC E10X Cargo [JAC, 2025b] is a direct example in the low-cost sphere for these services. Other small vehicles could be adapted. Olinia's dedicated cargo model targets this growing segment, driven by e-commerce [Islas, 2025]. There are other larger cargo EVs, but they are more expensive.

## 2. Methodology

This research is cross-sectional and descriptive in nature, using qualitative techniques to understand the perceptions of the adult population of Mexico regarding urban mobility.

It was conducted to establish some initial hypotheses to guide further, broader and more in-depth correlational research [Núñez Jiménez, 2017]. In accordance with market research standards, research was conducted on the current status of the availability and sale of electric vehicles through secondary sources [Coursera, 2023].

This study required a review of recent research on electric mobility in Mexico and the market supply, mainly for personal transport. As this is a trending topic, associated with the launch of the Olinia electric vehicle government project, the most important findings correspond to the different interest groups: government entities, professional and business associations in the field, non-governmental organizations, and some academic publications.

However, newspapers, magazines and blogs by authors from Mexico and other countries were also consulted, as well as commercial websites, both those of consultancies and car manufacturers themselves, and social networks such as X and LinkedIn [Stanat, 2025].

A questionnaire [UNADM] was designed as a tool to collect information from primary sources through fieldwork with a non-probabilistic sample [Morales Pérez, De la Torre Romero, & Aguerrebere Salido, 2003; Núñez Jiménez, 2017]. The questionnaire was distributed to a convenience sample of the urban population, of legal age, and living or working in one of the 48 metropolitan areas identified in Mexico [SEDATU/CONAPO/INEGI, 2024].

A metropolitan area [MA] is a group of municipalities whose relationship is based on a high degree of physical or functional inter-municipal or inter-state integration, and the total population of the municipalities that comprise it is 200,000 inhabitants or more. The urban locality or conurbation that gives rise to the metropolitan area has 100,000 inhabitants or more [SEDATU/CONAPO/INEGI, 2024, p. 43].

Therefore, urban mobility was considered a fundamental need in these MAs, warranting a study on the perception of their population.

The 20 MAs with the largest populations were reviewed [SEDATU/CONAPO/INEGI, 2024] and the first four were selected: Mexico City, Monterrey, Guadalajara and Puebla-Tlaxcala. Also, Tijuana as the largest on the northern border; Mérida, in the southeast; Tuxtla Gutiérrez, in the south; and Tampico, as the one where the study was conducted.

Those eight MAs comprised the population of interest for the study; however, others such as Toluca, León, Querétaro, Cancún, and Morelia were included to provide alternatives to respondents. All of them are shown in Table 3 with their respective populations and their position among the 20 most populated cities in Mexico. An option for 'Other MA' was also included for those respondents who did not identify with any of the above.

### Box 3

**Table 3**

Metropolitan areas considered for the survey

Top 20 position	Metropolitan Area	Population
1	Mexico City*	21,436,911
2	Monterrey*	5,322,117
3	Guadalajara*	5,110,617
4	Puebla-Tlaxcala*	2,776,893
5	Toluca	2,353,924
6	Tijuana*	2,049,413
7	León	1,935,928
8	Querétaro	1,530,820
10	Mérida*	1,324,771
15	Morelia	988,704
17	Cancún	934,189
18	Tampico*	927,379
20	Tuxtla Gutiérrez*	848,274

\*Priority metropolitan areas

Source: Owned based on [SEDATU/CONAPO/INEGI, 2024]

The questionnaire consisted of 30 items with following dimensions: 1] demographics, 2] knowledge of electric vehicles, 3] preferences, and 4] perceptions of the topic. The initial proposal was reviewed by five experts who made observations, and some adjustments were made.

Subsequently, a pilot test of the questionnaire was conducted with 50 people from the researchers' immediate environment, practically all from a single MA. Adaptations were made during this stage, and the final version is shown in Table 4.

#### Box 4

Tabla 4

Questionnaire composition

Dimension	Items	Characteristics
1. Demography	1, 2, 3, 4, 5, 6, 22, 23, 26, 28	All multiple choice
2. Knowledge	7, 12, 24, 29, 30	1 multiple choices 1 Likert scale 3 open questions
3. Preferences	8, 13, 14, 16, 18, 19, 20, 21, 27	1 open question 7 multiple choices 1 Likert scale
4. Perceptions	9, 10, 11, 15, 17, 25	3 Likert scale 1 10 scale 2 priority scale

Fuente: Owned

The information was collected in June 2025 using the Office Forms application. It was distributed through the public and private social networks of the research team members. The results were analyzed using Excel, and Word Cloud was used for word analysis and visualization.

### 3. Results

**Demographic data of the sample.** This questionnaire was answered by 148 people, who took an average of 25:25 minutes to complete it. The geographical location of the respondents was mainly in the following metropolitan areas: 22% in Mexico City, 22% in Tampico, 16% in Monterrey, 6% in Guadalajara, and the rest in other areas.

About the gender of the respondents, 51% identified as male and 47% as female. In terms of age ranges, 69.6% of respondents are between 25 and 54 years old, 15.5% are between 55 and 64 years old, 10.8% are between 18 and 24 years old, and 4% are over 64 years old.

Therefore, it can be said that 85% of respondents are in the most likely age range for purchasing a motor vehicle, between 25 and 64 years old.

Respondents reported a higher education level, bachelor's degree or postgraduate degree in 87% of cases, and 13% reported having a technical degree or high school diploma at most. Respondents could choose from several options regarding their occupation. The responses were as follows: 43% were employed in the private sector, 25% were civil servants, 18% were self-employed or freelancers, 15% were students, 7% were retired, and 5% were entrepreneurs.

In relation to their income, almost 20% of those who responded to the questionnaire preferred not to provide the information. The rest of the respondents reported an income range shown in Figure 1, which shows the diversification of purchasing power.

#### Box 5

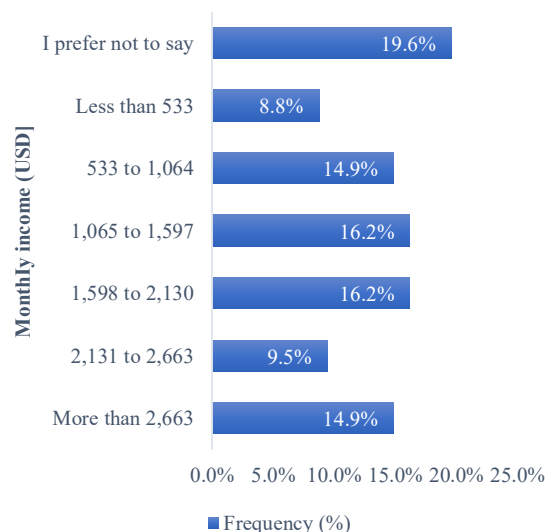


Figure 1

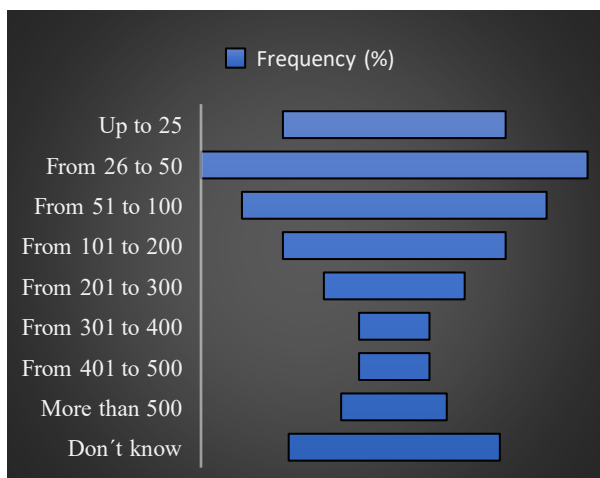
Average monthly tax-free income in 2025

Source: Owned

**Knowledge and use of motor vehicles.** Regarding access to a vehicle for urban mobility, 88% of respondents own a vehicle or have access to one belonging to their family. 94% use it for personal and family transport. Only 4% use it for public passenger transport and 4% for goods transport. The vast majority, 71% of respondents, have a small car or SUV, 15.5% have a large vehicle, and 5.5% have a motorcycle or small van. 8% said they had none of the above.

To verify their urban mobility needs, regardless of how they travel, respondents were asked about the mileage they travel daily. This considered their commutes to work or school, as well as their daily personal and family needs. The responses are shown in Figure 2, where 40% need to travel between 26 and 100 km; 13% up to 25 km; and another 13% from 101 to 200 km, while 8% from 201 to 300 km. However, 12% do not know the extent of their journeys. This implies that 74% of respondents travel up to 300 km for various personal and family activities within the MA where they live.

### Box 6



**Figure 2**

Average daily journey in urban mobility [km]

Source: Owned

**Knowledge and preference regarding electric vehicles.** 95% of respondents have heard of EVs or hybrids, but when asked about their preference, the majority responded that they prefer hybrids. The main reason for this response is uncertainty about battery range and recharging. 78% prefer hybrids for their versatility and reliability, mainly due to the lack of electrical infrastructure in their city. 17% of respondents prefer the efficiency of EVs.

This is associated with the respondents' assessment of the quality of their city's infrastructure for private electromobility. The average response was 7.3 on a scale of 10, with a standard deviation of 2.29. Among respondents, 26% said the infrastructure was a 10, and they live in the MAs of Mexico City, Monterrey, Guadalajara, Mérida, Querétaro, Tampico, and others; while 25% said it deserved a 7, living in the same metropolitan areas mentioned above, as well as those of Puebla, Toluca, and León. At the other extreme, five people gave it a rating of 1 or 2, living in Mexico City, Tampico, and another.

They were also asked about their willingness to purchase an electric vehicle soon. Forty-five per cent of respondents said yes, and 43 per cent said possibly yes. However, when asked if they would be willing to pay more for an EV than for a petrol vehicle, opinions were divided into four groups: 28% said maybe, 26% said not, and 23% each said they were willing to pay more and would prefer a hybrid.

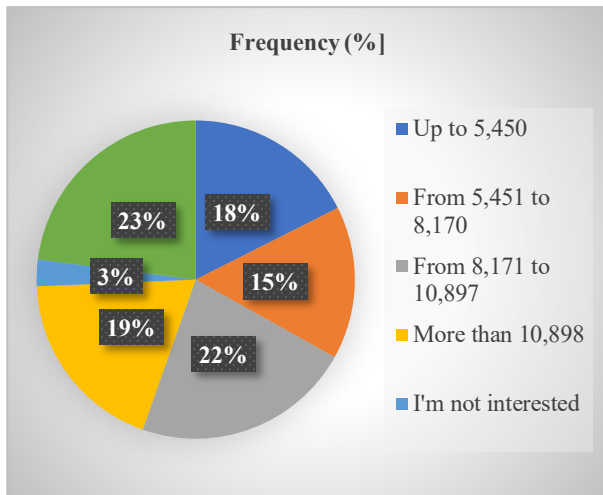
Similarly, when respondents were asked about the type of EV they would buy, if applicable, 41% said their first choice would be a 5-seater, and another 41% said it would be their second choice. Meanwhile, 43% preferred a hybrid as their first choice, and 21% as their third choice. Meanwhile, 41% chose a 2-seater car as their second choice, and 32% as their third choice.

Regarding the factors influencing the purchase of an electric vehicle, 47% of respondents said that price was a key factor, 24% said battery range, and 22% said the availability of charging stations.

Respondents were also asked where they would prefer charging stations to be located. 68% chose petrol stations, 66% shopping centers, and 55% public car parks. In relation to charging, respondents were asked if they would be willing to purchase a fast charger for their battery. Fifty-two per cent answered affirmatively, and 43% said it depended on the price of the chargers.

Respondents were then asked how much they would be willing to pay for a domestic fast charger that could recharge their battery in less than an hour. Forty-one per cent of them responded that they would pay up to 162 USD, and 32 per cent said up to 325 USD. Ten per cent said they were not willing to purchase one.

When respondents were asked how much they would be willing to pay for an EV. The responses are shown in Figure 3. Once again, 23% of respondents reiterated that they would prefer a hybrid vehicle. 3% said they were not interested in purchasing this type of vehicle. The rest of the options are very divided in the selection, in a manner very similar to the variety in the purchasing power of the respondents.

**Box 7****Figure 3**

Preferential cost of electric vehicles

*Source: Owned*

Finally, respondents were asked about their knowledge of the government's Olinia project. Thirty-six per cent said they were unaware of the project, while the rest mentioned some elements associated with EVs, as already discussed. Some mentioned the importance of having low-cost EVs available.

**Perceptions about electric vehicles.**

Respondents were asked about the advantages they perceived in choosing an EV over a petrol vehicle. They considered the following to be essential or important: 89% reduction in carbon emissions, 74% lower operating costs, 69% lower maintenance costs and 67% easier handling. It is noteworthy that 18% of respondents were unaware of tax incentives for purchasing this type of vehicle, while 18% were also unaware of the advantages in terms of freedom of urban mobility, particularly for metropolitan areas such as Mexico City, which have programs to reduce traffic for environmental reasons.

Regarding the disadvantages of choosing an EV over a petrol vehicle, 90% of respondents indicated that the lack of charging stations is serious or very serious, while 75% said the same about the high price, 71% about the battery life, and 68% about the vehicle's range.

At the other extreme, 33% of respondents said they did not care or did not know about the speed ranges that electric vehicles could reach, and 27% said the same about their performance.

This is consistent with the factors influencing the purchase of an EV.

Regarding the lack of information about EVs, 99% of respondents considered it important or very important to have knowledge about safety systems and the quality and reliability of vehicles. Meanwhile, 96% said it was very important to know the charging times, and 91% considered it important or very important to have clear information about the energy savings from petrol to electric power.

Respondents were asked for suggestions to encourage the adoption of low-cost EVs in their urban mobility. Their responses reiterate the need to improve the necessary metropolitan infrastructure, such as the availability of charging stations. Above all, this is due to uncertainty about battery range, as you can see in Figure 4.

Many respondents want more information through comparative tables between brands and electric vehicle performance, costs and maintenance. But they also want information about the car's performance and safety.

**Box 8****Figure 4**

Word cloud on promoting the purchase of electric vehicles

**4. Conclusions**

This study focused on understanding Mexican consumers' perceptions of electric cars. Surveys identified that the main barrier to adoption is the high initial cost, although many consumers showed interest in the environmental benefits and fuel savings.

Regarding Mexican consumers' preferences for electric vehicles for urban mobility, the research also revealed that the lack of charging infrastructure is a critical factor limiting purchases. Therefore, certainty about battery range is a fundamental element in promoting electromobility.

However, there was growing interest in low-cost electric cars, especially among young people and those with environmental awareness. The urban electromobility ecosystem in Mexico's major metropolitan areas must grow in line with the needs of the population, in harmony with the environment and with a vision for the future.

### Declarations

### Conflict of interest

The authors declare that they have no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the vehicles reported in this article.

### Contribution of the authors

*Soto-Hernández, Ana María*: Contributed to the project idea, research method and technique, writing and editing.

*Rodríguez-Zapata, J. F. Franklin*: Contributed to the research on context analysis.

*Reyes-García, Brenda Lizeth*: Contributed to data collection with surveys and blog review.

*Maldonado-Soto, Otilia Georgina*: Contributed to the analysis of the results.

### Availability of data and materials

The data obtained are not available.

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### Abbreviations

EV	Electrical Vehicle
MA	Metropolitan Area

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Competitiveness of Mexican avocado exports to the United States based on external macroeconomic variables: a multiple linear regression approach for the period 2012–2024

Competitividad de las exportaciones de aguacate Mexicano a Estados Unidos en función de variables macroeconómicas externas: un enfoque de regresión lineal múltiple en el periodo 2012 – 2024

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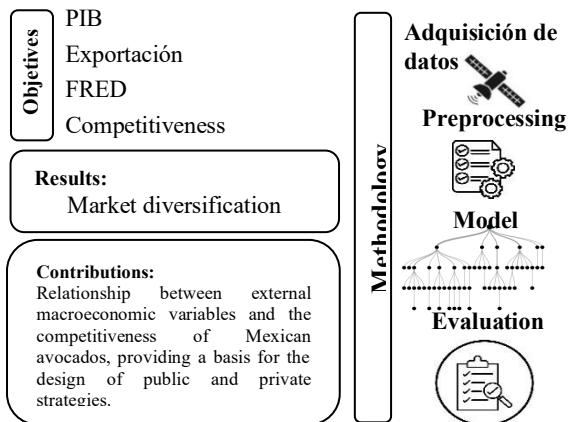
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Abstract

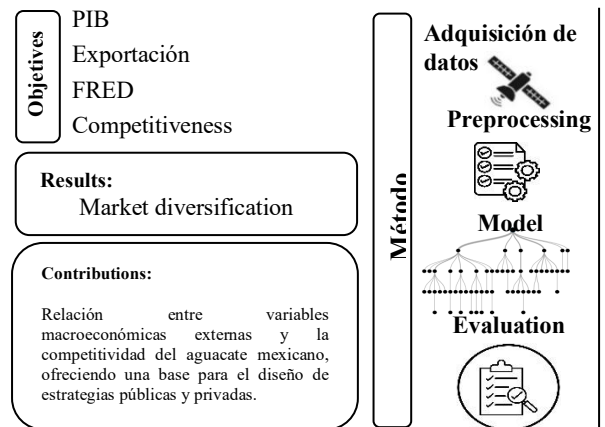
Mexican avocado has become one of the most important agro-export products worldwide, with the United States as its main destination market. However, this high concentration exposes exports to the volatility of external macroeconomic factors. This article analyzes the impact of the U.S. Gross Domestic Product [GDP], Federal Reserve interest rate, U.S. inflation, and the peso-dollar exchange rate on the competitiveness of Mexican avocado exports during 2010–2024. Using a multiple linear regression model in SPSS, results show that U.S. GDP and exchange rate have a positive effect on exports, while interest rates and inflation exert negative pressures. Findings highlight the importance of market diversification and financial hedging to reduce risks derived from international economic conditions.

Resumen

El aguacate mexicano se ha consolidado como uno de los principales productos agroexportadores a nivel mundial, siendo Estados Unidos el mercado de destino más relevante. Sin embargo, la alta dependencia de dicho país expone a las exportaciones a la volatilidad de factores macroeconómicos externos. Este estudio analiza el efecto del Producto Interno Bruto [PIB] de Estados Unidos, la tasa de interés de la Reserva Federal, la inflación estadounidense y el tipo de cambio peso-dólar en la competitividad del aguacate mexicano durante el periodo 2012–2024. A través de un modelo de regresión lineal múltiple en SPSS, se evidencia que el PIB de Estados Unidos y el tipo de cambio influyen de manera positiva en las exportaciones, mientras que las tasas de interés y la inflación ejercen efectos negativos. Los resultados refuerzan la necesidad de diversificar mercados y aplicar instrumentos de cobertura para mitigar los riesgos asociados a la coyuntura internacional.



Mexican avocado, agricultural exports, U.S. GDP, inflation, exchange rate, multiple linear regression.



Aguacate mexicano, exportaciones agrícolas, PIB EUA, inflación, tipo de cambio, regresión lineal múltiple

Area: Advocacy and attention to national problems

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## Introduction

Mexican avocados have experienced sustained growth in exports over the last two decades, consolidating their position as Mexico's leading agricultural export [USDA, 2024]. This performance is due to both internal factors—such as comparative advantages in climate and productivity—and external factors, mainly growing demand in the United States, which accounts for more than 80% of national exports [López & Cervantes, 2022].

Avocado production has maintained steady growth in volume, which has helped consolidate its position as Mexico's leading agricultural export [SIAP, 2023].

The competitiveness of Mexican avocados is closely linked to the performance of the US economy. In particular, gross domestic product [GDP] is directly associated with household purchasing power and, therefore, with the consumption of differentiated fruits such as avocados [Coltrain, 2019; FAO, 2020].

On the other hand, the Federal Reserve's decisions on interest rates affect financing conditions and the level of economic activity, which in turn has an impact on the demand for agricultural imports [Taylor, 2019; Blanchard, 2017].

The avocado sector has become strategic for policies to promote agri-food exports, given its growing share of the US market [SAGARPA, 2018].

Inflation in the United States also affects consumers' real income, changing consumption patterns and reducing purchases of non-essential products when prices rise significantly [Krugman & Wells, 2020; BLS, 2023]. Finally, the peso-dollar exchange rate plays a decisive role in competitiveness, as a depreciation of the peso lowers export prices in the US market, favouring the placement of the product [Krugman & Obstfeld, 2014; Ocampo, 2021].

The economic literature has documented the influence of these variables on agricultural trade [Anderson & Martin, 2021; Lederman, Olarreaga & Rubiano, 2020]. However, there are few studies that integrate them into an econometric model applied specifically to a product of high strategic value such as avocados.

In this context, this article proposes an analysis using multiple linear regression to determine the magnitude and direction of the effects of GDP, interest rates, inflation and the exchange rate on Mexican avocado exports in the period 2020–2024.

How do US GDP, the Federal Reserve interest rate, US inflation and the peso-dollar exchange rate influence the competitiveness of Mexican avocado exports during the period 2010–2024?

Mexican avocados have been considered a strategic product for the national economy, with the United States as their main export destination [USDA, 2024]. However, high concentration in a single market entails risks.

As Lederman, Olarreaga, and Rubiano [2020] argue, countries dependent on a strong trading partner are particularly vulnerable to external shocks.

The Federal Reserve's monetary policy directly influences credit conditions, exchange rates and the consumption capacity of US households [Blanchard, 2017]. Similarly, inflation erodes purchasing power and changes consumption patterns for differentiated agricultural products [BLS, 2023; Krugman & Wells, 2020].

The central problem is that the competitiveness of Mexican avocados does not depend solely on domestic productivity, but also on external macroeconomic variables that are beyond the direct control of the exporting country [Anderson & Martin, 2021; López & Cervantes, 2022].

H1: US GDP has a positive and significant effect on Mexican avocado exports [FAO, 2020; Coltrain, 2019].

H2: The Federal Reserve interest rate has a negative influence on Mexican avocado exports [Taylor, 2019; Blanchard, 2017].

H3: US inflation negatively affects export value [BLS, 2023; Krugman & Wells, 2020].

H4: The depreciation of the peso against the dollar increases the competitiveness of avocado exports [Krugman & Obstfeld, 2018; Ocampo, 2021].

The overall objective of the study is to analyse the impact of external macroeconomic variables—GDP, interest rates, US inflation, and the peso-dollar exchange rate—on the competitiveness of Mexican avocado exports during the period 2010–2024. The specific objectives are:

1. To identify the relationship between US GDP and the demand for Mexican avocados.
2. To evaluate the effect of the Federal Reserve's monetary policy on export performance.
3. To determine the impact of US inflation on export value.
4. To analyse the role of the peso-dollar exchange rate in the price competitiveness of exports.

### The competitiveness of avocado exports to the United States.

The concept of competitiveness in agri-food trade could be defined at different levels:

**Price competitiveness:** linked to relative costs and the effects of the exchange rate on international prices [Porter, 1990; Krugman & Obstfeld, 2014]

**Non-price competitiveness:** related to quality, innovation, logistics and certifications [Esser et al; 1996; Cervantes & López, 2022].

In the case of Mexican avocados, competitiveness depends both on internal productive factors [productivity, plant health, logistics costs] and on external variables that affect demand and export value [FAO, 2020].

This study contributes to the academic literature in three main areas: international trade and competitiveness, international monetary policy, and agricultural economics.

From an international trade perspective, the findings confirm that competitiveness does not depend exclusively on internal factor endowments, as classical Ricardian theory maintains, but is strongly influenced by external macroeconomic variables [Krugman & Obstfeld, 2018; Lederman, Olarreaga, & Rubiano, 2020].

Empirical analysis shows that exchange rate depreciation and US GDP growth have a positive impact on avocado exports, while inflation and interest rates have negative effects.

This result reinforces the systemic competitiveness approach, where internal and external factors are integrated into the explanation of export performance [Esser, Hillebrand, & Messner, 1996].

Therefore, international agricultural competitiveness does not depend solely on internal factors, but also on the economic situation of trading partners [Anderson & Martin, 2021].

In the case of avocados, US GDP is a critical factor, as it reflects disposable income and the consumption of healthy and differentiated products [Coltrain, 2019; FAO, 2020].

Secondly, with regard to international monetary policy theory, research shows that the Federal Reserve's decisions transcend the financial sphere and are transmitted to agricultural trade. This broadens the understanding of US monetary policy as an indirect determinant of demand for differentiated agri-food goods in emerging markets [Blanchard, 2017; Taylor, 2019].

It also corroborates that the exchange rate operates as a key transmission mechanism, which coincides with the postulations of Krugman and Obstfeld [2018], but applied specifically to the case of agricultural products.

With regard to the exchange rate, the theory of Krugman and Obstfeld [2018] highlights that the depreciation of the national currency encourages exports by improving relative prices.

Empirical studies confirm that this mechanism favoured Latin American agricultural products during periods of high exchange rate volatility [Ocampo, 2021; Calderón & Schmidt-Hebbel, 2019]. The peso-dollar exchange rate is one of the most important determinants of the competitiveness of agri-food exports, as it directly affects relative prices [Banco de México, 2023].

On the other hand, the Federal Reserve's restrictive monetary policy makes credit more expensive and appreciates the dollar, which affects both importers and consumers [Taylor, 2019; Blanchard, 2017]. Similarly, inflation reduces purchasing power and leads to substitution towards cheaper products [Krugman & Wells, 2020; BLS, 2023].

Finally, in the field of agricultural economics and development, the study emphasises that the high concentration of exports in a single market creates structural vulnerability [Anderson & Martin, 2021; López & Cervantes, 2022]. This evidence strengthens the debate on the need for diversification of destinations and provides an analytical framework that can be replicated in other commodities such as berries, tomatoes or beer, integrating the dynamics of agri-food competitiveness with the theory of external vulnerability.

Studies on Latin American fruit trade show that the income elasticity of products such as mangoes, papayas, and avocados is positive and significant [Hernández & Morales, 2021].

This implies that growth in US GDP proportionally increases Mexican exports.

Studies on agricultural development emphasise that the high concentration of exports in a single market such as the US almost entirely generates structural vulnerability [Anderson & Martin, 2021]. In the case of avocados, more than 80% are exported to the US [USDA, 2024], which exposes producers to external shocks.

Diversification of destinations is identified as a mitigation strategy that is also applicable to other commodities such as berries and tomatoes [López & Cervantes, 2022].

Beyond macroeconomic factors, systemic competitiveness incorporates institutional, commercial and regulatory elements:

*International treaties* such as the USMCA regulate conditions for preferential access to the US market [SADER, 2023].

*Non-tariff and phytosanitary barriers* condition permanence in high-value markets.

*National promotion policies* [health programmes, logistics infrastructure and export promotion] affect the ability to sustain long-term competitiveness [BANCOMEXT, 2023].

Taken together, the research contributes to building a theoretical bridge between international macroeconomics and agricultural competitiveness, establishing an interdisciplinary framework that allows us to understand how global monetary and financial factors affect the international integration of strategic agricultural export products such as Mexican avocados.

## Methodology

A quantitative approach with multiple linear regression in SPSS was used, in line with the methodological recommendation of Gujarati and Porter [2020] to analyse the influence of macroeconomic variables.  
Period: 2012–2024.

Dependent variable: Mexican avocado exports to the US [millions of USD, SIAVI, USDA].

Independent variables:

US GDP [FRED, 2024].

Federal Reserve interest rate [FRED, 2024].

US inflation [BLS, 2023].

Peso–dollar exchange rate [Banxico, 2024].

The selection of variables responds to the literature linking agricultural trade to disposable income, financial conditions, and price competitiveness [Krugman & Obstfeld, 2018; Anderson & Martin, 2021]. However, the model faces potential endogenities derived from the simultaneity between exports and the exchange rate, the omission of internal factors such as infrastructure or productivity, and the collinearity between inflation and interest rates, given that monetary policy responds to inflationary dynamics.

To mitigate these biases, VIF multicollinearity tests were applied and the robustness of the coefficients was verified. Future research should use time series models [VAR] to identify the effects more accurately.

The dependent variable was Mexican avocado exports to the United States [millions of USD, source: SIAVI and USDA], while the independent variables included: US GDP [FRED], Federal Reserve interest rate [FRED], US inflation [BLS] and peso-dollar exchange rate [Banxico].

The analysis period corresponds to 2012–2024. To ensure the validity of the results, multicollinearity tests [VIF] were applied, and the assumptions of homoscedasticity and normality were verified.

The model showed a high fit, with  $R^2 = 0.983$  and adjusted  $R^2 = 0.970$ , confirming that the combination of the selected variables largely explains the variation in exports.

**Box 1**

**Table 1**

Variables added/removed<sup>a</sup>

Model	Input variables	Variables removed	Method
1	US inflation rate [%], exchange rate, FED interest rate [%], US nominal GDP [US \$trillion] <sup>b</sup>		Enter

a. Dependent variable: Avocado exports [US \$Mill]

b. All requested variables entered.

**Box 2**

**Table 2**

Summary of the model<sup>b</sup>

Model	R	R squared	Adjusted R-squared	Standard error of the estimate
1	.992 <sup>a</sup>	.983	.970	152.689

a. Predictors: [Constant], US inflation rate [%], exchange rate, FED interest rate [%], US nominal GDP [US \$trillion]

b. Dependent variable: Avocado exports [US \$million]

**Box 3**

**Table 1**

ANOVA<sup>a</sup>

Model	Sum of squares	gl	Quadratic mean	F	Sig.
1 Regression	6947180.6014	4	1736795.1504	74.496	.000 <sup>b</sup>
Residual	116569.7995	233	500.300		
Total	7063750.4009	237			

a. Dependent variable: Avocado exports [US \$Mill]

b. Predictors: [Constant], US inflation rate [%], Exchange rate, FED interest rate [%], US nominal GDP [US \$Billions]

**Box 4**

**Table 4**

Coefficientes<sup>a</sup>

Model		Non-standardised coefficients		Standardised coefficients	t
		B	Desv. Error	Beta	
1	[Constant]	-3811.109	459.583		-8.293
	FED interest rate [%]	-159.598	58.023	-.328	-2.751
	Exchange rate	100.966	26.627	.276	3.792
	Nominal GDP of the USA [US \$trillion]	209.009	26.180	.983	7.984
	Tasa de inflacion de EUA [%]	56.035	30.852	.140	1.816

a. Variable dependiente: Exportaciones de aguacate [US \$Mill]

PIB EUA positivo y altamente significativo [p<0,001];

Tipo de cambio positivo y significativo [p=0.13];

Tasa de interés negativa y significativa [p=0.40];

Inflación de EUA positiva pero no significativa [p=0.129] debido a posibles razones de multicolinealidad, concretamente con la propia tasa de interés.

**Box 5**

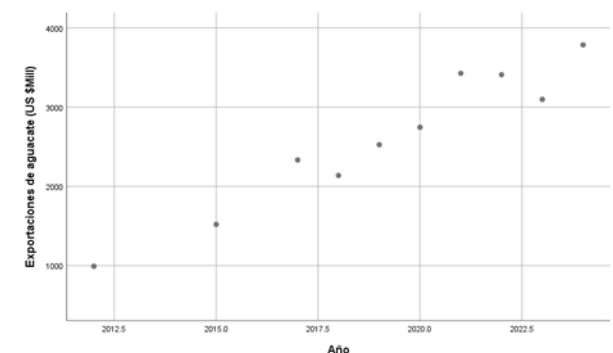
**Table 5**

Diagnóstico de colinealidad<sup>a</sup>

Modelo	Dimensión	Autovvalor	Índice de condición	Proporciones de varianza				
				(Constante)	Tasa de interés de la FED (%)	Tipo de cambio	Tasa de inflación de EUA (%)	PIB de EU \$Bil
1	1	4.471	1.000	.00	.00	.00	.01	
	2	.373	3.460	.01	.13	.00	.08	
	3	.144	5.568	.00	.23	.00	.84	
	4	.007	25.039	.85	.00	.57	.07	
	5	.005	30.907	.14	.64	.43	.00	

a. Variable dependiente: Exportaciones de aguacate (US \$Mill)

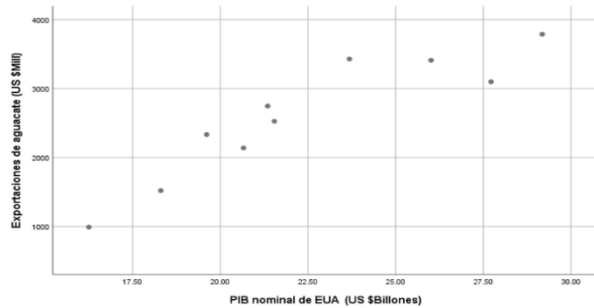
**Box 6**



**Figure 1**

Trends in avocado exports

Source: own creation

**Box 7****Figure 2**

Competitiveness of Mexican avocado exports

*Source: Own elaboration***Results**

The main results can be summarised in the following points:

**US GDP**

A positive and highly significant effect was found; higher economic growth in the US drives demand for Mexican avocados.

**Peso-dollar exchange rate**

Here the effect was positive and significant; a depreciation of the peso improves competitiveness via relative prices.

**Federal Reserve interest rate**

A negative and significant effect was found; higher contractionary rates make financing more expensive and reduce external demand.

**US inflation**

US inflation had a negative but not statistically significant effect; although theory suggests an adverse impact on demand, the empirical results show weakness in this relationship, suggesting that indirect or lagged effects should be explored. Overall, the model confirms that Mexican avocado exports are critically dependent on US macroeconomic conditions, explaining about 97% of the variance in the data analysed.

These results are consistent with other studies: GDP and the exchange rate are the main drivers of export competitiveness [Coltrain, 2019; Anderson & Martin, 2021], while inflation and interest rates in the US act as brakes, in line with the expected effects of contractionary monetary policy [Blanchard, 2017; Taylor, 2019].

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**Conclusions and recommendations**

The model confirms that Mexican avocado exports are critically dependent on US macroeconomic conditions. US GDP and the exchange rate strengthen exports, while inflation and interest rates reduce their competitiveness.

These results are consistent with those found in other studies of agricultural commodities in Latin America [Lederman et al., 2020; Hernández & Morales, 2021; Calderón & Schmidt-Hebbel, 2019]. Mexican avocados have established themselves as Mexico's main agricultural export product, and their dependence on the US exposes them to international volatility.

This research provides empirical evidence that factors such as US GDP and the exchange rate are key aspects of their competitiveness. These results present areas of opportunity and possibilities for improvement:

1. Need for market diversification strategies to reduce vulnerability to shocks in the US.
2. The implementation of exchange rate hedging instruments as a business policy is suggested.
3. Relevant baseline information for agro-export public policy, especially in trade negotiations and in the design of support for producers.
4. US GDP is the main positive driver of Mexican avocado exports, as it is an income-dependent commodity.
5. Federal Reserve interest rates have a contractionary effect on trade, reducing competitiveness [Taylor, 2019; Blanchard, 2017].
6. US inflation negatively affects demand, which is consistent with consumption theory [Krugman & Wells, 2020; BLS, 2023].
7. The depreciation of the peso-dollar exchange rate strengthens the position of Mexican avocados in the international market [Krugman & Obstfeld, 2018; Ocampo, 2021].

Multiple linear regression shows that Mexican avocado exports to the US are 98.3% dependent on the variables of nominal GDP, inflation, exchange rate and interest rate. The positive effects correspond to US GDP and the exchange rate, while the negative effects come from inflation and interest rates.

This study provides empirical evidence on the relationship between external macroeconomic variables and the competitiveness of Mexican avocados, offering a basis for the design of public and private strategies.

Although the model has a high  $R^2=0.983$  fit, the small number of observations [2012–2024] relative to the number of predictors creates a potential risk of overfitting.

This bias may limit the generalisability of the results and increase the sensitivity of the coefficients to small variations in the data. In future research, it would be advisable to expand the temporal frequency of the database [quarterly or monthly series] and incorporate robust methodologies such as VAR [Vector Autoregressive] models or regularisation techniques to mitigate the problems associated with sample size [Wooldridge, 2016]. In addition, the analysis should be extended to other markets such as Europe and Asia and incorporate internal factors such as logistics infrastructure and agricultural productivity, as well as use quarterly or monthly series to detect short-term impacts, specific external shocks, analyse the relationship with other destinations such as Canada, Japan or the European Union, compare avocados with other Mexican commodities [tomatoes, beer] in order to assess whether dependence on the US is a general pattern, or study how currency hedging, agricultural insurance, and subsidies influence export resilience.

## Declarations

## Conflict of interest

The authors declare that they have no conflict of interest. They have no known competing financial interests or personal relationships that could have influenced the article reported in this paper.

## Contribution of authors

*Hernández-Salas, José Esteban*: Contributed to the project idea, research method and technique. *Ortega-Montes, Fabiola Iveth*: Contributed to the data analysis and research method.

*Macías-López, María Guadalupe*: Contributed to the development of the study.

*Domínguez-Aragón, Héctor Hugo*: Contributed to the review of information and editing. Availability of data and materials

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## Abbreviations

GDP	Gross Domestic Product
EUA	United States of America
FED	The interest rate of the United States Federal Reserve
FRED	Federal Reserve Economic Data
PIB	Gross Domestic Product
T-MEC	Agreement between Mexico, the United States and Canada
VIF	Inflation Variance Factor

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# Innovation in total quality management: strategy for operational improvement in the real estate sector

## Innovación en la gestión de calidad total: estrategia para la mejora operativa en el sector inmobiliario

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### Abstract

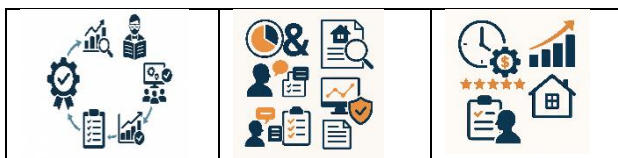
The real estate sector faces growing challenges in competitiveness, customer satisfaction and sustainability. The objective of this study is to design a Total Quality Management Plan for a real estate company located in the Mexican southeast, in order to improve operational efficiency and customer satisfaction. To do this, quality standards and trends were reviewed, and a mixed methodology was applied that included interviews with managers, surveys of clients, employees and suppliers, in addition to the analysis of hypothetical data. The process was developed in three phases: diagnosis, design and implementation. The results show deficiencies in procedures, access to real-time information and customer service. It is concluded that a Total Quality model supported by emerging technologies strengthens operational efficiency, competitiveness and institutional reputation in the real estate sector.

### Resumen

El sector inmobiliario enfrenta retos crecientes en competitividad, satisfacción del cliente y sostenibilidad. El objetivo de este estudio es diseñar un Plan de Gestión de la Calidad Total para una inmobiliaria ubicada en el sureste mexicano, con el fin de mejorar la eficiencia operativa y la satisfacción del cliente. Para ello, se revisaron estándares y tendencias de calidad, y se aplicó una metodología mixta que incluyó entrevistas a directivos, encuestas a clientes, empleados y proveedores, además del análisis de datos hipotéticos. El proceso se desarrolló en tres fases: diagnóstico, diseño e implementación. Los resultados evidencian deficiencias en trámites, acceso a información en tiempo real y atención al cliente. Se concluye que un modelo de Calidad Total apoyado en tecnologías emergentes fortalece la eficiencia operativa, la competitividad y la reputación institucional en el sector inmobiliario.

### Innovation in total quality management: strategy for operational improvement in the real estate sector

Objectives	Methodology	Contribution
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Quality, Operational Efficiency and Real Estate Sector

### Innovación en la gestión de calidad total: estrategia para la mejora operativa en el sector inmobiliario

Objectives	Methodology	Contribution
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Calidad, Eficiencia operativa y Sector inmobiliario

Area: Development of strategic leading-edge technologies and open innovation for social transformation

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## 1 Introduction

The real estate sector faces growing challenges related to competitiveness, customer satisfaction and sustainability. Traditional quality management, based on standards and procedures, has proven to be necessary but insufficient in an environment marked by digitalisation and Industry 4.0.

Incorporating advanced technologies [automation, artificial intelligence] into quality [known as Quality 4.0] can anticipate failures and optimise processes from the design stage. However, problems such as delays in procedures, lack of real-time information and deficiencies in customer service persist in real estate practice, which reduces operational efficiency and the company's reputation [Estrada, 2015].

In this regard, this project proposes to design a Total Quality Plan for a real estate agency in southeastern Mexico, applying advanced quality management principles. This section is organised into three phases [diagnosis, design, and implementation] and follows a doctoral thesis outline with an introduction, theoretical framework, methodology, detailed plan, expected results, and conclusions.

This study conducted a case study using a qualitative and quantitative approach: interviews with managers, surveys of customers/employees/suppliers, and analysis of hypothetical data to diagnose deficiencies. It also conducted an exhaustive literature review of quality standards and trends. Based on this, an integrated quality system was constructed.

### 1.1 Problem statement

The real estate sector faces real challenges such as a lack of clear communication with customers, poor documentation management, and post-sales follow-up, which affects user satisfaction and the company's image [Estrada, 2015]. Industry studies indicate that a high percentage of consumers [73%] consider service quality to be key to their loyalty [AENOR, 2020], meaning that operational problems associated with quality have a direct impact on competitiveness.

Additionally, the fragmentation of systems and technological tools in the sector produces 'hidden costs' that undermine operational efficiency [AENOR, 2020].

From a practical point of view, the application of quality standards [e.g., ISO 9001] in property management has been shown to systematise processes and generate 'greater cost and process efficiency' [AENOR, 2020], which increases asset profitability and business competitiveness.

Academically, this research is relevant because it addresses a theoretical gap: while there is abundant literature on Total Quality in manufacturing or healthcare, few studies explore comprehensive quality models for real estate services. Technological innovation [PropTech, AI] is transforming the real estate sector and requires new management tools [Ruiz, 2024].

This project seeks to fill that gap by proposing a model based on the Total Quality philosophy adapted to a real estate agency in southeastern Mexico, incorporating elements of Quality 4.0 and sustainability. This justifies the operational efficiency of the business.

Taking into account the above, the following general objective is presented: To design and implement a quality management model based on the Total Quality philosophy that will improve the operational efficiency of the real estate company.

And as specific objectives: a) To analyse the current state of operational efficiency and quality practices [baseline], b) Review the literature on quality philosophies [Deming, Juran, Crosby, etc.] and regulatory standards [ISO 9001, EFQM, Baldrige] to theoretically substantiate the model, c) Design the components of the quality plan: policy, objectives, roles and responsibilities, procedures, indicators and mechanisms for continuous improvement. d) Simulate the implementation of the quality model in key operational processes to assess its effect on performance indicators. e) Quantitatively and qualitatively analyse the results of the simulation [e.g., response times, error reduction, customer satisfaction] to validate the model for possible generalisation to other real estate agencies.

## 2 Theoretical framework

### 2.1 Classical schools of quality [Deming, Juran, Crosby, Ishikawa, etc.]

Total quality management [TQM] is based on the contributions of gurus such as W. Edwards Deming, Joseph Juran and Philip Crosby. Deming promoted a paradigm shift in the post-war period, proposing 14 key points [e.g., adopting a new quality philosophy, eliminating dependence on mass inspection] to improve processes [Ceballos and Cruz, 2024].

Juran defined quality as ‘the absence of defects’ and structured a management trilogy [planning, control and quality improvement]. Crosby, with his slogan ‘quality is free’, emphasised the principle of ‘zero defects’ and considered quality to be an investment, not a cost.

For example, he argues that quality drives business profitability. In addition, Kaoru introduced tools such as fishbone [cause-and-effect] diagrams and promoted quality circles in Japan [Padilla, 2002]. Together, these classical schools emphasise the importance of management commitment, continuous staff training, continuous improvement and a proactive attitude towards quality in all areas of the organisation.

### 2.2 Normative quality management models [ISO 9001, EFQM, Baldrige].

Normative models provide structured frameworks for quality. ISO 9001:2015 is an international standard that establishes requirements for a quality management system [García and Ruiz, 2021]. In the real estate sector, its application systematises operations to maintain the company's profitability and competitiveness [Paltín, 2022]. In addition, the standard promotes continuous improvement and process management.

The EFQM [European Foundation for Quality Management] model is a framework of excellence that considers comprehensive criteria [leadership, strategy, people, processes, and results]. It offers a ‘comprehensive perspective that covers all aspects of business management,’ helping to identify areas for improvement and promoting operational innovation. Its objectives include increasing customer satisfaction, fostering innovation and sustainability, and ensuring continuous improvement.

Finally, the Malcolm Baldrige Model [USA] guides excellence by focusing on values such as visionary leadership, customer focus, innovation, and social responsibility. Baldrige defines interrelated criteria [leadership, planning, customer focus, measurement/analysis] that organisations use to evaluate their overall performance [REMS, 2018].

In summary, these normative models complement each other by providing practical tools for evaluating and optimising organisational quality and efficiency.

### 2.3 Modern concepts: Quality 4.0, Artificial Intelligence and sustainability

Recent developments in the industry have introduced Quality 4.0, a concept that arises from the convergence of quality management and Industry 4.0 technologies. It is characterised by the integration of advanced automation, artificial intelligence [AI], big data and the Internet of Things to improve processes from design to production.

In Quality 4.0, operations are continuously reviewed using predictive algorithms that prevent defects before they occur. AI in particular aids decision-making and improves productivity [Hernández and Hernández, 2024]. It should be emphasised that AI does not replace the human factor, but rather enhances its work by automating repetitive tasks and alerting to anomalies, so that those responsible for quality can focus on judgement and strategic improvement.

Sustainability is another essential component. Modern quality models incorporate environmental and social criteria. For example, the EFQM model promotes ‘operating in an ethical and sustainable manner, minimising environmental impact and maximising social and economic well-being’. Similarly, the 2015 version of ISO 9001 suggests aligning the QMS with the Sustainable Development Goals [SDGs], integrating with environmental management systems [ISO 14001] to contribute to corporate sustainability [Paltín, 2022].

Together, Quality 4.0 and AI prepare organisations for digital transformation, while sustainability ensures that operational improvements are compatible with social and environmental criteria.

## 2.4 Applied organisational theories [systems, contingency and innovation]

From a systems theory perspective, an organisation is conceived as an open system, whose subsystems [technical and social] interact to achieve common goals.

Traditional total quality management [TQM] tends to focus on stability and process control, while socio-technical theory emphasises flexibility and worker empowerment. Estrada [2015] points out that combining both approaches [TQM and SST] can lead to better organisational results. Implementation will depend on contextual factors such as company size, the competitive environment, and available technology. Finally, organisational innovation theory highlights the need for a creative culture and structured change processes. In this sense, an effective quality system must encourage continuous improvement [PDCA cycles, Kaizen] and innovative adaptation to new challenges.

The literature suggests that TQM facilitates the development of incremental innovations and organisational competencies, providing support for innovation in companies [Esponda, 2023]. In summary, these organisational theories provide the conceptual framework for understanding how total quality interacts with the structure, environment and innovation of the company.

## 3 Methodology

The research adopts a mixed approach [qualitative and quantitative], justified by the need to address a complex problem from multiple perspectives. The methodological literature emphasises that mixed methods ‘involve the use of quantitative and qualitative methods in the same study when faced with a complex research problem’ [Juárez, 1999, p.7].

In this way, numerical data [statistics, indicators] are integrated with qualitative information [perceptions, discourses] to obtain a holistic view. The design is a case study: a case is constructed for the real estate agency and its current and post-implementation operational processes are simulated.

Data collection combines simulated interviews, structured surveys, and document review.

Semi-structured interviews will be conducted with the various key roles [management, operations management, simulated customers] to identify problems and perceptions. Structured surveys will measure quantifiable variables [e.g., satisfaction, management times]. Observation and analysis of internal documents [manuals, records] will provide an understanding of current processes.

Quantitative techniques [descriptive statistics of indicators, comparison of pre- and post-KPIs, basic regression analysis] and qualitative techniques [thematic analysis of responses, triangulation of sources] will be used for the analysis.

Computer simulation tools will be used to model operational scenarios and measure quantifiable impacts [percentage improvement in efficiency, reduction in defects, etc.]. Ethical considerations are taken into account: since an organisation is being simulated, participants [actors in interviews/simulations] will be informed volunteers.

The confidentiality of the data obtained will be respected and informed consent will be applied, protecting the privacy of those involved. In business research, the dignity and rights of stakeholders must be safeguarded, ‘ensuring that participants are informed, voluntary, protected from harm, and that their information is confidential’ [Pérez, 2023, pf.11]. The project will request approval from company management before beginning interviews and surveys.

## 4 Results

### 4.1 Assessment of the model's impact on operational efficiency

The application of the proposed quality model is expected to generate quantifiable improvements in the real estate agency's operational efficiency: reduction in average times for key processes, lower costs associated with errors and rework, increased customer satisfaction, and greater compliance with deadlines.

By simulating the implementation, it is anticipated that increases in the defined KPIs [e.g., increase in the percentage of error-free transactions and higher agent productivity] can be demonstrated thanks to systematic quality practices.

## 4.2 Theoretical contributions: integration of Total Quality and Quality 4.0

In terms of contributions, this work will provide an original theoretical-practical approach: from a theoretical point of view, it enriches the TQM literature by adapting it to the real estate services sector and combining it with the concepts of Quality 4.0 and AI, an integration that has been little explored until now. Methodologically, it proposes a case study accompanied by simulation as a validation technique, which can serve as a reference for future research in complex environments.

## 4.3 Practical contributions and application in the real estate sector

In practical terms, it provides the real estate industry with an applied systemic total quality model, specifically designed to improve efficiency; this can guide other companies in the industry to implement robust quality systems. Likewise, the resulting quality plan [with its tables, procedures, and metrics] could be transferred to real estate or similar organisations, constituting a tangible resource for business management and operational innovation.

## 4.4 Implementation plan and required resources

Implementation will take place in several stages with an approximate timeline of 12 months. In the initial phase [months 1-3], a detailed literature review and situational diagnosis of the real estate agency will be carried out. In months 4-6, the quality model and its components [policy, procedures, metrics] will be designed. In months 7-9, the computer simulation will be developed and the data collection instruments [surveys, interview guides] will be implemented. Months 10-11 will be devoted to data analysis, model validation and writing up the results. Finally, in month 12, the final report and implementation recommendations will be prepared. A summary Gantt chart is presented below: [Table 1]

### Box 1

**Table 1**

Implementation schedule

Stage	month 1-3	month 4-6	month 7-9	month 10-11	month 12
Literature review and initial diagnosis	✓				
Quality model design		✓			
Simulation and instrument development			✓		
Data collection and analysis				✓	
Preparation of results and recommendations					✓

Note: Example of a schedule for implementing the quality plan.

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The necessary human resources include a principal investigator [responsible for the study], support from at least one research assistant for data collection/analysis, and the collaboration of quality experts [e.g., academic mentor]. In terms of infrastructure, computer equipment [statistical and simulation software], access to simulated case databases, and digital document management tools are required. Estimated financial resources include fees [if applicable] and minimal operating expenses [software licences, survey printing], as most of the work is based on simulation and light fieldwork. In summary, the project will require qualified personnel, technological resources [computer and software], and a modest budget to cover administrative and publication costs.

## 5 Conclusions

This research culminates in the design and implementation of a quality management model based on the philosophy of Total Quality Management [TQM] as a strategy to improve operational efficiency in the real estate sector, specifically in the case of the real estate company.

This work was developed with the aim of remedying structural, technological and procedural deficiencies observed in the field of real estate services, through a systemic approach geared towards continuous improvement, integrating the theoretical experience of classic quality models with the emerging potential of Quality 4.0 and corporate sustainability.

From an analytical perspective, the study managed to establish an accurate diagnosis of the current state of operational processes in the real estate sector, highlighting common problems such as fragmentation of information, delays in key procedures, poor traceability in customer service and the absence of a quality-focused organisational culture.

Through a mixed methodological approach, qualitative and quantitative data were collected, which made it possible to structure a robust intervention model based on international literature on quality management, contemporary organisational theories, and digital tools applied to the service sector.

The methodological proposal stood out for its originality in two fundamental dimensions: on the one hand, the integration of a total quality plan contextualised to the real estate environment, where there has traditionally been little implementation of formal quality systems; on the other, the incorporation of computer simulations to validate the potential impact of the model on key performance indicators [KPIs], demonstrating quantifiable improvements in response time, error reduction and greater customer satisfaction.

From an academic point of view, this research contributes to the theoretical body of quality management in intensive service sectors, providing evidence on the feasibility of applying the principles of Deming, Juran, Crosby and Ishikawa outside the manufacturing sphere. The fusion between TQM and Quality 4.0—still in its infancy in scientific literature—represents an innovative contribution to the field of study, showing how technologies such as artificial intelligence, KPI dashboards, and document management systems can enhance the effectiveness of the PDCA cycle in service organisations. The theoretical dimension is further strengthened by linking these practices to sustainability models, as promoted by ISO and EFQM standards, guiding quality management towards an ethical, resilient and long-term vision.

On a professional level, the designed model has direct and practical implications for real estate companies seeking to increase their competitiveness in dynamic and digitised markets. The structure of the proposed plan—comprising quality policy, objectives, procedures, metrics, roles, and improvement mechanisms—offers a replicable and adaptable guide for similar organisations. Furthermore, its implementation does not involve radical disruption, but rather gradual reengineering based on human talent training, strategic leadership and the progressive incorporation of technology.

Consequently, this work provides professionals in the sector with a pragmatic framework for action that links quality with operational results and customer satisfaction, two factors that are increasingly decisive in business sustainability.

The final reflection of this research refers to the need to rethink the concept of quality in sectors traditionally distant from systematic approaches. Quality should not be reduced to an administrative goal or a set of certifications, but rather assumed as a cross-cutting organisational philosophy that permeates every decision, process, and customer experience. In this sense, total quality is not a static state, but a culture of continuous learning, driven both by the voice of the customer and by the operational intelligence of the organisation.

As future lines of research, it is recommended to move towards the actual implementation of the proposed model in real estate or similar companies, in order to contrast the simulated results with empirical evidence obtained in real environments. Likewise, the expansion of the model could be explored with circular economy criteria, environmental certifications or ESG [Environmental, Social and Governance] indicators, deepening the synergy between quality, sustainability and innovation. Finally, it is suggested to examine the effects of the adoption of artificial intelligence and big data on strategic quality decision-making, especially in highly volatile contexts such as the post-pandemic real estate market.

Ultimately, this study demonstrates that the rigorous, adaptive and technological application of a total quality management system can be a driver of profound transformation for companies in the real estate sector, generating not only economic value, but also social and organisational value. Thus, quality ceases to be a tactical objective and becomes a guiding principle of business excellence.

## Declarations

## Conflicts of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the reported article.

## Contribution of the authors:

Guillermo-Chuc, Giselle: Developed the reference framework, the design of the tool and the conclusions.

*Alcocer-Martínez, Fidel:* Formulated the introduction and its elements and proposed the methodology.

*Quijano-García, Román:* Analysed the results.

*Patron-Cortes, Roger Manuel:* Constructed the theoretical framework.

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### Abbreviations

EFQM	European Foundation for Quality Management
ESG	Environmental, Social and Governance
TQM	Total Quality Management
AI	Artificial Intelligence
ISO	International Organisation for Standardisation
KPI	Key Performance Indicator
SDGs	Sustainable Development Goals
PDCA	Plan, Do, Check, Act
OHS	Occupational Health and Safety
TQM	Total Quality Management

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### Background

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# Resource optimization through the use of fiscal, financial, and administrative control strategies in SMEs

## Optimización de recursos mediante el uso de estrategias fiscales, financieras y de control administrativo en PyMes

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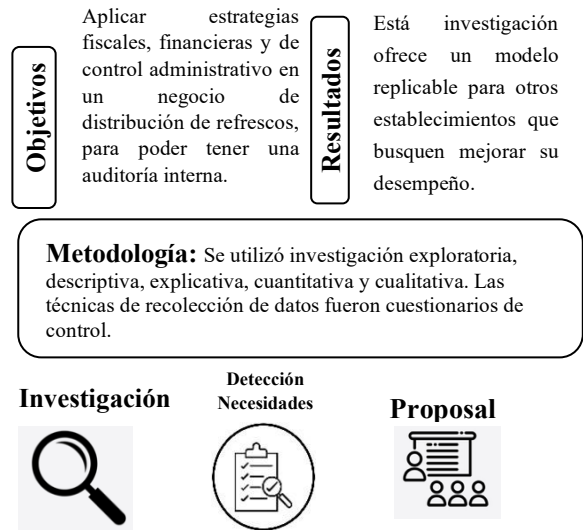
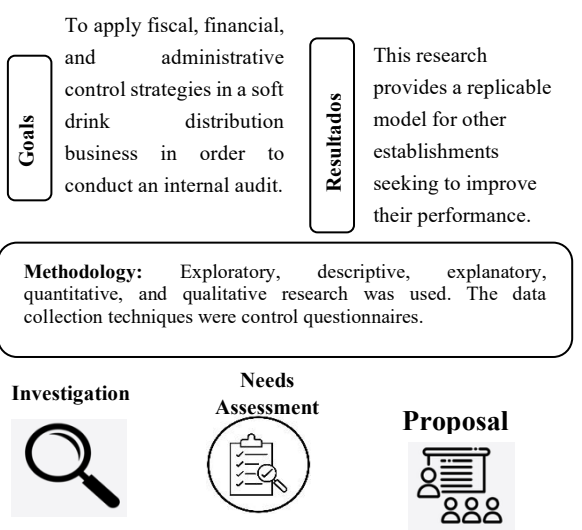
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### Abstract

The Optimization of Resources through the use of fiscal, financial, and Administrative Control Strategies in SMEs has the General Objective of applying fiscal, financial, and administrative control strategies in a beverage distribution business in order to conduct an internal audit. Exploratory, descriptive, explanatory, quantitative, and qualitative research was used. The data collection techniques were control questionnaires. This research offers a replicable model for other establishments seeking to improve their performance.

### Resumen

La Optimización de Recursos mediante el uso de Estrategias fiscales, financieras y de Control Administrativo en PyMes tiene como Objetivo General aplicar estrategias fiscales, financieras y de control administrativo en un negocio de distribución de refrescos, para poder tener una auditoría interna. Se utilizó investigación exploratoria, descriptiva, explicativa, cuantitativa y cualitativa. Las técnicas de recolección de datos fueron cuestionarios de control. Está investigación ofrece un modelo replicable para otros establecimientos que busquen mejorar su desempeño.



Tax strategies, Optimization and SMEs

Estrategias fiscales, Optimización y PyMes

**Area:** Development of strategic leading-edge technologies and open innovation for social transformation

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Peer review under the responsibility of the Scientific Committee **MARVID**<sup>®</sup> - in the contribution to the scientific, technological and innovation Peer Review Process through the training of Human Resources for continuity in the Critical Analysis of International Research.



## Introduction

This research was conducted with the aim of supporting SMEs located in the geographical area of San Martín Texmelucan, Puebla, Mexico, and helping them to control their resources and manage their financial and tax information correctly.

The main problem encountered in SMEs is the lack of efficient administration, preventing the deduction of expenses that, according to the law, allow the authority to reduce the tax base for the payment of taxes. This results in very high taxes for each period due to the tax base obtained, in addition to the lack of effort to advise or develop strategies to support SMEs in maintaining their sales in the face of growing competition in the area.

This was compounded by changes in consumer behaviour, with people unwilling to purchase products with high sugar content that affect health. These problems, combined with the lack of administrative control of accounting records or financial statements that could serve as guides for owners, enabling them to make more correct and informed decisions with the support of information, meant that this type of control was not in place.

Therefore, there was a need to create fiscal, financial, and administrative control strategies, for example, to have a backup of financial information in a file or system for control purposes. It was also possible to further understand the need for change that had to be made within the business, which is why this opportunity was taken to write the thesis so that the problems presented could be resolved.

The general objective of the research was to apply fiscal, financial and administrative control strategies in SMEs in order to have an internal audit.

The specific objectives were: To analyse the fiscal, financial and administrative situation, applying strategic planning tools. To develop fiscal and financial strategies to seek growth and stability for companies, so that they do not generate any problems with the tax authorities.

And to establish administrative strategies for controlling inventory inflows and outflows.

The research questions posed were: Can improvements be made in the administrative area of SMEs by implementing fiscal, financial and administrative control strategies to optimise their resources?

## Hypothesis

### - Null Hypothesis H0

The design of fiscal, financial and administrative control strategies in SMEs allows for improved control within the administrative area, optimising resources to maintain efficient finances.

### - Alternative Hypothesis H1

The design of fiscal, financial and administrative control strategies in SMEs does not allow for improved control within the administrative area, and resources were not optimised to maintain efficient finances.

Variables. Dependent variable: Resource optimisation. Independent variables: Fiscal strategies, financial strategies and administrative control strategies.

According to González [2024]: "Fiscal optimisation is an essential strategy for ensuring the financial health of any business. It consists of analysing a company's operations in detail to identify opportunities to reduce its tax burden legally and efficiently. By implementing optimisation strategies, companies can free up financial resources that can be reinvested in growth, innovation, and other key aspects of the business.

According to the SAT website [2025], "The tax regime is a set of rights and obligations to which a citizen is entitled based on performing a specific economic activity. Depending on your activities and the income you receive in a given period of time, you are assigned to a specific activity."

Without a doubt, the tax regime is the set of tax obligations that apply to individuals and companies according to their economic activity, and because of the income they receive, they must contribute to public expenditure.

This is in accordance with the provisions of the Federal Tax Code [CFF] [2024], 'Individuals and legal entities are obliged to contribute to public expenditure in accordance with the respective tax laws.' [Art. 1, paragraph 1]

According to authors Puentes, Bautista, and Sánchez [2024]: "Tax planning is a fundamental tool for all types of entities, as it contributes to better decision-making by enabling more accurate budgeting and projections and ensuring the optimisation of resources. In addition to the economic benefits it brings, it also allows taxpayers to meet their tax obligations within the established deadlines, thus reducing the expenses incurred by penalties or interest when filing tax returns late or with errors.

On the other hand, to ensure better financial planning, companies need to make projections regarding income, expenses, and costs, as this will make it easier to plan and budget for taxes and other tax burdens, thereby making good use of resources and effectively and efficiently fulfilling their obligations and objectives. Tax planning is not just a strategy to save money; it is an essential tool for efficiently managing your resources and ensuring the sustainable growth of your finances. By developing a solid tax plan, you are taking control of your financial situation and ensuring that you meet your tax obligations in a smart and legal manner.

According to Corvo, H. [2023], integral percentages are defined as: "Integral percentages are one of the techniques used for vertical analysis of financial statements. This method can be used to analyse a company's financial structure for a given period. It consists of a representation of the standard headings in a financial statement, expressed as a percentage of a base heading.

It is used to show the relative sizes of the different accounts in a financial statement. It is done by taking the amount of the most significant heading in the financial statement and comparing it with all the other individual items in the statement. It is also known as the percentage reduction method or common percentage method."

The Mexican Council for Research and Development of Financial Reporting Standards [CINIF] is the independent body responsible for issuing accounting standards in Mexico, under the name of Financial Reporting Standards [NIF], which seek to harmonise the local standards used by the various sectors of our economy.

The above is mentioned to provide context on who develops these financial standards, and to complement the above. Pacheco [2023], defines these standards as, "NIFs are the governing authority in the world of accounting. They ensure that the information provided to users of financial information is reliable and trustworthy for decision-making.

This is where their relevance and importance lie.'

'Financial Reporting Standards [NIF] are the regulatory pronouncements issued by the Mexican Financial Reporting Standards Board, A.C. [CINIF] that regulate the preparation of financial information contained in financial statements. The NIFs are basically made up of two large groups of regulatory pronouncements: the NIF Conceptual Framework [MC] and the specific NIFs" [Mexican Council for Financial and Sustainable Information Standards, 2024, p. 20].

## Methodology

In the course of the research, it was analysed that a combination of exploratory, descriptive, explanatory, quantitative and qualitative research constitutes a well-structured methodological strategy to comprehensively support the analysis and improvement that was carried out, providing different perspectives that enrich the interpretation and application of the results. The data collection techniques were control questionnaires.

The procedures carried out in this research to test the initial hypothesis are as follows:

- Authorised deductions were added to the provisional payments for each period, as this benefit allowed by law was not being used, allowing for the deduction of expenses such as internet, telephone top-ups, electricity and stationery.

- A comparison was made in an Excel spreadsheet so that SMEs could see the benefits of their tax regime, comparing it with the RESICO, and thus understand that deductions are of great help when making the corresponding declarations.
- An Excel file was created to keep an accounting record in a daily ledger of the establishment's sales transactions, on a weekly basis.
- The taxes payable in the final and provisional payments were calculated correctly, because before declaring them, a worksheet was used to determine the income and deductions for each corresponding period.
- Financial statements were prepared in an Excel file, in accordance with the current NIF [National Tax Identification Number], so that they could be used to determine the financial situation of SMEs.
- An Excel spreadsheet was created for inventory, in order to make it easier to control and keep an up-to-date record of product entries and exits.
- A spreadsheet was created to serve as a backup so that, if necessary, the sales notes delivered to customers could be controlled digitally.
- A financial analysis of the SME information was prepared in the corresponding Excel file using financial ratios, integral percentages and profitability ratios.
- A worksheet was created in an Excel workbook to help control monthly expenses and understand how the establishment's resources were being used.
- Based on the guidelines of Strategic Management, a new logo and slogan were created for the establishment to improve the situation of SMEs.
- The mission, vision and values of the selected SMEs were created based on what has always characterised them.
- A BCG matrix was created so that SME owners could see, based on the sales of their products, which ones are in greatest demand and which ones are better not to invest too much in, using those resources for other products instead.
- A SWOT analysis was carried out for the establishment so that it could identify areas for improvement, as well as its strengths, in order to remain competitive in the face of growing competition and changes in consumer demand.

## Results

Results of Specific Objective 1: 'Analyse the fiscal, financial and administrative situation, applying strategic planning tools'

At the start of the research, the situation of SMEs was that there was a need to make innovative changes to the way they did their accounting. From there, an analysis was carried out to find out what else needed to be improved in terms of finances. An analysis was made of how resources were being spent and what was deductible for tax purposes.

It was then found that the financial and administrative situation was not being exploited to the full to make the establishment stand out and not fall behind the growing competition. For this reason, the areas of improvement necessary for SMEs were sought. Below is a detailed analysis of what each company found before these changes and strategies were implemented.

**Fiscal Analysis.** This section shows the analysis of the fiscal information that was declared in the previous financial year, to see what areas needed to be improved and reinforced. The main problem was that there were not many deductions in their payments, only the purchase of goods, which is why their tax payments were high.

Results of specific objective 2: 'Develop fiscal and financial strategies to seek growth and stability for SMEs, so that they do not generate any problems with the tax authorities.'

**Increase in deductions:** a notable reduction in tax payments was achieved, due to the fact that the expenses incurred by SMEs were not taken into account for invoiced taxes.

Correct calculation of provisional and final payments: a digital file was created to support the correct calculation of tax based on sales and purchase information verified on the SAT portal.

Comparison of the Business Activity regime with RESICO: the most optimised and convenient regime for SMEs was sought using information from the 2024 and current financial years.

Results of specific objective 3: 'Establish administrative strategies for controlling inventory inflows and outflows.'

To meet this initial objective, strategies were developed to help efficiently control inventory inflows and outflows. The first thing that was considered in order to implement these strategies correctly was the importance of understanding and knowing the degree of demand for each product. To this end, an analysis was carried out using a BCG matrix to find out which products have the highest sales, which have average sales, and which are no longer worth investing in due to their weak demand in the market.

Thanks to this matrix, it became clearer which products should be kept in stock in the warehouse and which were the strongest consumption periods for keeping the product in stock.

The first strategy implemented was the development of a digital system in Excel to better understand the tracking and control of product entries and exits in each respective period. This is corroborated with the physical inventory that is done each week to verify that the records are correct and that there is no erroneous or missing product data due to non-registration.

The evidence of this record was shown above. This is mentioned so that the information presented is not repetitive. Another strategy implemented was the creation of a layout to guide how to arrange the product in an organised manner based on the products that have the highest consumption and are quickly available for any order, efficiently organising high, medium and low turnover.

Cyclical counts were also implemented as a strategy to continuously review inventory segments. This supports the correct weekly review of product entry and exit, allowing for the identification and correction of any discrepancies. As can be seen, this monitoring is important for making continuous adjustments and improvements.

### **Verification of the hypothesis**

The implementation of fiscal, financial and administrative control strategies in SMEs has conclusively demonstrated the validity of the hypothesis put forward from the outset, namely that the strategic management of these three areas has not only optimised resources but also improved the finances of SMEs, opening the door to better product investments and innovative development. The results of this project were the submission of a correct tax return at the beginning of the 2025 fiscal year, in a timely manner and in accordance with tax regulations.

The relationship between fiscal, financial and administrative control strategies allowed for the optimisation of all internal processes. In addition to prioritising compliance with all legal obligations, it served as an opportunity to improve the management of SMEs' financial resources, turning the hypothesis into a reality that has met initial expectations.

The implementation of the strategy design in these three predominant areas has achieved the expected results, because from the first timely and correct tax return, it served as a solid basis for a series of improvements that translated into more robust financial management, greater investment in products, and improved SMEs in all administrative aspects.

This research demonstrates that a comprehensive and well-coordinated approach to taxation, finance, and administrative control is essential for the optimisation of resources and the sustainability of any SME.

### **Conclusions**

This research has shown that the implementation of fiscal, financial, and administrative control strategies was not only a means of achieving stability for SMEs, but also a way of transforming their internal processes in a comprehensive manner.

This research has demonstrated that by systematically addressing the fiscal, financial and administrative situation of SMEs and applying a set of procedures aimed at optimising each of these areas, it is possible to achieve a total overhaul of the way in which resources are managed, decisions are made and the challenges presented by the environment are addressed.

The analysis of the fiscal situation that was prepared from the outset to review the data that was presented and conducting an analysis of the SME information at the end of the financial year provided a guideline for identifying the needs for change and support. Based on this, the decision was made to create strategies as stated in the objectives of this research, without affecting the provisions imposed by the tax authority.

The first step was to incorporate authorised deductions into provisional payments, which allowed for optimal use of the benefits granted by law through the deduction of expenses such as internet, telephone top-ups, electricity and stationery. The preparation of a comparison in Excel between the current tax regime and RESICO offered SMEs a clear view of how deductions support a more favourable tax return, promoting greater transparency and efficiency in accounting management and assisting in the final payment. The development of fiscal and financial strategies aimed at promoting stable long-term growth was reflected in the systematisation of accounting records and the correct calculation of final and provisional taxes. The creation of a document for purchase and sale transactions, the use of spreadsheets to support the calculation of income and deductions, and the preparation of financial statements are tools that not only enable decision-making based on accurate data for the future, but also reinforce credibility with the tax authorities.

This approach has made it possible to identify areas for improvement and has provided assurance that every action taken complies with legal guidelines, avoiding future problems and promoting a healthy long-term financial structure. The development of a digital worksheet for inventory control enabled up-to-date and accurate recording for product management, while financial analysis using indicators such as comprehensive percentages, profitability ratios and financial ratios allowed for an up-to-date diagnosis of the economic situation.

Control of monthly expenses was another tool for understanding how resources were being used.

The creation of a logo and a distinctive slogan, as well as the formulation of the mission, vision and values of each SME, responded to the need to coherently convey the essence and commitment of the establishment to quality, transparency and customer focus.

These aspects are relevant in an environment where external perception and reputation influence the acquisition of new customers and positioning within the competition. The BCG matrix made it possible to identify the products that were in greatest demand and were a priority in terms of investment, while those with less potential received limited resources. The SWOT analysis provided an informative perspective on internal strengths and weaknesses, as well as an assessment of opportunities and threats in the environment, consolidating a guide for decision-making and strategy implementation in contexts such as the one presented, characterised by high competitiveness and constant change in product demand.

This research can offer a replicable model for other establishments seeking to improve their performance. The accumulated experience, the systematisation of processes, and the implementation of coherent strategies adjusted to the reality of the establishment demonstrate that the administrative, fiscal, and financial areas are related to generating value and promoting transformation. This work thus reaffirms the importance of strategies in resource management and invites further exploration of these issues in order to successfully face the challenges of a constantly evolving market. Clearly explain the results and possibilities for improvement.

## Declarations

## Conflict of interest

The authors declare that they have no conflict of interest. They have no financial interests or personal relationships that could have influenced this book.

## Contribution of the authors

*Aguilar-Pérez, Esmeralda*: Contributed to the project idea, research method and technique.

## Article

*Soto-Rivas, Soledad*: Contributed to research method

*Hernandez-Hernandez, Maria Elena*: Contributed to the results

### Availability of data and materials

The data and materials from this research are available for consultation and use in future research.

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





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## Critical Factors for the Successful Performance of TPM

### Factores críticos para el desempeño exitoso del TPM

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**Abstract**

Total Productive Maintenance [TPM] is a continuous improvement philosophy widely adopted by industry to enhance production efficiency. Successful implementation of TPM contributes to increased productivity and, when properly deployed, nearly eliminates breakdowns, reduces production stoppages, and aims to achieve zero accidents and zero defects, while emphasizing worker involvement and commitment. However, its implementation faces challenges due to the influence of latent variables that make it difficult to measure its effectiveness. Therefore, the objective of this research is to identify and substantiate the Critical Success Factors [CSFs] of TPM. It is proposed that considering these CSFs can optimize decision-making, improve quality, increase Overall Equipment Effectiveness [OEE], and reduce waste and failures.

**Abstract**

El Mantenimiento Productivo Total [TPM] es una filosofía de mejora continua ampliamente adoptada por la industria para mejorar la eficiencia de la producción. El éxito del TPM impacta en el incremento de la productividad y, al desplegarse correctamente, reduce casi por completo las averías, disminuye los paros de producción y busca su objetivo de cero accidentes y cero defectos, considerando el involucramiento y compromiso de los trabajadores. Sin embargo, su implementación enfrenta desafíos debido a la influencia de variables latentes que dificultan medir su efectividad. Por ello, esta investigación tiene como objetivo identificar y fundamentar los factores críticos de éxito [FCE] del TPM. Se plantea que considerar estos FCE puede optimizar la toma de decisiones, mejorar la calidad, aumentar la eficiencia total del equipo [OEE] y reducir desperdicios y fallas.

Critical factors for successful TPM performance		
Objective	Methodology	Contributions
Determining the CSF for the successful performance of TP, based on scientific studies.	This study conducts a comprehensive literature review based on the methodology proposed by Colicchia & Strozzi (2012), structured in two stages followed by a discussion.	*Identification of key factors for the successful development of TPM philosophy. *Proposal of a theoretical framework to improve industrial productivity. *Extensive discussion in the CSF variables.

"Total Productive Maintenance", "Critical Success Factor", "TPM implementation"

Factores críticos para el desempeño exitoso del TPM		
Objetivo	Metodología	Contribuciones
Determinar los FCE del desempeño exitoso del TPM, basado en estudios científicos.	Se realiza una revisión exhaustiva de la literatura, siguiendo la metodología propuesta por Colicchia & Strozzi [2012], a través, de dos etapas y una discusión.	*Identificación de factores claves para el desarrollo exitoso de la filosofía TPM. *Propuesta de un marco teórico para mejorar la productividad industrial. *Discusión de amplitud en las variables de los FCE.

Mantenimiento Productivo Total, Factores críticos de éxito, implementación del TPM

**Area:** Dissemination of and universal access to science

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## Introduction

In the year 2025, **Total Productive Maintenance [TPM]** continues to be a highly demanded topic. According to Google Trends [2025], interest in TPM ranges between 78% and 100% in search trends. It is worth noting that successful implementation records date back to the early emergence of the methodology, such as the case of Toyota in 1989 [Nakajima, 1989], and continue with current success stories that empirically demonstrate its effectiveness [Gallesi-Torres et al., 2020; Reis et al., 2025].

As mentioned, TPM remains a relevant topic within the maintenance field, and when discussing maintenance, one inevitably refers to production—two inseparable concepts. To improve production, equipment must be effective and efficient at all times. Among the most efficient maintenance theories is TPM, which is commonly developed to increase productivity [Mutaqiem et al., 2022]. When properly deployed, TPM nearly eliminates breakdowns, reduces production stoppages, and aims for zero accidents and zero defects, always considering worker involvement and commitment [Agustiady & Cudney, 2018].

Likewise, TPM is a philosophy that seeks continuous improvement at all times [Agustiady & Cudney, 2018; Rey Sacristan, 2002], which is necessary to remain competitive in an increasingly challenging world [Agung Prabowo et al., 2020]. The most common condition for measuring the success of TPM implementation is through Overall Equipment Effectiveness [OEE] [Ali, 2019; Bataineh et al., 2019; Prabowo & Adesta, 2019; San, 2021].

However, beyond exact production figures, it has been observed that the TPM philosophy presents greater difficulty in defining its success due to latent variables that directly impact implementation effectiveness [Hernández et al., 2014; Luis et al., 2012].

It is important to consider these variables during implementation. Therefore, this research aims to identify the few but vital **Critical Success Factors [CSFs]** to improve the implementation of the TPM strategy.

Critical Success Factors [CSFs] are those indispensable elements for achieving the proposed objective.

Thus, if the CSFs of the TPM strategy are known from the beginning of implementation, there is greater certainty of improving results. Current studies on CSFs related to TPM lack general consensus on implementation, as the causes of effectiveness are multivariate. The objective of this research is to establish the theoretical foundations of the CSFs for successful TPM implementation. Additionally, previous studies related to TPM philosophy implementation are analysed, where different methodologies have been applied.

By contributing a recent list of CSFs in TPM philosophy, the general hypothesis emerges: industries that consider these factors and apply the theory derived from this research may benefit by improving decision-making during TPM strategy implementation, enhancing product quality, increasing overall equipment effectiveness [OEE], reducing unplanned machine stoppages, and thereby contributing to waste reduction, improving the Mean Time To Failure [MTTF] and Mean Time To Repair [MTTR] indices.

## Article Sections

This article is structured into three main sections: the first stage, the second stage, and finally, the results.

- **First stage:** This stage involves a search for articles addressing the topic of Total Productive Maintenance [TPM] and its factors, using databases that most effectively present relevant information. It also includes an exploratory reading of the selected texts to identify key concepts related to TPM, followed by a more detailed review that highlights the critical factors involved in TPM development, as well as the different ways of classifying and defining the identified Critical Success Factors [CSFs].
- **Second stage:** In this stage, the identified factors are organized according to their priority and frequency of coincidence among the different authors.
- **Results:** The final stage presents the specific CSFs identified in this research, along with the construction of their definitions based on an exhaustive review of the literature.

Methodology

A comprehensive literature review was conducted. This process involved a bibliographic search following the methodology proposed by Colicchia & Strozzi [2012]. Various internationally recognized and peer-reviewed journals were explored, available in databases such as ResearchGate, ScienceDirect, Emerald, Google Scholar, IEEE, among others. Additionally, books supporting the theory and relevant doctoral theses were included.

As aforementioned, a documentary research design was used with a critical analysis of secondary sources, including scientific articles and specialized studies on CSFs in the successful deployment of TPM. Furthermore, criteria were established for literature selection to ensure the validity and depth of the analysis, as follows:

- **Thematic relevance:** Scientific studies were included, primarily with statistical support that demonstrate key factors for determining success in TPM implementation.
- **Timeliness and temporal relevance:** Only publications from the last 9 years were used to reflect current trends, due to their impact on today's industry.
- **Academic rigor:** Articles indexed in recognized databases such as Scopus, Web of Science, and institutional reports with scientific backing were selected.

First Review Stage

The first literature review was based on the systematic analysis of literature networks [Colicchia & Strozzi, 2012], examining theory through various search engines: ResearchGate, ScienceDirect, Emerald, Google Scholar, IEEE, among others. A total of 89 articles were found that mention implementations and characteristics of the TPM philosophy. Emphasis was placed on CSFs of TPM reported in the most recent period, from 2017 to the present.

Figure 1 shows the number of relevant articles found by database:

- ResearchGate: 38 articles [highest count]
- ScienceDirect/Elsevier: 21 articles
- Emerald: 1 article
- IEEE: 19 articles
- Other sources: 10 articles

Box 1

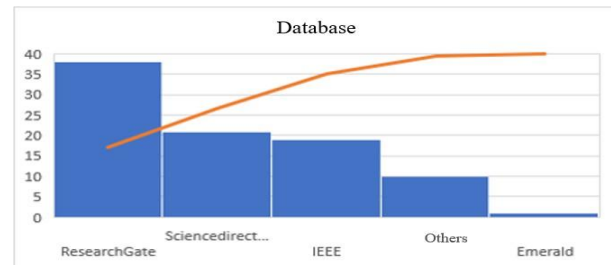


Figure 1

Search by database

Source: Own elaboration

From the mentioned articles, those that reference CSFs in TPM implementation were selected. It was found that there is a wide variation in styles for determining them. Mishra et al. [2021a] used the largest number of factors in their analysis— 56 factors divided into 7 categories.

However, only 4 of the 7 categories demonstrated impact on effective TPM implementation. In contrast, Hooi & Leong [2017] reported only one: top management commitment, describing it as the critical success factor for effective TPM implementation.

Current studies on CSFs related to TPM lack general consensus on implementation, as the causes of effectiveness are multivariate and involve different factors [Gallo & Santolamazza, 2021; Seleem et al., 2018].

Depending on the researchers, decisions are made to group or not group these factors when reporting multiple CSFs [Table 1]. That is, depending on the case, factors are defined as a category or as individual factors, even though they can be categorized by nature [Table 1].

Box 2

Table 1

Grouping of CSFs

Author[s]	Categories	CSFs
Pinto et al. [2020]	None	1. Worker resistance. 2. Time to adapt to different routines. 3. Implementation and maintenance of new routines.
Mishra et al. [2021b]	Organizational, Cultural, Behavioral, Technological, Operational, Financial, Departmental	Organizational Cultural 3. Behavioral 4. Technological
Gupta et al. [2015]	None	1. Lack of top management commitment

Source: Own elaboration

Some literature reports CSFs through empirical TPM implementation and describe CSFs based on their analysis. In other cases, literature reviews compile previous research to identify CSFs based on frequency. Lastly, a combination of these techniques is used along with more objective methods such as statistical analysis and specific parameters to validate CSFs. The literature reports multiple TPM CSFs extracted from the first literature review. Considering that CSFs are temporary by theory, only articles from 2017 to the present were analyzed, identifying 43 different CSFs [Table 2].

### Box 3

**Table 2**

CSFs 2017 - Present

Priority Order	Critical Factor
1	Attitude of middle management to empower lower-level workers
2	Technological aspects
3	Quality in the production system
4	Shift toward a continuous improvement mindset
5	Management commitment
6	Organizational communication
7	Connection with strategic objectives
8	Consideration of TPM rules
9	Interdepartmental coordination
10	Education and training
11	Organizational structure
12	Managerial experience
13	Lack of knowledge of quality and productivity
14	Lack of experience and knowledge
15	Flexibility in the production system
16	Raising employee awareness
17	Resource management
18	Ineffective top management to execute TPM practices
19	Employee skills
20	Financial limitations
21	Ineffective organization for changes in employee attitudes
22	Ineffective organization for changes in work culture
23	Integration and visibility of TPM objectives, clear understanding of TPM
24	Employee involvement
25	Employees consider TPM as additional work
26	Poor management attitude toward other levels
27	Employee motivation
28	Quality perception
29	Strategic planning
30	Preference for traditional practices
31	Employee rewards and promotions

32	Relationship between production and maintenance departments
33	Company resistance to adopting a new implementation
34	Resistance to change, individual and organizational
35	Employee resistance to adapting to new changes
36	Resistance to organizational culture change
37	Monitoring and evaluation
38	Adequate services for workers
39	System for effectively measuring organizational performance
40	System for effectively measuring organizational reliability
41	Time required to adapt to other routines
42	Sufficient time for implementation/improvement
43	Teamwork

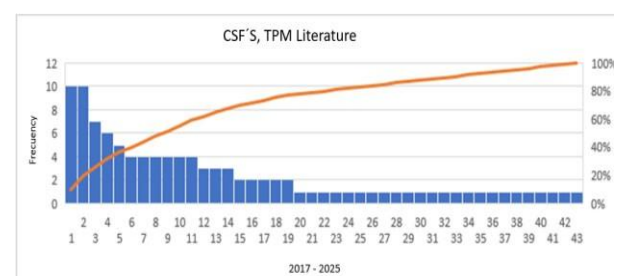
Source: Own elaboration

Of the 43 identified Critical Success Factors [CSFs], it is difficult to address each and every one during the implementation of TPM. The implementation of TPM philosophy is inherently a multifactorial issue.

#### Second Review Stage

From the 43 CSFs identified in the first phase, they were ordered according to the frequency of occurrence across different reports. It was found that only 19 factors coincided in at least two of the various studies reviewed. Based on the frequency order, a Pareto diagram was constructed [Figure 2].

### Box 4



**Figure 2**

Pareto of the CSF of TPM

Source: Own elaboration

Among the 43 CSFs identified and ordered by frequency of occurrence across different authors, Table 3 shows the prioritization of factors. The first and second positions correspond to the most frequently cited factors, as shown in the Pareto diagram [Figure 2]. Likewise, factors ranked from 20 to 43 only appeared in two sources.

**Box 5**

Table 3

Prioritization of Critical Success Factors

Priority Order	Critical Factor
1	Top management commitment
2	Education and training
3	Employee involvement
4	Resistance to change in organizational culture
5	Resistance to change, individual and organizational
6	Organizational communication
7	Teamwork
8	Technological aspects
9	Strategic planning
10	Integration and visibility of TPM objectives, clear understanding of TPM
11	Resource management
12	Alignment with strategic objectives
13	Staff motivation
14	Sufficient time for implementation/improvement
15	Interdepartmental coordination
16	Organizational structure
17	Relationship between production and maintenance departments
18	Ineffective organization for changes in work culture
19	Monitoring and evaluation
20	Managerial experience
21	Shift toward a continuous improvement mindset
22	Lack of knowledge in quality and productivity
23	Financial constraints
24	Organizational resistance to new implementation
25	Lack of experience and knowledge
26	Poor attitude of management toward other levels
27	Ineffective organization for changes in employee attitudes
28	Employee resistance to adapting to new changes
29	Time required to adapt to new routines
30	Employees perceive TPM as additional work
31	Raising employee awareness
32	Ineffective senior management for executing TPM practices
33	Consideration of TPM rules
34	Middle management attitude toward empowering lower-level workers
35	System for effectively measuring organizational performance
36	Employee rewards and promotions
37	Adequate services for workers
38	Quality perception
39	Employee skills
40	Preference for traditional practices
41	System for effectively measuring organizational reliability
42	Flexibility in the production system
43	Quality in the production system

**Results**

According to the prioritization of factors from the second review stage and based on the Pareto principle, the top three factors define the vital few, exceeding 20% and reaching 25.71%. According to Thompson et al. [2012], CSFs are a few crucial points—typically between one and four—that enable competitive advantage.

Therefore, the first four factors are established as critical for the successful deployment of TPM philosophy. These are described below based on research reports from 2017 to the present.

**Top Management Commitment**

As shown in Figure 2, the most frequently mentioned CSFs are top management commitment and education/training. This section discusses the former.

Top management commitment is considered a critical factor for successful implementation of TPM programs [Ali, 2019; Mishra et al., 2021a; Rathi et al., 2021; Samsudin & Hasan, 2017]. Management serves as the main support and promoter for project success [Zennaro et al., 2019] through its backing and contribution [Ahmed & Karmaker, 2019].

Badia et al. [2023] report that administrators and senior employees are critical before initiating TPM implementation, as they are responsible for fostering team spirit. Rathi et al. [2021] state that TPM programs can only be implemented and function properly if top management is 100% committed. Mishra et al. [2021a] demonstrate that an organizational barrier is the ineffective execution capacity of senior management to implement TPM. Ngoy & Israel [2021] report that a major challenge for TPM implementation is the lack of management support and understanding of the approach.

Agung Prabowo et al. [2020] conducted research on barriers and facilitators for TPM implementation, reporting that the main facilitator is management support and involvement at 91.49%. Similarly, Hooi & Leong [2017] confirm this as a critical factor in the initial stage for determining the master plan and launching the entire program.

## Education and Training

Another CSF in TPM implementation is developing TPM knowledge across all personnel through training [Ahmed & Karmaker, 2019; Ngoy & Israel, 2021; Samsudin & Hasan, 2017; Seleem et al., 2018]. An adequate training program must exist where employees learn about TPM and its benefits [Agung Prabowo et al., 2020; Rathi et al., 2021].

From management to the production department, management must deeply understand TPM, and operators need training to initiate the new cultural mindset and acquire the required skills [Zennaro et al., 2019].

Ali [2019] states that training not only aims to teach how to do things but also why they are done. It should also help eliminate employee fatigue and make work more enjoyable, seeking 100% participation.

Mishra et al. [2021a] report that among technological barriers, employee lack of knowledge about new technologies results from inadequate training.

Ahmad et al. [2017] found that after training, operators became more concerned with production and additional maintenance activities, reducing defects by 49.53%. Thus, training is considered a CSF in TPM implementation.

This critical factor is not only a CSF but also one of the pillars of TPM philosophy.

## Employee Involvement

Another fundamental factor for successful TPM implementation is employee involvement. This refers to employees participating in all activities and goals pursued during implementation [Farné, 2020; Ngoy & Israel, 2021; Rathi et al., 2021]. Zennaro et al. [2019] mention that to achieve participation, synergy between departments must exist, with regular meetings scheduled. Pascal et al. [2019] highlight the importance of participation from all personnel, including supervisors, engineers, maintenance teams, operators, etc.

Various authors investigate TPM success through barriers that hinder its achievement, emphasizing lack of employee participation [Rathi et al., 2021].

Mishra et al. [2021a], in their category of cultural barriers, highlight the lack of employee involvement in decision-making.

Article

Agung Prabowo et al. [2020] report that the main barrier, at 82%, is lack of employee involvement.

## Resistance to Change in Organizational Culture

This factor is considered one of the greatest challenges when implementing a new way of working in any industry.

Rathi et al. [2021] identify confrontation with organizational culture change as a barrier to successfully developing TPM philosophy.

Mishra et al. [2021a] define barriers to successful maintenance strategies implementation, including resistance to change within organizational, cultural, and behavioral categories. Therefore, this factor must be considered before, during, and after implementing any strategy.

Through empirical research, Pinto et al. [2020] demonstrate that one of the main limitations is resistance to change. It has also been shown that successful TPM implementation is characterized by individuals willing to change and be flexible [Aspinwall & Elgharib, 2013].

## Conclusions

Companies that successfully implement TPM while considering the identified CSFs will benefit globally by remaining competitive in their respective sectors, efficiently meeting customer demands for quality and service, and identifying potential problems. Additionally, they will improve environmental conditions and organizational culture, enhance communication, and strengthen interdepartmental relationships, as TPM philosophy involves all personnel within the company.

An area of opportunity would be to conduct research using primary sources from the region where TPM philosophy is intended to be implemented, considering that CSFs are temporary.

## Declarations

## Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

## Author contribution

*Castillo-Salcido, Paola Fernanda*: Contributed to the project idea, research method, and technique.

*Aguilar-Duarte, Gladys Melissa*: Contributed to research.

*Castillo-Pérez, Martha Lina*: Contributed to proofreading.

*Carrillo-Carballa, Sergio Jesús*: Contributed to research and translation.

## Availability of data and materials

All data obtained is available online and in research engines.

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## Abbreviations

CSF	Critical Success Factor
TPM	Total Productive Maintenance

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## Implementation of a safety monitoring and control system in warehouse operations: a case study in the beverage industry using the lean six Sigma DMAIC methodology





### Implementación de un sistema de supervisión y control de la seguridad en las operaciones de almacén: un estudio de caso en la industria de bebidas utilizando la metodología Lean Six Sigma DMAIC

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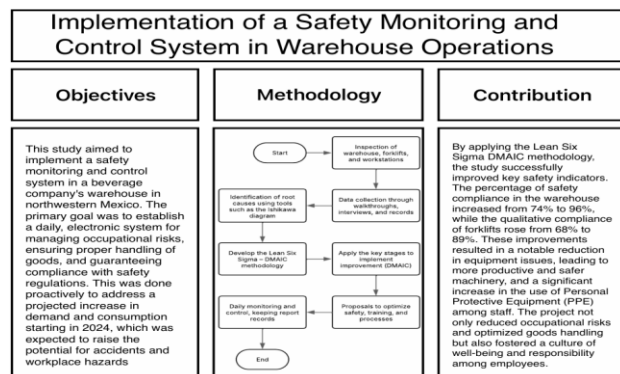


#### Abstract

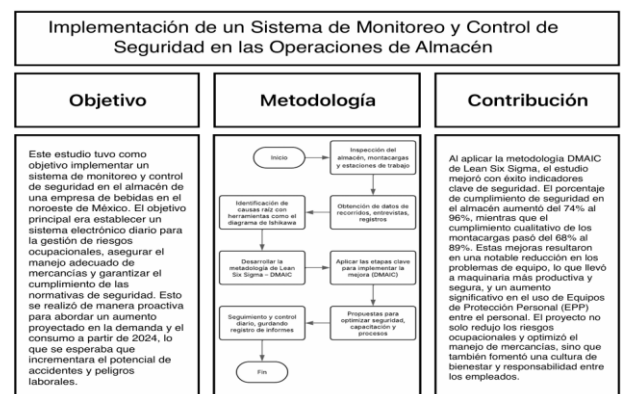
This study examines the implementation of a safety monitoring and control system in the warehouse of a beverage company in northwestern Mexico, anticipating higher demand and occupational risks from 2024. Using the Lean Six Sigma DMAIC methodology, the project aimed to manage risks, improve goods handling, and ensure safety compliance through daily updates. Results included increased safety verification compliance [74% to 96%] and improved forklift performance [68% to 89%]. Checklist issues decreased, PPE use improved, and workplace risks were reduced. The system optimized operations while fostering a stronger culture of safety, responsibility, and well-being among employees.

#### Resumen

Este estudio analiza la implementación de un sistema de monitoreo y control de seguridad en el almacén de una empresa de bebidas en el noroeste de México, anticipando mayor demanda y riesgos laborales a partir de 2024. Con la metodología Lean Six Sigma DMAIC, el proyecto buscó gestionar riesgos, optimizar el manejo de mercancías y garantizar el cumplimiento normativo mediante actualizaciones diarias. Los resultados incluyeron mayor cumplimiento en verificaciones [74% a 96%] y mejor desempeño de montacargas [68% a 89%]. Se redujeron fallas, mejoró el uso de EPP y disminuyeron riesgos, fortaleciendo una cultura de seguridad y responsabilidad.



#### Warehouse safety, occupational risk control, Lean Six Sigma



#### Seguridad en almacén, control de riesgos laborales, Lean Six Sigma

Area: Development of strategic leading-edge technologies and open innovation for social transformation

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Peer review under the responsibility of the Scientific Committee MARVID®- in the contribution to the scientific, technological and innovation Peer Review Process through the training of Human Resources for continuity in the Critical Analysis of International Research.



## 1. Introduction

Warehouse safety offers a series of significant benefits, such as a reduction in workplace accidents, improved operational efficiency, compliance with regulatory protocols, guaranteed preservation of stored products, and the development of a better safety culture awareness. [ERM, 2019]. The main beneficiaries of this project would be the company, its clients, and, fundamentally, all company personnel. Conversely, not implementing this project could lead to an increase in accident risks, operational inefficiency, loss of valuable goods, and the creation of an unsafe environment that could demotivate staff

The company under study faces a significant challenge in the safety of its warehouse in the northwestern region of Mexico. An increase in the demand and consumption of beverages is projected starting in 2024, which will increase the number of operations and, consequently, the possibility of incidents within the warehouse. Contributing factors to this insecurity include a lack of ergonomic design in work areas and frequent corrective maintenance of equipment, which affects warehouse operations. [Harvard Business Review, 2021]. It is imperative to address these factors to reduce insecurity, protect the safety of workers and products, and identify risks to propose solutions that improve safety protocols, reduce accidents, and optimize inventory management. This analysis is essential to align with industrial safety standards and improve the work environment, positively impacting both productivity and employee well-being.

This challenge requires identifying the strategies that should be initiated for safety control in the flavored beverage warehouse in northwestern Mexico, leading to a risk prevention and work environment improvement system that complies with industrial safety standards for the organization's type of warehouse.

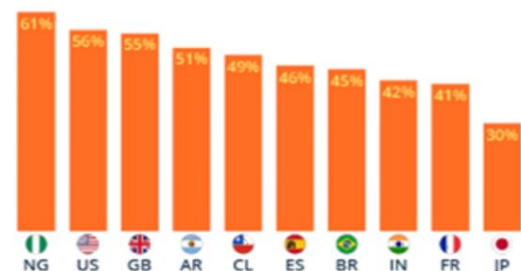
The current proposal is to measure the effects of implementing a safety monitoring and control system in the company's storage operations, with the aim of establishing a system for controlling occupational risks, ensuring proper handling of goods, and guaranteeing compliance with safety regulations through daily electronic updates.

## Background

Warehouse management is a fundamental logistical process that encompasses the reception, storage, and movement of materials, products, or services. Its correct application is crucial for successful companies in various industries, including manufacturing, food, and beverages. [Flamarique, 2019]. The beverage industry, in particular, has experienced growth driven by trends such as innovation in healthy products, expansion into emerging markets, [Euromonitor International, 2022]. and a concern for sustainability, which has led to diversifying product portfolios with low-sugar options and sustainable packaging. Globally, flavored beverages generated approximately 800 billion U.S. dollars in 2022, with Mexico being one of the main consumers, with 62% of the population regularly choosing them. [Roa, 2023].

### Box 1

*Percentage of respondents in selected countries who regularly consume soft drinks.*



De 500 a 10.000 encuestados (18-64 años) online por país de abril de 2022 a marzo de 2023.  
Fuente: Statista Consumer Insights

### Figure 1

How common is it to drink soft drinks?

Source [Statista Consumer Insights]

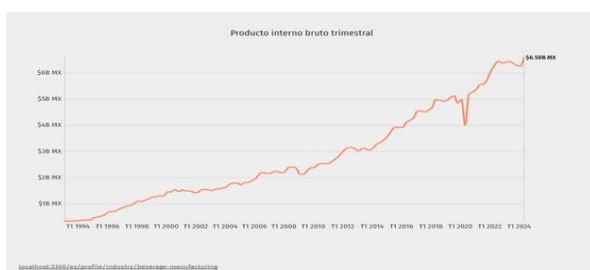
In this context, due to the high volume of operations, safety in beverage warehouses is crucial for operational efficiency and product protection. Security measures range from the implementation of international standards such as ISO 45001:2018 and OSHA regulations for the reduction of workplace accidents, to protection against theft and losses through surveillance and access control systems. For perishable products like beverages, quality control, a clean environment, and proper cold chain management are essential to prevent contamination and maintain freshness.

The use of advanced technologies such as

the Internet of Things [IoT] and Warehouse Management Systems [WMS] allows for real-time condition monitoring, optimizing storage and reducing human errors. [InLog Supply Chain, 2023] In addition, food and specific flammable liquid regulations [NFPA 30] require strict controls. In the context of food and beverage production logistics, operational efficiency is as crucial as safety. This stems from the industry facing intense pressure to reduce the consumption of valuable resources and eliminate all forms of waste. For example, in the pasta manufacturing sector, significant losses are commonly observed during the packaging phase due to issues such as overfilling or inadequate equipment settings.

These inefficiencies, though they may seem minor, result in a substantial loss of raw material and increase production costs. Therefore, proactively addressing operational challenges—whether safety risks, goods handling, or packaging efficiency—is essential for maintaining the industry's competitiveness and sustainability in the market. [Dabic-Miletic, 2025]. In Mexico, the beverage manufacturing industry has shown significant growth, with a Gross Domestic Product [GDP] of \$6.58 billion pesos in the second quarter of 2024, showing an increase of 5.06% from the previous quarter and a sustained annual growth of 2.27%. [Data México, s.f.]

## Box 2



**Figure 2**

Gross Domestic Product of the Beverage Industries

Source [Instituto Nacional de Estadística y Geografía [INEGI]]

Within this dynamism, the company under study has established itself as a key bottler and distributor of products for international companies with operations in Latin America, with a strategic plant that supplies the northwestern region of Mexico. The company focuses on efficient distribution, sustainable practices, and social responsibility.

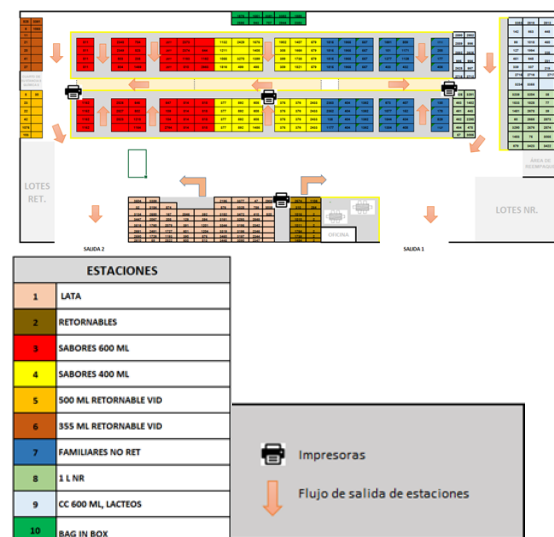
## 3. Method

This section describes the process carried out for the development of the research, detailing the techniques and methods applied for data collection and analysis, in order to clearly describe the study's approach and facilitate its understanding

### 3.1 The Subject Under Study

The subject of this research was the finished product warehouse at the Distribution Center [CEDI] in Sonora, Mexico where products are stored.

## Box 3



**Figure 3**

Layout of the finished product warehouse

Source [Obregón Distribution Center]

The warehouse uses an efficient Push-back Dynamic storage system, which employs inclined rails and mobile carts to handle beverage pallets under the LIFO [Last In, First Out] principle.

The warehouse layout [Figure 1] shows areas assigned by colors for different types of products such as cans, returnables of various capacities, non-returnable family sizes, dairy products, and bag-in-box. In addition, lot areas where pallets are stacked outside the racks are identified, as are flow zones for forklifts, jacks, and workers, locations of printers for packaging labels, a chemical substances room, and a repackaging area. The warehouse staff includes 7 packers, 3 checkers, and 1 shift supervisor in the office area.





This deficit implied a higher risk of workplace accidents, a compromise in the quality of stored products, and the possibility of regulatory sanctions, which would affect corporate reputation. The need to adopt corrective measures such as continuous training programs, follow-up control strategies, and warehouse design optimization became evident.

### 4.2 Measure

Before the implementation of the daily control follow-up, the safety formats reflected the following initial conditions:

#### 4.2.1 Warehouse Safety Verification [Table 1]:

The compliance percentage was 74%. This percentage was considered low due to the details detected in the safety requirements

### Box 10

Table 1

#### Warehouse Safety Verification

Unidad de negocio	Edificio Identificador	Area	Logística	Fecha	28.09.2024
REQUISITO	Orden de limpieza		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Plano Compartmental (Estratos, categorización, almacenaje, acceso y EPP)		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Orden de máquinas / Energías peligrosas		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Seguridad Eléctrica (Cables, empalmes, extensiones, bornas, enchufes y EPP)		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Protección contra caídas (Escaleras, puentes y equipos de protección personal)		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Equipos de Protección Personal		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Extintores y equipos en buen estado y certificados conforme a su utilidad		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Control de incendios / Líquidos inflamables		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Seguridad en Almacenamiento		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Orden del Trabajo		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Plan de Emergencia		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Señales y zonas para protección (EPP, Cáscaras, barreras y Almacenaje)		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Equipos de Protección Personal (Cascos, botines y Almacenaje)		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Señales de áreas de trabajo (Organización de almacenamiento)		PUNTO	RESULTADO	SEGUIMIENTO
REQUISITO	Señales de áreas de trabajo (Organización de almacenamiento)		PUNTO	RESULTADO	SEGUIMIENTO

4.2.2 Forklift Qualitatives [Table 2]: The compliance percentage was 68%. This value was considered very low, indicating that the forklifts were dangerous for workers and drivers inside the warehouse

### Box 11

Table 2

#### Forklift Qualitatives

Reporte de Cualitativos Cedi Obregon										
Unidad de negocio Cedi Obregon Area Almacén Fecha 27/AGS/2024										
Punto de control	21873	17894	19219	4036	4027	13887	4039	4040	17895	
Claxon	OK	OK	OK	OK	OK	X	X	X	OK	
Luces traseras	OK	OK	OK	OK	X	X	X	X	OK	
Luces traseras	OK	OK	OK	OK	OK	OK	X	OK	OK	
Alarma de reversa	OK	OK	OK	OK	OK	OK	OK	OK	OK	
Editor	X	X	OK	OK	X	OK	OK	X	X	
Freno de mano	OK	X	X	X	X	OK	X	OK	OK	
Calibración de seguridad	OK	OK	OK	OK	OK	X	X	OK	X	
Luc delantero rojo	OK	X	OK	X	OK	X	OK	OK	OK	
Luc delantero Azul	OK	X	OK	X	OK	X	OK	OK	OK	
Gas	85%	85%	MUCHA CON MANGADOR	MUCHA CON MANGADOR	85%	85%	90%	85%	MUCHA CON MANGADOR	

INACTIVOS	19887	Calentador de cabeza de motor
Inactivos Temporalmente	4040	En espera puesta de cadena
13887	Instalación de cuñilla nuevas	

Observaciones	17895	Agujero quebrado

X	No funcional
OK	Funcional
INACTIVO	Faltar

% Cumplimiento	68%
----------------	-----

#### 4.2.3 Forklift Checklist [Table 3]:

Numerous external and internal details of the cabin and engine compartment were observed, which prevented the proper use of this equipment and affected warehouse productivity

### Box 12

Table 3

#### Forklift Checklist

ITEM	ESTÁNDAR	INSPECCIÓN												
		Apl	LUN	MAR	MIE	JUE	VIE	SAB	DOM					
		Ci	C	C	C	C	C	C	C	C	C	C		
<b>PARTE EXTERNA</b>														
Espejos laterales	Sin roturas, sin manchas y ajustado	X	X											
Luces traseras	de freno: mínimo dos / de color rojo / Direccional: mínimo dos de color amarillo / Retroceso: mínimo dos de color blanco	X	X											
Alarma de reversa	Función automática con el cambio de reversa.	X	X											
Extintor de incendio	Extintor PQS de 20 Libras / Recargado / Revisado	X	X											
Llantas	Libres de rajaduras y sin desgaste excesivo	X	X											
Placa de montacargas	En buena estado y legible	X	X											
Cilindros de elevación e inclinación	Libres de escape o daños	X	X											
Montura de los cilindros	Firme	X	X											
Indicadores luces frontales altas	Funcionando correctamente.	X	X											
Indicadores luces direccionales	Mínimo dos funcionando correctamente.	X	X											
Lámparas Luces delanteras	Lintes sin roturas/ funcionando / de color blanco / amarillo	X	X											
Indicador luces de parqueo	Mínimo dos / funcionando correctamente.	X	X											
Tanque de combustible	Sin fugas / ajustado / con tapa original y ajustada	X	X											
<b>COMPARTIMIENTO DEL MOTOR</b>														
Fuente de energía	Sin rajaduras/ Aislado adecuadamente	X	X											
Conexiones eléctricas	Firmes y en buen estado	X	X											
Nivel agua refrigeración / máscara	Nivel correcto / mangueras sin fugas	X	X											
Estado de las líneas hidráulicas	Líneas sin fugas y en buen estado	X	X											
Niveles de aceite motor / hidráulico	Niveles de acuerdo al fabricante.	X	X											
Cableado eléctrico	Aislado / sin roturas / ajustados	X	X											
Botella de dirección / Nivel aceite	Sin fugas/ bien asegurado / nivel de acuerdo al fabricante	X	X											
<b>INTERIOR DE LA CABINA</b>														
Espejos retrovisor interior	Sin roturas / sin manchas / ajustado	X	X											
Indicador de combustible	La barra o indicador debe mostrar el nivel de combustible	X	X											
Indicador presión de aceite motor	Que se ilumine al encender el motor	X	X											
Pedales freno / clutch / acelerador	Con forro antideslizante / sin juego excesivo	X	X											
Gobernador	10 km/hora	X	X											
Claxon	Funcionando / que se oiga mínimo a 50 m.	X	X											
Timón o volante	Funcionando en perfectas condiciones	X	X											
Frenos	Pedales con antideslizante/ nivel de líquido de acuerdo al fabricante	X	X											
Horómetro	Funcionando, legible y dentro del rango del mantenimiento	X	X											
Recomendaciones / Observaciones:														
Fecha de seguimiento:	08 DE OCTUBRE DE 2024				Responsible:									

**3.4.4 Personal Protective Equipment [PPE] Compliance Format [Table 4]:** During the first week of inspection, it was found that only 2 workers complied daily with the use of PPE. This situation was alarming, revealing a lack of commitment and awareness of occupational risks.

**Box 13**

**Table 4**

Personal Protective Equipment Compliance Format [EPP].

CONTROL DE USO DE EPP																					
SEMANA 1 (30 DE SEPTIEMBRE - 04 DE OCTUBRE 2024)																					
TRABAJADORES	LUNES				MARTES				MIÉRCOLES				JUEVES				VIERNES				RESULTADOS
	CASCO	CHALECO	LENTES	GUANTES	ZAPATO	CASCO	CHALECO	LENTES	GUANTES	ZAPATO	CASCO	CHALECO	LENTES	GUANTES	ZAPATO	CASCO	CHALECO	LENTES	GUANTES	ZAPATO	
DIA ASUETO	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	16
	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	10	
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	12
	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14

**4.3 Análisis**

The Ishikawa Diagram [Figure 10] was used to identify the root causes of the lack of a safety monitoring and control system, which generated insecurity in the warehouse. The causes were grouped into six main categories:

**Box 14**



**Figure 10**

Ishikawa Diagram

The causes were grouped into six main categories:

- **Man:** Insufficient personnel training and lack of supervision. The need for continuous training programs and better follow-up by supervisors was identified.
- **Machinery:** Deficient maintenance of safety equipment. A preventive maintenance plan was deemed necessary to ensure that all equipment was in good condition.

- **Environment:** Inadequate working conditions, such as poor lighting or disorder. It was proposed to improve lighting and apply the 5S methodology for a more organized environment.
- **Materials:** Inadequate storage of materials and scarcity of PPE. The importance of better organization of hazardous materials and ensuring the availability of protective equipment was highlighted.
- **Methods:** Lack of clear procedures for inspections and absence of audits. It was recommended to establish defined protocols and periodic reviews.
- **Measurement:** Lack of a system to evaluate safety. It was suggested to implement a real-time safety monitoring system.

**4.4 Improvement**

After the application of the methodology and follow-up control of each of the safety formats, the following improvements were obtained:

- **Forklift Qualitatives [Table 5]:** The compliance percentage in the qualitative evaluation of forklifts significantly increased from 68% [initial] to 89%. This made the forklifts safer for workers and decreased risks within the warehouse.

**Box 15**

**Table 5**

Forklift Qualitatives after improvements

Reporte de Cualitativos Cedi Obregon																									
Unidad de negocio Cedi Obregon Area Almacén Fecha 22/NOV/2024																									
Puntos de control	4036	4037	4039	4040	4043	13887	15828	15987	17895	17896	21873														
Claxon	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	13887 INACTIVOS													
Luces delanteras	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	15987 CHEQUEADO													
Luces traseras	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	4043 PILA													
Refrénico	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK														
Alarma de reversa	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK														
Editor	OK	OK	OK	OK	OK	OK	OK	OK	X	X	X														
Carga correcta	OK	OK	OK	OK	OK	OK	OK	OK	X	X	X														
Friete de mano	OK	X	OK	OK	OK	OK	OK	OK	X	X	X														
Cinturón de seguridad	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK														
Asiento	X	OK	OK	OK	OK	OK	OK	X	OK	X	OK														
Anti-desarranque	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK														
Luz delimitante roja	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK														
Luz delimitante Azul	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK														
Gas	90%	90%	95%	95%			90%		85%	85%	85%														
Observaciones	NO TIENE BASE PARA EXTINTOR, ASENTITO QUEBRADO																								
17895	EL ASENTITO ESTA DESPEGADO																								
15828	LE HACE FALTA EXTINTOR																								
21873																									
<table border="0"> <tr> <td>X</td> <td>No funcional</td> <td>TOTAL</td> </tr> <tr> <td>OK</td> <td>Funcional</td> <td>93</td> </tr> <tr> <td>INACTIVOS</td> <td>Taller</td> <td></td> </tr> <tr> <td colspan="2">% Cumplimiento</td> <td>89%</td> </tr> </table>														X	No funcional	TOTAL	OK	Funcional	93	INACTIVOS	Taller		% Cumplimiento		89%
X	No funcional	TOTAL																							
OK	Funcional	93																							
INACTIVOS	Taller																								
% Cumplimiento		89%																							

- **Forklift Checklist [Table 6]:** The problems previously detected decreased thanks to the daily inspection of the checklist. This had a positive impact on the productivity and safety of the equipment both inside and outside the warehouse

Box 16

Table 6

Forklift Checklist after improvements

ITEM	ESTÁNDAR	INSPECCIÓN											
		AG	LUN	MAR	ABR	MAY	JUN	JUL	AGO	SEPT	OCT	NOV	DIC
		S	N	C	S	N	C	S	N	C	S	N	C
<b>PARTE EXTERNA</b>													
Espejos laterales	Sin roturas, sin manchas y ajustado	X			X		X	X					
Luces traseras	De freno: mínimo dos / de color rojo / Direccionales: mínimo dos de color amarillo / Retrovisos: mínimo dos de color blanco	X			X		X	X					
Alarma de reversa	Función automática con el cambio de reversa.	X			X		X	X					
Extintor de incendio	Extintor PQT5 de 20 Libras / Recargado / Revisado	X			X		X	X		X			
Llaves	Llaves de aperturas y sin desgaste excesivo	X			X		X	X					
Placa de montacargas	En buena estado y legible	X			X		X	X					
Cilindros de elevación e inclinación	Libres de escape o daños	X			X		X	X					
Montura de los cilindros	Firme	X			X		X	X					
Indicadores luces frontales altas	Funcionando correctamente.	X			X		X	X					
Indicadores luces direccionales	Mínimo dos funcionando correctamente.	X			X		X	X					
Lámparas Luces delanteras	Lentes sin roturas/ funcionando / de color blanco / amarillo	X			X		X	X					
Indicador luces de parqueo	Mínimo dos / funcionando correctamente.	X			X		X	X					
Tanque de combustible	Sin fugas / ajustado / con tapa original y ajustada	X			X		X	X					
<b>COMPARTIMIENTO DEL MOTOR</b>													
Fuente de energía	Sin reajustes/ Aislado adecuadamente	X			X		X	X					
Conexiones eléctricas	Firmes y en buen estado	X			X		X	X					
Nivel agua refrigeración / Manijas	Nivel correcto / mangueras sin fugas	X			X		X	X					
Estado de las líneas hidráulicas	Líneas sin fugas y en buen estado	X			X		X	X					
Niveles de aceite motor / hidráulico	Niveles de acuerdo al fabricante.	X			X		X	X					
Filtro de aire	En buen estado	X			X		X	X					
Cableado eléctrico	Aislado / sin roturas / ajustados	X			X		X	X					
Botella de dirección / Nivel aceite	Sin fugas/ bien asegurado / nivel de acuerdo al fabricante	X			X		X	X					
<b>INTERIOR DE LA CABINA</b>													
Espejos retrovisor interior	Sin roturas / sin manchas / ajustado	X			X		X	X					
Indicador de combustible	La barra o indicador debe mostrar el nivel de combustible	X			X		X	X					
Indicador presión de aceite motor	Que se ilumine al encender el motor	X			X		X	X					
Pedales freno / clutch / gobernador	Con forro antideslizante / sin juego excesivo	X			X		X	X					
Gobernador	10 km/hora	X			X		X	X					
Claxon	Funcionando / que se oiga mínimo a 50 m.	X			X		X	X					
Tímido o volante	Funcionando en perfectas condiciones	X			X		X	X					
Frenos	Pedales con antideslizante/ nivel de líquido de acuerdo al fabricante	X			X		X	X					
Hórmetro	Funcionando, legible y dentro del rango del mantenimiento	X			X		X	X					
<b>Recomendaciones / Observaciones:</b>													
Fecha de seguimiento	22 DE NOVIEMBRE DE 2024	Responsable											

**Personal Protective Equipment [PPE] Compliance [Table 7]:** Notable improvements were observed in the use of PPE. Daily inspection and the application of incentives [souvenirs] encouraged all personnel to use the equipment daily during their workday.

Box 17

Table 7

Personal Protective Equipment [PPE] Compliance after improvements.

CONTROL DE USO DE EPP														
SEMANA 8 (18 DE NOVIEMBRE - 22 DE NOVIEMBRE 2024)														
TRABAJADORES	LUNES		MARTES		MIÉRCOLES		JUEVES		VIERNES		VIERNES		RESULTADOS	
	CASCO	CHALECO	CHALECO	GUANTES	GUANTES	ZAPATO	ZAPATO	CASCO	CHALECO	CHALECO	GUANTES	GUANTES		ZAPATO
														0
														20
														20
														20
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														20

**Training and Talks:**

Training sessions were held on "Lifting heavy loads" to help workers avoid injuries and perform activities more safely.

Talks were held on the correct and preventive handling of forklifts, including permitted maneuvers, and informational brochures were given to drivers to raise awareness about safe handling inside and outside the warehouse.

**Safety Verification Checklist [Table 8]:** All these improvements positively impacted the safety compliance percentage. By implementing a control follow-up, daily scoring the verification sheet, and reporting to the managers of each area, a compliance percentage of 96% was reached.

Box 18

Table 8

Safety Verification Checklist

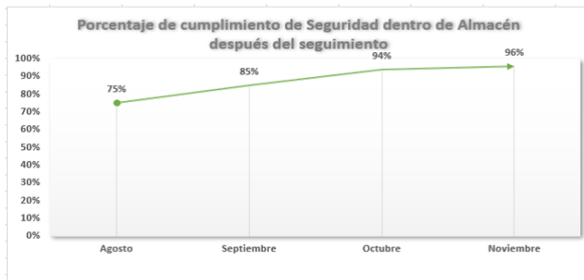
REQUISITO	EVIDENCIA	PUNTOS	RESULTADO	SEGUIMIENTO
<b>REQUISITO</b> Normas Específicas	En Orden	3	3	
<b>REQUISITO</b> Gases Comprimidos (Buzones, compresores, amoníaco, oxígeno y CO2)	En Orden	4	4	
<b>REQUISITO</b> Señales de advertencia / Etiquetas peligrosas	En Orden	5	5	
<b>REQUISITO</b> Seguridad Eléctrica (Jalisco, empalmes, cables, herramientas eléctricas y PPE)	En Orden	2	2	
<b>REQUISITO</b> Protección contra caídas (Escaleras, permisos y equipo de protección personal)	En Orden	3	3	
<b>REQUISITO</b> Equipo de Protección Personal	En Orden	9	9	
<b>REQUISITO</b> Herramientas y equipos en buen estado y utilizados conforme a su diseño	En Orden	2	2	
<b>REQUISITO</b> Control de líquidos - Líquidos inflamables	En Orden	6	6	
<b>REQUISITO</b> Seguridad en Almacenamiento	Mantencargas al día de hoy 60%.	6	6	
<b>REQUISITO</b> Botón de Tránsito	En Orden	2	2	
<b>REQUISITO</b> Chapa	En Orden	3	3	
<b>REQUISITO</b> Señales y avisos para protección GPE, Colores, formas y símbolos a utilizar	En Orden	4	4	
<b>REQUISITO</b> Ergonomía	En Orden	2	2	
<b>REQUISITO</b> Trabajos Peligrosos (Alturas, Calles, Espacios Confinados, con Electricidad)	En Orden	3	3	
<b>REQUISITO</b> Otros aspectos (Orden y Limpieza, Instalaciones, manejo de vidrio, manejo de cargas, etc)	En Orden	3	3	
		<b>57</b>	<b>55</b>	<b>96%</b>

This demonstrated that the warehouse became more optimal and safer for both workers and the product. Figure 10 graphs these achieved improvements.

## Box 19

**Table 11**

Graph showing the percentage of safety compliance within the warehouse after monitoring.



The results obtained show a considerable reduction in occupational risks, an optimization in the handling of goods, and an increase in the level of compliance with safety regulations. These indicators highlight the effectiveness of the applied methodology in strengthening safety and operational efficiency within the organization.

### 4.5 Control

To ensure the sustainability of the implemented improvements and guarantee their continuity, specific control measures were structured:

**Daily Inspection System:** The use of formats was established to evaluate the condition and use of forklifts, checklists, and compliance with the proper use of PPE, allowing for the identification of areas for improvement and the recording of relevant details.

**Structured Communication:** The results of the inspections are processed and communicated by sending email reports to the supervisors responsible for each area, facilitating immediate corrective actions.

**Weekly Reviews:** A system of scheduled meetings was implemented at the beginning of each week with supervisors and workers to analyze progress, discuss pending issues, and reinforce the importance of improvements for operational and product safety.

**Feedback Channels:** A continuous improvement approach was fostered by creating channels that allow for gathering personnel's perceptions about the implemented changes, which strengthens team commitment and identifies new opportunities for optimization.

These activities will be carried out by a checker, alternating weekly with a supervisor, to conduct the inspections and reports. Together, these actions ensure that the control of the improvements made is effective and sustainable, impacting both working conditions and operational results.

## 5. Conclusions

The successful implementation of a safety monitoring and control system in the company's warehouse operations has demonstrated its effectiveness in protecting the integrity of personnel and products, in addition to fostering an organizational culture of well-being and responsibility. The Lean Six Sigma DMAIC methodology was fundamental in this process, providing a structured framework and a robust database for the precise identification of problematic areas.

Thanks to this methodology, it was possible to exhaustively analyze the root causes of the safety challenges and establish sustainable solutions that guaranteed the protection of personnel and products, marking a milestone in warehouse safety management.

To ensure the continuity and constant improvement of safety conditions in the warehouse, the following recommendations are formulated for future work:

- Perform periodic and systematic evaluations that allow for proactively identifying new opportunities for continuous improvement in safety protocols and systems.
- Establish constant monitoring of key risk indicators to anticipate possible deviations and ensure a rapid response to any anomaly.
- Maintain open and transparent communication with all personnel, in order to reinforce commitment to safety and continuous motivation towards the adoption of safe work practices.

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## Student perceptions of Microsoft Teams as a collaborative learning environment in higher education

### Percepciones estudiantiles sobre Microsoft Teams como entorno de aprendizaje colaborativo en la educación superior

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#### Abstract




This study explores the perceptions of students from the Faculty of Mechanical and Electrical Engineering [FIME] at the Autonomous University of Nuevo León [UANL] regarding Microsoft Teams as an institutional platform for academic interaction. A digital questionnaire consisting of 35 questions was designed and distributed via institutional email to all students in the Faculty. The survey remained open for five days. A total of 483 responses were received, of which 352 included consent to participate. About 97.4% of respondents believe that Microsoft Teams facilitates communication and collaboration, and over 80% agree that the platform is easily accessible from various devices, centralizes course content, and provides effective tools for managing team organization. However, 18% reported some difficulty uploading and downloading files, indicating potential areas for improvement in user training or platform configuration.

#### Resumen

Este estudio describe la percepción que tienen los estudiantes de la Facultad de Ingeniería Mecánica y Eléctrica [FIME] de la Universidad Autónoma de Nuevo León [UANL] sobre Microsoft Teams como plataforma institucional para la interacción académica. Se diseñó un cuestionario digital conformado por 35 preguntas, que fue enviado por correo electrónico institucional a todos los estudiantes de la Facultad y estuvo accesible durante cinco días. Se recopilaron 483 respuestas, de las cuales 352 otorgaron consentimiento para participar. El 97.4% de los encuestados considera que Microsoft Teams facilita la comunicación y colaboración, y más del 80% está de acuerdo en que la plataforma se puede acceder fácilmente desde diferentes dispositivos, contiene el contenido del curso y tiene herramientas efectivas para gestionar la estructura organizativa del grupo. Sin embargo, un 18% expresa cierta dificultad para subir y descargar archivos, lo que indica posibles mejoras en la formación o la configuración del sistema.

Percepciones estudiantiles sobre microsoft teams como entorno de aprendizaje colaborativo en la educación superior		
Objectives	Methodology	Results
		

*Microsoft Teams, Collaborative learning, Higher education*

Percepciones estudiantiles sobre microsoft teams como entorno de aprendizaje colaborativo en la educación superior		
Objetivos	Metodología	Resultados
		

*Microsoft Teams, Aprendizaje colaborativo, Educación superior*

**Area:** Dissemination of and universal access to science

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## Introduction

The emergence and expansion of Virtual Learning Environments [VLEs] has dramatically changed teaching practices in higher education. In the specific case of collaborative work, this has evolved into new modalities due to digital platforms that allow students to interact, even remotely. This phenomenon was exacerbated by the COVID-19 pandemic, which forced educational institutions to abruptly switch to virtual learning, and the use of tools such as Microsoft Teams became one of the official instruments for ensuring academic continuity [UNESCO, 2021].

Different forms of collaborative work have been present in virtually every discipline throughout history, but they have become particularly relevant in recent years as a result of technological developments. Currently, these tools have been transferred to the educational sphere through the use of e-learning. The use of distance learning platforms facilitates the performance of certain tasks and improves performance. However, this change is conditioned by a series of factors such as instructional design, teacher mediation, and the attitudes of different actors in education towards the platform used [Rodríguez & Espinoza, 2017; García-Peñalvo, 2020].

In this regard, Microsoft Teams is one of the most preferred platforms by higher education institutions due to its combined use with other Office 365 applications, its structure in 'teams' and 'channels,' as well as its multitasking function, which integrates chat, video calls, file storage, and tasks. These aspects have been positively commented on in previous studies, which pointed out that it facilitates group work and provides experience in certain tools [Cabero-Almenara, Llorente-Cejudo & Marin-Diaz, 2020]. These points are summarised in Table 1.

However, the use of Microsoft Teams as a collaborative environment requires more than just a user-friendly interface. It is essential that students develop the necessary skills to use digital resources independently and responsibly. In the study by González-Sanmamed, Esteban-Guitart and Muñoz-Carril [2022], it was found that the usefulness of the platform is mediated by the level of digital literacy, previous experience with virtual environments, and the way in which teachers organise tasks and activities.

From the students' perspective, satisfaction with the virtual environment depends on clarity of purpose, immediate communication, and organisation of tasks by teachers. Research such as that by Mora-Vicarioli and Hooper-Simpson [2016] indicates that students experience an increase in motivation and sense of belonging to the working group when collaborative activities are well structured and supervised by a teacher. However, there are also limitations such as an unbalanced workload, low active participation, or the use of extra-institutional platforms such as WhatsApp or Google Drive, which are assumed to be more user-friendly. [Galván Orozco, Martínez Ávalos & Ortega Álvarez, 2022].

### Box 1

**Table 1**

Previous studies on digital platforms and student collaboration.

Author[s]	Year	Key findings
Galván Orozco et al.	2022	Students use other platforms due to familiarity and usability
González-Sanmamed et al.	2022	Positive perception depends on level of digital skills
Cabero-Almenara et al.	2020	Facilitates group work and task management
Rodríguez & Espinoza	2017	Lack of teaching guidance limits collaboration
Mora-Vicarioli & Hooper-Simpson	2016	Positive perception if there is interaction and clear structure

According to the table above, several studies have found positive results when using different platforms to improve knowledge transfer from teacher to student. Similarly, pedagogical support is one of the fundamental components for the successful use of these platforms. Therefore, the absence of monitoring by a teacher in a VLE often leads to disorganisation, lack of motivation and a decline in the quality of collaboration [Rodríguez & Espinoza, 2017; García-Peñalvo, et al. 2020].

Teacher mediation, understood as the provision of materials, space for dialogue and feedback, as well as a clear definition of expectations and assessment criteria, is crucial, particularly in virtual environments.

Ultimately, these considerations support the rationale for examining how students evaluate the application of Microsoft Teams as a collaborative learning environment. Understanding student experiences informs institutional decisions regarding frameworks, instructional design, and tools that truly align with collaborative patterns of activity in the university classroom.

## Methodology

To explore students' perceptions of their use of Microsoft Teams as a VLE in higher education, a mixed-method, cross-sectional, descriptive study was designed to assess students' perceptions of the use of Microsoft Teams. Information was collected using a self-administered digital questionnaire consisting of 35 items: 1 on consent to participate; 3 on personal data [age, gender, and educational programme]; 3 on the use of Microsoft Teams during the pandemic and currently; 22 evaluative items on a Likert scale on their perception of the platform; 1 dichotomous question on its overall usefulness; 2 multiple-choice questions on the use of alternative tools and platforms; and 3 open-ended questions on experiences and opinions.

The Likert scale was selected to evaluate perception and degree of agreement with the statements presented [1 = Strongly disagree, 5 = Strongly agree] because it has been used successfully in studies of attitude and perception in education [Joshi et al., 2015].

An invitation to participate was sent via institutional email to all students enrolled in the Faculty of Mechanical and Electrical Engineering [FIME] at the Autonomous University of Nuevo León [UANL]. Participation was completely voluntary, so the sampling process was self-selected. Data collection took place over a period of five consecutive days after the link to receive responses became available.

The questionnaire included questions related to accessibility, functionality, communication, organisation of collaborative work and, finally, general use and evaluation. The clarity of the items was reviewed by educators in educational technologies to ensure that all statements were understandable at the university level.

A total of 483 responses were received. Of these, 352 participants [72.9%] gave their consent to participate in the study, so only these responses were included in the analysis. The data were automatically stored in an Excel template, which allowed the data to be filtered and sorted according to the most relevant variables. Subsequently, tables and graphs were created to visually represent the distribution obtained.

The results were analysed using descriptive statistics, with a focus on the prevalence of certain findings and relationships regarding student perceptions. This allowed for an initial assessment of the degree of institutional acceptance and appreciation of Microsoft Teams, as well as possible pedagogical integration gaps that could be used in future training initiatives [García-Peñalvo et al., 2020].

## Results

Among the results obtained when applying the instrument, as well as in their analysis, the data were organised according to the thematic blocks of the instrument, allowing the identification of student perceptions regarding the functionality, accessibility, and usefulness of Microsoft Teams as a platform for collaborative work in the university context.

Table 2 shows the distribution of respondents with regard to their decision to participate in the research. Of 483 responses, 352 participants, representing 72.9% of the total, agreed to participate in the research. Of this group, 90 participants were female and 262 were male. At the same time, 131 people decided not to participate, so their responses were not considered in the subsequent analysis.

### Box 2

**Table 2**

Distribution of respondents according to their willingness to participate, n = 483

Respondents			
Agree to participate	352	Feminine 90	Male 262
Do not agree to participate	131		
<b>Total</b>	483		

Regarding perception questions, the seven most representative questions were selected from a block of 28 questions.

Table 3 summarises the responses obtained, which evaluated students' perceptions of the key features of Microsoft Teams as a platform for collaborative work. The statements were rated on a five-point Likert scale, ranging from "Strongly disagree" [1] to "Strongly agree" [5], considering a total of 352 valid responses.

### Box 3

**Table 3**

Responses received to the seven most representative questions through the self-administered digital questionnaire,  $n = 352$ . Interpretation: 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree.

Question / Likert scale	1	2	3	4	5
1. It allows you to easily access its platform from any device.	16	12	33	140	151
2. It allows you to access course content and documents.	16	18	29	136	153
3. It has the essential tools to carry out the teaching-learning process.	11	7	38	162	134
4. It allows you to upload and/or download documents of any type.	32	38	40	115	127
5. It allows synchronous and asynchronous communication.	11	3	17	137	184
6. It has effective communication tools and channels.	10	11	38	145	148
7. It helps you maintain organisation among team members.	13	7	39	150	143

The first of these explores whether Microsoft Teams allows easy access from any device. Here, there is a strong positive trend, as 82.7% of respondents [sum of categories 4 and 5] indicated that they agreed or, even better, strongly agreed with this statement.

This shows that the platform is considered accessible and functional from different devices, which is essential in contexts of mobility and technological diversity.

Secondly, respondents were asked whether the platform allows access to course content and documents. Students who agree or strongly agree represent 86.6%, a highly positive result and even higher than the previous one, suggesting that the system for storing and distributing digital resources in Teams is suitable for the academic needs of students.

The third point inquired about the availability of tools that make up the kit necessary to carry out teaching and learning activities.

The perception is that 84.1% affirm that Teams not only allows for the exchange of files or messages, but is also equipped with tools that manage educational processes in a broad sense.

In contrast, the fourth item responded to flexibility, where the responses were more dispersed. It was measured whether the platform allows the uploading or downloading of documents of any type and whether the level of difficulty was at acceptable levels. In this regard, 65.6% agreed; however, up to 20% stated that they disagreed or strongly disagreed. This result may be associated with a lack of technical skills, lack of knowledge, or restrictions on certain types of documents.

The fifth element focused on one of the most important dimensions of collaborative work: synchronous and asynchronous communication. Based on the results, 91.2% of students responded that they strongly agreed. This reinforces the potential of Microsoft Teams as a multifunctional tool that allows for synchronous and asynchronous interactions, which is essential for coordinating teams with different levels and schedules.

Regarding point number six, which explores whether the platform has communication tools and channels that meet the needs, 83.2% of respondents agreed or strongly agreed. This suggests that, beyond providing multiple channels, the platform integrates them in such a way that teamwork is possible.

Finally, item seven dealt with the extent to which Microsoft Teams was considered to help keep group members organised. In this case, a total of 83.8% of students agreed and strongly agreed, highlighting the value that the platform offers for structuring, coordinating, and following up on shared activities and processes.

In conjunction with the above aspects, a dichotomous [Yes/No] question was asked about whether students considered Microsoft Teams to enable communication and collaboration to fulfil academic duties.

Table 3 presents the responses to this question. Of the total 352 valid responses, 343 students [97.4%] responded positively, which seems to be a very favourable view of the interaction and collaborative work that can be done through the platform in the university setting.

**Box 4****Table 4**

Perception of Microsoft Teams as a useful tool for activities, n = 352

Do you consider that Microsoft Teams enables you to communicate and collaborate with others in carrying out academic activities?			
Total responses	352	Yes 343 [97.4%]	No 9 [2.6%]

In contrast, nine participants [2.6 per cent] indicated that they disagreed with this statement, representing a minimal percentage. This finding supports the hypothesis that, in general, Microsoft Teams is seen as a tool that enables the use of online collaboration resources, in line with the requirements of digital higher education. The widespread acceptance also indicates that there is considerable use of the tool, as well as a favourable attitude towards its applicability in group academic work.

**Conclusions**

The results obtained in this study support the view that Microsoft Teams is perceived in a largely positive light by students at the Faculty of Mechanical and Electrical Engineering [FIME] as a virtual environment for collaborative learning. Virtually all participants [97.4%] affirm that the platform aids communication and collaborative work in the completion of academic activities, and more than 80% agree that it facilitates access and is useful for organising tasks.

These perceptions are consistent with the literature and emphasise the functionality of Microsoft Teams in concentrating resources, promoting asynchronous and synchronous communication, and assisting in collaborative activities in higher education environments [Cabero-Almenara et al., 2020; González-Sanmamed et al., 2022]. In any scenario, it should be noted that the efficiency of e-learning environments is not only determined by the tool they use, but also by how the tool is used in the teaching process with clear guidance, established learning objectives, and thoughtful instructional design [Rodríguez & Espinoza, 2017; García-Peñalvo, et al, 2020].

On the other hand, the information gathered also reveals some areas of opportunity that require attention. For example, students report some concerns, particularly with the functionality of file upload and download features, with 18% disagreeing due to the difficulties encountered.

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This point demonstrates both the need to improve the digital literacy skills of students and teachers and to verify the compatibility of the files they wish to share. It should be remembered that Microsoft Teams is an additional tool for improving collaborative knowledge building, and its functions should not be automated without periodic reviews, nor should it be expected to completely replace face-to-face lessons.

From a teaching perspective, the results obtained indicate that teachers should reflect on their role within virtual environments. Although tools such as Microsoft Teams offer countless resources and communication possibilities, they must be used with a clear objective to prevent true collaboration from being reduced to simply completing and submitting tasks. Thus, it is essential that faculty members take responsibility for actively designing, monitoring, and evaluating collaborations, systematising the flow of knowledge towards equitable and active construction by the group.

In terms of future lines of research, it is pertinent to delve deeper into individual and group experiences with the use of these platforms, as well as previous technological experience or course type. It could also be interesting to conduct a comparative study of teachers' perceptions and behaviour regarding the strategic implementation of Microsoft Teams in other institutional contexts.

**Declarations****Conflict of interest**

The authors declare that they have no conflict of interest. They have no known competing financial interests or personal relationships that could have influenced the article reported in this article.

**Contribution of the authors**

*Torres-Díaz, Anel Jacaranda:* contributed to the project idea and research technique.

*Esparza-Mendoza, Francisco Javier:* contributed to the research method to be used.

*Quiroz-Aguilar, Jesús Alejandro:* contributed to the analysis of results and preparation of the document.

## Funding

The research was conducted independently and on the basis of the merits of the data developments.

## Availability of data and materials

Public domain.

## Abbreviations

FIME. Faculty of Mechanical and Electrical Engineering  
UANL. Autonomous University of Nuevo León  
VLE. Virtual Learning Environments

## References

### Background

Cabero-Almenara, J., Llorente-Cejudo, M. C., & Marín-Díaz, V. [2020]. [Entornos virtuales de aprendizaje y tecnologías emergentes: Una visión desde la innovación educativa.](#) *Educación XX1*, 23[1], 83–106.

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## Discusión

Cabero-Almenara, J., Llorente-Cejudo, M. C., & Marín-Díaz, V. [2020]. [Entornos virtuales de aprendizaje y tecnologías emergentes: Una visión desde la innovación educativa.](#) *Educación XX1*, 23[1], 83–106.




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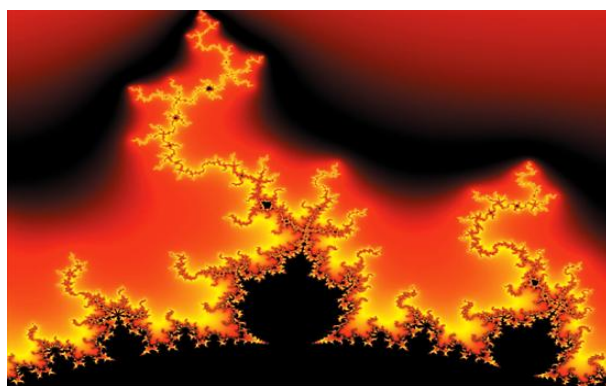
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