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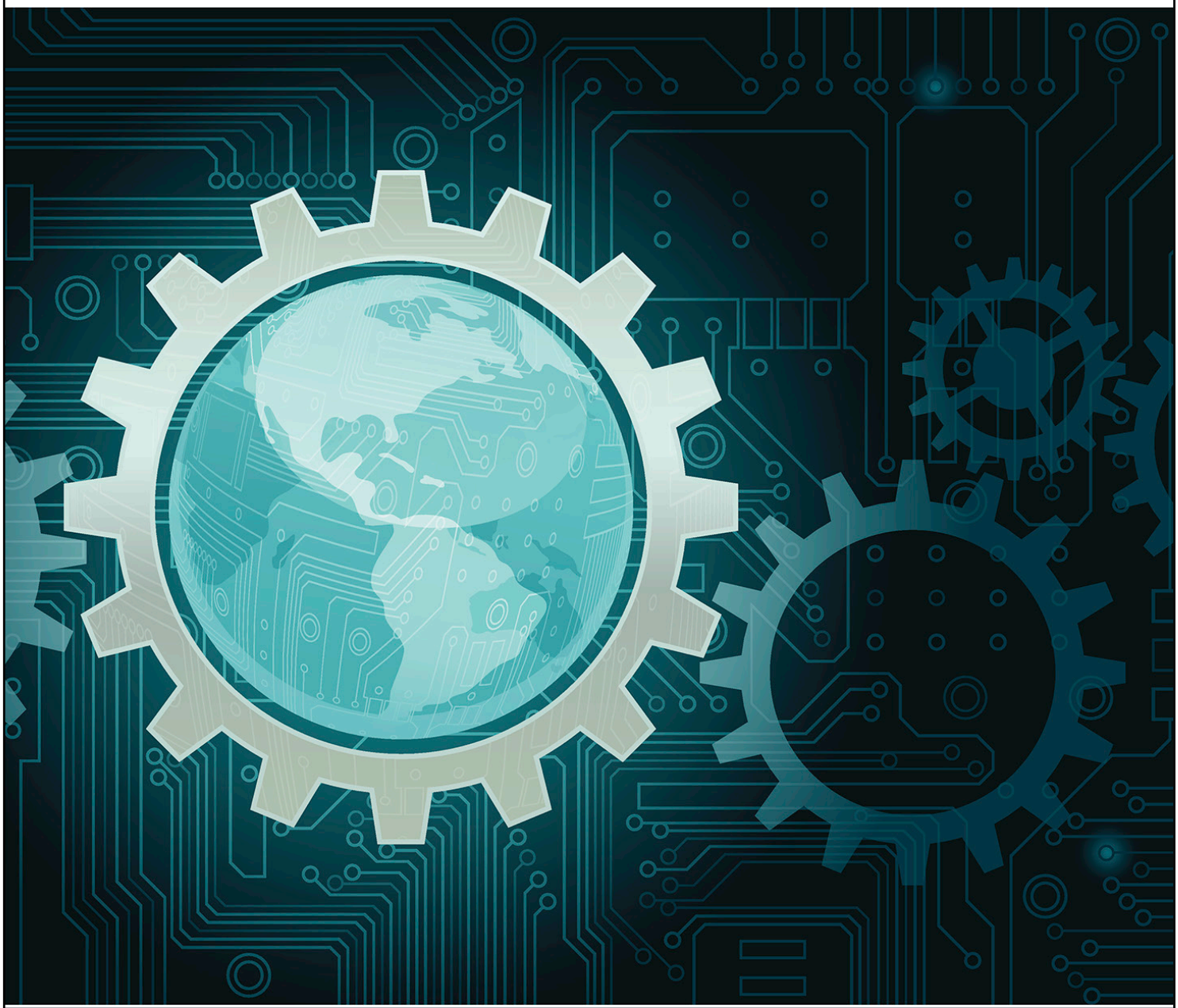

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SUMARIO ● SUMMARY ● RESUMO

Formulation of a new electrical safety management system and assessment of its impact throught a case study in chilean large-scale mining

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Editorial

This issue of Project Design & Management consolidates in a multidisciplinary framework the academic and scientific research of our collaborators in the design, development, implementation and validation of tools and instruments applicable to business development, integrated projects and engineering. Innovation in scientific-technological development is a fundamental feature reflected in the main objectives of the journal as part of its lines of research and dissemination. This new edition presents nine articles selected for their content in technological innovation and methodology implemented by the authors for their publication. The main research corresponds to the discipline of management and business development integrating optimization methodologies in Project Management Offices (PMO) and the design proposal for projects under consolidated global practices that will allow an efficient operation that maintains an adequate social impact. Research reflecting versatile and innovative engineering techniques and methods highlights the challenges and obstacles that can arise in the technological transition from traditional cities to smart cities. Within the engineering, technological and multidisciplinary research, this new edition presents the integration of civil engineering construction issues with methods that conserve the environment and reduce negative impacts on ecosystems, through the development of construction elements with construction waste from various buildings. The effective use of BIM methodology is presented under a futuristic new trend scenario to develop intelligent infrastructure projects implemented in hospital infrastructure. In a transition of business disciplines, social policies and mining engineering, a comparative analysis of policies applied to the oil sector in Latin America and the proposal of an electrical safety system that will optimize mining production are presented.

The first article presents the creation and systematic validation of an agile and practical tool to identify knowledge, attitudes and practices (KAP) on competitive intelligence (CI). This tool was validated by experts and culminated with a pilot application to measure its reliability through Cronbach's Alpha index, resulting in a tool that favors management, scientific, commercial or governmental methodologies or actions that promote the competitive permanence of microenterprises and, therefore, the sustainable economic development of the regions.

The World Class Manufacturing (WCM) is an innovative system of integrated management of manufacturing operations that is presented in the second article applied in the automotive sector in Mexico by conducting 201 surveys to experienced professionals in WCM, where the results indicate that management commitment, comprehensive skills, type of leadership, involvement and organizational culture directly influence the benefits of organizations that implement the WCM in this way it is established that organizations can develop actions to mitigate risks and to strategically plan the results and resources needed in the short, medium and long term.

The third article analyzes the effectiveness of Project Management Offices (PMO) in the Dominican Republic, under an empirical approach, using information from 57 companies, evaluating the impact of the existence of a PMO on the fulfillment of key objectives, such as schedule, budget, scope, and client and team satisfaction. The results indicate that, although the presence of a PMO may be associated with greater formalization and structure in project management, it does not necessarily guarantee greater success in all the dimensions evaluated. The study concludes that the implementation of a PMO must be accompanied by a comprehensive approach that considers the specific cultural and organizational context of each company.

The research presented in the fourth article of this issue confirms that effective project management is a central pillar for organizational success, particularly under results-oriented methodologies such as Project Management for Results (PM4R). This study proposes an innovative maturity model for PM4R, based on a synthesis of the most recognized maturity models such as CMMI, OPM3, Kerzner Model, PRINCE2 Maturity Model and P3M3. The findings reveal that an integrated, results-oriented maturity model not only improves the efficiency and effectiveness of project management, but also facilitates a culture of continuous improvement and adaptability in diverse contexts.

The objective of the fifth article, reflects the important points that the main managers and decision makers must solve, such as digital infrastructure, citizen participation and sustainable urban planning, to make possible a smart city in Juazeiro do Norte, Brazil, detailing which are the most important challenges that must be faced by the municipal administration. The article concludes by emphasizing the need for collaborative strategies and investments to drive smart city transformation.

The sixth article integrates the relationship between construction technology and the environment, to be used in the construction of housing using the system of non-structural lightened walls. With this construction system, this new non-traditional construction technology is made known, since it integrates materials of regional origin and low ecological impact, in order to achieve environmental, economic and social constructive sustainability. The above reflects a replicable methodology for the proper management of construction waste in different geographical sectors at the local, national and international levels.

The seventh article, as a documentary research with a socio-critical approach, presents a comparative analysis of the actions and results shown by three Latin American oil companies (Ecopetrol, Pemex and Petrobras) in their annual corporate social responsibility reports. The research presents the most important data related to the three dimensions of sustainability: economic, environmental and social, based on the annual sustainability reports of the three companies. The article concludes that, although the three Latin American oil companies prepare their reports based on the three dimensions of sustainability, they have not yet reached the optimal levels of social and environmental investment required to achieve the sustainable development goals set out in the 2030 Agenda.

Finally, the eighth research presents the design of an electrical safety management system based on the requirements of ISO 45001 and technical standards such as NFPA 70E and IEEE 3007.2. The system was validated through diagnostic audits of companies from various economic activities that evaluated their electrical safety management. The results of these audits indicated that all the companies audited carried out specific actions, but electrical safety management was not performed. They also demonstrate the positive impact of the system on the benefits obtained by increasing compliance with legal regulations, such as reducing accidents to people, reducing costs due to damage to equipment and facilities and optimizing operational costs, seeking the safe and efficient use of electrical energy.

Before concluding this editorial, it is important for all of us who collaborate in this new project to thank the team of collaborators, IT and technical, as well as the Ibero-American University Foundation (FUNIBER) and the Universities that have provided all the material support so that this issue can be carried out, with the conviction that we are on the right path towards international recognition.

Dr. Luis A. Dzul López
Dr. Roberto M. Álvarez
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CREACIÓN Y VALIDACIÓN DE UNA HERRAMIENTA PARA IDENTIFICAR CONOCIMIENTOS, ACTITUDES Y PRÁCTICAS DE INTELIGENCIA COMPETITIVA EN MICROEMPRESARIOS

CREATION AND VALIDATION OF A TOOL TO IDENTIFY KNOWLEDGE, ATTITUDES AND PRACTICES OF COMPETITIVE INTELLIGENCE IN MICROENTREPRENEURS

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microenterprise, sustainability, competitiveness, competitiveness, tool, competitive intelligence

ABSTRACT

One out of every two microenterprises survive during the first 5 years of its operation, due to factors such as lack of knowledge about the business environment and its administrative and financial structures, on the part of its managers and employees. In this scenario, competitive intelligence (CI) represents an alternative solution in the midst of the current changing and accelerated pace of doing business, including those associated with the Covid19 pandemic. However, the existing competitive intelligence implementation methodologies are currently very complex and costly for smaller companies, which is why this non-experimental cross-sectional research is based on the creation and systematic validation of an agile and practical tool to identify knowledge, attitudes and practices (KAP) on CI, starting with a systematic review of the state of the art related to the concepts of microenterprise and CI, a review of Competitive Intelligence questionnaires and Knowledge, Attitudes and Practices (KAP) questionnaires; and then a content validation by experts, and culminating with a pilot application to measure its reliability through Cronbach's Alpha index; resulting in a tool that favors methodologies or managerial, scientific, commercial or governmental actions that promote the competitive permanence of

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microenterprises, and therefore, the sustainable economic development of the regions.

Palabras clave:
microempresa, sostenibilidad, competitividad, herramienta, inteligencia competitiva

RESUMEN

Una de cada dos microempresas sobrevive durante los primeros 5 años de su funcionamiento, debido a factores como la falta de conocimiento sobre el entorno empresarial y sus estructuras administrativas y financieras, por parte de sus directivos y empleados. En este escenario, la inteligencia competitiva (IC) representa una alternativa de solución en medio del actual ritmo cambiante y acelerado de hacer negocios, incluyendo los asociados a la pandemia de Covid19. Sin embargo, las metodologías de implementación de inteligencia competitiva existentes, resultan hoy por hoy muy complejas y costosas para las empresas más pequeñas, razón por la cual, la presente investigación transeccional no experimental, se basa en la creación y validación sistemática de una herramienta ágil y práctica para identificar conocimientos, actitudes y prácticas (CAP) sobre IC, partiendo de una revisión sistemática del estado del arte relacionado con los conceptos de microempresa e IC, una revisión de cuestionarios de Inteligencia Competitiva y sobre Conocimientos Actitudes y Prácticas (CAP); para luego ejercer una validación de contenido por expertos, y culminando con una aplicación piloto, para la medición de su confiabilidad a través del índice Alfa de Cronbach; dando como resultado una herramienta, favorecedora de metodologías o acciones gerenciales, científicas, comerciales o gubernamentales, que promuevan la permanencia competitiva de las microempresas, y por ende, el desarrollo económico sostenible de las regiones.

Introduction

Microenterprises are the backbone of the world's economies and a key factor in reducing poverty and promoting sustainable development globally (ILO, 2019). They represent more than 90% of enterprises, generate between 60% and 70% of employment and are responsible for 50% of the world's GDP (Stefanikova, Rypakova & Moravcikova, 2015).

According to International Labor Organization (2019), in most countries in the world, more than 90% of all companies can be considered micro, small and medium-sized enterprises (MSMEs), and many of these are classified as microenterprises when they have fewer than ten workers; This size may be considered very small when viewed in isolation, but when considered as a whole, microenterprises account for 70% of global employment and more than 50% of new jobs worldwide (Dini, Marco & Stumpo, 2018).

However, they tend to disappear every year, since in countries in Europe, North, Central and South America and the Organization for Economic Cooperation and Development (OECD), during the first year of operation, they disappear between 20 and 30%, reaching more than 50% in the fifth year. This can be explained by the need to strengthen factors such as schooling, knowledge in the management of administrative and financial structures and the market to which microentrepreneurs and their employees belong (ONU, 2019; Sustainable Development Goals Fund, 2017).

According to Dini & Stumpo (2018) and García et al. (2015) this may be due to the fact that MSMEs have heterogeneous structures specialized in low value-added products, which in turn is related to the difficulty they have in incorporating technical or technological advances, in having bargaining power with their customers and suppliers, in accessing social networks and in having options for upward occupational mobility throughout their working lives; all of this directly influences their performance and their competitive permanence in the market, generating vicious circles of low economic growth, poverty and reduced structural change in the region (see Table 1).

Table 1
Business survival in the world

Country	Survival business in 1 year	Survival business in 3 years	Survival business in 5 years
France	77.9	66.4	51.5
United States	79.4	61.9	51.0
Spain	76.4	55.1	49.5
Chile	85.2	63.0	49.4
Argentina	-	60.1	49.1
Italy	83.3	61.3	47.1
Netherlands	92.6	68.1	45.3
Bulgaria	79.2	60.3	43.9
Poland	87.9	55.7	43.8
Norway	83.7	53.4	43.6
Colombia	78.3	61.0	42.9
United Kingdom	86.3	49.6	39.7
Germany	76.8	50.2	39.6
Mexico	67.0	-	35.0
Portugal	69.0	35.3	29.6

Note. Source: Confecámaras (2017).

These microenterprise survival rates have been explained by various authors from different points of view, including Cordero et al. (2019) and ILO (2019) who describe as contributing factors the type of family relationships, operational costs, lack of financing, market competition, regulatory complexity and the knowledge and experience of both managers and their workforce.

The first are associated with psychological factors, under which entrepreneurial activity and its survival are related to the person's ability to identify business opportunities and transform them into companies. The second, or managerial factors, are associated with the experience, training, knowledge and skills necessary for decision making.

Similar panorama is observed in Colombia and in the Department of Santander, where, in the latter, there are two Chambers of Commerce that cover the total data on companies registered in the region, corresponding to the Jurisdictions of the cities of Bucaramanga and Barrancabermeja respectively, according to which, the total number of new ventures registered in 2018 was 16. 004, of these, 99% were microenterprises represented mainly in the Commerce (42%) and Services (27%) sectors (Bucaramanga Chamber of Commerce, 2019; Barrancabermeja Chamber of Commerce, 2020).

The above, according Remacha (2017) highlights the decisive role that microenterprises play in achieving the SDGs, giving governments the responsibility to develop policies, plans and programs for sustainable development, promoting an ideal scenario where markets are stable, regulated and competitive, financial systems are

transparent, government institutions are free of corruption, raw materials and energy are accessible, consumers have purchasing power and employees are qualified.

In this scenario, CI, defined by Gógova (2015) as the dynamic, systematic and recursive process that transforms, using specific analytical techniques, the relevant and legally obtained information on the competitive environment of companies, with the purpose of facilitating decision making for their benefit; today, the definition of Competitive Intelligence continues to evolve and remains a matter of debate among different authors or experts in the field, describing in Table 2 the closest to the object of this study.

Table 2

Current Concepts on Competitive Intelligence (CI)

Authors/Entities	Concept
Silva e De Muylder (2015)	Systematic process that transforms dispersed data into strategic knowledge. It is information about specific products and technology, it is monitoring external information that affects the organization's market, related to economic, regulatory, political and demographic aspects.
Strategic and CompetitiveIntelligence Professionals (2015)	It is an ethical and systematic process of collecting, analyzing and disseminating relevant, accurate, specific, timely, predictable and active information about the business environment, competitors and the organization itself.
Gógova (2015)	Dynamic, systematic and recursive process that transforms, using specific analytical techniques, the relevant and legally obtained information on the competitive environment of the past, present and future, with the purpose of facilitating decision making for the benefit of the company.
Ortoll and Garcia (2015)	A management process that provides a methodological framework for establishing the necessary mechanisms for capturing information from the environment, analyzing it and obtaining value-added information to be applied to the decision-making process in any part of the organizations' value chain. The function and process of intelligence are widely accepted, but there is a lack of consensus on the terminology used to define them.
AENOR (2018)	The ethical and systematic process of gathering and analyzing information about the business environment, competitors and the organization itself, and communicating its meaning and implications for decision making.

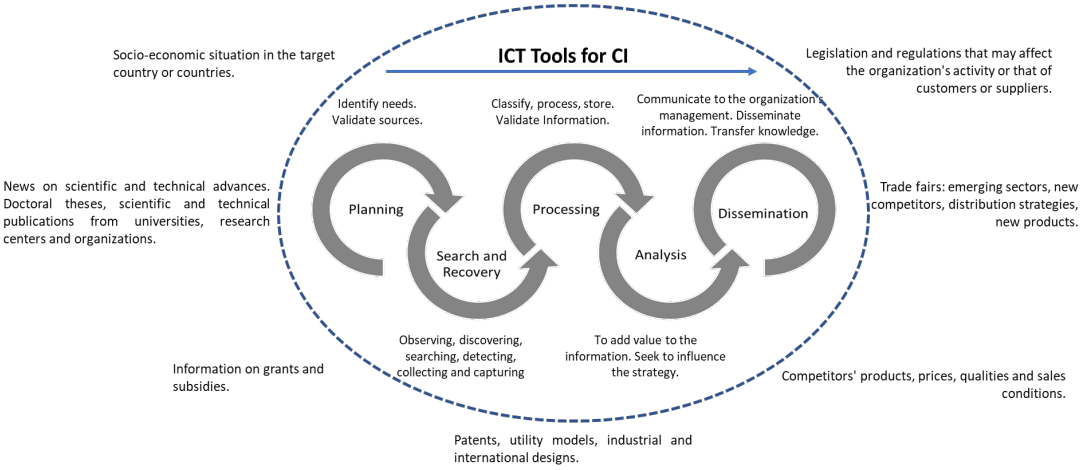
Thus, Competitive Intelligence at the enterprise level, is proposed by Stefanikova et al. (2015) as a management strategy that should be integrated into the structure of organizations and that begins with the definition of a specific business problem, where having clear knowledge of the internal and external aspects of the organization, strategic decision making is reached with the implementation of the best alternative solution, which efficiently responds or anticipates the current changing and accelerated pace of business environments, where business survival no longer depends on the strongest company, but on the one that best and fastest adapts to such changes as those generated in the current pandemic by Covid19.

Therefore, CI in the business environment is understood as a cycle that begins with a specific business problem or need, passing through the knowledge of the internal and external aspects of the organization, and ending with strategic decision making based on evidence, facilitating the identification and implementation of the best alternative solution, according to the characteristics of each organization and its environment. However, as well as the concept of competitive intelligence, the different stages that must be fulfilled for its implementation in the companies is a matter of discussion, being the most accepted for the purposes of this study the proposal described below (Seyyed, et al.,

2016; Gógova, 2015; The Innovation Agency of Bizkaia, 2015; Ortoll & Montserrat, 2015; Spanish Association for Standardization, 2018). According to these authors, it involves collecting data to determine usable information, which can be classified into three types: Open source information or White Information, Gray Information which represents non-public domain information 95 and Dark Information / Espionage which corresponds to illegally collected information (see Figure 1).

Figure 1

Phases of Competitive Intelligence in the business context.



Taking into account the objectives of this study, which are described business competitiveness concepts of several authors such as (Chamber of Commerce of Spain, 2020; Porter, 2016), which, can be adopted by microenterprises, according to business competitiveness models based on innovation models described in this research (Kuratko & Frederick, 2016; Porter, 2016).

Table 3

Concepts of Business Competitiveness

Author	Concept	Characteristics
Michel E. Porter (2016)	Value that a company manages to create for its customers. It can be translated into lower prices than competitors, equivalent benefits or by offering special benefits that compensate for a higher price.	A company's ability to do things better than its competitors, whether in terms of service, product, production, costs, prices or quality, in such a way as to represent an advantage over its competitors.
Cámara de Comercio de España (2020)	Companies are the ones that compete and must possess competitive advantages, but it recognizes the crucial role played by the environment in which the company operates.	They vary according to geographic location or economic sector, because it is essential to identify the critical factors that can lead to business differentiation and actions to improve them.

According to Fuentes et al. (2016), it is correct to state that currently, the definition of business competitiveness has not yet reached a global consensus, which is still under development, without precise limits and without a single definition, generating ambiguities or academic or technical debates when trying to define it. However, there is

unity on the criteria involved in its genesis, such as the creation of sustainable advantages and the production of goods and services with added value, which give businesses the ability to achieve an advantage or superior performance over their competitors.

Thus, the research was based on the systematic generation of a tool that allows the identification of KPIs for strategic business planning and management by microentrepreneurs in the department of Santander, located in northeastern Colombia.

The article is structured as follows: first the population and sample are described, then the systematic process of creating the tool, starting from the conceptualization and relationship between microenterprise and Competitive Intelligence, and finally, the results and discussion of the process of construction and validation of the tool in the microenterprise environment are presented, taking into account the current context of the Sustainable Development Goals (SDGs) in the midst of the Covid19 pandemic.

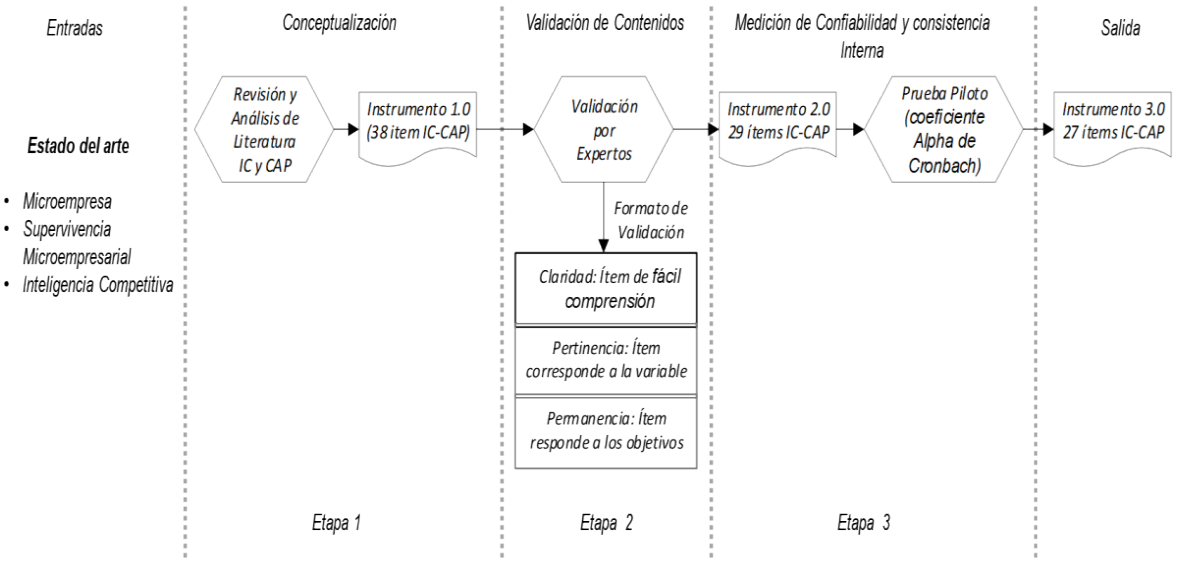
Methods

The methodological design used was non-experimental, transectional or transversal, since the information was collected at a single moment during the research, without modifying the phenomenon or object of study, recording the data collected from the selected sample, without any type of manipulation of the variables or cause-effect correlation between them. Thus, the KAP-CI identification instrument was created in a systematic process in several stages, starting from the state of the art or conceptualization related to microenterprise, Competitive Intelligence, methodologies and methods of implementation of CI at the enterprise level and the questionnaires on Knowledge, Attitudes and Practices (KAP).

After the systematic review of the literature following the PRISMA methodology, an initial instrument called 1.0 was proposed with 38 items, distributed in the variables to be measured, such as: (i) educational level, (ii) knowledge about CI, (iii) attitude about CI, establishing the level of agreement or disagreement with a Likert-type scale, and finally, CI practices.

The next step was a content validation by experts, and, culminating with the measurement 122 of reliability and/or internal consistency, by determining the Cronbach's Alpha index of each of its sections, which, for the purposes of the research, was taken as a minimum reference an index of 0.7 in ascending direction approaching one (see Figure 2).

Figure 2
Systematic construction process of the instrument



The variables measured and analyzed are quantitative in nature and are defined below:

- *Micro-entrepreneurs*: In Colombia, it corresponds to the Legal Entity that according (Law 905, 2004) has the category of microenterprise for having up to 10 workers and total assets below 500 minimum monthly salaries in force.
- *Knowledge of CI*: Set of things known, of knowledge, of "science" about CI, which includes the capacity to represent oneself, the own way of perceiving or understanding CI. The degree of knowledge ascertained makes it possible to situate the areas where information and education efforts are needed (Medecins Du Monde, 2010).
- *Attitudes towards CI*: A way of being, a position of microentrepreneurs about CI. It is about tendencies, about "dispositions to". It is an intermediate variable between the situation and the response to that situation (Medecins Du Monde, 2010).
- *CI practices*: These are observable actions of an individual in response to a stimulus. They are the concrete aspect, the action on the use of CI and way of doing it (Medecins Du Monde, 2010).

Population and Sample

The population consisted of 242 microenterprises registered during 2019 in the database of a non-governmental organization, which are scattered in the department of Santander; for this reason, and given the current biosecurity conditions for Covid19 in the country and the world, which limit access to the sample units in person, the pilot test of the instrument was applied virtually to a sample, thus facilitating access to each entrepreneur, respecting the biosecurity measures against Covid19, and the efficient use of resources during the process; The pilot test of the instrument was applied virtually to a sample, which made it easier to reach each entrepreneur, respecting the biosecurity measures against Covid19 and the efficient use of resources during the planning, logistics and data 152 collection processes.

Subsequently, with the obtaining of a sample of 30 non-probabilistic microentrepreneurs for the application of the pilot test, according to Salgado (2019) with a confidence level of 95%, error of 5% and a variability of 95%, we proceeded to the selection of the sample elements, according to (Hernández Sampieri & Mendoza Torres, 2018), through a table of random numbers, selecting every 3 elements to the entrepreneur until reaching the number of the established sample, in the department of Santander, independently and with the same possibility of being chosen.

Results

The instrument was validated, through the following stages (Berges, 2018; Bolio & Pinzón, 2019; Fernández, Santos & Carvalho; 2015):

Content Validation

The 1.0 instrument was reviewed by a group of experts, who analyzed the following aspects of each item:

- *Clarity*: the approach is easy to understand or is confusing. If the item is confusing.
- *Relevance*: correspondence between the item and the variable
- *Permanence*: whether the item should remain as part of the instrument, since it responds to the objectives of the study.

Thus, taking Instrument 1.0 as a basis, the validation was carried out by experts, who considered its 38 items in the light of the following sections of the research: i) Description of the Instrument Validation Process; (ii) Statement of the Study Problem; (iii) General and Specific Study Objectives; (iv) Study Research Questions; and (v) Study Hypotheses.

With the above, the group of experts reviewed and evaluated the clarity, relevance and permanence of each item in the instrument, making the adjustments recommended by them to the instrument 1.0, resulting in the instrument 2.0 accepted and/or validated by the technical experts, with a number of 29 questions or items, distributed in the variables, as follows: (i) it was renamed "Basic Data of the Interviewee and the Company", (ii) the "Knowledge about CI" (See table 3.11), (iii) the "Attitude about CI", establishing the level of agreement or disagreement with a Likert-type scale, to which was eliminated within the possible answers "I don't care" and remained, the option to answer "I don't know"; and finally, (iv) the "CI Practices".

Reliability and Internal Consistency Measurement

At this stage, the instrument 2.0 is subjected to a pilot test on 30 microentrepreneurs with the pertinent informed consent, randomly selected from a database, with the results of which the Cronbach's Alpha coefficient is estimated section by section or variable of the instrument: i. Basic Data of the Interviewee and Company, ii. Basic Data of the Respondent and the Company, ii. Knowledge about CI iii, Attitude about CI and v. CI Practices section by section of the instrument. CI Practices section by section of the instrument Thus, the internal consistency of the instrument is determined in each section, where regarding its interpretation according to (Hernández & Torres, 2018) citing several authors, and for the purposes of this study, taking into account that it is the first time that an investigation of this type is carried out in the department of Santander and worldwide there are few instruments based on KAP on CI, the minimum value of the

reliability coefficient taken as acceptable, was 0.7 ; resulting in the 3.0 or final version; with a total number of 29 items distributed in the different sections of the tool.

The measurement of Cronbach's α coefficient was carried out section by section of the instrument, obtaining in the first instance a coefficient of 0.69 in section (i) Basic Data of the Interviewee and the Company. With this global data of the Cronbach's Alpha coefficient of section i, we proceeded to analyze each of its reagents or items with less bivariate correlation, finding that by eliminating item S.1.5, we would obtain a Cronbach's α of 0.806 (see table 3).

Table 3
Cronbach's Alpha Coefficient Analysis Section i.

Items	Total correlation of corrected elements	Cronbach's alpha if itemis deleted
S.1.1 Indicate the total years of your work and/or professional experience.	0.943	0.314
S.1.2 Indicate your company's average annualincome (in Colombian pesos)	0.875	0.37
S.1.3 Indicate your education level	0.612	0.583
S.1.4 Indicate the Sector to which your company belongs	0	0.738
S.1.5 Indicate your company's business scope	-0.153	0.806

Similarly, when analyzing section (ii) Knowledge about CI, a Cronbach's α of 0.856 was obtained, indicating a bivariate correlation that allowed the total permanence of the items in this section (see Table 4).

Table 4
Cronbach's Alpha Coefficient Analysis Section ii.

Cronbach's alpha	Number of elements
0.856	6

In the global analysis of section (iii) Attitudes on Competitive Intelligence, an indicator of 0.575 was found, for which reason it was necessary to analyze the bivariate correlation of each of its elements, finding that, according to the forecast provided by the statistical program, by eliminating item A.1.8, a satisfactory result of Cronbach's α of 0.701 would be obtained (see Table 5).

Table 5
Analysis of Cronbach's Alpha Coefficient Section iii

Item	Total correlation of corrected elements	Cronbach's alpha if item is deleted
A.1.1 The use of Competitive Intelligence in the company is key to make decisions focused on the sustainability, development and/or growth of the company.	0.26	0.568
A.1.2 Obtaining information on the company's competitive market environment in an ethical and systematic manner is complex and costly.	0.988	0.146
A.1.3 Analyzing and interpreting the information obtained in an ethical and systematic manner from the company's competitive market environment requires hiring specialized personnel.	0.059	0.636
A.1.4 Obtaining, analyzing and interpreting information from the company's competitive market environment in an ethical and periodic manner is key to identifying new technology for the benefit of the company.	0.948	0.432
A.1.5 Obtaining, analyzing and interpreting information from the company's competitive market environment in an ethical and periodic manner is key to identifying new technology for the benefit of the company.	0.284	0.557
A.1.6 Obtaining, analyzing and interpreting information from the competitive environment of the market the company in an ethical and periodic manner is key to the generation of new products or services.	0.639	0.49
A.1.7 Obtaining, analyzing and interpreting information from the company's competitive market environment in an ethical and systematic manner is key to making decisions that benefit the company.	0.284	0.557
A.1.8 Analyzing and interpreting information on the company's competitive trading environment obtained in an ethical and systematic manner requires complex and costly technological tools or techniques.	-0.249	0.701

Finally, when analyzing section (iv) Competitive Intelligence Practices, a Cronbach's α of 0.894, without the need to suppress any item to achieve a better confiability of this section (See Table 6).

Table 6
Cronbach's Alpha Coefficient Analysis Section iv

Cronbach's alpha	Number of elements
0.894	10

With the data obtained, the reliability of the instrument was determined, resulting in the 3.0 or final version; with a total number of 27 items, distributed among the variables, as follows: (i) "Basic Data of the Interviewee and the Company", from which the initial item S.1.4 was eliminated, leaving 4 items of the 5 initially present (See table 7), (ii) the "Knowledge about CI" (See table 8), (iii) the "Attitude about CI", establishing the level of agreement or disagreement with a Likert-type scale, in which the item A.1.4 was eliminated, giving 7 items of the 5 initially present (See table 8), (iv) the "Attitude about CI", establishing the level of agreement or disagreement with a Likert-type scale, in which the item A.1.1 .4 was eliminated, leaving 7 items out of the 8 initially present in stage 2 (see Table 9); and finally, (iv) "CI practices" (see Tables 7, 8, 9 and 10).

Table 7
Competitive Intelligence Knowledge, Attitudes and Practices Identification Instrument: Basic Data Section of the Interviewee and the Company

Variable	Question/Item	Response Options
S.1 Basic Data on the Interviewee and Company	S.1.1 Indicate your last level of studies attained	Completed elementary or high school
		Graduate Technician or Technologist
		University Graduate
		Graduate Postgraduate
	S.1.2 Indicate the total number of years of your work and/or professional experience	Less than one year
		Between 1 and 5 years
		Between 6 and 10 years
		More than 10 years
	S.1.3 Indicate the Sector your company belongs to	Manufacturing
		Service
		Trade
		Another
	S.1.4 Indicate the average annual revenue level of your company	Less than 50 million
		Between 50 and 100 million
		Between 101 million and 500 million
		More than 500 million

Table 8

Competitive Intelligence Knowledge, Attitudes and Practices Identification Instrument: Competitive Intelligence Knowledge Section

Variable	Question/Item	Response Options
C.1 Knowledge of Competitive Intelligence	C.1.1 Of the following definitions, which one is most closely related to Competitive Intelligence. (Check only one option)	Ethical and systematic process of gathering and analyzing information for strategic decision making.
		Conjunto de actividades coordinadas, con fecha de inicio y final, para lograr un objetivo estratégico
		Set of coordinated activities, with a start and end date, to achieve a strategic objective
		I don't know
	C.1.2 Competitive Intelligence at a business level, is understood as a cycle that begins with: (Check only one option)	Knowledge of the internal and external aspects of the company.
		A specific business problem or need
		Strategic decision making
		I don't know
	C.1.3 The main benefit of using Competitive Intelligence in the company is related to: (Check only one option)	Allows tools or practices to spy on and obtain confidential information from competitors
		Allows for research and/or market studies
		It allows transforming information into knowledge for decision making focused on the company's sustainability.
		I don't know
	C.1.4 Of the following stages, which one corresponds to the logical and orderly cycle of competitive intelligence? (Check only one option)	Analyze - Interpret - Communicate - Plan - Procure - Organize
		Planning - Obtaining - Organizing - Analyzing - Interpreting - Communicating
		Planning - Analyzing - Interpreting - Communicating - Obtaining - Organizing
		I don't know
	C.1.5 ¿Which of the following sources of information do you consider to be the most used in the process of Competitive Intelligence by the companies? (Check only one option)	Internet search engines (example: Google, Yahoo, Microsoft)
		Social Networks (Facebook, LinkedIn, Twitter)
		Free Software
		Software at cost
		Family and friends
		Company's employees and/or marketing employees
		Private detectives
		Academic events, trade or professional fairs
		International Patent System
		Own knowledge and experience
		I don't know
		None
	C.1.6 ¿Which of the following techniques for analyzing information on the competitive business environment do you consider to be the most widely used by companies? - (Check only one option)	PEST Analysis
		Value Chain
		Porter's Five Forces
		SWOT Analysis
		ROI
		SPIN Method
		I don't know
		None

Table 9

Competitive Intelligence Knowledge, Attitudes and Practices Identification Instrument: Competitive Intelligence Attitudes Section.

Variable	Question/Item	Response Options
A.1 Competitive Intelligence Attitudes	A.1. The use of Competitive Intelligence in the company is key to make decisions focused on the sustainability, development and/or growth of the company.	Completely disagree
		Disagree
		Agreed
		Completely agree
		I don't know
	A.1.2 Obtaining information on the company's competitive market environment in an ethical and systematic manner is complex and costly.	Completely disagree
		Disagree
		Agreed
		Completely agree
		I don't know
	A.1.3 Analyzing and interpreting the information obtained in an ethical and systematic manner from the company's competitive market environment requires hiring specialized personnel.	Completely disagree
		Disagree
		Agreed
		Completely agree
		I don't know
	A.1.4 Obtaining, analyzing and interpreting information from the company's competitive market environment in an ethical and systematic manner is key to making decisions that benefit the company.	Completely disagree
		Disagree
		Agreed
		Completely agree
		I don't know
	A.1.5 Obtaining, analyze and interpret information from the competitive environment of the market the company in an ethical and periodic manner, it is key to the generation of new products or services.	Completely disagree
		Disagree
		Agreed
		Completely agree
		I don't know
	A.1.6 Obtaining, analyzing and interpreting information on the company's competitive market environment in an ethical and regular manner is key to identifying and accessing new markets or customers.	Completely disagree
		Disagree
		Agreed
		Completely agree
		I don't know
	A.1.7 Obtaining, analyzing and interpreting information from the company's competitive market environment in an ethical and periodic manner is key to identifying new technology for the benefit of the company.	Completely disagree
		Disagree
		Agreed
		Completely agree
		I don't know

Table 10

Competitive Intelligence Knowledge, Attitudes and Practices Identification Instrument: Competitive Intelligence Practices Section

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Variable	Pregunta/Ítem	Opciones de Respuesta
P.1 Competitive Intelligence Practices	P.1.1 ¿Have you used Competitive Intelligence in your company to make decisions focused on the sustainability, development and/or growth of the company?	YES
		NOT
		I don't know
	P.1.2 Of the following sources of information, ¿which have you used most frequently in the last year to obtain, analyze and interpret information about your company's environment? (Check only one option)	Internet search engines (example: Google, Yahoo, Microsoft)
		Social Networks (Facebook, LinkedIn, Twitter)
		Free Software
		Software at cost
		Family and friends
		Company's employees and/or marketing employees
		Private detectives
		Academic events, trade or professional fairs
		International Patent System
		Own knowledge and experience
		Other, which one?
		None
	P.1.3 Which of the following information analysis and interpretation techniques ¿have you used in the last year in your company? (Check only one option)	PEST Analysis
		Value Chain
		Porter's Five Forces
		SWOT Analysis
		ROI
		SPIN Method
		Other, which one?
		None
	P.1.4 Was gathering information about the company's ¿Was it complex and expensive?	YES
		NOT
		I have not done it
	P.1.5 To analyze and interpret the information obtained from the company's competitive market environment, Do you have specialized personnel hired exclusively for these tasks?	YES
		NOT
		We do not perform these tasks
	P.1.6 For monitoring the competitive environment of the company's market, ¿Do you use complex and expensive technological tools or techniques?	YES
		NOT
		I have not done it
	P.1.7 In the last year, have concrete decisions been made in the company, thanks to the process of obtaining, analyzing and interpreting information from the environment?	YES
		NOT
		We make decisions without the need to obtain, analyze and interpret information from the environment.
		We obtain the information, but it is not communicated within the company for decision making.

	P.1.8 Has obtaining, analyzing and interpreting information on the company's competitive market environment facilitated the generation of new products or services?	YES
		NOT
		We generate new products or services, without the need to obtain, analyze and interpret information from the environment.
		We obtain the information, but we have not used it to generate new products or services.
	P.1.9 Has obtaining, analyzing and interpreting information on the company's competitive market environment helped you to identify and access new markets or customers?	YES
		NOT
		We have gained access to new markets or customers without the need to obtain, analyze and interpret information from the environment.
		We obtain the information, but have not used it to identify and access new markets or customers
	A.1.10 ¿Has obtaining, analyzing and interpreting information on the competitive market environment of your business enabled you to identify and access new technology to the benefit of the company in the last year??	YES
		NOT
		We have accessed new technology without the need to obtain, analyze and interpret information from the environment.
		We have not used the information obtained to identify and/or access new technology for the benefit of the company.

Discussion and conclusions

The main objective of this research was the generation and systematic validation of an instrument to identify the KAP on KI in the management of microenterprises in the department of Santander, located in northeastern Colombia, and thus offer microentrepreneurs the possibility of identifying the need to acquire new knowledge in line with market trends, the SDGs and the type of business in which they operate or expect to operate, perhaps translated into a greater investment to innovate in their own products, services and/or production and/or marketing processes, which would result in the competitive sustainability of their companies.

With the results of the study, a solution is also given to the postulates proposed by Pereira & De Souza (2016) who state that currently, the application of CI in business environments, is complex, costly and with few studies that provide complete and practical information on how to apply them; which represents a barrier to access the selection of the most appropriate by managers, in the search for tools that enable intelligent decision making in pursuit of sustainable and competitive business; which according to Moya & Moscos (2017); hinders the implementation of Competitive Intelligence in microenterprises, since they also state that they imply robust data processing systems and/or technologies and a specialized human resource of high performance for its use, in the analysis and consequent strategic decision making, which together, may represent costs above the possibilities of microentrepreneurs, when applying or adapting CI to their business needs (Djerdjouri, 2020) agrees, stating that although today, microentrepreneurs are more aware of the crucial role that CI plays in the performance and competitiveness of their businesses, the main reasons for its non-use, specifically in smaller companies, are the complexity and high cost of implementing and managing current models.

Likewise, at the scientific, political or trade union level, it focused on providing an agile, useful and low-cost way of collecting information that could be used as a basis or reference for the creation or strengthening of methodologies, initiatives, training programs or lines of research, not only related to the generation of innovation and entrepreneurship, but also to the permanence or competitive survival of microenterprises according to the region or commercial geography where they operate, impacting positively on the creation of formal jobs and therefore on the sustainable economic development of the regions, incorporating the questionnaire as an instrument to arrive at results with analysis based on chi-square or the relationship or grouping of variables.

The tool, product of the study, is proposed to be applied according to the possibilities or needs of access of researchers in future studies, both in person and by remote communication channels, through virtual media or mechanisms, which although they favor reaching distant and dispersed places at low costs, and to a larger population, this modality, confirming the postulates of Torres et al. (2019) and Alarcón & García (2018), have the limitation of presenting a low response rate of the people who access or participate in the research, making it difficult to reach 100% of both the target population and the sample of each study according to each particular case.

Finally, it should be taken into account that the content recorded in section "i" of the instrument, on Basic Data of the interviewee and the company, is proposed according to the conceptualization of the country where the study was conducted, so that the authors of future research or applications of the instrument should consider the need to adapt the response options corresponding to items S.1.2 - S.1.3 and S.1.4 to the characteristics of their own countries or regions.

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CRITICAL SUCCESS FACTORS OF WORLD CLASS MANUFACTURING IN THE MEXICAN AUTOMOTIVE INDUSTRY: AN ANALYSIS THROUGH STRUCTURAL EQUATION MODELS

FACTORES CRÍTICOS DE ÉXITO DEL WORLD CLASS MANUFACTURING EN LA INDUSTRIA AUTOMOTRIZ MEXICANA: UN ANÁLISIS A TRAVÉS DE MODELOS DE ECUACIONES ESTRUCTURALES

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ABSTRACT

World Class Manufacturing (WCM) is an innovative system for comprehensive management of manufacturing operations, characterized by the economic monetization of manufacturing activities and the determination of holistic impact on the organization. *WCM* enables prioritization of actions based on the economic needs of manufacturing operations, thus directing appropriate resources directly to these needs. This research aims to characterize the critical success factors of *WCM* and the achievement of objectives in organizations within the automotive sector in Mexico. The study was conducted in Mexico's automotive sector, identified as the country's most important manufacturing industry, representing nearly 4% of the National GDP and 20.5% of the manufacturing GDP. Through literature review and interviews with *WCM* system experts, six Critical Success Factors (CSFs) were identified, evaluated through 30 constructs. A data collection instrument was applied, subjected to reliability and validity tests through a pilot study. Empirical verification and validation of the instrument were conducted through exploratory factor analysis, confirmatory factor analysis, reliability analysis, and structural equation modeling in a sample of 201 valid surveys directed at experienced *WCM* professionals. The results indicate that managerial commitment, comprehensive competencies, leadership type, employee involvement, and organizational culture type directly influence the increased benefits of organizations implementing *WCM*. By understanding the various factors affecting *WCM* implementation, organizations can develop actions to mitigate risks and strategically plan the necessary short-, medium-, and long-term outcomes and resources.

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Palabras clave:
World Class Manufacturing, factores críticos de éxito, implementación de costos, sistema estratégico de gestión, despliegue de costos.

RESUMEN

World Class Manufacturing (WCM) es un sistema innovador de gestión integral de operaciones de manufactura, caracterizado en la monetización económica de las actividades de manufactura y la determinación del impacto holístico en la organización. WCM permite priorizar acciones basadas en las necesidades económicas de las operaciones de manufactura y así focalizar los recursos directamente a estas necesidades. El objetivo de este trabajo es caracterizar los factores críticos de éxito del WCM en organizaciones del sector automotriz en México a través de modelos de ecuaciones estructurales. La investigación se llevó a cabo en el sector automotriz de México por caracterizarse esta como la industria más importante de las manufacturas del país. A través de la revisión de literatura y entrevistas con expertos del WCM se identificaron seis CSF, evaluándose por medio de 30 constructos. Se aplicó un instrumento de recolección de datos el cual fue sometido a pruebas de confiabilidad y validez durante una fase piloto de evaluación. Se realizó la verificación y validación del instrumento mediante análisis factorial exploratorio, y modelo de ecuaciones estructurales en una muestra de 201 encuestas a profesionales experimentados en WCM. Los resultados indican que el compromiso gerencial, las competencias integrales, el tipo de liderazgo, el involucramiento y la cultura organizacional influyen directamente en los beneficios de organizaciones que implementan el WCM. Conociendo los CSF del WCM, las organizaciones pueden desarrollar acciones para mitigar los riesgos y poder planificar estratégicamente los resultados y recursos necesarios a corto, mediano y largo plazo.

Introduction

Changes in consumer behaviors resulting from globalization have motivated companies to engage in competition on a global scale, which has had a direct impact on the production and distribution of products and services (Gonçalves, da Silva, Ferreira, Tecilla, & dos Santos, 2016). Those organizations that still cling to inflexible mass production systems and traditional practices will not be able to keep pace with global changes and demands (Monge and Cruz, 2015; Flynn, Schroeder and Flynn, 1999; Lee and Paiva, 2018).

According to Avella and Vázquez (2005), the need to adopt a new business paradigm based on agility and the ability to adapt to change is manifesting itself in a new era of business. This business era is based on change as its main characteristic, revealing new trends in the management and organization of companies. In order to face the conditions of extreme turbulence and constant market change, the importance of greater flexibility in business management is perceived (Fortunato, 2009). Global competition has generated fundamental changes in the industrial competitive environment (De Felice, Petrillo and Monfreda, 2013).

Although the Manufacturing Management Systems also known as *XPS* of automotive companies seek to improve efficiency, quality, productivity and flexibility, they can be considered heterogeneous due to their differences in approach, prioritization of improvements and use of resources. According to Goes, Satolo, Ramos, Correa and Martins (2017), among the existing theories, the *World Class Manufacturing* (*WCM*) approach proves to be an effective transformation model to eliminate operational losses and support organizations in achieving high levels of performance.

There are several conditions, variables or critical factors that can affect the implementation of *WCM* in organizations. These factors may be internal or external to the organizations and have not been taken into account to mitigate them, either due to underestimation or lack of knowledge. Some factors may include human, cultural, technological, economic, geographic, political or social factors. One of the most important objectives for managers is quality and efficiency, which can be ensured by identifying and eliminating factors that result in poor performance. Therefore, it is essential to have a better understanding of the critical success factors (CSFs) and how to measure them (Belassi and Tukel, 1996).

In recent years, the automotive industry in Mexico has been characterized as the most important manufacturing industry in the country, boosting and energizing the country's growth and development. According to data from the National Institute of Statistics and Geography (INEGI), in the year 2023, the automotive industry will represent almost 4% of the national GDP and 20.5% of the manufacturing GDP. Due to the relevance of this sector and the benefits mentioned when implementing continuous improvement transformation models, it is common that manufacturing organizations in Mexico seek to adopt *WCM* as a strategy to improve their economic and productive performance, as well as to reduce the activities that do not add value in their processes.

Based on the above statements, the need to identify the Critical Success Factors (CSFs) that affect the achievement of objectives during the implementation of *WCM in* manufacturing organizations in the automotive sector in Mexico is revealed. Through knowledge of the various factors that affect *WCM* implementation, organizations can develop actions to mitigate risks, thus enabling strategic planning of the results and resources needed in the short, medium and long term.

This article explains the steps necessary to develop and statistically validate an instrument to reliably evaluate the degree of implementation of the Critical Success

Factors (CSFs) during the execution of the *WCM* model in companies of the automotive sector in Mexico and a structural equation model identifies and correlates the factors and determines their significance with respect to the benefits.

World Class Manufacturing

World Class Manufacturing or *WCM* is a model focused on the management of manufacturing operations, based on applied methodologies and performance achieved by the best companies in the world. The model is based on the concepts of Total Quality (TQC), Total Productive Maintenance (TPM), Total Industrial Engineering(TIE) and Just in Time (JIT) (Midor, 2012; De Felice et al., 2013). The main objective of *WCM* is the continuous improvement in the manufacturing areas to guarantee the quality of the final product. Projects developed under the *WCM* methodology, aim at eliminating all forms of loss and waste with the ultimate goal of achieving zero accidents, zero waste, zero breakdowns and zero inventories (Fiat Chrysler Automobiles, 2014). Dudek (2016) and Netland (2014) state that *WCM* is an organization-specific production system, known as XPS, which has been implemented by organizations such as Fiat Chrysler Automobiles and initially by Fiat Corporation in 2005, as well as asserting that the current *WCM* model was developed by Professor Hajime Yamashina at Kyoto University in Japan. According to Fiat Chrysler Automobiles Corporation (2018) the *WCM* model is recognized as a common production system among the group of companies that are part of the *WCM Association*, with the objective of improving manufacturing performance by sharing knowledge and practices of excellence in manufacturing processes.

The *WCM Association* is a non-profit organization established for the purpose of improving the performance of manufacturing operations through the *WCM* model. In addition, it is responsible for developing and implementing the best manufacturing technologies, setting manufacturing standards, and increasing the competitiveness and economic benefits of members (Unilever, 2022). In 2021 the list of *WCM Association* member organizations included: Unilever, Iveco, CNH, FiatChrysler Automobiles, Royal Mail, Whirlpool Corporation, Semperit Corporation, ArcelorMittal, Elica Corporation, Ariston Thermo Group, CNH Industrial, Leonardo, Atlas Copco, Magneti Marelli, Iveco and Saint-Gobain.

According to De Felice et al., (2013), Yamashina (2013), Stellantis Corporation (2021), the *WCM* model covered by the *WCM Association* is composed of ten technical pillars and ten managerial pillars, which are usually illustrated inside a temple. The ten technical pillars are: 1) Safety, 2) Cost Deployment, 3) Focused Improvement, 4a) Autonomous Maintenance, 4b) Workplace Organization, 5) Professional Maintenance, 6) Quality Control, 7) Logistics and Customer Service, 8) Early Equipment Management, 9) Personnel Development and 10) Environmental and Energy Management. The ten management pillars are: 1) Management commitment, 2) Clarity of objectives, 3) Roadmap to *WCM*, 4) Allocation of highly qualified people, 5) Organizational commitment, 6) Organizational competence towards improvement, 7) Time and budget, 8) Level of detail, 9) Level of expansion and 10) Operator motivation.

Critical Success Factors

Critical Success Factors (CSFs) are characteristics, conditions or variables that, if properly maintained or managed, can have a significant impact on the success of a company in a type of industry (Villegas, 2012). According to (Näslund, 2013), apart from some slight variations, CSFs are similar in most quality improvement initiatives and appear to be relatively constant over time. An important finding is that CSFs tend to be

more related to how an organization addresses specific factors of the change effort than to the change methods themselves. Management commitment and involvement, as well as organizational culture, are often characterized as fundamentally critical.

Other factors such as type of leadership, human, conceptual and technical competencies that make up the integral competencies are known as key ingredients; that is, essential factors for the successful implementation of any continuous improvement transformation strategy (Mckinley, Manku-Scott, Hastings, French, and Baker, 1997). Therefore, they are commonly found or transferred to different improvement strategies. In fact, the main reason behind the transfer of concepts such as Six Sigma, Lean Manufacturing or other improvement strategies to other organizations is the success they have had in companies such as Motorola and Toyota (Snee and Hoerl, 2003).

According to Soti, Shankar and Kaushal (2010) CSFs were popularized by Rockart (1979). Specifically, CSFs are a series of essential factors for an organization, without which any improvement initiative has a low probability of success. The concept systematically highlights the key areas that management must carefully consider in order to achieve its performance objectives. By understanding the CSFs for implementing a system, an organization can successfully determine the difficulties that critically affect the process, mitigating or avoiding any risks that may contribute to its failure (Yaraghi and Langhe, 2011).

Due to the above, it is important to develop and validate a reliable instrument that allows the collection of data on the CSFs that affect *WCM* implementation in the specified study sector. This is in agreement with that mentioned by (Alkarney and Albraithen, 2018), who states that by understanding the CSFs for implementing a system, an organization can successfully determine the difficulties that critically affect the process, eliminating or avoiding any problems that may contribute to its failure.

Method

This study used a cross-sectional survey design to collect data on the critical success factors when implementing the *WCM* model with the objective of supporting the knowledge of organizations in the Mexican automotive sector. Following the classification proposed by Creswell and Plano-Clark (2007), Tashakkori and Teddlie (2010), and Vara (2012), the methodology was adopted with a mixed or quali-quantitative approach. This is because systematic, empirical and critical research processes were applied to support data collection and analysis, both qualitative and quantitative. Consequently, the methodology is considered qualitative as it is based on research and approaches of the *WCM* model proposed by Yamashina (2000, 2006, 2009 and 2013) and the *WCM* Association. In addition, it is considered quantitative by collecting data related to *WCM* experts from various Mexican organizations.

The survey design and validation process was developed in three stages, which are discussed below: A) Instrument design, which consists of construct and indicator definitions, B) Instrument administration, which includes data collection, and C) Statistical analysis for instrument validation, which consists of assumption checking, data analysis using factor analysis, and construct validation.

Instrument Design

The first step in the design of the instrument is to identify the constructs that will be used during the study. Consequently, a detailed review of the literature was carried out by consulting various databases, such as: Scielo, Emerald, Scopus, Proquest, Elsevier,

Springer, Ebsco, Nature, Jstor, Sage, Wiley, IEOM Society International, Academic Journals, CORE, Taylor And Francis Group, SPELL, Web Of Science, Semantic Scholar, Scientific Research Publishing. The review covered publications of the last fifteen years focused on the Critical Success Factors of the *WCM* model in Mexican automotive organizations. Keywords used for the search included *World Class Manufacturing*, Critical Success Factors, World Class, Yamashina, *World Class Association*, Total Quality Management, Lean Manufacturing, Total Productive Maintenance.

In the first phase of the instrument design, one hundred and twenty-seven (127) articles were examined to identify the Critical Success Factors (CSFs) with the highest number of mentions in the literature; in total, 9 CSFs were identified. The factors that accounted for more than 75% of the mentions were then selected to be used as the basis for the design of the data collection instrument. In a second phase of the instrument design, the 9 selected CSFs were reviewed with a panel of *WCM* experts (*WCM*) composed of seven members of the manufacturing sector, each with more than 7 years of work experience implementing *WCM*. Once the review with the panel of experts was completed, 6 Critical Success Factors (CSFs) that affect the successful implementation of the *WCM* were selected.

The selected constructs can be conceptually defined as follows. Integral competencies (IC) comprise technical, human and conceptual skills, fundamental for success in business management. Moreover, the different hierarchical levels of an organization demand varying combinations of these skills (Katz, 1974). The type of leadership (TL) involves characteristics, attitudes and practices that constructively influence the team and the work environment. It encompasses effective communication, empathy, trust, talent development, resilience, ethical leadership and collaboration (Castillo and Romero, 2021; Villarruel, 2021). According to Araneda (2016), positive leadership fosters a healthy work environment, increases team motivation and productivity, and helps retain talent. Managerial commitment (MC) is crucial for the success of organizational change and the promotion of employee involvement, as well as for cultivating an innovative culture (Avlonitis and Karayanni, 2000). In addition, its influence on the formulation of corporate sustainability strategies and the integration of environmentally responsible practices is highlighted (Bravo and Cassano, 2019). Employee Involvement (EI) refers to the active participation and collaboration of organizational members in decision-making processes and operational activities within the workplace. According to Vila, Laguillo and Faura (2020), staff participation can generate benefits in terms of organizational continuity and improve organizational efficiency and effectiveness. Organizational culture (OC) type encompasses shared values, beliefs, and practices that influence employee behavior (Akpa, Asikhia, and Nneji, 2021; Azeem, Ahmed, Haider, and Sajjad, (2021); Drozdowski, 2022). Their understanding and management are crucial for leaders seeking to create an effective work environment (Pujol-Cols, 2018). Benefits (B) relates to the positive results obtained by implementing improvement strategies in organizations, such as efficiency and waste reduction through Lean (Romero, 2020). These benefits are associated with positive actions or outcomes that favor both individuals and the organization (Maciel-Monteon, Limon-Romero, Gastelum-Acosta, Tlapa, Baez-Lopez, & Solano-Lamphar, 2020).

Operationalization of Variables

The six Critical Success Factors (CSFs) represent the latent variables that were studied through the survey. Since these variables cannot be measured directly, it was required to carry out their operationalization (Hernández, Fernández, & Baptista, 2010;

and Padua, 2018); that is, to transform subjective variables into directly observable objective variables (Condori, 2015; and Jöreskog, Olsson, & Wallentin, 2016). The final survey was developed from this operationalization process. To achieve this, it was necessary to work from the conceptual definitions of the constructs. Subsequently, a series of indicators were listed for each construction and then at least one element was provided to measure that indicator.

The operationalization processes of the latent variable Integral Competencies (IC) is explained below as an example. IQ can be described by three indicators, such as: *WCM* Technical Competencies, Human Competencies and Conceptual Competencies. Thus, the indicator labeled " *WCM* Technical Competencies" is measured through item CI-1; and "Human Competencies" is measured through items CI-2 and CI-3. On the other hand, items CI-4 and CI-5 measure the "Conceptual Competencies" indicator.

The instrument consists of 30 items distributed in 6 constructs. A Likert scale was used to collect the responses to each item, covering a range of perception in an interval of 5 units, from 1 = Never to 5 = Always. The choice of the five-point Likert scale in this specific study is widely accepted and considered appropriate for assessing latent variables through a series of interrelated items (Carpita and Manisera, 2012; Maciel-Monteon et al., 2020)

Content Validation

The survey was reviewed by the panel of seven *WCM*experts to verify content validity. The relevance and clarity of the questions, the clear meaning of slang commonly used in the industry, and the time required to complete the entire survey were evaluated. Subsequently, based on the experts' comments, the instrument was modified. Its final structure consisted of five sections: The first section provides a brief introduction to the objectives of the survey, the second section collects information on the professional data of the respondents. The third section evaluates the Critical Success Factors (CSFs) in *WCM* implementation, and the fourth section contains an analysis of *WCM* tools. The last section aims to learn about the benefits for companies implementing the *WCM* model.

Instrument Administration

This study focuses on manufacturing organizations within the automotive sector in Mexico with experience in implementing the *WCM* model proposed by the *WCM Association*. The companies were identified through interviews with *WCM* experts and experienced WCM experts from founding companies of the *WCM Association*. The target survey participants were employees in middle to senior management positions; i.e., from supervisors at the lower end, to corporate leaders, engineers, managers, CEOs and corporate global vice presidents with *WCM*experience. The survey was administered using *Google Forms* and access was sent via an internet link. A total of 990 links were sent through different digital media such as: *Whatsapp*, email, *Facebook* and *LinkedIn*. The response rate was 22%, with 218 surveys completed with professionals from 11 different companies. The demographic characteristics of the sample were: Professionals of female gender 15.38% and male 77.78%; Type of organizations where the professionals work was Tier1 with 78.63% and Tier2 with 14.53%; Professionals with WCM experience between 1 to 3 years were 7.26%, between 3 to 5 years were 20.94%, between 5 to 7 years were 27.35%, between 7 to 10 years were 20.09% and between 10 to 15 years were 17.52%. The leadership roles of the professionals were Executive Leadership (global operations) with 3.85%, Executive Leadership (local operations) with 25.21%, Functional Area Leaders with 32.91%, Middle Level Leaders with 8.97%, Middle Level Supervisors with 20.94% and Others with 1.28%

Statistical Analysis for the Validation of the Instrument

To validate the instrument, the method used by De La Vega, Baez-Lopez, Limon-Romero, Tlapa, Flores, Rodríguez, and Maldonado-Macías (2020) was followed. The validation of the questionnaire comprises two fundamental tests: reliability and validity. Factor analysis was used to assess the reliability and validity of indirectly observable variables (Rodrigues, Jacinto, Antunes, Amaro, Matos, & Monteiro, 2023). Initially, four crucial aspects in survey validation were checked (Byrne, 2016): the presence of missing data, outliers, compliance with univariate and multivariate normality assumptions, and the presence of multicollinearity.

Factor Analysis

The EFA of the correlation matrix was used to establish the latent factors that explain the variability of the observed variables. A Promax rotation was performed and sample adequacy was assessed using the Kaiser Meyer Olkin index (KMO) and Bartlett's test of sphericity. Non-significant factor loadings were removed and a Confirmatory Factor Analysis (CFA) was performed using SPSS and SmartPLS.

Construct Validity

Convergent, discriminant, and nomological validity were assessed as recommended by Hair, Black, Babin, and Anderson (2014). Cronbach's alpha was estimated to evaluate the internal consistency of the instrument.

Results

In order to avoid missing data, only those surveys that were complete in *google forms* were included in the analysis. Subsequently, the database was checked for outliers, identifying observations with unique characteristics that clearly differed from the rest (Cohen, G. Cohen, P., West and Aiken, 2002). This procedure was carried out by applying the Mahalanobis distance. A total of 17 surveys identified as outliers were eliminated as they did not meet a conservative level of statistical significance, following Kline's recommendation, with $p < 0.001$ (Kline, 2016). Thus, the subsequent calculations for the validation of the survey were performed considering only 201 responses. This measure was necessary to improve the normality of the database, since, by meeting this assumption, it was possible to use the maximum likelihood method to extract the factor (Schumacker and Lomax, 2015) following the same methodology used in this research study.

Verification of univariate normality was necessary as an essential, although not sufficient, condition for multivariate normality (De la Vega et al., 2020). To assess the normality of the variable data, it is proposed to rely on skewness and kurtosis; therefore, these two indices were used to measure the univariate normality of each variable in the instrument (De Carlo, 1997, cited by De la Vega et al., 2020). This resulted in absolute values of less than 1.96, corresponding to an error level of 0.05, for skewness and absolute values of less than 3 for kurtosis, as detailed in Table 1. These results corroborate Mardia's (1974) assertion that for a normal distribution, the measure of skewness should have a value of ±1.96 and the standardized kurtosis, a value equal to or less than 3.

Next, multivariate normality was evaluated using Mardia's test, which is based on the normalized value of multivariate kurtosis (Mardia, 1974). This procedure involves

comparing Mardia's coefficient for the data under study with a calculated value obtained using the formula *p x (p + 2),* where *p* represents the number of variables observed in the model (Khine, 2013). The verification of this assumption was carried out by contrasting the multivariate kurtosis value obtained through the statistical calculations of the virtual program *"WebPower - Statistical power analysis online"* with the value calculated by means of the proposed formula. With a total of 30 variables in the survey, the calculation yielded a value of 960, thus exceeding the multivariate kurtosis index obtained with *WebPower*. By meeting the condition that the calculated value is greater than the obtained value (931.404), the assumption of multivariate normality in the data set is also satisfied (De la Vega et al., 2020).

Ultimately, the presence of multicollinearity in the data was examined to rule out the possibility that two or more variables were highly correlated (Hair, Anderson, Tatham and Black, 1998). Two tests were used for this purpose: the first calculated bivariate correlations, since, according to Hair et al. (1998), any pair of variables with a correlation higher than 0.85 should be interpreted as evidence of possible problems. However, this analysis did not reveal such a situation, since the highest bivariate correlation was 0.83. The second test evaluated the variance inflation factors (VIF), which determine whether a variable could be redundant by presenting values greater than 10 (Hair et al., 1998). The VIF results in the study indicated a maximum value of 5.92 (see Table 1). Therefore, based on the two tests performed, it can be concluded that this data set does not present multicollinearity problems.

Table 1

Results of construct validity tests

Constructs / Variables		**Asymmetry** *(Skewness)*	**Kurtosis** *(Kurtosis)*	**Inflation Factor** *(VIF)*	**Factor Loading** *(Factor Loading)*	**Eigenvalues** *(Eigenvalues)*	**Composite Reliability** *(rho_c)*	**Crombach's alpha** *(Crombach Alpha)*
B	B1	-0.328	-0.867		0.924	4.272	0.958	0.958
	B2	-0.092	-0.938	5.203	0.923			
	B3	-0.233	-0.833	4.418	0.918			
	B4	-0.167	-0.927	5.418	0.931			
	B5	-0.270	-0.847	4.968	0.925			
TL	TL1	-0.113	-0.681	2.858	0.866	3.571	0.901	0.901
	TL2	-0.211	-0.562	2.874	0.854			
	TL3	-0.192	-0.922	2.558	0.813			
	TL4	-0.057	-0.808	2.511	0.839			
	TL5	-0.019	-0.739	3.073	0.852			
IE	IE1	-0.183	-0.700	3.166	0.858	3.745	0.917	0.917
	IE2	-0.046	-0.626	3.024	0.869			
	IE3	-0.469	-0.117	3.103	0.853			
	IE4	-0.180	-0.261	3.101	0.872			
	IE5	-0.194	-0.708	3.177	0.876			
GC	CG1	-0.319	-0.289	2.020	0.754	3.297	0.873	0.871
	CG2	-0.347	-0.485	2.550	0.821			
	CG3	-0.373	-0.411	2.116	0.795			
	CG4	-0.128	-0.629	2.473	0.835			
	CG5	-0.048	-0.682	2.647	0.851			
CO	CO1	-0.992	0.742	4.045	0.898	4.035	0.941	0.941
	CO2	-0.835	0.554	3.943	0.888			
	CO3	-0.804	0.526	3.946	0.901			
	CO4	-0.840	0.584	3.813	0.898			
	CO5	-1.028	0.863	4.363	0.906			
CI	CI1	-0.211	-0.870	5.925	0.930	4.272	0.958	0.958
	CI2	-0.289	-0.810	5.601	0.936			
	CI3	-0.174	-0.930	4.773	0.919			
	CI4	-0.254	-0.784	5.143	0.914			
	CI5	-0.300	-0.825	5.177	0.922			

Exploratory factor analysis (EFA) of the correlation matrix established the latent factors that explain the variability of the observed variables, and the results were used as an indicator of the validity of each construct analyzed. According to Brown (2015) instrument validity refers to the degree to which the instrument faithfully measures what it purports to measure. In the factor analysis, maximum likelihood estimation was used to extract the factor and Promax oblique rotation. Factor rotation is essential in EFA and is considered by many to be the most crucial tool in the interpretation of EFA (Lorenzo-Seva and Ferrando, 2019). In this study, a Promax rotation was chosen because, in addition to meeting distributional assumptions, it is less likely to generate inappropriate solutions or uncorrelated factors (Raykov and Marcoulides, 2008).

The first step in conducting an EFA involves assessing sample adequacy by calculating the Kaiser Meyer Olkin index (KMO). The KMO test provides a measure to determine whether the partial correlations between variables are small (Romero, 2020). Values above 0.7 are considered regular, meritorious if they are above 0.8 and very good if they are above 0.9 (Kaiser and Rice, 1974). Another method used to verify the feasibility of a factor analysis is Bartlett's test of sphericity. In this context, a factor analysis is feasible as long as the null hypothesis is rejected. This study reported a KMO value of 0.932 and a significant Bartlett's test of sphericity ($p < 0.001$), confirming the applicability of factor analysis.

The second crucial step in an EFA is to eliminate non-significant factor loadings. Hair et al., 2014 suggest that the appropriate value of a factor loading is adjusted to the sample size. The study is based on 201 reliable surveys; therefore, factor loadings greater than 0.4 as recommended by Hatcher, 1994 were considered significant for the analysis. Factor rotation is essential in EFA and is considered by many to be the most important tool in interpreting the results (Hair et al., 2014).

After performing the EFA and applying the promax rotation, 6 constructs composed of a total of 30 variables with significant factor loadings were identified. Similarly, 78.15% of the total variance of the data was explained. It should be noted that the eigenvalues of all the components were greater than 1. To assess the reliability and consistency of our findings, we adopted a confirmatory approach. After performing the EFA, we conducted a Confirmatory Factor Analysis (CFA) using *SPSS ® and SmartPLS*. Multivariate normality and multicollinearity of the data were assessed, and outliers were checked. No problems related to the first two assumptions were detected and no additional surveys had to be eliminated from the analysis due to the presence of outliers. In summary, subsequent tests were carried out with 201 surveys. Table 2 shows the results of the factor structure of the 30 variables for the total sample.

Table 2
Factorial Structure of Constructs

Variables	*Factors*					
	1	2	3	4	5	6
CO1	0.807					
CO2	0.789					
CO3	0.811					
CO4	0.807					
CO5	0.821					
IE1		0.735				
IE2		0.755				
IE3		0.728				
IE4		0.760				
IE5		0.767				
B1			0.854			
B2			0.852			
B3			0.842			
B4			0.868			
B5			0.856			
CI1				0.866		
CI2				0.876		
CI3				0.844		
CI4				0.836		
CI5				0.851		
TL1					0.749	
TL2					0.729	
TL3					0.661	
TL4					0.704	
TL5					0.727	
CG1						0.569
CG2						0.674
CG3						0.633
CG4						0.698
CG5						0.725
Eigenvalues *(Eigenvalues)*	7.58	6.34	8.68	8.41	7.14	5.00
% Variance Explained	39.53	13.54	9.90	7.04	4.74	3.41
% Accumulated Variance	39.53	53.07	62.97	70.00	74.74	78.15

The validity of a measurement model is based on establishing acceptable levels of goodness-of-fit and finding specific evidence of construct validity. According to Hair et al., (2014) the use of three to four indices usually provides adequate evidence of model fit. Kline (2016) indicates that, when attempting to validate a measurement model, it is essential to estimate at least the following model fit indices: the static χ^2/df statistic, the root mean square error of approximation (RMSEA), the comparative fit index (CFI), the standardized root mean square residual (SRMR). From these perspectives, it is assumed that investigators should report at least one incremental and one absolute index, in addition to the χ^2 value and associated degrees of freedom. Therefore, estimation of the χ^2 value, the CFI or the Tucker-Lewis index (TLI) and the RMSEA will provide sufficient information to evaluate a model. Also, to compare models of different complexities, researchers can incorporate the normalized fit index (NFI).

The results of the confirmatory factor analysis (CFA) indicate an excellent fit, with an X^2/df of less than 2.0. In addition, the CFI and TLI values are greater than 0.9, the RMSEA value is less than 0.08 and the SRMR value falls below 0.05. These fit indices confirm the validity of the measurement model. The findings presented in Table 5 reveal that an NFI index of 0.922 indicates an acceptable level of complexity for the initial model. In addition, the R2 values for the main indicators CG, TL, IE, CO, CI and B range between 0.42 and 0.60. These results suggest that these six constructs can be used to evaluate the

critical success factors that influence the implementation of *WCM* in the automotive manufacturing industry in Mexico.

Convergent validity is commonly assessed using the Average Variance Extract (AVE) index. Generally, an AVE value greater than 0.5 indicates good convergent validity, confirming that a set of items are indicators of a specific construct Hair et al., (2014), by converging or sharing a high proportion of variance in common. In our study, Table 3 below presents the AVE values on the main diagonal of the matrix (in bold) for each construct or latent variable. It is important to note that all values are greater than 0.5.

Table 3
Correlations between constructs, average extracted variance and squared correlations squared

	B	GC	CI	CO	IE	TL
B	**0.82**[a]	0.29	0.27	0.36	0.18	0.24
GC	*0.54*	**0.58** [a]	0.04**	0.12	0.01**	0.04**
CI	*0.52*	0.20**	**0.82** [a]	0.[16a]	0.41	0.39
CO	*0.60*	*0.35*	*0.41*	**0.76** [a]	0.09	0.32
IE	*0.42*	0.08**	*0.64*	*0.30*	**0.69** [a]	0.06
TL	*0.49*	0.21**	*0.62*	*0.56*	*0.24*	**0.65** [a]

*Note:*The values of the main diagonal with the symbol (a) correspond to the Average Variance Extract (AVE). Values in *Italic type* represent correlations between constructs, significant at p level <= 0.001. Values with the symbol (**) have non-significant values since they have p-values > 0.001. The values above the main diagonal are the squared correlations.

As for the internal consistency of the instrument, it was evaluated by estimating Cronbach's alpha (Cronbach, 1951). This coefficient helps to determine whether the different items or questions of a scale are related. Its values range from 0 to 1, with values closer to 1 indicating greater internal consistency. In this context, George and Mallery (2016) suggest relying on values above 0.7, as lower values could be questionable. According to the results presented in Table 3, all latent variables demonstrate adequate convergent validity, since all Cronbach's alpha values are greater than 0.872. These results were obtained using the SPSS program.

Discriminant validity measures the extent to which a construct is truly different from others. High discriminant validity provides evidence that a construct is unique and captures phenomena different from the others (Martínez-García and Martínez-Caro, 2009). One way to calculate this indicator is to compare the AVE values for two constructs with the squared correlation. The AVE must be greater than the squared correlation to confirm that the two constructs are independent of each other. Table 3 shows that the constructs have an AVE value greater than the squared correlation in all cases. This supports the discriminant validity of the constructs or latent variables.

Finally, nomological validity confirms that correlations between constructs in a measurement theory make sense. The correlation matrix provides information to identify how the constructs are related to each other. The results of the nomological validity test performed in this research are summarized in Table 4, where all the correlations between the constructs are positive and significant except for 3 cases where they were not significant because the *p* was greater than or equal to 0.001: CG-CI, CG-IE and CG-TL.

TABLE 4
Results of the Initial Structural Equation Model (SEM) Proposed

Trajectory Analysis	Parameter estimates	Standard errors	T-values	P-values	Results
B	1.178	0.142	8.310	0.000	Accepted
GC	0.464	0.090	5.185	0.000	Accepted
CI	1.206	0.142	8.505	0.000	Accepted
CO	0.838	0.109	7.711	0.000	Accepted
IE	0.544	0.078	6.984	0.000	Accepted
TL	0.790	0.114	6.941	0.000	Accepted
CG <-> B	0.399	0.072	5.538	0.000	Accepted
IQ <-> B	0.615	0.101	6.086	0.000	Accepted
IC <-> GC	*0.149*	*0.060*	*2.488*	*0.014*	*Rejected*
CO <-> B	0.597	0.090	6.659	0.000	Accepted
CO <-> CG	0.220	0.054	4.047	0.000	Accepted
CO <-> CI	0.408	0.082	4.951	0.000	Accepted
IE <-> B	0.337	0.067	5.007	0.000	Accepted
IE <-> CG	*0.042*	*0.040*	*1.065*	*0.288*	*Rejected*
IE <-> CI	0.520	0.077	6.791	0.000	Accepted
IE <-> CO	0.203	0.055	3.717	0.000	Accepted
TL <-> B	0.471	0.084	5.594	0.000	Accepted
TL <-> CG	*0.128*	*0.050*	*2.555*	*0.011*	*Rejected*
TL <-> CI	0.608	0.091	6.655	0.000	Accepted
TL <-> CO	0.457	0.075	6.088	0.000	Accepted
TL <-> IE	0.157	0.053	2.967	0.003	Accepted

Note. Values in *italic type* represent rejected results with P-values >=0.001.

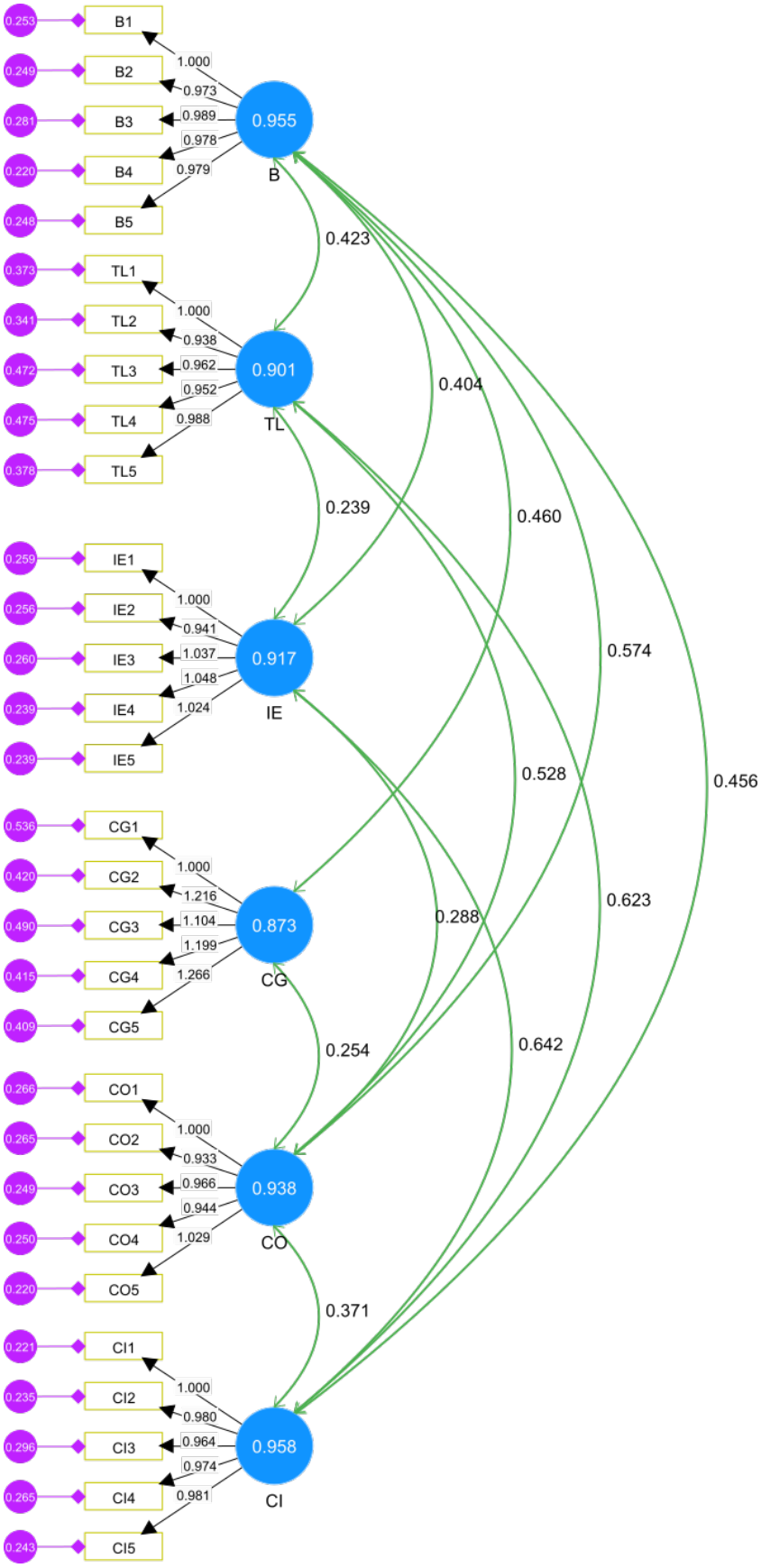
In order to propose a final structural equation model that describes the relationships between the significant variables, the relationships between the variables CI - CG, IE - CG and TL - CG were eliminated, since they did not show statistical significance. Figure 1 represents the final proposed model that includes only the significant variables, while Table 5 presents their Fit Indices.

Table 5
Final Model Fit Indices for Model Measurement

Statistical Adequacy of Fit	Recommended Values for a Satisfactory Model Fit	References	Initial Model	Final Model
X^2/df	- Good fit: X2/df < 2	- Bollen, 1989	1.120	1.133
TLI	- Acceptable fit: TLI > 0.90 - Good fit: TLI > 0.95	- Hair et al (2014) - Schumacker, 2015	0.990	0.989
IFC	- Acceptable fit: CFI > 0.90 - Good fit: CFI > 0.95	- Hair et al (2014) - Schumacker, 2015	0.991	0.990
RMSEA	- Acceptable fit: RMSEA < 0.08 - Good fit: RMSEA < 0.05	- Browne and Cudeck (1993) - Hair et al (2014)	0.024	0.026
SRMR	- Acceptable fit: SRMR < 0.08 - Good fit: SRMR < 0.05	- Steiger (1990)	0.039	0.070
NFI	- Acceptable fit: NFI > 0.90 - Good fit: NFI > 0.95	- Mulaik, James, Van Alstine, Bennett, Lind, and Stilwell (1989)	0.922	0.921

Figure 1

Final Proposed Structural Equation Model (SEM)



Discussion and Conclusions

The purpose of this research was to determine the critical success factors (CSFs) in the implementation of the *WCM* model in the automotive sector in Mexico, through the creation and evaluation of a data collection instrument (survey). The design of the instrument included the process of operationalization of variables, which allows direct measurement of unobservable variables through measurable indicators, as is the case of CSFs (Padua, 2018). Construct validity was assessed using the EFA, confirming that the items measured truly reflect the theoretical latent variables they were intended to measure. Finally, the study evaluated the three types of construct validity (convergent, discriminant and nomological), and each yielded a statistically satisfactory result.

During the validation of the instrument, the responses obtained were analyzed, making it possible to evaluate the perceived level of implementation of CSFs in the implementation of the *WCM* model in the sector studied. Table 6 presents the overall mean and standard deviation for each factor used to investigate the level of CSF implementation perceived by respondents.

Table 6

Critical Success Factor Ratings

Construct	Variable	Media	Standard Deviation (SD)	Average Mean	Average SD	Range
Integral competencies (IC)	CI-1	3.23	1.20	3.237	1.182	6
	CI-2	3.20	1.17			
	CI-3	3.23	1.20			
	CI-4	3.28	1.16			
	CI-5	3.24	1.18			
Type of leadership (TL)	TL-1	3.25	1.08	3.317	1.074	4
	TL-2	3.28	1.02			
	TL-3	3.39	1.10			
	TL-4	3.35	1.09			
	TL-5	3.31	1.08			
Management Commitment (GC)	CG-1	3.62	0.90	3.583	0.900	2
	GC-2	3.52	0.86			
	GC-3	3.61	0.92			
	GC-4	3.53	0.92			
	GC-5	3.63	0.90			
Employee Involvement (EI)	IE-1	3.38	1.00	3.320	1.043	3
	AR-2	3.31	1.06			
	AR-3	3.37	1.03			
	AR-4	3.28	1.04			
	AR-5	3.26	1.08			
The type of organizational culture (OC)	CO-1	3.80	1.05	3.745	1.026	1
	CO-2	3.75	1.00			
	CO-3	3.69	1.02			
	CO-4	3.70	1.00			
	CO-5	3.80	1.06			
Benefits (B)	B-1	3.28	1.20	3.245	1.190	5
	B-2	3.18	1.18			
	B-3	3.26	1.19			
	B-4	3.26	1.19			
	B-5	3.23	1.19			

The average values range from 3.245 to 4.745, with an average standard deviation of 1.07, indicating a good level of *WCM* model implementation. The information revealed

that the CSFs Organizational Culture Type (OC) and Managerial Commitment (MC), with values of 3.745 (±1.026) and 3.583 (±0.9) respectively, were considered the most relevant factors in the implementation of the *WCM*model. In third and fourth place were the employee involvement factor (EI) and the leadership type (TL), with values of 3.32 (±1.043) and 3.317 (±1.074) respectively. Finally, respondents perceived CSF Benefits (B) and comprehensive competencies (CI) to have the least influence during *WCM* model implementation, with values of 3.245 (±1.19) and 3.237 (±1.182) respectively. It is important to note that the six factors were considered by the respondents as "always" and "almost always", that is, as elements usually present in the implementation of this type of improvement projects.

The research results revealed that Organizational Culture (OC) emerges as the most prominent Critical Success Factor (CSF) compared to the other factors analyzed. Organizational culture has proven to be a fundamental element for the successful implementation of continuous improvement processes (Akpa et al., 2021). Characteristics such as cohesion, shared values, and adaptability stand out in organizations that have achieved successful implementation in previous studies Quinn and Cameron (2019). The advantage of a strong CO is reflected in goal alignment, proactive behaviors, and reduced resistance to change (Paais and Pattiruhu, 2020). These findings support the importance of Organizational Culture in the context of *WCM* implementation in the Mexican automotive sector.

Management Commitment (MC) stands out as a very important CSF, according to the ranking derived from the factor analysis, being an essential component for the success of *WCM* implementation. Distinctive features of effective managerial engagement include appropriate resource allocation, active leadership, and consistent involvement in project phases (Bravo and Cassano, 2019). Previous studies have shown that top management commitment creates an environment conducive to the adoption of transformational practices, generating an organizational culture aligned with the principles of the model (Vega, Fuentealba, & Patiño, 2016). Observed benefits range from improved operational efficiency to a boost in employee motivation and engagement (Flores and Cervantez, 2018). These results underline the relevance of Management Commitment in the success of *WCM* initiatives in the Mexican automotive sector.

According to the respondents the next relevant factor of the research was Employee Involvement (EI), being one of the essential components to achieve success in *WCM*implementation. The active participation of employees in continuous improvement processes, the generation of innovative ideas and organizational adaptability to operational changes are elements that create an environment conducive to innovation and organizational flexibility, thus supporting the success of transformation models (Tuuli and Rowlinson, 2009). Other key features of effective engagement encompass open communication, encouragement of active participation, and promotion of feedback between employees and management (Pujol-Cols, 2018). These aspects not only strengthen internal collaboration, but also contribute to building a dynamic organizational culture that is receptive to continuous improvement (Vila et al., 2020). According to Gonzalez, Pozo, Grob and Quijada (2021) positive interaction between employees and management not only benefits the implementation of efficient processes, but also enhances the organization's ability to adapt and thrive in a dynamic environment. The benefits range from increased creativity and identification of improvement opportunities to a strengthened sense of employee ownership and commitment.

In the context of the implementation of the *WCM* model in automotive organizations in Mexico, the Leadership Type (TL) emerges as one of the most outstanding CSFs. The literature on leadership reveals its breadth and complexity,

generating considerable interest and recognizing its fundamental role in organizations (Jiménez, 2010). The emotional intelligence approach highlights the relevance of understanding and managing emotions to achieve effective leadership results (Goleman, Boyatzis and Mckee, 2002). Previous studies have identified diverse leadership styles, including visionary and personal, particularly evident in female leaders, highlighting their ability to lead change (Changúan, Parrales, Higuera, & Cadena, 2020). In addition, the importance of styles that balance well-being and organizational objectives is highlighted (Campos, Morcillo, Rubio and Celemín, 2020). Authentic leadership, characterized by faithfulness and transparency, has gained attention and is associated with virtuous organizations (Villafuerte and Lupano, 2020). Leadership, shared by leaders and followers, is presented as essential in continuous improvement initiatives, as it influences the success of such initiatives (Kuei, Madu and Lin, 2001). According to Eckes (2001) improvement initiatives fail due to weak project leadership and management skills, so commitment, effective communication, project participation, selection and evaluation ensure the achievement of goals and objectives.

Integral competencies (IC) stands out as the CSF with the lowest weighting in the implementation of the *WCM* model according to the respondents. Organizational competencies, fundamental to success, evolve over time and require commitment to continuous learning (Khandii, 2021). Previous studies underline the essentiality of technical, conceptual and human competencies for successful leadership (Robbins and Coulter, 2004 and Koontz, Weihrich and Cannice, 2014). While conceptual competencies involve strategic thinking, human competencies focus on interpersonal skills crucial to assessing, guiding and leading teams (Vitaza, 2020). Effective communication, adaptability and commitment are key to human competencies, fundamental for a healthy work environment and achievement of objectives (Van-der-Hofstadt-Román and Gómez-Gras, 2006). IQ, enriched by skills in strategic management, teamwork, effective communication and decision making, is presented as a fundamental pillar for successful, competitive and transformational leadership (Cavagnaro and Carvajal, 2020; Araneda-Guirriman, Neumann-González, Pedraja-Rejas, and Rodríguez-Ponce, 2016).

This research study succeeded in meeting the objective of examining the relationship between the Critical Success Factors of *WCM* and the achievement of the objectives, as well as its effective implementation in the analyzed sector. However, there are two fundamental limitations to this work. First, the survey focused exclusively on the automobile manufacturing sector of the Mexican manufacturing industry. Nevertheless, it is considered that the instrument could be applied in other industrial sectors in different countries with conditions similar to those in Mexico. However, it is recommended that the validity of the instrument be verified and adjusted if necessary before using it in sectors other than those for which it was originally designed and validated. Second, the Critical Success Factors considered for the development of the instrument were derived from a comprehensive literature review and evaluation by *WCM* experts in the automotive sector. Therefore, it is likely that there are Critical Success Factors that influence other sectors with different levels of maturity in manufacturing processes and technology if different industrial areas are analyzed.

As future research possibilities, the authors are interested in exploring the structural relationships between WCM implementation and the benefits obtained by developing them in other industrial sectors. The survey developed in this study can be used in other manufacturing industries with similar characteristics; therefore, the authors will seek to apply and validate the instrument in other manufacturing sectors

manufacturing sectors in the nation with the objective of supporting, through the WCM model, the strengthening of industrial competitiveness.

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THE EFFECTIVENESS OF PMOS IN PROJECT MANAGEMENT: EMPIRICAL EVIDENCE FROM THE BUSINESS ENVIRONMENT IN SANTIAGO, DOMINICAN REPUBLIC

LA EFICACIA DE LA PMO EN LA GESTIÓN DE PROYECTOS: EVIDENCIA EMPÍRICA DEL ENTORNO EMPRESARIAL EN SANTIAGO, REPUBLICA DOMINICANA

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ABSTRACT

This article analyzes the effectiveness of Project Management Offices (PMO) in project management within private companies in Santiago, Dominican Republic. Through an empirical approach, it evaluates the impact of having a PMO on meeting key objectives, such as schedule, budget, scope, and satisfaction of both the client and the team. Based on data collected from 57 companies, it employs correlation techniques and descriptive analysis to examine the relationship between PMO implementation and project outcomes. The results indicate that, although the presence of a PMO may be associated with greater formalization and structure in project management, it does not necessarily guarantee greater success in all evaluated dimensions. A significant positive correlation was observed between the existence of a PMO and the fulfillment of scope and requirement objectives. However, correlations with schedule, budget, and satisfaction were not statistically significant, suggesting that additional factors, such as organizational culture and resource availability, also influence results. The study concludes that the implementation of a PMO should be accompanied by a comprehensive approach that considers the specific cultural and organizational context of each company. These findings highlight the complementary role of PMOs, suggesting that their effectiveness depends on integration with other organizational elements and providing a basis for future research in similar business contexts.

Palabras clave:
PMO, Santiago, República Dominicana, cumplimiento de

RESUMEN

Este artículo analiza la eficacia de las Oficinas de Gestión de Proyectos (PMO) en la gestión de proyectos en empresas privadas de Santiago, República Dominicana. A través de un enfoque empírico, se evalúa el impacto de la existencia de una PMO en el

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objetivos, satisfacción del cliente, gestión de proyectos	cumplimiento de objetivos clave, como cronograma, presupuesto, alcance y satisfacción del cliente y del equipo. Basado en datos recopilados de 57 empresas, utiliza técnicas de correlación y análisis descriptivo para examinar la relación entre la implementación de una PMO y los resultados de los proyectos. Los resultados indican que, aunque la presencia de una PMO puede estar asociada con una mayor formalización y estructura en la gestión de proyectos, no garantiza necesariamente un mayor éxito en todas las dimensiones evaluadas. Se observó una correlación positiva significativa entre la existencia de una PMO y el cumplimiento de los objetivos de alcance y requisitos. Sin embargo, las correlaciones con el cronograma, presupuesto y satisfacción no fueron estadísticamente significativas, lo que sugiere que factores adicionales, como la cultura organizacional y la disponibilidad de recursos, también influyen en los resultados. El estudio concluye que la implementación de una PMO debe ir acompañada de un enfoque integral que considere el contexto cultural y organizacional específico de cada empresa. Estos hallazgos subrayan el rol complementario de las PMO, sugiriendo que su efectividad depende de la integración con otros elementos organizacionales y proporcionando una base para futuras investigaciones en contextos empresariales similares.

Introduction

Project management has emerged as a central element in organizational development, especially in an increasingly globalized and competitive business environment. Organizations, regardless of their size or sector, seek to maintain their competitiveness in changing and dynamic markets by implementing strategies that ensure efficiency and success in the execution of their projects. In this context, the creation of Project Management Offices (PMO) has gained relevance as a strategic tool to standardize processes, improve decision making and ensure greater alignment between projects and business objectives (Aubry, Hobbs, & Müller, 2010). By providing centralized control, PMOs enable organizations to more effectively monitor key performance indicators and better manage resources, contributing to higher performance throughout the project lifecycle.

However, despite their theoretical advantages, the actual effectiveness of PMOs remains a matter of debate. Several studies have pointed out that the results obtained by companies that implement PMOs can vary significantly depending on internal and external factors, such as organizational culture and flexibility in resource management (Hobbs & Aubry, 2007). While it has been shown that a well-implemented PMO can standardize best practices and improve overall performance, its success is not guaranteed. The complexity of the environment in which PMOs operate and their ability to adapt to the particularities of each organization play a crucial role in their impact (Unger, Gemünden, & Aubry, 2012).

Recent studies have highlighted the importance of PMOs evolving towards more strategic roles, adapting to constantly changing business environments. The Project Management Institute's (PMI, 2023) Pulse of the Profession 2023 report highlights how organizations that prioritize interpersonal skills in their PMOs, also called "power skills," tend to achieve greater project management maturity and achieve significant bottom-line benefits. Along these lines, The PMO Leader's PMO Success in 2023 and Beyond study emphasizes the need for PMOs to adopt agile and strategic approaches, enabling them to effectively align with business objectives in a dynamic context. These trends show that the role of the PMO must go beyond operational oversight, aiming at delivering organizational value in a tangible way.

Other recent analyses highlight the relevance of digitization and data management in PMOs. For example, Assystem's PMO Insights Report (2023), based on surveys of professionals in sectors such as construction and engineering, reveals that digitization and data control are essential to the effectiveness of PMOs today. Complementarily, a PwC (2023) analysis of the "PMO of the future" proposes that these offices integrate a focus on benefits realization and alignment with the organization's strategic objectives. These trends reflect the need for a renewed vision in the implementation of PMOs, especially in environments where there are resource constraints or organizational challenges, as is the case in Santiago, Dominican Republic (Wellingtone, 2023).

In Santiago, Dominican Republic, many companies have adopted PMOs to improve project management in an attempt to increase operational efficiency and meet their strategic goals. However, empirical evidence on the effectiveness of PMOs in this specific context is limited. Unlike in more developed environments, where the implementation of a PMO follows standardized guidelines and with access to greater resources, in Santiago companies face challenges such as limited availability of specialized personnel, insufficient funding and, in many cases, cultural resistance to change. These factors can

significantly influence project outcomes, and suggest that the presence of a PMO alone does not guarantee success in all cases.

Previous studies have highlighted the ability of PMOs to align projects with the strategic objectives of organizations, bringing value to the business by optimizing processes and efficiently managing resources (Müller, Gluckler & Aubry, 2013). However, it has also been observed that the effectiveness of PMOs depends on their ability to adapt to the particular needs of each organization and the degree of integration they have with other levels of management (Too & Weaver, 2014). In many cases, PMOs that do not achieve this flexibility may generate additional bureaucratic processes, leading to delays and additional costs, contrary to their initial purpose.

Globally, reports such as the State of the PMO 2022 have pointed to an evolution of PMOs towards more strategic structures, which not only focus on operational management, but also play an active role in the formulation and monitoring of corporate strategies. However, despite this evolution, the Project Management Institute (PMI, 2022) reports that only 42% of organizations with a PMO consistently meet their time and budget objectives, reinforcing the idea that the existence of a PMO alone is no guarantee of success. This challenge is even more pronounced in regions such as Latin America, where economic and cultural conditions can significantly influence the implementation and effectiveness of PMOs (Kerzner, 2017).

In this context, the present study seeks to fill a gap in the literature by providing empirical evidence on the effectiveness of PMOs in private companies in Santiago, Dominican Republic. In examining whether PMOs contribute to project success, this study will also explore how factors such as organizational culture, change management, and available resources influence project outcomes. With this research, it is hoped to provide a stronger knowledge base to serve as a guide for organizations seeking to implement or improve their PMOs in similar environments.

Method

This study adopted a quantitative approach designed to investigate the relationship between the existence of Project Management Offices (PMO) in private companies in Santiago, Dominican Republic, and their impact on success in meeting various key project management objectives. The research was cross-sectional in nature, since the data were collected at a single point in time. This methodology made it possible to capture an accurate picture of the conditions prevailing in the companies during the period in which the study was carried out.

For this purpose, a structured questionnaire was designed and distributed to a sample of 57 private companies belonging to different economic sectors in Santiago. The questionnaire was subjected to an internal consistency analysis using Cronbach's alpha coefficient, obtaining a value of 0.904, which indicates a high level of reliability of the instrument and ensures that the questions used consistently reflect the aspects evaluated. The questionnaire included a series of closed questions that explored different aspects related to project management. These aspects included the presence or absence of a PMO in the company, as well as the degree of compliance with various project objectives, such as adherence to schedule, adherence to budget, compliance with the requirements established for the scope, and customer satisfaction. The questions were formulated on a

5-point Likert scale, allowing participants to express their level of satisfaction or dissatisfaction, from "very dissatisfied" to "very satisfied"

As for the selection of the sample, a non-probability sampling based on convenience was used, which allowed the inclusion of companies that were accessible and willing to participate in the study. The population of this research included private companies in the city of Santiago, Dominican Republic, registered with the Asociación de Industriales de la Región Norte Inc. (AIREN), which has a total of 172 companies in its public database. From this population, 7 financial institutions were excluded because, although they have branches in the Northern region, their main headquarters are not located in this area. Also excluded were companies whose main operation is managed from the province of Santo Domingo, such as Cervecería Nacional Dominicana and Ambev Dominicana, as well as companies located in cities near Santiago. After these exclusions, a sample of 78 companies in Santiago was obtained, of which 57 participated in the study. The final sample was composed of companies from various industrial sectors, which provided a representative view of the impact of PMOs in the Santiago business context. This sectoral diversity offered the opportunity to capture a broad spectrum of experiences and approaches to PMO implementation and management, thus enriching the results and conclusions of the study and providing more generalizable findings for the region.

Data collection was carried out through electronic surveys, which were sent primarily to project managers and other key decision makers within the participating companies. In order to ensure the confidentiality of the participants and to promote sincere and honest responses, the surveys were completely anonymous. Respondents were given a period of three weeks to complete the surveys, which maximized the response rate, thus contributing to the robustness of the data obtained.

Subsequently, the data collected were subjected to statistical analysis, which included descriptive techniques and correlation analysis. Initially, the normality of the data was evaluated using the Kolmogorov-Smirnov and Shapiro-Wilk tests. These tests revealed that the data did not follow a normal distribution ($p < 0.05$). Because of this finding, it was decided to use Spearman's correlation coefficient, which is appropriate for data that do not meet the assumption of normality. This coefficient was used to examine the relationships between the variables of interest, specifically the relationship between the existence of a PMO in the companies and the degree to which several key project objectives were met.

The correlation analysis focused on exploring how the presence of a PMO influenced success in four key areas of project management. These areas included the degree of compliance with the schedule, i.e., the success in completing the projects within the initially established deadline; compliance with the budget assigned to the project; success in delivering the required products and services according to the scope and requirements initially defined; and, finally, the level of client satisfaction with the final results of the project. Spearman's coefficient provided a reliable measure to identify possible relationships between these variables, without the need to assume a normal distribution in the data. In addition, significance values ($p < 0.05$) were analyzed to determine whether the observed correlations were statistically significant, which provided a solid basis for interpreting the study results and drawing relevant conclusions about project management in the context of PMOs

Results

This chapter presents the findings obtained from the analysis of the data collected from the 57 companies participating in the research. The purpose of this section is to describe and analyze in detail the responses obtained in relation to the presence of Project Management Offices (PMO) and their impact on the fulfillment of the main project objectives, such as schedule, budget, scope, client satisfaction and satisfaction of the team involved in the execution process.

To this end, a comprehensive correlational analysis was conducted, designed to identify the relationships between the presence of a PMO and the success of projects in each of these key aspects. This approach offers a comprehensive and nuanced view of how PMOs directly and indirectly influence the results obtained, considering the particular characteristics of the business environment in Santiago, Dominican Republic, and the differences in the implementation of these offices in local organizations.

Presence of a PMO (Project Management Office) in the Companies

Table 1 and Figure 1 present the distribution of companies according to the existence of a Project Management Office (PMO). The data collected reflect whether the companies have a PMO, do not have a PMO, or have another equivalent structure.

Table 1
Presence of a PMO (Project Management Office) in Companies

PMO in the Company	Number of Responses	Percentage (%)
No PMO	33	57.89%
Another	4	7.02%
If it has PMO	20	35.09%
Total	**57**	**100%**

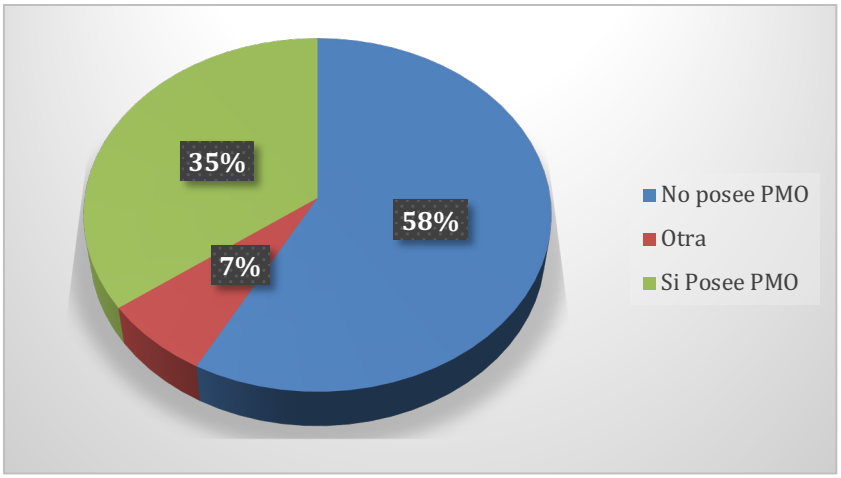
Of the 57 respondents, 33 indicated that their companies do not have a PMO, representing 57.89% of the total responses. This group constitutes the majority of respondents, suggesting that many companies have not yet established a formal PMO for managing their projects.

On the other hand, 20 participants indicated that their companies do have a PMO, representing 35.09% of the responses. This percentage shows a significant presence of PMOs in the companies, although not a majority.

In addition, 4 respondents indicated that their companies have another structure or approach to project management, representing 7.02% of the total responses.

Figure 1

Presence of a PMO (Project Management Office) in the companies



These results indicate that most of the companies surveyed have not yet implemented a formal PMO. However, a significant proportion do have a PMO, which may signal a growing recognition of the importance of a dedicated project management structure.

Correlation Between the Existence of a PMO and the Compliance with the Timeline

The data analysis began with the evaluation of the normality of the variables "Existence of a PMO in the companies" and "Success in meeting the schedule", using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The results, summarized in Table 2, indicated that both variables do not follow a normal distribution. The significance values for "Existence of a PMO" were 0.361 and 0.709 in the Kolmogorov-Smirnov and Shapiro-Wilk tests, respectively, while for "Success in meeting the schedule", these values were 0.227 and 0.877. As both values are less than the threshold of 0.05, it is concluded that the variables do not have a normal distribution, which justifies the choice of Spearman's correlation coefficient to measure the relationship between them. In addition, a scatter plot was used to visualize the relationship between "Existence of a PMO" and "Success in meeting schedule" (Figure 2). This graph shows an upward trend, reflecting the weak positive correlation observed in the data, and provides a complementary visual representation to the statistical analyses.

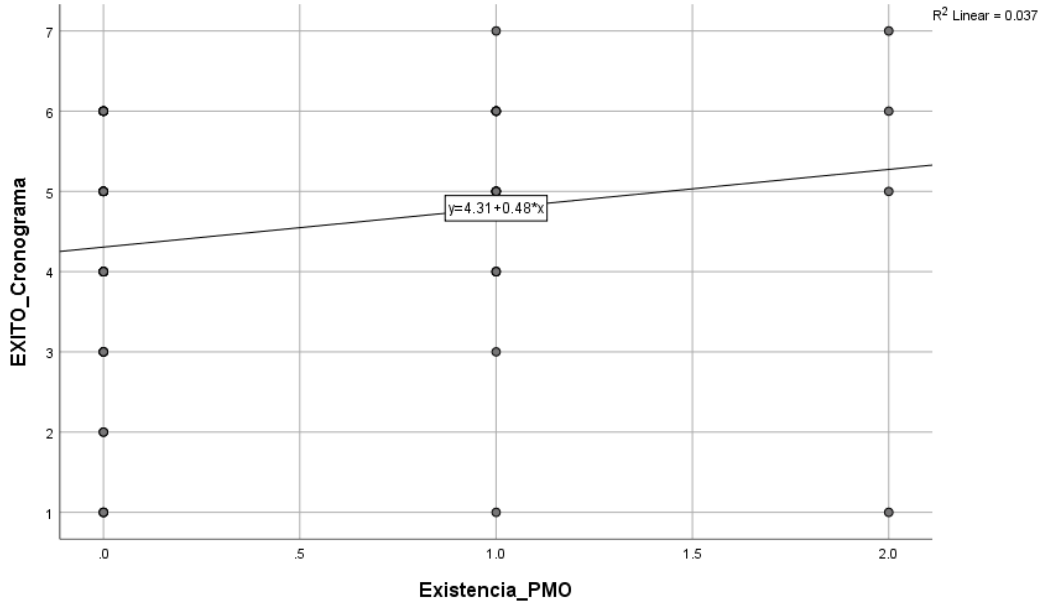
Table 2

Results of Normality and Spearman's Correlation Tests between the Existence of a PMO and the Compliance with the Schedule

Variable	Kolmogorov-Smirnov Statistic (Sig.)	Shapiro-Wilk Statistic (Sig.)	Spearman's Correlation Coefficient	Significance (p-value)
Existence of PMO	0.361 (0.000)	0.709 (0.000)	0.25	0.061
Successful Timeline	0.227 (0.000)	0.877 (0.000)	-	-

Figure 2

Relationship between PMO and Schedule Compliance



Subsequently, Spearman's correlation analysis was performed, obtaining a coefficient of 0.250 between the "Existence of a PMO in the companies" and "Success in meeting the schedule". This value indicates a weak positive correlation between the two variables, suggesting that, in general, as the existence of a PMO increases, success in meeting the schedule also tends to improve slightly. However, the associated significance value (p = 0.061) is slightly above the 0.05 threshold, suggesting that this correlation is not statistically significant in this context, although it is close to being so. This could indicate that with a larger sample or under other conditions, the relationship could be marginally significant.

In summary, although a weak positive correlation was observed between "Existence of a PMO" and "Success in meeting schedule", the results are not statistically conclusive enough. It is possible that other factors play a more decisive role in the success of the chronogram, so future studies should consider the inclusion of additional variables or a larger sample size to further investigate this relationship.

Correlation Analysis Between the Existence of a PMO and the Achievement of the Project Budget Objective.

The analysis of the relationship between "Existence of a PMO" and "Meeting the project budget target" began with the evaluation of the distribution of the variables, using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The results, presented in Table 3, revealed that neither variable follows a normal distribution, with significance values less than 0.05 in both cases. For the variable "Existence of a PMO", the values obtained were 0.361 and 0.709 in the Kolmogorov-Smirnov and Shapiro-Wilk tests, respectively. The variable "Compliance with the project budget objective" presented values of 0.165 and 0.924. Since the data do not follow a normal distribution, Spearman's correlation coefficient was used to analyze the relationship between these variables.

In addition, a scatter plot was generated to visualize the relationship between "Existence of a PMO" and "Project budget compliance" (Figure 3). This graph shows a slight upward trend, consistent with the very weak positive correlation obtained in the data, and helps to visually interpret the connection between the two variables.

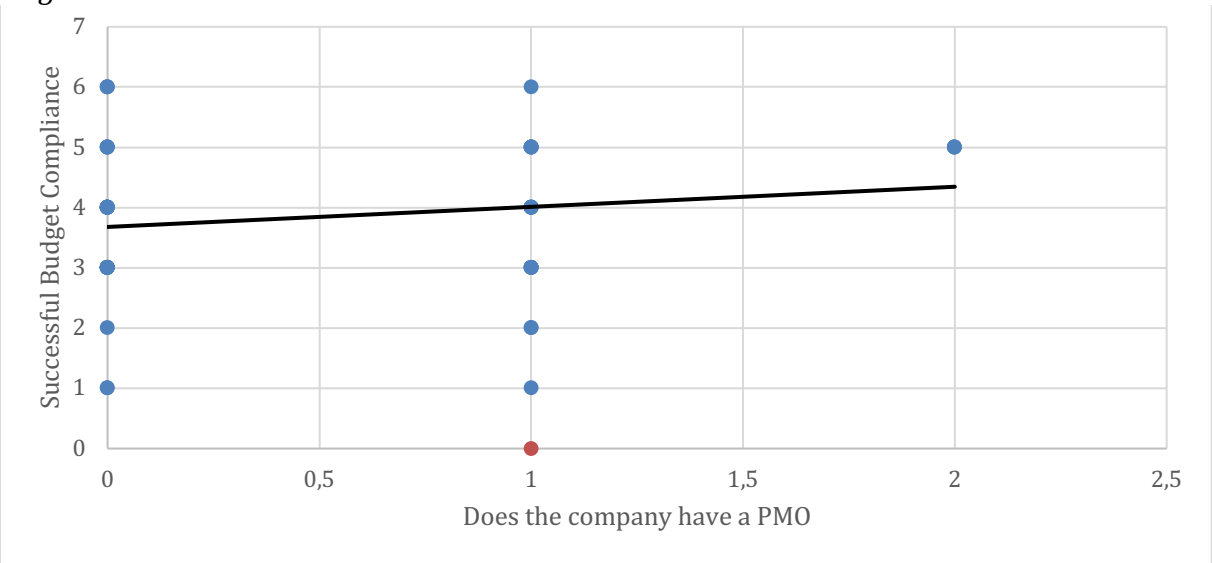
Table 3

Results of normality and spearman's correlation tests between the existence of a pmo and compliance with the project budget

Variable	Kolmogorov-Smirnov Statistic (Sig.)	Shapiro-Wilk Statistic (Sig.)	Spearman's Correlation Coefficient	Significance (p-value)
Existence of PMO in the Company	0.361 (0.000)	0.709 (0.000)	0.163	0.226
Successful Budget Compliance	0.165 (0.000)	0.924 (0.001)	-	-

Figure 3

Relationship between the existence of a pmo and the achievement of the project's budgetary targets



The Spearman correlation coefficient between "Existence of a PMO" and "Meeting the budget target" was 0.163, suggesting a very weak positive correlation between the two variables. However, the associated p-value (0.226) indicates that this correlation is not statistically significant, as it does not reach the 95% confidence level. This implies that, although a slight positive trend was observed, the relationship is not sufficiently conclusive to affirm that the existence of a PMO has a significant influence on budget compliance.

Despite the slight correlation observed, the results suggest that other factors, such as risk management or project team experience, may be playing a more decisive role in budget success.

Correlation Between the Existence of a PMO and the Achievement of Scope and Requirements Objectives

The analysis of the relationship between "Existence of a PMO" and "Compliance with scope and requirements objectives" began with the evaluation of the normality of the variables using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The results

obtained, which are consolidated in Table 4, showed that none of the variables follow a normal distribution. In the case of the variable "Existence of a PMO", the significance values were 0.361 in the Kolmogorov-Smirnov test and 0.709 in the Shapiro-Wilk test. Similarly, for the variable "Compliance with scope and requirements objectives", the values obtained were 0.184 and 0.923, respectively. These values, all less than 0.05, confirm the absence of normality, which justifies the use of Spearman's correlation coefficient, a suitable tool for nonparametric data.

Table 4

Results of Normality Tests and Spearman's Correlation between the Existence of a PMO and Compliance with Scope and Requirements Objectives

Variable	Kolmogorov-Smirnov Statistic (Sig.)	Shapiro-Wilk Statistic (Sig.)	Spearman's Correlation Coefficient	Significance (p-value)
Existence of PMO in the Company	0.361 (0.000)	0.709 (0.000)	0.334	0.011
Achievement of Scope Objectives	0.184 (0.000)	0.923 (0.001)	-	-

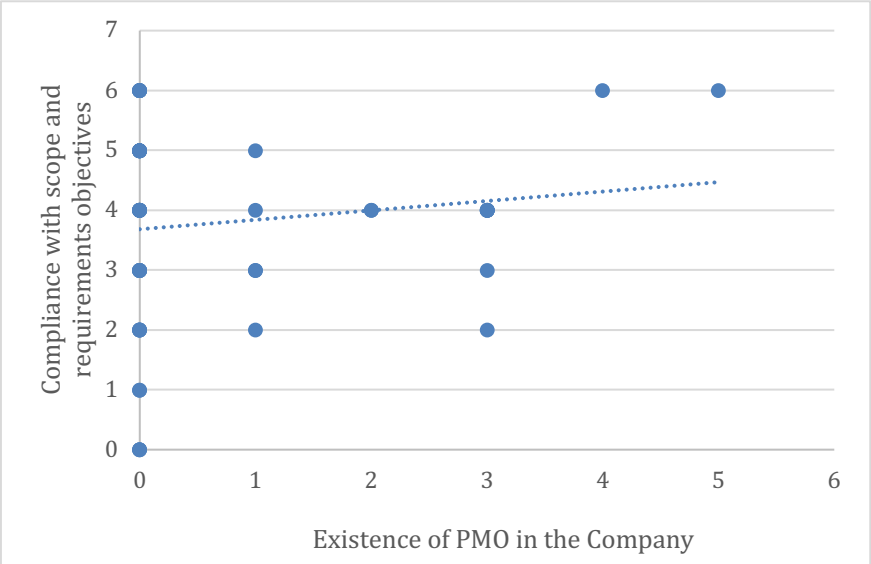
On the other hand, a scatter plot was generated to visualize the relationship between "Existence of a PMO" and "Compliance with scope and requirements objectives" (Figure 4). The graph shows a slight upward trend, reflecting the positive correlation observed in the data and allowing a visual interpretation of the connection between these variables

After applying Spearman's coefficient, a value of 0.334 was obtained, indicating a weak positive correlation between the existence of a PMO in the companies and the success in meeting the scope and requirements objectives. However, unlike previous analyses, this correlation is statistically significant, since the associated p-value was 0.011, i.e. below the 0.05 threshold. This finding suggests that the presence of a PMO may be positively related to the achievement of scope and requirements objectives, although the magnitude of this relationship is modest.

The consolidation of these results is presented in Table 4, where the values corresponding to the normality tests and Spearman's correlation are shown. Although the correlation is not particularly strong, its statistical significance reinforces the idea that the PMO could play a role in the successful achievement of these objectives in projects, offering a positive and relevant influence.

Figure 4

Relationship between the Existence of PMO and Compliance with Scope and Requirements Objectives



In summary, the results highlight the possibility that the existence of a PMO can contribute to improve the fulfillment of scope and requirements objectives in projects. However, it is important to consider that other factors may be involved in this process, which opens the door to future research that seeks to identify and better understand these additional influences.

Correlation between the Existence of a PMO and the Satisfaction of the Team, Client and End Users with the Project's Outcomes

The importance of a Project Management Office (PMO) in organizations has been the subject of several studies, which have explored its relationship to successful project delivery and the satisfaction of the various stakeholders involved. For example, Hobbs and Aubry (2007) highlighted that PMOs play a crucial role in providing methodological and administrative support, which can improve project performance. Also, more recent studies have indicated that the existence of a PMO may be associated with higher customer and project team satisfaction by facilitating process standardization and alignment of project objectives with expected outcomes (Too & Weaver, 2014). This analysis focuses on the correlation between the existence of a PMO and satisfaction in three key areas: the project team, the client and the end users. The results of the normality and correlation tests, consolidated in Table 5, provide an integrated view of how the PMO can influence these critical areas.

As the analysis of the results obtained deepens, it will be observed how the presence of a PMO can generate different levels of impact on the satisfaction of the different key stakeholders of the project. The sections that explore these relationships in greater detail will be presented below, starting with the project team's satisfaction, followed by the client's satisfaction, and finally the end-users' satisfaction with the results obtained.

Table 5

Results of Normality and Spearman's Correlation Tests between the Existence of a PMO and the Satisfaction of the Team, Client and End-Users

Variable	Kolmogorov-Smirnov Statistic (Sig.)	Shapiro-Wilk Statistic (Sig.)	Spearman's Correlation Coefficient	Significance (p-value)
Existence of PMO in the Company	0.361 (0.000)	0.709 (0.000)	-	-
Project Team Satisfaction	0.349 (0.000)	0.796 (0.000)	0.2	0.135
Customer Satisfaction	0.321 (0.000)	0.826 (0.000)	0.233	0.082
End User Satisfaction	0.184 (0.000)	0.923 (0.001)	0.084	0.535

Project Team Satisfaction

The first aspect addressed is the relationship between the existence of a PMO and the satisfaction of the project team. It is hoped that a PMO, by providing support and structure, can contribute to greater satisfaction within the team. However, the results of the normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) showed that none of the variables evaluated follow a normal distribution, with significance values of 0.361 for "Existence of a PMO" and 0.349 for "Team satisfaction". These results justified the use of Spearman's correlation coefficient, which yielded a value of 0.200, indicating a low positive correlation between PMO and team satisfaction. However, the p-value of 0.135 suggests that this correlation is not statistically significant.

Although the presence of a PMO may be associated with higher satisfaction in some contexts, the results of this analysis suggest that its direct impact on the perception of the project team is inconclusive. Other factors, such as team dynamics, leadership styles or project characteristics, could be having a more decisive influence on team satisfaction.

Although the presence of a PMO may be associated with higher satisfaction in some contexts, the results of this analysis suggest that its direct impact on the perception of the project team is inconclusive. Other factors, such as team dynamics, leadership styles or project characteristics, could be having a more decisive influence on team satisfaction.

Client Satisfaction with Project Results

Customer satisfaction is another crucial factor for the success of a project. In this analysis, we explored how the existence of a PMO could influence the client's perception of the results obtained. As in the case of team satisfaction, normality tests indicated that the variables do not follow a normal distribution, with significance values of 0.361 for "Existence of a PMO" and 0.321 for "Customer satisfaction". These results led us to use Spearman's correlation coefficient again.

The correlation coefficient between the existence of a PMO and customer satisfaction was 0.233, suggesting a weak positive correlation between the two variables. However, the associated p-value was 0.082, indicating that this relationship is not statistically significant. Although there is a slight trend toward higher customer satisfaction in companies with a PMO, the data are not conclusive.

Other factors may have a more significant influence on customer satisfaction, such as the quality of the delivered product or service, communication throughout the project, and

on-time delivery. The existence of a PMO may contribute to a greater formalization of processes, but it does not seem to be sufficient to guarantee significantly higher customer satisfaction.

End-User Satisfaction with Project Outcomes

Finally, the relationship between the existence of a PMO and end-user satisfaction with project results was evaluated. Normality tests showed that neither variable follows a normal distribution, with significance values of 0.361 for "Existence of a PMO" and 0.184 for "End-user satisfaction". Again, Spearman's correlation coefficient was used.
The result of the analysis yielded a correlation coefficient of 0.084, indicating a very weak correlation between the existence of a PMO and end-user satisfaction. The associated p-value was 0.535, which means that the observed relationship is not statistically significant. This suggests that the PMO does not have a significant impact on the end users' perception of satisfaction.

In this case, end users are likely to focus their attention on the quality of the product or service delivered, rather than on the management structure that supports the project. Elements such as ease of use, product functionality and satisfaction with performance could have a greater weight in the evaluation of results than the existence of a PMO. This observation, together with the correlations identified in the areas of team and customer satisfaction, suggests that although the PMO can bring benefits to project management, its direct influence on the satisfaction of the different stakeholders is limited.

In reviewing the results presented in Table 5, it is clear that, although the existence of a PMO may be weakly related to higher satisfaction of both the project team, client and end users, none of these correlations are strong or significant enough to claim that the PMO is a determining factor. In all cases, the correlation values were positive but low, and the associated p-values indicated that these relationships are statistically inconclusive.

Discussion and Conclusions

Discussion

This study explored the influence of Project Management Offices (PMO) on different key aspects of project management in companies in Santiago, Dominican Republic. The findings are then discussed in relation to previous studies and the practical and theoretical implications of the results are discussed. This discussion focuses on the adoption and effectiveness of PMOs in areas such as schedule, budget, scope and stakeholder satisfaction, highlighting both the advantages and limitations observed.

Presence of PMO in Companies

35.09% of the companies surveyed indicated having a PMO in place, suggesting a moderate adoption of this structure in the local business context. This result is consistent with previous studies showing that PMO implementation in developing regions tends to be more limited compared to advanced economies, where PMOs are seen as a standard practice in project management (Hobbs & Aubry, 2007). However, the low adoption rate observed in Santiago could be related to the perception that PMOs require significant investment in human and technological resources, which may be a barrier for smaller companies or those with budgetary constraints (Kerzner, 2017). In addition, the lack of knowledge about the tangible benefits that a PMO can bring may be contributing to the fact that many local companies choose not to implement this tool.

It is critical that companies that have already implemented a PMO continually evaluate its effectiveness and ensure that it is aligned with the organization's strategic objectives. PMOs should not be seen only as bureaucratic structures, but as facilitators of project success through the standardization of processes and the optimization of the use of resources. For companies that have not yet adopted a PMO, it is important to consider that the implementation of this office may take time and require specific adjustments to suit the particular needs of the organization.

Compliance with the Schedule

The finding of a positive but weak correlation between the existence of a PMO and schedule adherence (rho = 0.25) reflects the complexity of managing time on projects, even in environments with a formal project management structure. The lack of statistical significance in this finding suggests that, while PMOs may contribute to improved planning and schedule tracking, they are not the only factor influencing the temporal success of projects. Elements such as the experience of the team, the management skills of the project leader and the availability of resources play a crucial role in meeting schedules (Müller et al., 2013).

This result is consistent with the literature indicating that the PMO can be most effective when complemented with advanced technological tools for schedule tracking and ongoing staff training to improve their planning and execution skills (Too & Weaver, 2014). Companies that have implemented a PMO in Santiago could benefit from the integration of specialized time management software, as well as the promotion of an organizational culture that values meeting realistic deadlines.

Budget Compliance

The low and non-significant correlation between the existence of a PMO and budget compliance (rho = 0.163) underscores the need to strengthen financial capacity within project management. While PMOs can provide a structure for managing costs, this study suggests that their presence alone is not sufficient to ensure that projects stay within the allocated budget. Effective financial management depends on a combination of factors, including constant monitoring of expenditures, the ability to anticipate unforeseen costs, and the flexibility to adjust the budget when necessary (Unger, Gemünden & Aubry, 2012).

Many companies in Santiago are likely to face financial constraints that limit their ability to implement more robust cost control systems. Therefore, it is recommended that PMOs in these organizations consider implementing software tools that allow for better real-time tracking of expenses, as well as financial management training for project leaders.

Compliance with Scope and Requirements Objectives

The strongest finding of the study was the positive and significant correlation (rho = 0.334, $p < 0.05$) between the existence of a PMO and success in meeting scope and requirements objectives. This result suggests that PMOs play an important role in ensuring that projects are delivered according to agreed specifications. The standardization of processes provided by the PMO seems to be especially useful in scope management, allowing greater clarity in the definition of objectives and in the alignment of these with available resources.

This finding is consistent with studies indicating that well-structured PMOs can act as gatekeepers of project scope, preventing uncontrolled expansion of objectives from

occurring (Kerzner, 2017). Companies in Santiago that already have a PMO in place could capitalize on this advantage by focusing on strengthening scope management processes, ensuring that client expectations are clearly defined from the outset and that there is rigorous follow-up to avoid deviations.

Customer and Team Satisfaction

Finally, the low and non-significant correlations between the existence of a PMO and customer (rho = 0.233) and project team (rho = 0.2) satisfaction suggest that the PMO alone is not sufficient to ensure high satisfaction in these groups. Rather than relying solely on the PMO structure, companies should pay attention to other factors, such as effective communication, organizational culture, and team dynamics (Müller et al., 2013). Client and team satisfaction can be further influenced by the quality of interactions and responsiveness to issues that arise during the project.

This finding reinforces the idea that the implementation of a PMO must be accompanied by efforts to improve the organizational culture, promoting a collaborative work environment focused on customer needs. In the Santiago context, companies could benefit from training in interpersonal and communication skills for project leaders, which could increase both team and client satisfaction.

Theoretical and Practical Implications

The findings of this study have relevant implications for both project management theory and business practices in environments similar to Santiago. Theoretically, the results reinforce the idea that the implementation of a PMO can contribute to success in specific areas, such as scope compliance, but its effectiveness depends on additional contextual factors, such as organizational culture and resource availability. These results suggest that PMO theories should consider the importance of an adaptive and contextual approach for success in emerging markets. In terms of practical implications, this study underscores the need for companies not only to implement a PMO as a formal structure, but also to promote comprehensive management practices that facilitate communication, continuous training and the use of advanced technology. This is especially critical for organizations in resource-constrained environments, which can optimize their results by tailoring the PMO to their specific needs and fostering an organizational culture of project support.

General Conclusion

This study suggests that the presence of a PMO can influence some aspects of project management success, such as schedule, budget and stakeholder satisfaction, although this influence is not always decisive. The implementation of a PMO should not be seen as a one-size-fits-all solution to project management problems; rather, it should be integrated with other organizational practices that promote communication, flexibility and continuous learning.

The PMO showed a significant positive impact on meeting scope and requirements objectives, indicating that, when used properly, it can be a valuable tool to ensure that projects remain aligned with initial objectives. However, their impact on other key aspects, such as cost control and customer and team satisfaction, may depend on the integration of complementary practices and the maturity of their implementation.

Future research should focus on how to improve PMO implementation in resource-constrained environments, such as Santiago, and further explore how factors such as organizational culture, management flexibility and leadership can enhance the effectiveness of PMOs in different business contexts.

Limitations of the Study

Despite the significant findings, the study has some limitations that should be considered:

- Sample size: The sample was limited to 57 companies in Santiago, which may not be representative of all companies in the region or the country. More data could provide more robust and generalizable results.
- Cross-sectional design: The study was conducted at a single point in time, which precludes observing the long-term effects of implementing a PMO in projects. A longitudinal study could provide a clearer picture of how the effectiveness of a PMO evolves over time.
- Uncontrolled factors: Variables such as organizational culture, leadership and resource availability were not deeply explored in this analysis, but are likely to significantly influence project outcomes. These factors could have affected the relationship between the PMO and the success of the project.
- Reliance on self-reporting: Data were collected through surveys, which may lead to self-reporting biases, as respondents may have overestimated or underestimated the success of their projects.

These limitations offer opportunities for future studies, which could expand the sample, explore other organizational factors, and adopt a longitudinal approach to obtain a more complete picture of the impact of PMOs on project management.

Suggestions for Future Research

To enrich the understanding of the effectiveness of PMOs, it is recommended that future research expand the sample size and consider a longitudinal design, allowing the effects of PMOs to be evaluated at different stages and in different industries. In addition, it would be valuable to investigate additional factors that may mediate or moderate the relationship between PMOs and project success, such as the level of organizational maturity, the use of advanced technological tools, and the role of organizational culture. These approaches will contribute to a more precise understanding of the conditions under which a PMO maximizes its effectiveness and provide practical recommendations for implementation in different business contexts.

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PROPOSAL FOR THE DESIGN OF A MATURITY MODEL FOR DEVELOPMENT AND SOCIAL IMPACT PROJECTS BASED ON CONSOLIDATED GLOBAL PRACTICES

PROPUESTA DE DISEÑO DE UN MODELO DE MADUREZ PARA PROYECTOS DE DESARROLLO E IMPACTO SOCIAL BASADO EN PRÁCTICAS GLOBALES CONSOLIDADAS

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ABSTRACT

Effective project management is a central pillar for organizational success, particularly in development and social impact projects where tangible and sustainable results are crucial for the well-being of the communities involved. In this context, results-oriented methodologies like Project Management for Results (PM4R) have proven to be essential tools to ensure that strategic objectives translate into concrete benefits. However, the adaptability and effectiveness of PM4R can be enhanced through a specific maturity model that integrates established global practices and is focused on achieving tangible outcomes. This study proposes an innovative maturity model for PM4R, based on a synthesis of the most recognized maturity models such as CMMI, OPM3, Kerzner's Model, PRINCE2 Maturity Model, and P3M3. Using a qualitative comparative research approach, key features of these models are analyzed and adapted to formulate a framework that specifically addresses the challenges and needs of PM4R. The findings reveal that an integrated, results-oriented maturity model not only improves the efficiency and effectiveness of project management but also fosters a culture of continuous improvement and adaptability in diverse contexts. This model represents a significant advancement in project management literature and offers a practical guide for organizations seeking to enhance their delivery capacity and result measurement in projects.

Palabras clave:
gestión de proyectos, PM4R, modelos de madurez, integración, mejora continua.

RESUMEN

La gestión de proyectos efectiva es un pilar central para el éxito organizacional, especialmente en proyectos de desarrollo e impacto social donde los resultados tangibles y sostenibles son cruciales para el bienestar de las comunidades involucradas. En este contexto, metodologías orientadas a resultados como Project Management for Results (PM4R) han demostrado ser herramientas esenciales para asegurar que los objetivos estratégicos se traduzcan en beneficios concretos. Sin embargo, la adaptabilidad y eficacia de PM4R pueden

verse potenciadas mediante un modelo de madurez específico que integre prácticas globales consolidadas y esté orientado a la obtención de resultados tangibles. Este estudio propone un modelo de madurez innovador para PM4R, fundamentado en una síntesis de los modelos de madurez más reconocidos como CMMI, OPM3, Modelo de Kerzner, PRINCE2 Maturity Model y P3M3. Mediante un enfoque de investigación cualitativa comparativa, se analizan y adaptan características clave de estos modelos para formular un marco que responda específicamente a los desafíos y necesidades de PM4R. Los hallazgos revelan que un modelo de madurez integrado y orientado a resultados no solo mejora la eficiencia y efectividad de la gestión de proyectos, sino que también facilita una cultura de mejora continua y adaptabilidad en contextos diversos. Este modelo representa un avance significativo en la literatura de gestión de proyectos y ofrece una guía práctica para organizaciones que buscan mejorar su capacidad de entrega y medición de resultados en proyectos.

Introduction

In academia, the concept of project maturity refers to the ability of an organization to evaluate and recognize itself autonomously, identifying its usual practices in comparison with an established standard. This organizational maturity is also linked to the capacity of the economic entity to evolve, improving its practices, processes and protocols in order to advance in the selected maturity scale (Solarte and Sanchez, 2014, cited in Higuera, 2019, p. 13).

According to Aguiar, Pereira, Vasconcelos and Bianchi (2018), a maturity model presents a sequence of levels applicable to a category of elements, which represents an anticipated or desired evolution of these objects in well-defined stages.

Project maturity in an organization can be understood as its ability to advance in both strategic and operational project management competencies. Wojciechowska (2023) defines project maturity as the ability of an organization to effectively select and manage a portfolio of projects, aligned with its strategy and objectives, and apply management methodologies that facilitate successful execution.

In this context, maturity models also serve as tools that foster common understanding and consensus among the organization's managers. Klimko (2002) and Paulk (cited in Solarte and Sanchez, 2014, in Higuera, 2019) explain that, although ISO 9000 standards establish minimum criteria for quality management, maturity models provide a complete view of the continuous improvement process.

Bartolome (2022) argues that maturity models are concepts that allow organizations to structure their processes and areas, progressing in maturity levels that reflect improvements in efficiency and organizational success. In addition, Garcia-Mireles, Moraga and Garcia (2019) describe a process maturity model as a structured set of elements that characterizes efficient and effective processes at different stages of development, providing an evolutionary path that guides the organization towards higher quality products and services.

Atoum and Ayyagari (2019) indicate that CMMI is a reference model in software process improvement, which increases efficiency and productivity in organizational projects, although it leaves room for each organization to implement its own development methods.

The Capability Maturity Model (CMM) was developed in 1987 by the Software Engineering Institute (SEI) at the Carnegie-Mellon University Research Center (USA), in response to the need of the U.S. military and government structures to assess the capability of contractors in software development. Later, in 2000, this model evolved into the Capability Maturity Model Integrated (CMMI®), which allows to evaluate not only the maturity in development processes, but also in organizational processes, such as procurement and material support. Since 2006, CMMI® has been divided into three specific models (Nikolaenko and Sidorov, 2023, p. 3).

Woźniak and Sliż (2023) note that most project maturity models focus exclusively on project management processes. However, Kerzner's PMMM model offers a more comprehensive perspective by incorporating elements of the EFQM excellence model, which allows for a more complete organizational assessment in terms of project management. According to Kerzner, project maturity involves the development of repetitive systems and processes, which, although they do not guarantee success, increase its probability.

Khan and Mansur (2013) explain that project management maturity models (PMMMs) are fundamentally divided into two categories: one based on a staged

representation of maturity, as in the case of CMMI, which follows the incremental maturity approach proposed by Watts Humphrey, and one based on a non-staggered representation, as in the OPM3 model. The CMMI staged structure has been widely accepted among academics and organizations, and has influenced most of today's maturity models, with a few exceptions such as OPM3.

According to Piña Ararat and Bazurto Roldán (2022), the project management maturity model is defined as a structured set of elements, such as best practices, measurement tools and analysis criteria, that allow evaluating project management capabilities in an organization, identifying areas for improvement and promoting continuous improvement processes. In this sense, the OPM3 model offers a structure for organizations to assess their level of project management maturity and draw up an improvement plan, promoting a culture of project management and return on investment.

For its part, the P3M3 model (Portfolio, Programme, and Project Management Maturity Model), according to AXELOS (2019), is composed of three specific models covering project management (PjM3), programs (PgM3) and portfolios (PfM3). This facilitates an integral improvement in each of these areas of organizational management, allowing the model to be adapted to the specific needs of each organization and its different contexts.

In the field of social impact assessment, the Social Impact Assessment (SIA) approach of the Inter-American Development Bank (IDB) promotes the integration of social issues in the planning and implementation of projects, which improves their quality and sustainability (Kvam, 2018; Inter-American Development Bank (IDB)).

Although the smart city maturity model developed by MDPI is not specifically oriented to social development projects, Aljowder et al. (2023) note that it offers a framework for assessing performance in functional areas, including social, providing a comprehensive view of strengths and weaknesses.

Once the maturity models have been analyzed and their similarities and differences have been highlighted, it can be inferred that there are sufficient inputs to propose the design of a new maturity model focused on development and social impact projects. To this end, it is also necessary, from a methodological point of view, to select a best practices guide or appropriate methodology for the management of these projects, in order to achieve a precise and effective approach in the new model to be designed. This is precisely what this article will work on, developing an effective conceptual and methodological framework to address the specific challenges of development and social impact projects.

Method

In order to select the most appropriate project management methodology for the design of the proposed project maturity model, it is crucial to perform an exhaustive analysis of 9 project management methodologies and best practices. This analysis will be based on ten essential elements for the management of development and social impact projects: 1) legal and policy framework, 2) social context assessment, 3) stakeholder analysis and meaningful participation, 4) identification of benefits and opportunities, 5) identification of risks, 6) definition of indicators, baseline and data collection methodology, 7) reflection of social aspects in project design and implementation, 8) incorporation of social aspects in the project management system, 9) production and dissemination of reports and plans, and 10) monitoring, adaptive management and

evaluation. Elements as proposed by (Kvam, 2018) (Inter-American Development Bank (IDB)).

Using an inductive categorization approach (Pantoja Vallejo, 2015, p. 306), the analysis of the information sources was carried out in order to answer the research questions: what is the most appropriate project management methodology to propose a maturity model design for development and social impact projects? How are the methodologies studied classified and how was the most appropriate one selected?

In order to carry out this analysis, the methodologies and/or best practices identified in PMBOK, PRINCE2, P2M, ITIL, SCRUM, PM4R, PMDPRO, ICB IPMA and ISO 21500 were evaluated. Each methodology is weighted according to how well it meets the ten key elements of social impact assessment, which are described below:

1. Legal and Regulatory Framework

The methodology must be able to integrate with local and international legal and regulatory frameworks. PMBOK and PRINCE2 are known for their adaptability to different regulatory contexts, providing a solid basis for compliance with legal and regulatory requirements. PM4R is also aligned with regulatory frameworks, especially in the context of projects financed by the World Bank, Inter-American Development Bank and other development entities.

2. Evaluation of the Social Context

For development and social impact projects, the evaluation of the social context is fundamental. PMDPRO and PM4R are specifically designed for development projects and excel in social environment assessment. PM4R provides specific tools and methods to understand and address the social and economic needs of the beneficiary communities.

3. Stakeholder Analysis and Meaningful Participation

Stakeholder management is crucial to the success of social development projects. PMBOK and PRINCE2 include robust processes for stakeholder analysis and management. However, PM4R and PMDPRO focus on meaningful stakeholder participation, which is essential to ensure community buy-in and support.

4. Identification of Benefits and Opportunities

Evaluating and maximizing benefits is essential. PRINCE2 focuses on continuous business justification and benefits realization. PM4R, on the other hand, focuses on specific results and tangible benefits for development projects, which makes it highly suitable for social impact projects.

5. Risk Identification

Risk management is a key component in all methodologies. PMBOK is particularly strong in this area with well-defined processes for risk identification and management. PM4R also includes sound risk management adapted to development projects, considering social, economic and environmental factors.

6. Definition of Indicators, Baseline and Data Collection Methodology

PMBOK and PRINCE2 provide solid frameworks for defining indicators and data management, essential for establishing baselines and measuring project success. PM4R excels in this aspect, offering specific tools for data collection and impact measurement in development projects.

7. Reflection of Social Aspects in Project Design and Implementation

PMDPRO and PM4R stand out in the integration of social aspects in all phases of the project, from design to execution. PM4R, in particular, incorporates social and economic development elements into its approach, ensuring that projects are inclusive and sustainable.

8. Incorporation of Social Aspects into the Project Management System

ISO 21500 are methodologies that allow the incorporation of social aspects within a project management system, promoting holistic management. PM4R, with its focus on results and development, also effectively integrates social aspects into project management.

9. Production and Dissemination of Reports and Plans

PRINCE2 and PMBOK have detailed structures for the production and disclosure of reports, ensuring transparency and effective communication with all stakeholders. PM4R emphasizes the importance of accountability and transparency in development projects, providing clear guidelines for reporting and planning.

10. Monitoring, Adaptive Management and Evaluation

SCRUM, with its agile and iterative approach, is effective for monitoring and adaptive management. However, PM4R and PMDPRO provide a more specific and results-oriented framework for ongoing and adaptive evaluation, which is crucial for development and social impact projects.

Justification for the Selection of Methodologies

The selection of the nine project management methodologies is based on their ability to address the unique requirements of development and social impact projects, with an emphasis on adaptability to different contexts and applicability in diverse regulatory frameworks. Each methodology was carefully evaluated in relation to the ten key management elements, through a process of analysis that made it possible to identify and classify its strengths and limitations. This comparative approach seeks to establish a solid basis for the design of the proposed maturity model, ensuring that it incorporates practices that optimize social impact and promote efficient and adaptive management.

Results

The analysis revealed that the PM4R (Project Management for Results) methodology stood out as the most appropriate due to its strong alignment with development and social impact objectives. PM4R provides specific tools for social context assessment and stakeholder management, integrating social aspects in all project phases. It also emphasizes the importance of accountability and transparency, which is crucial for development projects (World Bank, 2021).

PMDPRO (Project Management for Development Professionals) also scored highly, being particularly strong in the evaluation of social context and stakeholder involvement. It is specifically designed for development projects, which makes it well suited for these types of initiatives (PM4NGOs, 2017).

ISO 21500 provides guidelines that can be aligned with international standards and allows the incorporation of social aspects within a project management system. Its flexibility and focus on quality make it suitable for development and social impact projects (ISO, 2012).

PRINCE2 stands out for its continuous business justification and benefits realization, in addition to its robust processes for stakeholder analysis and management. Its detailed structure for the production and disclosure of reports ensures transparency and effective communication (Axelos, 2017).

PMBOK (Project Management Body of Knowledge) is strong in risk management and in the definition of indicators and data collection methodologies. Although not specifically designed for development projects, its adaptability and robust structure make it a viable option (Project Management Institute, 2021).

ICB IPMA (International Competence Baseline for Project, Programme & Portfolio Management) offers a comprehensive approach to project, program and portfolio management, but does not focus specifically on social development projects (International Project Management Association, 2015).

P2M (Project and Program Management for Enterprise Innovation) provides a good framework for project and program management, but does not focus specifically on social development, which limits its suitability for these types of projects (P2M Consortium, 2017).

SCRUM, with its agile and iterative approach, is effective for monitoring and adaptive management. However, its lack of specificity in social and normative aspects makes it less suitable for social development projects (Schwaber & Sutherland, 2020).

ITIL (Information Technology Infrastructure Library) is primarily a methodology for IT service management and, although it has some elements applicable to project management, it is not well suited to the specific requirements of development and social impact projects (AXELOS, 2019).

Results of the Analysis

The analysis of the nine project management methodologies under the ten essential elements yielded the following results, ordered from the most appropriate to the least appropriate to be considered as a standard methodological line to design a maturity model for development and social impact projects:

1. PM4R (Project Management for Results)
2. PMDPRO (Project Management for Development Professionals)
3. ISO 21500
4. PRINCE2
5. PMBOK (Project Management Body of Knowledge)
6. ICB IPMA (International Competence Baseline for Project, Programme & Portfolio Management)
7. P2M (Project and Program Management for Enterprise Innovation)
8. SCRUM
9. ITIL (Information Technology Infrastructure Library).

After a detailed analysis of the aforementioned methodologies, the result is that PM4R is the most appropriate methodology for the management of development and social impact projects. Its focus on specific results, integration of social aspects, and specific tools for social context assessment and stakeholder management make it highly effective for these types of projects. In addition, PM4R's flexibility to adapt to regulatory frameworks and its emphasis on accountability and transparency make it a robust option for designing a maturity model for development and social impact projects.

The following is a weighting matrix that evaluates the suitability of each methodology in terms of the ten elements mentioned above:

Table 1

Weighting of project management methodologies with respect to the 10 elements (SIA)[a]

Element	PMBOK	PRINCE2	P2M	ITIL	SCRUM	PM4R	PMDPRO	ICB IPMA	ISO 21500
Legal and regulatory framework	8	8	7	6	6	8	7	7	8
Evaluation of the social context	6	6	6	5	5	9	9	6	7
Stakeholder analysis and meaningful participation	8	8	7	6	6	9	9	7	7
Identification of benefits and opportunities	7	9	7	6	6	9	8	7	8
Risk identification	9	8	7	6	6	8	7	7	8
Definition of indicators, baseline and data collection methodology	8	8	7	6	6	9	8	7	8
Reflection of social aspects in project design and implementation	7	6	7	5	5	9	9	6	7
Incorporation of social aspects into the project management system	7	7	7	6	6	9	8	7	8
Production and dissemination of reports and plans	8	9	7	6	6	9	8	7	8
Monitoring, adaptive management and evaluation	7	7	7	6	8	9	8	7	8
Total weighting	75	76	69	58	60	88	81	68	77

Once the analyses, which were categorized inductively, were carried out, the results demonstrate the need to use the PM4R methodology and, together with the 10 elements considered by the Social Impact Assessment (SIA) approach, as fundamental tools for the design of the Maturity Model for development and social impact projects.

[a] Social Impact Assessment (SIA) approach

Design of the Maturity Model for Development and Social Impact Projects

Based on a review of the specialized literature on maturity models, we propose a maturity model design for development and social impact projects based on the PM4R (Project Management for Results) methodology and the 10 elements considered by the Social Impact Assessment (SIA) approach. This maturity model design aims to provide a clear and effective structure for assessing and improving the capabilities of organizations in the management of social development projects. The design of the model is structured in five levels, following the trend of most of the existing maturity models:

Level 1: Initial (Ad hoc)

At this level, project management is informal and reactive. There are no standard processes and projects are managed on an ad hoc basis. Practices are inconsistent and depend on the individual skills of project managers.

- Legal and regulatory framework: The organization lacks defined processes to comply with legal and regulatory requirements.
- Evaluation of the social context: There is no formal evaluation of the social context.
- Stakeholder analysis and meaningful participation: Stakeholder identification and management is limited and not systematic.
- Identification of benefits and opportunities: Benefits and opportunities are not formally identified.
- Risk identification: Risk management is reactive and not systematic.
- Definition of indicators, baseline and data collection methodology: There are no formal indicators or methodologies for data collection.
- Reflection of social aspects in project design and execution: Social aspects are inconsistently considered.
- Incorporation of social aspects in the project management system: Social aspects are not formally integrated into project management.
- Production and dissemination of reports and plans: The preparation of reports and plans is informal and not systematic.
- Monitoring, adaptive management and evaluation: Monitoring and evaluation are carried out on an ad hoc basis.

Level 2: Managed

At this level, basic processes and standard practices for project management begin to be established. The organization has some repetitive processes and there are attempts at formalization.

- Legal and regulatory framework: Basic procedures are established to comply with legal and regulatory requirements.
- Evaluation of the social context: Initial assessments of the social context are conducted.
- Stakeholder analysis and meaningful participation: Stakeholders are beginning to be identified and managed more systematically.
- Identification of benefits and opportunities: Benefits and opportunities are identified in a more structured way.
- Risk identification: Basic risk management processes are implemented.
- Definition of indicators, baseline and data collection methodology: Initial indicators and basic methodologies for data collection are established.

- Reflection of social aspects in project design and implementation: Social aspects are considered more consistently.
- Incorporation of social aspects in the project management system: Social aspects are beginning to be integrated into project management.
- Production and dissemination of reports and plans: The production and dissemination of reports and plans is formalized.
- Monitoring, adaptive management and evaluation: Basic monitoring and evaluation processes are implemented.

Level 3: Defined

At this level, project management processes are well defined and documented. The organization follows a standard approach for all projects and ensures consistency in the application of management practices.

- Legal and regulatory framework: Procedures to comply with legal and regulatory requirements are well defined and documented.
- Evaluation of the social context: Social context assessments are conducted in a systematic and documented manner.
- Stakeholder analysis and meaningful participation: Systematic and documented processes for stakeholder identification and management are implemented.
- Identification of benefits and opportunities: Benefits and opportunities are systematically identified and documented.
- Risk identification: Risk management is carried out in a systematic and documented manner.
- Definition of indicators, baseline and data collection methodology: Well-defined indicators and documented methodologies for data collection are established.
- Reflection of social aspects in project design and implementation: Social aspects are consistently integrated into project design and execution.
- Incorporation of social aspects in the project management system: Social aspects are formally integrated into the project management system.
- Production and dissemination of reports and plans: The production and dissemination of reports and plans is carried out in a systematic and documented manner.
- Monitoring, adaptive management and evaluation: Monitoring and evaluation processes are well defined and documented.

Level 4: Quantitatively Managed

At this level, the organization uses metrics and quantitative data to manage and control project management processes. Advanced tools are used to measure project performance and effectiveness.

- Legal and regulatory framework: Metrics are used to ensure compliance with legal and regulatory requirements.
- Evaluation of the social context: Social context assessments are conducted using quantitative data and metrics.
- Stakeholder analysis and meaningful participation: Metrics are used to measure stakeholder participation and impact.
- Identification of benefits and opportunities: Benefits and opportunities are quantified and metrics are used to measure their impact.

- Risk identification: Metrics are used to assess and manage risks in a quantitative manner.
- Definition of indicators, baseline and data collection methodology: Advanced methodologies and metrics are used for data collection and analysis.
- Reflection of social aspects in project design and implementation: Social aspects are integrated using quantitative data and metrics.
- Incorporation of social aspects in the project management system: Metrics are used to evaluate the integration of social aspects in project management.
- Production and dissemination of reports and plans: Reports and plans are produced using quantitative data and metrics.
- Monitoring, adaptive management and evaluation: Advanced tools and metrics are used for project monitoring and evaluation.

Level 5: Optimized

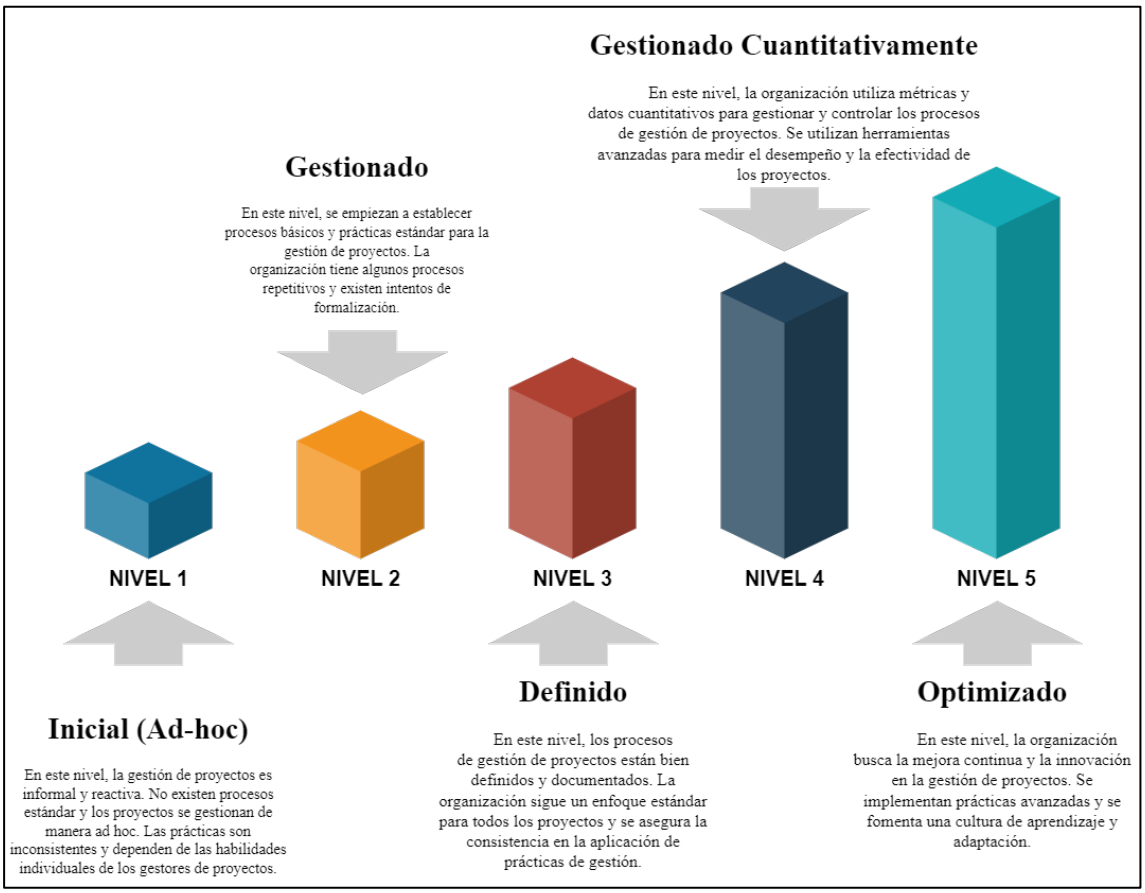
At this level, the organization seeks continuous improvement and innovation in project management. Advanced practices are implemented and a culture of learning and adaptation is fostered.

- Legal and regulatory framework: Advanced practices are implemented to ensure continuous compliance and improvement of legal and regulatory processes.
- Evaluation of the social context: Innovative approaches are used and continuous improvement is sought in the evaluation of the social context.
- Stakeholder analysis and meaningful participation: Advanced practices for meaningful engagement and stakeholder management are implemented.
- Identification of benefits and opportunities: New opportunities are continuously sought and project benefits are optimized.
- Risk identification: Advanced approaches are used for proactive risk management.
- Definition of indicators, baseline and data collection methodology: Advanced practices are implemented for indicator definition and data collection.
- Reflection of social aspects in project design and implementation: New ways of integrating social aspects into projects are continually sought.
- Incorporation of social aspects in the project management system: Processes are continuously optimized to integrate social aspects into project management.
- Production and dissemination of reports and plans: Advanced practices are implemented for the production and dissemination of reports and plans.
- Monitoring, adaptive management and evaluation: A culture of continuous improvement is fostered and advanced practices for project monitoring and evaluation are implemented.

The design of the maturity model for development and social impact projects, based on the PM4R methodology and the 10 elements of the Social Impact Assessment (SIA) approach, provides a clear and effective structure for assessing and improving the capabilities of organizations in the management of social development projects. This five-level model allows organizations to progress from initial and ad hoc practices to optimized and advanced practices, ensuring the integration of social aspects and the fulfillment of sustainable development objectives.

Figure 1

Proposed maturity levels for development and social impact projects



The image illustrates a maturity model of development and social impact projects through five levels, each represented by a bar of different height and color. The levels are ordered from lowest to highest, indicating upward progress in project management capability and sophistication. The arrows between the bars suggest a continuous transition and evolution between each level. This type of visual representation helps to understand how an organization can progress from initial, ad hoc practices to an optimized level, where continuous improvement and full integration of social aspects in project management is sought.

Interpretation of findings and comparison with previous studies

The findings highlight PM4R as the most appropriate methodology for development and social impact projects, due to its focus on the integration of social aspects, accountability and adaptation to regulatory frameworks, in line with studies by the World Bank (2021). In comparison, PMDPRO also shows high adequacy in managing social context and stakeholder engagement, as highlighted by studies by PM4NGOs (2017).

ISO 21500, although flexible and aligned with international standards (ISO, 2012), is less specific on social development issues compared to PM4R. On the other hand, PRINCE2 and PMBOK provide robustness in business justification, risk management and reporting, but with less focus on social impact (Axelos, 2017; PMI, 2021).

Taken together, this analysis and previous literature reinforce the relevance of PM4R for social projects, given its alignment with the ten elements of Social Impact

Assessment (SIA). PM4R provides an ideal framework for building a maturity model that maximizes impact and sustainability in social development, an approach endorsed by Kvam (2018) and the IDB in moving towards the Sustainable Development Goals.

Discussion and Conclusions

The qualitative analysis conducted identified and adapted the key features of the most recognized maturity models, such as CMMI, OPM3, the Kerzner Model, PRINCE2 Maturity Model and P3M3, to formulate a framework that responds specifically to the challenges and needs of PM4R. This approach has revealed that an integrated, results-oriented maturity model not only improves the efficiency and effectiveness of project management, but also facilitates a culture of continuous improvement and adaptability in diverse contexts.

The PM4R methodology was highlighted as the most appropriate due to its strong alignment with development and social impact objectives. It provides specific tools for social context assessment and stakeholder management, integrating social aspects in all project phases. It also emphasizes the importance of accountability and transparency, which is crucial for development projects. These findings are consistent with existing literature, which suggests that a results-oriented approach is essential for the sustainability and success of social development projects (World Bank, 2021).

Proposed Maturity Model: The proposed maturity model design, based on PM4R and the 10 elements of the SIA approach, provides a clear and effective structure for assessing and improving the capabilities of organizations in the management of social development projects. This model design allows organizations to progress from initial and ad hoc practices to optimized and advanced practices, ensuring the integration of social aspects and the fulfillment of sustainable development objectives.

Importance of the PM4R Methodology: PM4R stands out for its focus on specific results, integration of social aspects and specific tools for social context assessment and stakeholder management. Its flexibility to adapt to regulatory frameworks and its emphasis on accountability and transparency make it a robust option for designing a maturity model for development and social impact projects.

Methodology Evaluation: The evaluation of the methodologies under the ten key elements revealed that PM4R is the most suitable methodology, followed by PMDPRO and ISO 21500. Methodologies such as PRINCE2, PMBOK, and ICB IPMA, while valuable, do not align as closely with the specific objectives of social development projects.

Limitations and Proposals for Continuity

Although the study provides a robust framework for the creation of a maturity model for social development projects, it has certain limitations. One of them is the reliance on the PM4R methodology and the ten elements of the Social Impact Assessment (SIA) as fundamental axes, which, although adequate for the social context, may require adjustments for different sectors or regions with different regulatory frameworks. In addition, by focusing on a qualitative analysis, the study does not quantitatively explore the impact of each methodology on the development of organizational capabilities, which could be a valuable area for further research.

This article is limited only to the proposed design of the project maturity model. The continuity of this work is being developed in a doctoral thesis that will propose the methodological development and implementation of the model, along with the data collection instruments, data processing and subsequent data analysis for the

establishment of the maturity level for an organization. This process involves a case study in an organization dedicated to the structuring and management of development and social impact projects in southwestern Colombia.

In the future, it is recommended that longitudinal implementation studies be carried out to observe the progress of organizations in the proposed maturity levels, as well as to validate the model in different contexts and sectors. This will facilitate greater adaptability of the model and allow it to be refined, increasing its applicability in various social development scenarios. In addition, the incorporation of quantitative data analysis methods and the use of performance metrics could strengthen the model and provide empirical evidence of its effectiveness in improving the sustainability and impact of social projects.

Process in the Organization Case Study

In order to implement the maturity model in the organization dedicated to the structuring and management of development and social impact projects in the southwest of Colombia, a structured process will be followed that includes the following phases:

Initial evaluation

- Diagnosis: Conduct an initial comprehensive diagnosis of the organization to assess its current status in terms of its capacity to manage development projects and social impact.
- Identification of Existing Practices: Document current project management practices, identifying both strengths and areas for improvement.

Definition of indicators and methodologies

- Establishment of indicators: Define key indicators based on the 10 elements of the SIA approach.
- Data Collection Methodologies: Develop specific methodologies for the collection of data needed to evaluate the defined indicators.

Development of data collection instruments

- Surveys and Interviews: Design surveys and structured interviews to collect data from various stakeholders.
- Documentary Review: Review existing documents, project reports and other relevant records.

Model implementation

- Application of the Maturity Model: Apply the maturity model in the organization, using the defined indicators and methodologies to evaluate its current state.
- Level Assessment: Assess the organization against the five proposed maturity levels, identifying its current position.

Data analysis

- Data Processing: Analyze the data collected to identify patterns, trends and areas for improvement.
- Benchmarking: Benchmark the organization's performance against nationally and internationally recognized standards and best practices.

Development of improvement plans

- Action Plans: Develop specific action plans to address identified areas for improvement.
- Training and Development: Implement training programs to develop the necessary skills in the organization's personnel.

Implementation of improvements

- Execution of Improvement Plans: Execute the improvement plans developed, making adjustments as necessary.
- Monitoring and Evaluation: Continuously monitor the organization's progress towards higher levels of maturity and perform periodic assessments.

Documentation and reporting

- Progress Reports: Produce periodic reports documenting the organization's progress in implementing the maturity model.
- Recommendations: Provide recommendations based on findings from data analysis and ongoing evaluation.

Validation and adjustments

- Continuous Review: Validate the results obtained and adjust the maturity model as necessary.
- Stakeholder Feedback: Involve stakeholders to obtain feedback and ensure that the model responds to their needs and expectations.

The implementation of the development and social impact project maturity model in the case study organization will not only validate the proposed design, but will also provide practical guidance for other organizations seeking to improve their capabilities in managing development and social impact projects. This detailed process ensures that improvements are sustainable and aligned with the organization's strategic objectives, thus promoting a positive and lasting social impact.

Based on what has been recorded in this document, we recommend the implementation of the proposed maturity model, based on the PM4R methodology and the 10 elements of the Social Impact Assessment (SIA) approach, in organizations dedicated to the management of development and social impact projects. This model will not only provide a clear and effective structure for evaluating and improving organizational capabilities, but will also promote a culture of continuous improvement, accountability and transparency. Validation of the model through specific case studies, such as the one being developed in southwestern Colombia, will be crucial to demonstrate its effectiveness and adapt its components to diverse contexts, thus ensuring that organizations can achieve higher levels of maturity and sustainability in their social development initiatives.

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CHALLENGES AND OBSTACLES TO TRANSFORMATION OF JUAZEIRO DO NORTE INTO A SMART CITY

DESAFIOS E OBSTÁCULOS PARA A TRANSFORMAÇÃO DE JUAZEIRO DO NORTE EM UMA CIDADE INTELIGENTE

DESAFÍOS Y OBSTÁCULOS PARA LA TRANSFORMACIÓN DE JUAZEIRO DO NORTE EN UNA CIUDAD INTELIGENTE

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ABSTRACT

This article addresses the challenges and obstacles that the city of Juazeiro do Norte currently faces in becoming a smart city and shows issues such as limited technological infrastructure, financial investments, technological education and community participation to be discussed and therefore prevent the city from achieve this much-desired purpose. The objective of this study is to verify what challenges need to be faced by municipal management to turn the city into a smart city. The methodology adopted was based on a bibliographical review and through data obtained from city hall websites to highlight the problems that need to be resolved and what actions should be taken. The analysis is enriched by dialogues with other authors who highlight the importance of collaboration and interoperability and mainly by data research that shows the flaws and what is still missing for the city to achieve the title of smart city. The article concludes by emphasizing the need for collaborative strategies and investments to drive the transformation of the city of Juazeiro do Norte into a smart city. It highlights the main points that managers need to resolve, such as digital infrastructure, citizen participation and sustainable urban planning, to make this desire real and effective.

Palavras-chave:
cidade inteligente, tecnologia, sustentável, infraestrutura.

RESUMO

Este artigo aborda os desafios e obstáculos que a cidade de Juazeiro do Norte enfrenta no atual momento para se tornar uma smart city e mostra questões como infraestrutura tecnológica limitada, investimentos financeiros, educação tecnológica e participação comunitária para serem discutidas e por isso impedem que a cidade alcance esse propósito tão almejado. O objetivo desse estudo é verificar quais os desafios que precisam ser enfrentados pela gestão municipal para tornar a cidade em uma smart city. A metodologia adotada foi baseada em revisão bibliográfica e através de dados obtidos em sites da prefeitura para

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evidenciar os problemas que precisam ser resolvidos e quais atitudes que devem vir a ser tomadas. A análise é enriquecida por diálogos com outros autores que destacam a importância da colaboração e interoperabilidade e principalmente por pesquisa de dados que mostram a falhas e o que ainda falta para a cidade alcançar o título de cidade inteligente. O artigo conclui enfatizando a necessidade de estratégias colaborativas e investimentos para impulsionar a transformação da cidade de Juazeiro do Norte em uma cidade inteligente. Destaca os pontos principais que os gestores precisam resolver, como infraestrutura digital, participação cidadã e planejamento urbano sustentável, para tornar esse desejo real e efetivo.

RESUMEN

Palabras clave:
ciudad inteligente, tecnología, sostenible, infraestructura.

Este artículo aborda los desafíos y obstáculos que enfrenta actualmente la ciudad de Juazeiro do Norte para convertirse en una ciudad inteligente y muestra temas como la infraestructura tecnológica limitada, las inversiones financieras, la educación tecnológica y la participación comunitaria que deben discutirse y, por lo tanto, impedir que la ciudad logre tanto. propósito deseado. El objetivo de este estudio es verificar qué retos debe afrontar la gestión municipal para convertir la ciudad en una ciudad inteligente. La metodología adoptada se basó en una revisión bibliográfica y a través de datos obtenidos de los sitios web de los ayuntamientos para resaltar los problemas que deben resolverse y qué acciones deben tomarse. El análisis se enriquece con diálogos con otros autores que resaltan la importancia de la colaboración y la interoperabilidad y principalmente con investigaciones de datos que muestran las fallas y lo que aún falta para que la ciudad alcance el título de ciudad inteligente. El artículo concluye enfatizando la necesidad de estrategias e inversiones colaborativas para impulsar la transformación de la ciudad de Juazeiro do Norte en una ciudad inteligente. Destaca los principales puntos que los gestores deben resolver, como la infraestructura digital, la participación ciudadana y la planificación urbana sostenible, para que este deseo sea real y efectivo.

Introduction

In the 21st century, faced with the challenges of urban overpopulation, environmental problems and the complexities of city planning and management, discussions on urban reorganization and the implementation of efficient and sustainable management strategies have become highly relevant topics on public agendas (LEITE, 2012).

According to the World Urbanization Prospects 2018 Report by the United Nations (UN, 2018), it is estimated that by 2050 around 6.6 billion people will live in urban conglomerations. Against this backdrop, debates on the organization of cities have intensified, and in 2015 the UN launched the 2030 Agenda, which sets out 17 goals with 169 targets for Sustainable Development (SD). These goals cover diverse national realities, capacities and levels of development, including social, economic, political and cultural issues, such as poverty eradication, reduction of inequalities, access to drinking water, basic sanitation, clean energy, sustainable agriculture, sustainable communities, responsible consumption and production, and action against global climate change, among others.

According to the Sustainable Cities Index 2016, most cities face challenges in balancing the three pillars of sustainability: social, environmental and economic. Many cities score favorably in up to two of these areas, but few achieve positive results in all three. The survey, carried out in 100 of the world's major cities, used 32 different indicators to develop a ranking indicative of sustainability.

Faced with the need to optimize services, improve quality of life and foster innovative and sustainable environments, the concept of Smart Cities has emerged, closely linked to technological innovations. In general, Smart Cities are characterized by the integration of Information and Communication Technology (ICT) with the needs of an ecologically balanced urban environment. These cities aim to use knowledge and technological advances to improve and optimize urban management, making it more sustainable and efficient for users (IDB, 2016).

The transformation of Juazeiro do Norte into a Smart City represents an ambitious and necessary step towards the future, seeking to optimize citizens' quality of life through the intelligent integration of innovative technologies. However, this journey is far from without its challenges and obstacles that need to be carefully analyzed and overcome. In this introduction, we will explore the various aspects that make the transition to a Smart City in Juazeiro do Norte a complex endeavor, from infrastructural issues to challenges related to social acceptance and governance, highlighting the importance of a comprehensive and collaborative approach to achieving this visionary goal.

Juazeiro do Norte, a Brazilian city known for its rich culture and traditions, has been the subject of discussions about the possibility of becoming a "smart city" - a city that uses information and communication technologies to improve the quality of life of its inhabitants. Although the concept of a smart city is attractive, several challenges and obstacles need to be overcome if Juazeiro do Norte is to effectively make this transition.

On June 14, 2018, Complementary Law No. 117/2018 was sanctioned, making Juazeiro do Norte the first municipality in the country to implement a municipal Innovation and Smart City law.

One of the main challenges facing Juazeiro do Norte is its limited technological infrastructure. The successful implementation of a smart city requires a robust network of high-speed connectivity, efficient communication systems and a solid digital

infrastructure. The lack of these essential elements can hinder the effective implementation of technological solutions that characterize a smart city.

Transforming a city into a smart city requires substantial investment in technology, research and development. Juazeiro do Norte may face difficulties in attracting the financial resources needed to implement large-scale projects. Without significant investment, it is difficult to achieve the technological infrastructure and innovations required to become a smart city.

In today's society, marked by global cities with a constantly growing population, the emergence of various local challenges is becoming increasingly noticeable. These issues often impact the daily lives of the population, requiring specific solutions and approaches to deal with complex urban dilemmas.

The successful adoption of innovative technologies depends on the training and education of the population. In Juazeiro do Norte, there may be a need for comprehensive training and education programs to ensure that residents have the necessary skills to interact with new technologies. The lack of technological training can hinder the acceptance and effective use of the solutions proposed for a smart city.

Another crucial point is the need for effective governance and community participation. The implementation of technologies on a large scale must be accompanied by solid policies, guaranteeing data security, privacy and fair access to technologies. The absence of an adequate regulatory framework and the lack of community involvement can jeopardize the success of the transition to a smart city.

The objectives of the study on "Challenges and Obstacles for the Transformation of Juazeiro do Norte into a Smart City" can be outlined to address different aspects related to the process of urban transformation and thus be able to verify the problems that the city faces in order to become a smart city, thus seeking to identify important points for this transformation.

Theoretical Foundation

Before we go into the analysis of the most recent academic production on the concept of Smart Cities, it is imperative to introduce the theoretical framework. In this sense, this section comprises a bibliographical review that aims to delimit the essential concepts, thus establishing the theoretical foundation underlying the theme in question.

The methodological approach of this article is based on an in-depth review of the literature related to smart cities, with an emphasis on the challenges faced by Juazeiro do Norte. The analysis includes discussion of relevant academic work and research on the topic, providing a comprehensive understanding of the barriers to city transformation.

Smart cities are a relatively recent phenomenon, coined from the case study of Singapore's initiative to become a smart city, as documented by Mahizhnan in 1999.

However, different research indicates that this concept addresses new technologies and their implementation in the urban environment (LIU et al., 2010; KUIKKANIEMI et al., 2011), as well as the adoption of technology-centered public management (ODENDAAL, 2003).

Definition of Smart City

Smart cities have become one of the main topics of study in relation to urban development (GIL-GARCIA et al., 2016; JOSS et al., 2017). This is mainly due to the challenges presented by the rapid process of urbanization on all continents, as well as the emergence of megacities, which are those with more than 10 million inhabitants. In 2020,

approximately 4 billion people lived in urban areas, and this number is projected to rise to 7 billion by 2050 (representing two-thirds of the world's population), according to data from the United Nations report (UN, 2018).

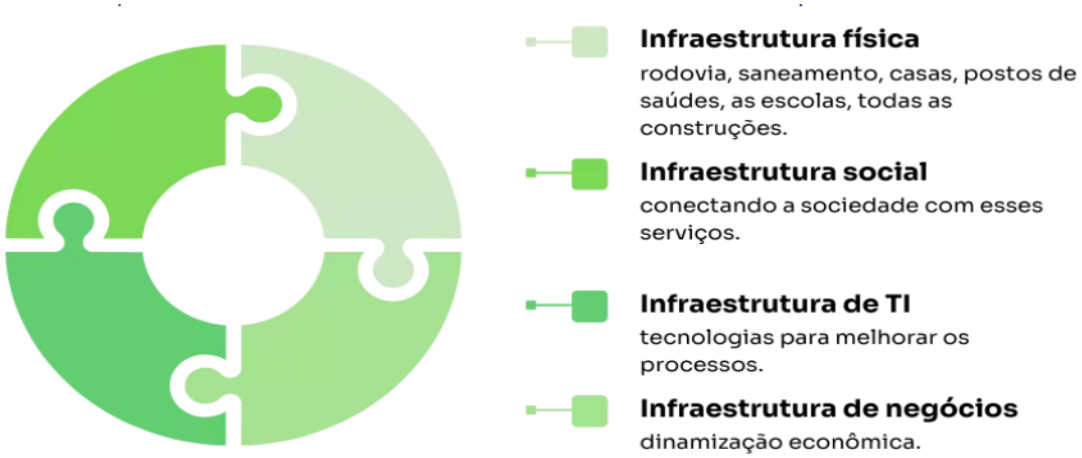
The term "smart cities" has various definitions, having emerged in the 1990s with a primary focus on the new Information and Communication Technologies (ICT) that were being integrated into urban infrastructure. The California Institute for Smart Communities was one of the pioneers in examining how communities could become smart and how cities could be designed to implement these information technologies (Alawadhi et al., 2012). Later, the Centre for Governance at the University of Ottawa criticized the idea that smart cities should only be linked to technical issues. In this vision, a smart city should adopt a governance-oriented approach, emphasizing the role of social capital in urban development. However, the term "smart city" spread in the early years of the 21st century as an "urban label" phenomenon. In recent years, researchers have drawn attention to the fact that cities that call themselves "smart" must demonstrate the various aspects that would justify this self-declared award of the label (Hollands, 2008).

In an IBM corporate document, Harrison et al. (2010) defined the term "smart city" as a city that is "instrumented, interconnected and intelligent". The term "instrumented" refers to the ability to capture and integrate citizen data through the use of sensors, meters, appliances, personal devices and other similar technologies. In turn, "interconnected" refers to the synchronization of this data on a computing platform that allows integration between the city's various services. Finally, "intelligent" refers to the inclusion of complex analysis, modeling, optimization and visualization services to support more efficient operational decisions (Harrison et al., 2010).

For Harrison et al. (2010), this is a city that integrates physical infrastructure, IT infrastructure, social infrastructure and business infrastructure to enhance the city's collective intelligence.

It is important to note that Harrison also emphasizes the interconnection of these parts as shown in figure 1.

Figure 1
Interconnecting Smart Cities



Note. Source: Harrison et al., 2010.

In the field of urban planning, the concept of the "smart city" is often considered an ideological dimension that implies strategic directions for a smarter approach. Governments and public agencies at all levels are adopting this notion of intelligence to differentiate their policies and programs, aiming for sustainable development, economic growth and improved quality of life for their citizens (Ballas, 2013). Alves et al. (2019) clarify that the term "smart" covers two broad areas: on the one hand, it brings a technopolis logic, involving the use of new technologies such as IoT, big data, algorithmic governance, among others; on the other hand, it represents the idea of an innovative city, with an emphasis on inclusion and citizen participation in urban governance.

Possibly the reason why there is no general consensus on the term "smart cities" is that it has been applied to two different types of "domains". On the one hand, it has been associated with more "hard" domains, such as buildings, energy networks, natural resources, water management, waste management, mobility and logistics (Neirotti et al., 2014), in which Information and Communication Technologies (ICT) can play a crucial role in system operations. On the other hand, the term has also been attributed to "soft" domains, such as education, culture, politics, social inclusion and governance, in which the application of ICT is generally not decisive.

Urban Sustainability

Urban sustainability encompasses a series of measures aimed at preserving and protecting the environment in which a city is located, which includes the conservation of local wildlife and plants. This allows inhabitants to remain in harmony with nature, without causing damage, through educational and awareness-raising initiatives.

The concept of "sustainable development", according to Sachs (1986), although it has often been interpreted in different ways, originates from a broader perspective that involves an analysis of the sustainable results of cities. In the 1960s, a new focus emerged on discussion agendas, with the environmental-economy-humanity triad, which sought to tackle the serious environmental impacts around the world (CARSON, 1962).

The changes in the situation in recent decades have highlighted the importance and scope of public policies in academic studies. Several factors have contributed to this growth, one of which is the adoption by governments of policies aimed at restricting

spending, saving resources and promoting social policies focused on health (SOUZA, 2007).

According to Mahler (2016), the Green City Index points to seven key elements for a city to become sustainable: i) effective governance, ii) integrated approaches, iii) promotion of the population's health, iv) encouragement of citizen participation, v) efficient use of technology, vi) balance between economic development and environmental preservation, and vii) actions by non-governmental organizations.

In this context, Secchi (2016) defines public policy, highlighting the importance of understanding two fundamental concepts: the public problem and public policy. The public problem is the starting point of the analysis and represents the difference between the current state and the desired state for a given public situation. On the other hand, public policy is a guideline designed to deal with a public problem.

Understanding these restrictions, it is important to reflect on their contributions to sustainability. According to Strapazzon (2009), with reference to the document drawn up by the European smart cities project, in order to be considered smart a city needs to perform adequately in six areas. These expressions define cities as suitable vital spaces, good places for economic development, in other words, they are essential when drawing up public policies.

Considering these concerns in the context of public policies, it becomes crucial to find a balance between the options available when implementing, for example, policies to encourage energy efficiency and decentralized energy generation, including the integration of surplus energy into the utility companies' grid (FERREIRA et al., 2015).

Thus, when developing public policies for smart cities, it is essential to consider the creation of healthy and sustainable environments. The interaction between local ecosystems is crucial, since the search for society's quality of life is one of the main contemporary challenges. To meet these challenges, it is essential to understand the social, economic and environmental aspects that are closely linked to the context of smart cities (CURY; MARQUES, 2017).

Smart Cities Around the World

The Inter-American Development Bank (IDB), in collaboration with the Korea Research Institute for Human Settlements (KRIHS), conducted a series of case studies on smart cities, financed by the Korean Knowledge Alliance Fund for Technology and Innovation of the Republic of Korea. The cities investigated included: Anyang, Medellín, Namyangju, Orlando, Pangyo, Rio de Janeiro, Santander, Singapore, Songdo and Tel Aviv. These case studies offer insights into the process of implementing a smart city and its impact on promoting urban sustainability.

Over the last thirty years, the global urban population has increased by an average of 65 million people a year, an unprecedented rate in history. By 2050, cities are expected to add another 2.5 billion inhabitants, almost 90% of which will be concentrated in Asia and Africa. However, as urbanization, industrialization and consumption grow, environmental pressures also intensify. Environmental degradation can have cascading effects on the health and quality of life of urban dwellers, as well as on the long-term sustainability of the city itself (McKinsey Company, 2018).

The city of Anyang in South Korea, with a population of over 600,000, began its smart city project in 2003. The initial focus of this project was the information system for public transport, aimed at improving the use of buses by citizens. This is how the Intelligent Transport System (ITS) came about, and in the last twelve years the Crime Prevention System and the Disaster Prevention System have also been developed, all integrated in a coordinated manner.

"The implementation of the crime prevention system resulted in a reduction in the crime rate, [...] Anyang city saw a significant average annual reduction in the crime rate, with a drop of 17.8%" (LEE et al, 2016, p. 34).

The control center developed in the city, known as U-City, was created to unify all these systems. Through the Anyang city center website, citizens have access to real-time information, based on videos and maps.

The city of Namyangju in South Korea, with a population of over 650,000, started its smart city project in 2008 in response to population growth. The initial focus was on implementing an intelligent traffic control and crime fighting system. The project has been divided into three main categories: ITS, which includes the Advanced Traffic Management System (ATMS), the Bus Information Service (BIS) and the U - Ubiquitous project. The active participation of citizens is crucial for collecting data on the performance of systems, using social media resources.

The city of Orlando, in the United States, with a population of over 250,000, has faced significant population growth and was also impacted by a natural disaster in 1997. In response to these challenges, a project to create the Orlando Operations Center (OOC) began in 1998 and was completed in 2001. This project integrated four essential sub-centers: the Traffic Management Center, the Emergency Operations Center, the 911 Communications Center (Fire Department and Police Department) and the Network Operations Support Center.

"The working group collects citizens' opinions and looks for ways to provide more accurate traffic information. Currently, there are 15,255 followers on twitter (@nyjtraffic) and 2,095 on facebook" (LEE, et al, 2016, p. 11).

Method

Juazeiro do Norte is a Brazilian municipality located in the state of Ceará, in the Cariri Metropolitan Region, in the south of the state, as we can see in figure 2. Located 491 km from the capital Fortaleza, the city is 350 meters above sea level and covers an area of 258.788 km^2. With an estimated population of 286,120, Juazeiro do Norte is the third most populous municipality in Ceará, surpassed only by Fortaleza and Caucaia. It is also the largest city in the interior of Ceará and ranks 104th in population in Brazil (IBGE, 2022).

Figure 2
Detailed area of the study region

Note. Source: Barros *et al* 2020.

Standing out as one of the main centers of popular religiosity in the country, Juazeiro do Norte gained notoriety due to the figure of Padre Cícero, and is considered one of the three largest centers of popular devotion in Brazil, alongside Aparecida (SP) and Nova Trento (SC). The city also stands out as a significant cultural hub, being recognized as one of the largest handicraft and cordel centers in the Brazilian Northeast (IBGE, 2022).

In addition to its cultural contributions, Juazeiro do Norte stands out as an important academic center in the interior of the Northeast, housing one of the largest academic centers in the region. The city is recognized as a "regional capital" and is considered the "metropolis of Cariri". With an urbanization rate of 95.3%, the city represents a central and dynamic point in the Northeast region of Brazil (IBGE, 2022).

As outlined by Caragliu, Del Bo and Nijkamp (2011, p. 6), a city achieves smart status by integrating investments in human capital, social capital and communication infrastructure, harmonizing traditional and modern elements. This process aims to drive sustainable economic development, promoting effective management of natural resources and adopting participatory governance, always keeping the focus on the quality of life of citizens. In a later contribution, the authors highlighted that smart cities emerge through the intelligent application of digital information, covering areas such as human health, mobility, energy consumption, education, knowledge transfer and urban governance (Caragliu et al., 2015, p. 114).

Sampaio and Mancini (2007) define a systematic review, along with other types of review studies, as a research approach that is based on analyzing the literature related to a specific topic. This methodology provides a summary of the evidence associated with a given intervention strategy, and is conducted through methods of searching, critically evaluating and synthesizing the information selected in an explicit and systematized way.

For this research, the inclusion criteria were articles related to the topic and that were current, as this brings recent research results to better support the discussion on the topic.

Results and Discussion

Presentation The results highlight the limited technological infrastructure, the need for financial investment, the importance of technological education and community participation as the main obstacles faced by Juazeiro do Norte. Dialogues with authors such as Caragliu et al. (2011) and Batty et al. (2012) emphasize collaboration and interoperability as essential elements to overcome these challenges.

When dialoguing with other authors on the subject, we see that the barriers faced by Juazeiro do Norte are not exclusive to this city. Many locations around the world face similar challenges in their quest to become smart cities. Authors such as Caragliu et al. (2011) highlight the importance of collaboration between the public and private sectors, as well as the need for clear government policies to overcome these challenges.

According to Batty et al. (2012), interoperability between different systems and the creation of innovative ecosystems are crucial aspects for the success of a smart city. Therefore, Juazeiro do Norte can benefit from learning from the experiences of other cities, implementing effective cooperation strategies and promoting public-private partnerships.

In the article "Smart Cities: A Conjuncture of Four Forces," published by Angelidou in 2015, the author carries out a comprehensive historical survey of discussions related to the use of technology in the urban environment. The historical journey, from the mid-1850s to the present day, highlights the significant transformations that have taken place in this scenario. The bibliographical research undertaken by the author aims to identify little-explored aspects of the meaning of intelligence in the urban context, while at the same time offering strategic guidelines for the planning and development of Smart Cities in contemporary times.

Among the most important elements in the Smart Cities concept, Angelidou highlights the integration between the urban environment, the Knowledge Economy and Innovation. In the context of technological advancement, the merging of these previously independent spheres promotes a fundamental transformation in the contemporary understanding of Smart Cities. The author emphasizes the importance of approaching urban and technological planning in a cohesive manner, ensuring that strategies balance demand and supply in the implementation of these technologies, as shown in figure 3.

Issues related to social concerns, such as quality of life, privacy and accessibility, have been addressed by scholars such as Van Zoonen (2016), Macke et al. (2018) and Alperstedt Neto, Rolt and Alperstedt (2018). On the other hand, Colding and Barthel (2017) were the only ones to highlight the problem associated with urban ecology and the growing concern about environmental aspects, questioning the dominance of economic interests in the implementation of smart cities, thus showing the difficulty that cities encounter in becoming smart cities.

Figure 3
Examples of sectors that could be impacted by Smart Cities

Note. Source: Adapted from http://www.blog.researchonglobalmarkets.com/.

It was possible to evaluate the current infrastructure of Juazeiro do Norte, and by analyzing the existing technological, communication and public services infrastructure in Juazeiro do Norte, it was possible to identify gaps and areas of improvement needed to become a Smart City, data from the City Hall show that Juazeiro do Norte had, in January 2021, more than 40% of its road network without any type of paving, Source, SEINFRA.

The topics below are information obtained from the city council's website. In order to identify technological barriers, the technological limitations that prevent the implementation of smart solutions in the city were analyzed. This includes issues related to information technology infrastructure, connectivity and interoperability of systems.

Regarding community acceptance, the local community's acceptance and willingness to adopt smart technologies was investigated. The population's perceptions, expectations and concerns regarding the city's digital transformation were understood.

When it comes to financial capacity, studies show that the city's financial capacity to invest in smart technologies includes identifying possible sources of funding, public-private partnerships and sustainable business models, and this has already been demonstrated in the city.

The challenge is already underway. The participation of the public, industry and other interested groups in the development of innovative governance solutions for Brazilian cities can be promoted through additional studies, such as this one, which highlight viable approaches to implementing smart cities. Finally, this work has summarized that, as well as the results presented, sharing knowledge and data represents a viable path on this journey. There is much more to be done, and more studies must be carried out to support the development and implementation of integrated solutions for smart, healthy and sustainable cities.

On the issue of security and privacy, cyber security and data protection issues were considered when implementing intelligent solutions. ensuring that the collection and

processing of information respects privacy and security standards, all of which is still in process.

In order to develop engagement strategies, the city government must propose strategies to actively involve citizens in the transformation process, promoting participation and collaboration, in figure 4 we can see the giradoudo square, which is an example of integration in the city. However, the results show that there have been few awareness-raising, education and public consultation initiatives.

Another important point is to promote sustainability by integrating environmental and sustainable aspects into the transformation plan, seeking solutions that contribute to reducing environmental impact and promoting sustainable practices.

Figure 4

Praça do Giradouro, in Juazeiro, is known as a model site with Wi-Fi and other services

Note. Source: Photo, Antonio Rodrigues

Finally, establishing strategic partnerships identified potential partners in both the public and private sectors who could collaborate in implementing smart projects and overcoming specific challenges.

Discussion and Conclusions

Although Juazeiro do Norte has the potential to become a smart city right now, it is essential to face and overcome the challenges mentioned. Collaboration between governments, the private sector and the community is key, and the city can benefit from experiences and lessons learned in other parts of the world. With adequate investment, technological education and a strategic approach, Juazeiro do Norte can pave the way to becoming a smart city and thus provide advantages for the well-being of its inhabitants.

There are many advantages to technological innovation. They provide significant improvements in various sectors, driving progress and efficiency. These innovations have the potential to positively transform society, optimizing processes, facilitating

communication, promoting advances in medicine, stimulating economic growth and contributing to solving global challenges. In short, technological innovations play a fundamental role in constantly improving quality of life and sustainable development.

A smart city in Juazeiro do Norte could include:

1. Connected Infrastructure: Streets equipped with sensors to monitor traffic, manage street lighting and optimize the use of resources.

2. Sustainable transportation: Promoting sustainable means of transport, such as cycle paths, efficient public transport and the implementation of electric vehicles.

3. Technology in Education: Schools equipped with state-of-the-art technology, high-speed internet access and innovative educational programs.

4. Digital Health: Use of digital health technologies to improve the provision of medical services, such as electronic patient records and telemedicine.

5. Smart Waste Management: Optimized waste collection systems, efficient recycling and the use of technologies to reduce environmental impact.

6. Citizen participation: Digital platforms for civic engagement, online voting and direct communication channels between citizens and the government.

7. Efficient energy: Adoption of renewable energy sources, such as solar and wind, and the use of smart technologies to monitor and optimize energy consumption.

8. Intelligent Public Security: Intelligent surveillance systems, camera monitoring, and the use of data to improve security in urban areas.

It is important to note that the transformation of a city into a smart city involves the collaboration of governments, companies, communities and other stakeholders to ensure the success and sustainability of these initiatives.

Given the challenges identified, the transformation of Juazeiro do Norte into a smart city requires collaborative strategies and substantial investments. The lesson learned from other cities highlights the importance of clear government policies and public-private partnerships. We conclude that, with targeted efforts, the city can overcome the obstacles and reap the benefits of technological innovation.

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THE TENDOM SYSTEM AND THE EVOLUTION OF ITS CONSTRUCTION TECHNOLOGY: A REVIEW

EL SISTEMA TENDINOSO Y LA EVOLUCIÓN DE SU TECNOLOGÍA CONSTRUCTIVA: UNA REVISIÓN

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ABSTRACT

Abstract. This research proposal integrates the existing relationship between construction technology and the environment, to be used in the construction of housing using the system of non-structural light walls. With this construction system, it is intended to publicize this new non-traditional construction technology, by integrating materials of regional origin and low ecological impact, in order to achieve construction sustainability at an environmental, economic and social level. Theoretically, it is based on Cardellach's philosophical principle, by incorporating the term of tendinous systems in the structures, as constructive forms that have their origin in the zoological architecture of vertebrates, where these structural and constructive forms are at a higher level of mechanical sensitivity and naturally inspired. Subsequently, Thomas integrates design, technology and culture, in an unconventional construction alternative called sinewy walls. The typology of this construction system consists of the on-site manufacture of flat rectangular modular panels, reinforced inside with a barbed wire mesh that acts as integrated tendons, covered on both sides with a mixture of mortar, to form a rigid structural frame, composed of sawn wood, guadua, in metal angle or concrete structure, thus constituting a monolithic structural element that will behave like a confined wall, which will give consistency and finish to the wall.

Palabras clave:
técnicas constructivas no convencionales, medio ambiente sostenible, muro tendinoso, mampostería no reforzada.

RESUMEN

La presente investigación integra la relación existente entre tecnología constructiva y medio ambiente, para ser utilizada en la construcción de vivienda empleando el sistema de muros aligerados no estructurales. Con este sistema constructivo, se da a conocer esta nueva tecnología constructiva no tradicional, ya que integrar materiales de origen regional y de bajo impacto ecológico, con el objeto de alcanzar sostenibilidad constructiva a nivel ambiental, económico y social. Teóricamente, el principio filosófico de

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	Cardellach, incorpora el término de sistemas tendinosos en las estructuras, como formas constructivas que tienen su origen en la arquitectura zoológica de los vertebrados, donde estas formas estructurales y constructivas están en un nivel superior de sensibilidad mecánica y de inspiración natural. En el 2002, Thomas integra diseño, tecnología y cultura, en una alternativa constructiva no convencional llamada muros tendinosos. La tipología de este sistema constructivo consiste en la fabricación in situ de paneles modulares rectangulares planos, reforzados en su interior con una malla de alambre de púas que hace las veces de tendones integrados, recubierta en sus dos caras por una mezcla de mortero, para conformar un marco estructural rígido, compuesto por alguno de las siguientes clases de materiales: madera aserrada, por bambú o guadua angustifolia (Colombia), por ángulo metálico o por estructura en hormigón; constituyendo de esta manera un elemento estructural monolítico que se comportará como un muro confinado, que le dará consistencia y acabado al muro.

Introduction

This research is part of a project that will develop the design of a constructive system of non-structural lightened tendon walls, with a matrix of environmentally friendly recycled cardboard tubes, emulating the zoological architecture of bees in their hives, forming a matrix as a whole. The research is framed in the field of Materials Engineering and Construction Techniques, and is approached from the environmental point of view in the area of recycling of construction materials. The proposed model investigated consists of a new construction system, composed of light tendinous walls for non-structural use, since it is necessary to search for alternatives and mainly for non-traditional raw materials, with the purpose of proposing technological solutions that optimize the use of these available resources, resulting in the welfare of the community, from the economic point of view, and the improvement of the environment.

With the delimitation of the research topic to a specific and restricted subject within the non-structural masonry, the attainment of the sources of information and bibliographic references also becomes less frequent and reduced, particularly because this subject was born exclusively in the department of Valle del Cauca, Colombia, Municipality of Santiago de Cali, Corregimiento de Pance, Vereda La Viga, (Thomas, 2002); that due to its constructive and geographical versatility has been extended to the coffee axis of the country and has been implemented by some universities of the Andean area. According to the various researches carried out on this subject in the region, it is feasible to find these research resources, which will be the bibliographic sources of consultation to answer and solve the problem. Derived from the above, it is necessary to perform not only a bibliographic analysis of the subject, but also a structural analysis of the proposals and prototypes that have been presented mainly in Latin America, for example, the study by Casas (2011) where he assures that the tendon wall construction system has been successfully used in the construction of one and two-story houses and in complementary buildings in rural and peri-urban areas of southwestern Colombia.

Method

Research Design

The existence of a proven objective reality, such as stone and brick masonry walls as a construction method since millenary times, has been transformed with the invention of new materials and construction methodologies. In modern times, this boom of new technologies in the construction sector is causing an environmental problem of incalculable proportions, as it is using large quantities of raw materials composed of non-renewable natural materials (Ramírez 2022). In order to solve this environmental problem, new construction alternatives that are more environmentally friendly are being developed.

The development and modification of traditional construction techniques need to evolve and adapt to the needs of societies, but are directly related to safeguarding the integrity of their inhabitants and the right to decent housing; however, we must consider the increase in climate changes such as floods, increased extreme temperatures, and droughts that have occurred in the last 10 years (Management Solutions, 2020). As a result of the above, it is necessary to design and propose new construction techniques that meet the structural requirements to reduce the high housing deficit in Colombia (Perera, 2012). In addition to meeting the challenge of structural requirements, it is

necessary that these proposals reduce the construction time of a project and maintain an optimal performance between materials, labor and equipment with proper planning and execution of its construction elements. Finally, a proposal for a lightweight wall system is presented, which consists of the on-site fabrication of flat rectangular modular panels, reinforced on the inside with a barbed wire mesh that serves as integrated tendons, covered on both sides with a mortar mixture, to form a rigid structural frame, composed of one of the following types of materials: sawn wood, bamboo or guadua angustifolia (Colombia), metal angle or concrete structure; thus constituting a monolithic structural element that will behave as a confined wall, which will give consistency and finish to the wall.

Instruments

For the definition of the structural evolution, updates and innovations of the tendon walls, a bibliographic search was carried out in the known specialized information systems, Google Scholar and Scopus or Reserach Gate. The search included keywords such as sinewy structures, ecology of sinewy walls, nonstructural masonry walls using sinewy systems, etc. Next, the selection of the scientific products to be studied was made from their origin to the year 2023, since this research will mark the importance of using this type of structural systems, their limitations and variables, which need constant updates to guarantee an optimal sustainable performance. A matrix was made using the purpose of each of the selected academic/scientific products to begin to trace a timeline in the evolution of constructive tendon systems. With the selection of the study area, the delimitation of the scientific products that marked the results and analysis of this research was completed. Derived from the type of construction system to which they respond, the type of society to be served and the infrastructure system for which they are designed, we proceeded to make a hierarchy of recommendations so that the tendinous systems, especially the nonstructural walls, are a first option in different constructions, whether for housing, commerce, educational facilities, urban or rural.

Results

The need for a paradigm shifts regarding traditional construction methods and the handling of materials from the technological point of view in order to implement and build more economical and efficient environmental housing, the non-traditional construction system of tendon walls, is not a new methodology, but it offers a viable and sustainable alternative through the analysis and chronological account of the technical and constructive evolution of the tendon wall.

Tendon Systems

Cardellach in 1910 expresses that man must be contemplative of nature, which is the great truth of all the material world that surrounds him; helped by his imagination he argues and reasons expressing his phenomena "in the form of geometric concepts and analytical mathematical expressions, constituting a spiritual gear of rational deductions that lead us quickly to the discovery of new truths", (1970, p. 1).

All structures are subject to the laws of external forces of nature, calling it the general mechanical principle, which must be satisfied by simplifying the complexity of natural phenomena by establishing simple hypotheses, to be possible the stability and strength of the structure, this he calls the principle of the structure. In nature we have an example, the zoological architecture of vertebrates formed by the animal skeleton.

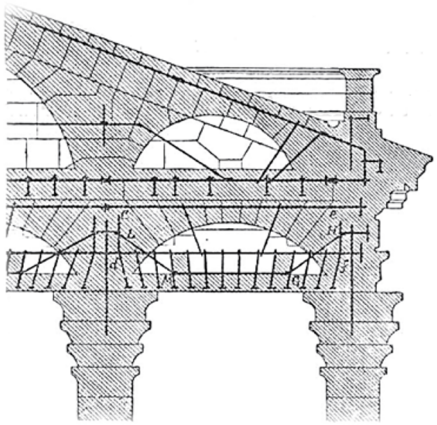
Concluding in this way that the engineer with this innovative spirit, must discover new forms of resistant frames for the present construction; the only origin of these structural and constructive forms is in a superior level of mechanical sensibility and natural inspiration, which are innate in man (architect, engineer) and which have constituted an important characteristic of his development, (Cardellach, 1970, p. 8-10). He synthesizes that structural forms should be classified or grouped by harmony of texture, mechanics and construction into two main groups:

1. Bi-resistant forms, suitable to withstand compressive and tensile stresses, are used in construction systems of steel tendons in the form of a lattice (skeleton) and articulated to each other to absorb these stresses.
2. Uni-resistant forms are suitable for supporting only compressive or tensile stresses, using construction systems of segments composed of flexible elements, (Cardellach, 1970, p. 12-16).

Structural configurations initially pointed out to the metal tendon its appropriate place in the masonry and due to economic circumstances facilitated the development of the tendon system, the masonry takes a back seat as a protector of the lattice system by fixing the tensioned tendon and transmitting its strength to the concrete, as shown in Figure 1.

Figure 1

Iron reinforcements in stone, St. Geneviève de Paris church



Note. Source: http://www.wikiwand.com/es/Jacques-Germain_Soufflot

This strategic placement of the tendinous system is a way to solve the structural problem, this ramification reaches the aspect of a network in the very core of the structure and in union with it, it manages to give forms to the structure, (Cardellach, 1970, p. 52-75). Cardellach concludes that

> Such is the fineness and elegance achieved by the tendinous system in the resolution of a problem of structural resistance, obtaining an original and economical structure, resistant and elastic, which synthesizes the advantages of construction that are proper to reinforced concrete..., here dies the mechanical rationalization of the Roman structures as a necessary consequence of the general characteristic of concrete, (1970, p. 83).

According to Cardellach, within the uniresistant systems of load transmission, he classifies the principle of stacking or overlapping of materials, as the principle of all constructive processes, which is defined as "a rudimentary arrangement inspired by those offered by natural piles and without apparent law of the material deposited by fortuitous accidents", (1970, p. 94). Structurally, it defines three classes of tendons:

1. Tendons by ligament, used to join critical points in masonry in order to avoid partial slippage and maintain the monolithism of the structure.
2. Apparent tendons, used to bind together the entire contact surface of the elements, in order to improve the mechanical resistance of all its elements.
3. Bonded tendons, used to be placed internally in the structure in order to form a single monolithic structure.

Torroja in 1957, expresses that reinforced concrete is an organically constituted stone, within whose mass the tendon complex of the reinforcement is optimally distributed, it is dosed to provide the concrete with the tensile strength it needs at each point, the joint work between the mass of concrete and the steel bars is confined to adhesion, ensuring the transmission of stresses from the reinforcement to the concrete and vice versa, (Torroja, 2010, p. 67-68). Concrete is a different material from reinforcing steel, since it is very weak when working in tension compared to its good performance in compression. For this reason, in structures, reinforcing rods are placed in the regions where tensile stresses occur, resulting in the cross section of the structure behaving as a section composed of two materials, concrete and reinforcing steel (White, 1980, p. 52-54).

Tendon Wall System in Colombia.

The following are the results of the research carried out at regional level, where the constituent materials, composition and structure of the tendon wall are explained in detail, when applying this non-traditional construction system in Colombia.

A) Thomas in the 90's, presents the Tendinoso System as "a research that integrates design, technology and culture, which responds to the felt need to live in a material house" (2002, p. 25), it is a non-conventional constructive alternative that starts from the traditional peasant architectural knowledge and techniques, optimizing this knowledge and responding to the need of these communities to build their own housing in more resistant, safe and durable building materials over time, (2015, p. 170).

The typology of this construction system consists of the on-site fabrication of flat modular panels, reinforced on the inside with a barbed wire mesh that serves as integrated tendons, joined by means of staples to vertical and horizontal elements forming a rigid structural frame composed of sawn or round wood, guadua, metal angle iron or reinforced concrete. The core of the partition walls is a biodegradable natural fiber lattice called costal, whose base is cabuya, mezcal or fique, which is interwoven with the barbed wire lattice, in order to serve as a support for the application of the mortar mixture, by successive layers to provide union between its elements and give rigidity to the framework, constituting a monolithic structural element that will behave as a confined wall, giving a final finish to the panel with average thicknesses of 4 to 5 centimeters (Torres, 2013, p. 1), (Figure 2). 1), (Figure 2).

Figure 2
Components of the tendon wall system

Note. Source:Mora (2022, p. 47)

The tendon wall system consists of the integration of two basic elements, the linear elements (horizontal and vertical) that act as a frame and structural support, and the flat elements of the modular panel or partition, composed of the barbed wire mesh or tendons intertwined with the fiber core to which the adhesive mortar will be adhered. Thomas argues that "the research bet consisted in stimulating an integral approach to environmental design, which recreates the positive aspects of the existing technoculture" (2002, p. 28), where there is a political boundary that comes from the conquest and subsequent colonization. (2002, p. 28), where there is a political boundary that comes from the conquest and subsequent colonization, since the architecture was imposed with durable materials such as brick, which he calls colonial technoculture, over the local biodegradable technoculture of wood (malocas and bahareque) which was excluded being of indigenous type, which he calls the great oblivion of technological education. From this ideological perspective, the tendinous system is materialized, developing construction techniques and using traditional wooden structures of the region, so that the inhabitants were their self-builders through the ancestral customs of the mingas and convites (indigenous tradition of community work), other important factors is that the resulting constructions are comfortable for its inhabitants (Figure 3).

Figure 3
Construction of the tendon wall system

Note. Source: http://www.zuarq.co/

Thomas defines it as "appropriate technology" when designing an environmentally friendly construction system that responds to the socio-cultural determinants of the place, from the aesthetic, structural and economic point of view (2002, p. 31).

B) Guerrero y Casas, analyzes the seismic aspect, emphasizing that the Pacific region is located in an area of high seismicity, the behavior of the different structures and their vulnerability to these events and the safety that buildings can guarantee against earthquakes, adding that the earthquake in Armenia in 1999 showed the high seismic vulnerability of buildings of less than one and two stories that were built without meeting the requirements of seismic-resistant design (2002, p. 51). This system can be classified as confined load-bearing walls and its basic structural system consists of a wood, guadua or steel frame, which when integrating the tendon wall panel to this structure works as a load-bearing wall, this construction system has been successfully used in one and two-story houses (Guerrero and Casas, 2002, p. 52-53).

C) Velázquez analyzes the tendon wall system: due to its versatility, speed of construction and economy, it was a pilot project of the Colombian Coffee Growers Federation (Federecafé) using this construction system in the Department of Valle del Cauca (Colombia) and specifically in the municipalities of the coffee axis (Caicedonia, Sevilla, Restrepo, Trujillo, La Victoria, Bolívar) among others, where there are large plantations of bamboo or bamboo, (Velázquez , 2010, p. 8-10).

Franco (2019), analyzed different traditional construction techniques in Colombia, mainly those based on the use of bamboo in the construction of one or two-story buildings, also studied the possible bioclimatic criteria to be taken into account to ensure optimal adaptation to the local climate, resulting in achieving user comfort without the need for high energy consumption. This system gradually became widespread in other regions mainly due to its ease of construction, since it does not require skilled labor and can be carried out by community self-construction methods (Figure 4).

Figure 4
Construction of the tendon wall system

This construction system is not endorsed by the Colombian Seismic Resistant Construction Regulation, (NSR-10), Title G, however it had its first fire test during the Armenia earthquake in 1999 (seismic magnitude on the Richter Scale of 6.1) where it showed an optimal behavior due to its inherent ductility that prevents the collapse of the walls, some of the houses built by this system and that were affected by the earthquake did not present major damages nor did their walls collapse, unlike the bad behavior of the traditional brick construction systems, (Velázquez, 2010, p. 8-10). Due to its ease of construction, speed of execution and low cost, this construction system has made it possible to respond to the needs of many people with low economic levels. These characteristics have made the tendon walls popular in these areas, reproducing and adapting the construction methods with new materials and various geometric configurations (Velázquez, 2010, p. 15-16). From the structural point of view, the tendon wall is heterogeneous, it is a composite material, anisotropic and its components present a non-linear mechanical behavior, its structural characteristics are the following:

- Confining structure, these elements work with a double structural function by transmitting the vertical loads to the foundation, horizontally confining the panel frame, as well as being the physical support for all the other elements of the system.
- Although it does not have a specifically structural function, its main function is to give consistency to the wall in the face of loads perpendicular to its plane of placement, it also gives adherence to the tendon wall as a whole.
- Barbed wire, its behavior is that of a tensioning cable that absorbs tensile loads in the horizontal direction of the wall, it also allows the grip and support of the natural fique lattice.
- Fique natural fiber lattice is the surface that allows the placement and cohesion of the mortar in the face of loads perpendicular to the plane of the wall (Velázquez, 2010, p. 21-22).

In addition, Velázquez differentiates the structural systems of the tendon wall with its various constituent materials:

- Structure with metallic profiles, the sections of these metallic profiles A-36 is small (1 1/2" to 2" x 1/8"), its anchorage to the foundation is totally embedded (the angle or profile is embedded) or its fixation can be made by the anchorage system with embedded bolts, the union between the elements of the framework is made by means of electric welding, this means that it can assume movements of the structure or framework without compromising the stability of the wall, to these profiles the galvanized hooks must be welded to fix the barbed wire tendons, as the sections of the profiles are small it does not reduce the architectural area of the houses.
- Wooden structure, the sections of this framework in sawn or round wood can be 4" x 4" x 6 meters, its anchorage to the foundation is totally embedded (the column is embedded), the union between the elements of the framework is made by means of bolts, it is required that the wood has undergone a process of immunization.
- Guadua structure, the sections of this framework can be from 10 to 15 centimeters in diameter, its anchorage to the foundation is totally embedded (the column is embedded), the union between the elements of the framework is made by means of bolts, it is required that the guadua has undergone a process of immunization.

The geometry of the panels of the tendon wall is rectangular in shape, the columns of the confining structure can be sized from 0.75 meters to a maximum of 1.2 meters, with an average height of 2.4 meters at most, the placement of the barbed wires can be between 20 and 30 centimeters, intercalating their distance between the parallels, (Velázquez, 2010, p. 24-26). The functionality of the tendon wall system is analyzed from a constructive point of view, as a whole of the house itself, highlighting the following functionalities:

- Enclosure, its basic function is to separate the different rooms of the house, it constitutes a solid matrix as a whole that is capable of resisting impacts perpendicular to its plane of action and is relatively light in comparison with conventional brick masonry construction systems.
- Resistance, the tendon wall is not self-supporting and its vertical structure must be embedded in the foundation, the resistance of the whole tendon wall system is subject to the confinement given in the structuring of the construction system, being suitable for one and two-story constructions.
- Insulation, it does not have any kind of acoustic or thermal insulation.
- Durability, the tendon wall requires adequate maintenance when there are cracks, flaking of the mortar, cracks in the construction joints, with timely patching a good durability can be guaranteed.
- Watertightness, the tendon wall by its nature is not watertight due to the porosity of the glue mortar, to avoid this phenomenon the wall must be waterproofed on its exterior face to avoid filtrations.
- Construction time, one of the most important advantages of the tendon wall system is its fast construction process.
- Versatility, this construction system is applicable to social interest housing (VIS), in country houses of high strata, due to its adaptability to all kinds of projects with different climates and topographies of the terrain.
- Aesthetically, constructions with tendon walls have a lot of freedom from the architectural point of view, (Velázquez, 2010, p. 42-44).

D) Bedoya emphasizes the aesthetic aspect of the structure, it is very necessary for the acceptance or rejection of a construction technique or construction material, (2011, p. 82). List the characteristics, properties and functions of the materials involved in the construction of a tendon wall, which are the following elements:

- Barbed wire, base material that acts as reinforcement in the tendon framework, its structural function is to absorb the tensile stresses in the wall panel.
- This material is the core of the panel and is composed of sacks or bags of fique, it acts as a mesh that covers the entire length of the panel. Its main function is to give adherence to the tendon system with the mortar that is loaded in successive layers until the desired thickness of the wall is obtained.
- This material is in charge of giving solidity to the panel of the tendon wall and at the same time giving it its final finish, the activities of the placement of this mortar is similar to the plaster, the first activity is the loading of the panel by means of a mixture of mortar rich in cement and water that is thrown on the natural fiber lattice in order to obtain adherence, then after the drying of this layer, the successive layers are placed that will give the necessary thickness to the tendon wall.
- The confinement structure is composed of vertical elements (columns) and

the materials used can be wood, guadua, angle iron, reinforced concrete, etc. (Bedoya, 2011, p. 82-83).

E) Builes analyzes the constructive aspect of the tendon wall, where the foundation is constituted by an overlying beam, on it is built a perimeter masonry wall of brick starting with the purpose of giving insulation to the structural system and to the tendon wall itself, on this wall are built the panels that make up the resistant structure and are formed by the columns and beams that provide confinement to the system, the columns are embedded in a sill both at the top and bottom in order to provide rigidity to the system (Builes, 2011, p. 44-45). 44-45).

F) Casas defines it as a non-conventional construction system, which must provide safety, stability and durability over time, (2011, p. 27). Defines the aspects of this system to be evaluated:

- Environmental aspect, this is composed of two orders:

1. Formal order, it is the urban or rural environment where the system will be implemented.
2. Functional order, which is composed of geography, climate and construction regulations.

- Technological aspect, this includes the level of use of the construction system.
- Socio-economic aspect, relates the economic situation of the region, (Casas, 2011, p. 28-36).

G) In his research Giraldo - Raigoza and Sanchez, emphasizes the construction of: Housing in the rural area with the application of bioarchitecture of tendon wall, based on the characteristics of the social environment, areas of influence with latent need for a model of improvement at the level of housing and need, it is considered urgently to meet the deficit presented. Environmental awareness, is another factor to be addressed in rurality from the incursion of the new rural housing model raised, (2016, p. 16). The guadua angustifolia is the most important raw material in the construction of a kind of tendon wall, it is a renewable and sustainable resource as it fixes carbon dioxide (CO_2), complying with the constructive sustainability.

H) Mora conducts an experimental research in the laboratory, manufacturing various types of tendon walls subjected to lateral loads, the dimensions of these tendon walls have a height of 2.20 meters, a width of 1.20 meters and a thickness varying between 5 and 7 centimeters, listing the following prototypes, (Mora, 2022, p. 47-49):

- Thomas type tendon wall, which consists of a guadua portico, an internal matrix made of fique sacking, barbed wire and covered on both sides with mortar mortar with cement and sand.
- Chacon type tendon wallconsisting of a guadua portal, an internal matrix of metal mesh with a vein, an internal grid reinforced with 3/8" corrugated steel and coated on both sides with cement and sand mortar.
- Morachá type tendon wall, which consists of a guadua portico, an internal matrix of guadua mat, reinforced with 3/8" corrugated steel and coated on both sides with cement and sand mortar.

From the bending test with lateral loads performed on the tendon wall specimens in the laboratory, the following results of the maximum ultimate load were obtained (Mora, 2022, p. 91) the following results are obtained for the maximum ultimate ultimate load, (Mora, 2022, p. 91):

- Thomas type tendon wall, $\underline{X}$ = 6.12 kN.
- Chacon type tendon wall, X = 7.00 kN.
- Morachá type tendon wall, X = 6.55 kN.

	CARGA MÁXIMA DE ROTURA		
	THOMAS	CHACÓN	MORACHÁ
Ensayo 1	6,75	8,2	6,9
Ensayo 2	5,99	6,15	6,64
Ensayo 3	5,4	7,55	6,47
Ensayo 4 _	6,33	6,08	6,2
X =	6,12	7,00	6,55
S =	0,5705	1,0506	0,2941
CV =	9,33	15,02	4,49

When performing a statistical analysis of the lateral flexural test values of the tendon walls, the highest arithmetic mean corresponds to the Chacón test, the Thomas value is lower by 12.6% and the Morachá value by 6.4%, with respect to the highest value. The coefficient of variation (CV) value of the Chacón trial has a high variation (15.02%), followed by the Thomas trial (9.33%) and the lowest coefficient for the Morachá trial. It is concluded that the various types of tension walls perform well under horizontal or lateral bending loads.

I) Garcia and Velasquez in their experimental laboratory research, propose a new alternative for tendon walls, by replacing the fique sack and barbed wire with a netting of PET (polyurethane terephthalate) bottles and banana rachis (stem), recycled waste materials, generating a new form of reuse of these products to be used in the manufacture of tendon walls for construction (2021, pp. 15-17). When the respective laboratory tests were carried out, it was concluded that the rachis fibers did not adhere well to the mortar; additionally, according to the compression and flexural tests, the PET meshes do not generate or provide resistance to the tendon wall. As a conclusion of the research carried out, the implementation of this kind of materials in the fabrication of tendon walls is not feasible, (García and Velásquez, 2021, p. 97).

Discussion and Conclusions

Tendon systems are considered constructive forms that have their origin in the zoological architecture of vertebrates, such as the combination of skeleton, muscles and tendons (Cardellach, 1970). In relation to this research, this constructive system proves to be useful in load-bearing and division elements, mainly in the direct relationship between the materials that make it up and the purpose for which it will be designed. This is supported by Cardellach (1970), who states that the sole origin of these structural and constructive forms is at a higher level of mechanical sensitivity and natural inspiration. Cardellach concludes that the engineer, with this innovative spirit, must discover new forms of resistant frames for the current construction.

The tendon wall system has been applied in Colombia since the 1990s and, because it is environmentally friendly, it has provided an answer to the need for low-income housing, since it does not require skilled labor. The confinement transmitted by the tendon wall system is highly resistant to gravity loads and very stable to seismic events as demonstrated in the Armenia (Colombia) earthquake of 1998 (Zuluaga, 2012, p. 14-15). From the technological point of view, the adoption of non-conventional alternative construction systems brings with it the innovation or improvement of these systems, either through the use of traditional regional materials, the implementation of new construction, organization and production methods to reduce construction costs, or the use of recycled materials in some cases, all these aspects listed are possibilities that at a given moment can become real and effective options for the use of existing resources, and in this way help the less favored classes to improve their living standards with the construction of decent housing, such as those built in the neighborhood La Independencia, Municipality of Restrepo, Valle del Cauca, Colombia, Figure 5.

Figure 5
Group of houses built with the tendon wall system

The advantages of this tendon wall system are as follows:

- Ancestral peasant building traditions can be applied and improved.

- Labor and material resources from the same region are used.
- Mortar-coated panels can be given a rustic finish, or they can be stuccoed and painted afterwards.
- The panel system allows the internal placement of all kinds of pipes for electrical, hydraulic and gas installations.
- The panels, due to their thickness, serve as thermal and acoustic insulation in the house.
- The tendinous system is very economical so that houses can be built at low cost, and houses can be built in both rural and urban areas of a locality.
- The behavior of this tendon wall system in the face of the seismic actions presented in the region was very positive with a value on the Richter scale of 6.5and the Armenia earthquake in 1998 with a Richter scale value of 6.4, both rated as strong. The houses built with the tendon wall system did not suffer structural damage.
- The tendon wall system does not overturn in earthquakes, as was the case with wattle-and-daub and simple brick walls. This seismic response factor is very important when it comes to safeguarding the lives of the occupants.
- It is an environmentally friendly construction system.
- This construction system is part of the framework proposed by the Regional Action Plan for Sustainable Development of Agenda 21 of the United Nations, regarding the recovery of traditional systems and materials, by using non-conventional and alternative systems.

The few disadvantages of this tendon wall system are:

- Direct humidity can occur in the walls located in the external parts of the house, as a result of rainwater, which can be prevented by performing periodic maintenance with impermeable plastic paint coatings.
- When building in wood or guadua, these must be well immunized to prevent attacks by xylophagous insects, in order to guarantee their durability over time and good structural behavior.
- Another very important factor to take into account are the construction errors that may occur in its execution, as a result of inexperience in self-construction.

The following aspects are left as a topic for research and technical discussion:

- Such is the importance achieved by the tendon system in solving a structural resistance problem that an original, economical, resistant and elastic structure is obtained.
- Thomas materializes the tendinous system, developing construction techniques and using traditional wooden structures of the region, implementing the self-construction system.
- This tendon wall construction system responds to the housing needs of the underprivileged classes and can be implemented in any geographical location.
- This new construction system technology is intended to comply with environmental requirements, taking into account, from this perspective, the application of new clean technologies in the field of construction.
- It is a basic tool that must guarantee a decent quality of life, responding to the unsatisfied primary needs of low-income families.
- The community self-construction system can be implemented, since it does not require prefabricated elements.
- As it is a very flexible construction system, the architectural spaces of the house can be easily adapted and modularized.

- The system is adaptable to any geographical area and topography, as well as being environmentally friendly.
- Because of its versatility in construction, it is possible to use various materials in the structure of the house, whether wood or guadua from the region.

The following conclusions are drawn from this research process:

1. The viability of the construction system to respond to the housing deficit problem in both urban and rural areas was demonstrated.
2. The tendon system results in a quality construction with local materials.
3. From its philosophical principle, it contributed the integrating concept of appropriate technologies.
4. From the professional and academic point of view, when working with the community, an apprehension of ancestral constructive knowledge is made.
5. Academically, the concept of exclusionary architecture is overcome by the evolutionarily creative function of inclusive architecture.
6. Philosophically, the social acceptance of this technology is significant, as the community qualifies it as appropriate to be implemented by them.
7. The construction projects of tendon walls in rural or urban developments must satisfy the physical and basic social needs of the communities, in accordance with sustainable construction and maintaining a balance between the existing ecosystems.

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COMPARATIVE ANALYSIS OF CORPORATE SOCIAL RESPONSIBILITY POLICIES IN THE OIL SECTOR OF LATIN AMERICA

ANÁLISIS COMPARATIVO DE POLÍTICAS DE RESPONSABILIDAD SOCIAL EMPRESARIAL EN EL SECTOR PETROLERO DE AMÉRICA LATINA

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ABSTRACT

This article presents a comparative analysis of the actions and results shown by three Latin American oil companies (Ecopetrol, Pemex and Petrobras) in their annual corporate social responsibility reports. Before doing the analysis, a review of the concept of corporate social responsibility and its evolution throughout history is exposed, as well as an overview of the oil industry in Latin America and its relationship with the key issue of environmental sustainability. Then the methodology of the study is explained, which basically, it is a mix diagnostic-descriptive investigation, with a socio-critical approach. Thirdly, the most important data related to the three dimensions of sustainability, economic, environmental and social, are presented. This data is gathered based on the annual sustainability reports of the three companies. Some news related to social and environmental aspects involving the three companies are also reviewed. Finally, the corresponding analysis of the exposed data is carried out; as a result, it is concluded that, although the three Latin American oil companies prepare their reports based on the

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three dimensions of sustainability, the optimal levels of social and environmental investment required for achieving the sustainable development goals outlined by the 2030 Agenda are not yet reached.

RESUMEN

Palabras clave:
responsabilidad social empresarial, sostenibilidad ambiental, petróleo, gases efecto invernadero.

En el presente artículo se expone un análisis comparativo sobre las acciones y los resultados que muestran tres empresas petroleras de América Latina (Ecopetrol, Pemex y Petrobras) en sus informes anuales de responsabilidad social empresarial. Previo al análisis se expone una revisión del concepto de responsabilidad social empresarial y su evolución a lo largo de la historia, así como un panorama general de la industria petrolera en América Latina y su relación con el tema de la sostenibilidad ambiental. Luego se explica la metodología del estudio, que en este caso es, fundamentalmente, una investigación mixta diagnóstica-descriptiva, con enfoque socio-crítico. En tercer lugar, se presentan los datos más importantes relacionados con las tres dimensiones de la sostenibilidad, esto es, la económica, la ambiental y la social, tomando como base los informes anuales de sostenibilidad de las tres empresas. También se revisan algunas noticias relacionadas con aspectos sociales y ambientales que involucran a las tres empresas. Por último, se procede al análisis correspondiente de los datos expuestos y se concluye que si bien las tres petroleras latinoamericanas elaboran sus informes con base en las tres dimensiones de la sostenibilidad, aún no se alcanzan los niveles óptimos de inversión social y ambiental que se requiere para lograr cumplir con los objetivos de desarrollo sostenible trazados por la Agenda 2030.

Introduction

The concept of Corporate Social Responsibility (CSR) or Corporate Social Responsibility (CSR) has been gaining increasing relevance, both in academia and in the business world itself, especially among large companies such as those in the oil sector. The concept of CSR has evolved throughout history, as will be explained below. Currently, large companies present Corporate Social Responsibility reports that usually contain three essential aspects: economic (or financial), social and environmental (Goloshchapova et al., 2019), focused on highlighting the company's commitment to the society of which it is a part, both within it (work environment-decent work), and outside it (social impact) and, of course, with the care of the environment, which includes measures against climate change and strategies to care for or restore the ecosystems in which it operates. Each company can follow a particular model to present its achievements and challenges. However, more and more companies are governed, for the preparation of these reports, by the parameters established by the *Global Reporting Initative* organization, which seeks to promote the preparation of reports focused on the sustainability (economic, social and environmental) of organizations (Benites-Lazaroa, Gremaudb, & Benitesc, 2018; Junco Trujillo & Martínez Acuña, 2021).

Growing concern about the adverse effects of gas emissions and industrial waste on the environment has prompted many companies to take action to help minimize, at least to some extent, the damage that their processes inflict on the ecosystems in which they operate. For the time being, most companies develop these actions more for economic interests and corporate image than out of their own will and awareness of the problem.

The concept of CSR has its origins in the early 20th century, but it was only in the 1950s and 1960s that it became established as an important aspect of management theories (Crezpo Razeg, 2010), but not yet as relevant as it is today. Already in the 1990s, new currents emerged that promoted the strengthening and development of this concept, reconfiguring it into what it is today (Pache Durán, 2017).

In its beginnings, this term was understood only as the responsibility, on the part of the company's management, to direct the efforts of the administration to maximize profits (Marcó, Loguzzo & Fedi, 2016). Now, in the 21st century, CSR is much more than that; it implies taking into account, in the decisions made and actions undertaken, ethical, social, economic and environmental aspects (Pache Durán, 2017; Tinoco Cantillo, Arango Buelvas & Benavides, 2012).

It should be noted here that there is no single definition of the concept of Corporate Social Responsibility, as argued by several authors (Crespo Razeq, 2009; Tinoco, Arango & Benavides, 2012; Nave & Ferreira, 2019; Bom-Camargo, 2021); moreover, there are multiple ways of understanding and explaining it, although common elements can be identified in almost all definitions or at least in many of them. It is possible that this is one of the reasons why some companies, small, medium and even large, do not have clear CSR policies and therefore do not carry out well-defined and effective actions to respond to the social, environmental and economic demands of their context.

However, although there is no consensus on what CSR is, they all point to the importance of promoting "good business practices", which implies that the company assumes responsibility for "the impacts generated by the productive activity to which it is dedicated" (Nuñez, 2003, p. 11). In the words of Kotler (2005, cited in Marietza & Ilhami, 2023),

Corporate Social Responsibility can be defined as "a company's commitment to improve the welfare of society through discrete business practices and through the contribution of (its) corporate resources" (p. 44).

Bathrinath et al. (2021), in a study on sustainability management within the oil industry, state that a sustainable company focuses on offering products and following economically viable processes that cause minimal adverse environmental impact, seeking to conserve natural resources and taking responsible care of employees and the environment. In addition, they emphasize the importance of companies assuming real responsibility for social justice issues, defining this characteristic as "the ability of a company to take action and be responsible for social and environmental impacts" (Bathrinath et al., 2021, p. 1); it should be noted that reference is made to the direct and indirect impacts of their activities both in the specific context where they operate, as well as on a medium and large scale.

In the context of the climate crisis that humanity is experiencing and the prospect of an unsustainable planet, the priority can no longer be mere economic gain (neither individual nor collective); it is now necessary to change the paradigm and work together (companies, governments and citizens) to promote true sustainable development; this implies, mainly, making a rational use of natural resources (Haimes, 1992; Shah, 2022); seeking an equitable distribution of wealth; and working towards the restoration of ecosystems that can still be restored, as pointed out by several authors (Tepper, 2022; Martins et al., 2022).

According to various reports and academic articles, there is sufficient evidence to affirm that one of the industries that has the greatest impact on the problem of climate change, due to its contribution to the emission of greenhouse gases and the increase in the global ecological footprint, is the oil industry (Castro, 2015; Delgado Ramos, 2011; Gudynas, 2011; Wilches, 2012; Çakmak & Acar, 2022). With this in mind, the following question then arises: how are oil companies in Latin America assuming and managing their social responsibility to promote sustainable development and thus contribute to reducing their impact on environmental degradation?

To answer this question, it is first necessary to define more precisely what is meant by environmental CSR and what elements are essential to determine whether or not companies engaged in the extraction, exploitation and production of hydrocarbons are managing their projects and operations from an environmental perspective, that is, giving priority to the truly responsible care of the ecosystems in which they operate.

In addition to the above definitions, CSR, with an environmental focus, clearly refers to the set of principles, policies and actions that a company undertakes in order to contribute effectively to the three pillars of sustainability (economy, environment and society), especially with regard to the care and protection of biodiversity and concrete actions against climate change, which are normally measured in terms of a company's contribution - positive or negative - to the emission of greenhouse gases.

At this moment in history, individuals, large, medium or small organizations, and a considerable number of NGOs are increasingly attentive to companies demonstrating that they are managing, in an honest, purposeful and responsible manner, "the consequences of their operations on the community and the environment" (George et al., 2016, p. 197). In this sense, CSR, with an environmental approach, is understood as the set of policies and actions that a company implements in the interest of contributing to the sustainable development of the planet (complying with the SDGs), which translates into seeking, by all possible means,

"the balance between economic advancement, social welfare, [and a] good use of [the] natural resources and [the] environment" (García Lozano, 2018, p. 54).

It should be noted that the issue of "environment" as an important element of Corporate Social Responsibility policies is not new. In fact, it is an aspect on which several authors have already spoken about, for a little more than fifty years, as pointed out by Pache Durán (2017). However, the results are not the best so far. This is corroborated by constant reports of droughts, torrential rains, melting of the poles, burning of forests and other natural disasters. It seems that companies do not see (or do not want to see) the urgency of the issue, nor the benefits, including economic ones, that can be derived from taking environmentally responsible actions.

In the case of Latin America, and in particular of oil companies, it is necessary to point out that, for several years now, these have been characterized by the fact that their administrative management is led by the State (Lertzman, Garcia & Vredenburg, 2013), either because it is the sole shareholder, or because it is the majority shareholder, with a minority participation of some private companies (national and/or foreign), as is the case of Ecopetrol, in Colombia, a "mixed economy company (...) the largest in Colombia, top seven in Latin America" (Murillo Vargas, Garcia Solarte & Azuero Rodriguez, 2022, p. 178). This particular characteristic has a direct impact on Corporate Social Responsibility policies, since companies, being state-owned, do not have it as a real priority (Vives, 2008; García-Rodríguez et al., 2013; Lertzman et al., 2013; Bathrinath et al., 2021) and therefore, they do not put it into practice as those affected expect (Giraldo González, 2017); in several cases they limit themselves to supporting the social programs of the government of the day or, simply to transfer the monies required by law.

Both the almost daily evidence of different natural phenomena that cause death and destruction, as well as the countless academic and journalistic articles that call for action to stop the 1.5° rise in global temperature, confirm that the measures taken so far have not been enough to stop a possible disaster of colossal dimensions. Companies, governments and a high percentage of ordinary citizens act as if the problem does not concern them or will wait. In the meantime, the same lifestyle continues; behavioral changes are minimal or even non-existent.

In the particular case of the oil industry, despite knowing that it is the sector that contributes most to the emission of greenhouse gases and the deterioration of the ecosystems where it operates, it continues in the same direction, extracting, exploiting and producing oil in ever greater quantities and with environmentally unfriendly technologies. There is evidence that the oil industry has not given greater importance to the urgency of working for the environmental and social sustainability of its environment and the planet in general (Bathrinath et al, 2021). Moreover, there is no research related to the implementation of CSR programs or effective strategies focused on achieving true sustainable development by oil companies (Angulo Muñoz, 2010; Lertzman et al, 2013). In attention to this approach, the main question sought to be answered is: how are oil companies in Latin America assuming and managing their Corporate Social Responsibility with a view to achieving true sustainable development?

Method

Documentary research, from a socio-critical approach. First, we start with the sustainability reports of three major oil companies in Latin America, namely: Petrobras, Pemex and Ecopetrol. In addition, some news websites have been consulted that record facts related to these companies and their socio-environmental actions, whether positive or negative. The Business and Human Rights Information Center website was consulted as a secondary source.

Of the companies currently operating, we have chosen to analyze three cases in particular, as follows: ECOPETROL, PEMEX and PETROBRAS. The first because it is the one with the most information and the other two because they are part of the largest oil companies in Latin America. The possibility of analyzing PDVSA was also considered; however, we did not find sufficient information on this company, at least not of the same quality and precision as the three companies mentioned above, in their annual corporate social responsibility reports, with emphasis on economic, social and environmental sustainability.

Analysis Based on CSR Reports

The Corporate Social Responsibility reports of the three companies chosen for this study are analyzed taking as a starting point the three dimensions of sustainability, i.e. economic, social and environmental. In economic terms, we simply identify the company's profits or losses during the last four years, as well as the main investments made during 2020 and 2021. In the social area, the amount allocated to this aspect and the most outstanding actions that each company carries out in the country where it operates will be identified. Finally, in the environmental dimension, we will identify the evolution of the amount of greenhouse gases they have reported over the last four years, as well as key actions or programs they have to mitigate the negative environmental impact of their operations, especially those related to the extraction and exploitation of crude oil.

First, the profits or losses of ECOPETROL, PEMEX AND PETROBRAS, between 2018 and 2021, have been identified and are shown in Table 1. In the case of Ecopetrol, 2018 and 2019 profits were above US$2.4 billion, but in 2020 (the year of the COVID-19 pandemic) the company's profits reached only US$362 million, 87% less than in 2019, and 85% less than in 2018. However, in 2021 the company achieved a significant recovery, reaching a record US$3.6 billion (ECOPETROL, 2021, 2022). This performance shows the company's financial strength, even in the midst of a world economic situation characterized by uncertainty and fluctuations in oil prices.

Table 1
Net income / Loss (in millions of US dollars)

COMPANY	2018	2019	2020	2021
ECOPETROL	2.490	2.854	362	3.600
PEMEX	(10.090)	(15.400)	(28.490)	(16.500)
PETROBRAS	11.063,4	14.606,0	23.562,2	33.710,6

The company also had the capacity to invest, in 2021, just over 41 billion dollars in R&D&I projects, almost double what it invested in 2020, and 24% above what it invested in this item in 2019. Similarly, in that year, ECOPETROL earmarked US$267 million for environmental management projects, 25% more than the amount invested in 2020. These figures show that 2021 was a very positive year for the company (ECOPETROL, 2022).

Secondly, PEMEX has been showing losses in excess of US$10 billion per year, with a peak of US$28.49 billion in 2020. According to annual reports and several newspaper articles, the Mexican oil company has been showing this behavior for approximately ten years. One of the reported causes is the high taxes paid by the company to the government. However, despite the losses in the financial statements, in 2021, this company allocated around US$19.4 billion in investments of different kinds, such as: infrastructure and industrial transformation, logistics and the fertilizer line, among others. According to the 2021 sustainability report, there are no direct investments in environmental projects, although a good part of the US$3.9 billion invested in infrastructure has been earmarked for improving operating and production systems to reduce greenhouse gas (GHG) emissions.

In third place, PETROBRAS, the largest of the three companies analyzed here and the second largest in Latin America after PDVSA, has presented an undoubtedly positive financial performance. Moreover, as can be deduced from the data presented in Table 1, by 2021 the Brazilian oil company managed to triple its net profits with respect to fiscal year 2018 and contrary to what happened with ECOPETROL in 2020, PETROBRAS managed to increase its profits by 61% with respect to 2019. In 2021, the Brazilian state-owned company invested a total of US$1,757.29 billion, the largest amount of the three Latin American oil companies. Of this amount, PETROBRAS invested 1,428,849 million in infrastructure. On the other hand, according to the 2021 report, the company allocated US$11.7 million to wind and solar energy projects, as well as US$7.23 million in the biofuels segment. Although it is a minimal percentage of the investment budget, these are significant figures, and this shows that PETROBRAS, like ECOPETROL, appears to be committed to its responsibility to care for the environment. However, it should be analyzed whether these investments are really sufficient to meet the goals set by the 2030 Agenda or whether they only represent a minimal effort that does not respond to the current needs of the planet - which is more likely - and are made only as a strategic measure to protect the company's image and maintain its reputation.

Table 2

Social investment (Millions of dollars)

COMPANY	2018	2019	2020	2021
ECOPETROL	11,2 (0,45%)	49,2 (1,72%)	48,5 (13,4%)	42,7 (1,2%)
PEMEX	117,5	129,7	98,6	83,6
PETROBRAS	44,2 (0,40%)	47,3 (0,32%)	24 (0,10%)	27,5 (0,08%)
Total	172,9	226,2	171,1	153,8

As previously stated, a fundamental axis of Corporate Social Responsibility is its social actions, which should not be understood as mere philanthropy but as an effective

contribution to social justice, more specifically as a response to Sustainable Development Goals 1 (end of poverty), 2 (zero hunger) and 10 (reduction of inequalities). From a broader perspective, the actions of large companies aimed at achieving true social justice must also include strategies that comply with SDGs 3 (health and well-being), 4 (quality education), 5 (gender equality) and 8 (decent work and economic growth).

Table 2 shows a comparative table of the amounts and percentages (of social investment with respect to net profits) allocated to social investment by the companies in this study. In the case of PEMEX, the percentage has not been calculated since the company has reported losses in the four consecutive years. However, it is worth noting that PEMEX is the company with the highest amount of social investment in millions of dollars of the three companies.

It should be noted that each of these companies has well-defined policies regarding the type of projects on which it focuses its social dimension investments. Thus, in the case of ECOPETROL, the company has five strategic lines of social investment, namely: i) Education, sports and health; ii) Inclusive rural development; iii) Entrepreneurship and business development (in the territories); iv) Public and community infrastructure; and v) Public services (ECOPETROL, 2020, 2021). Each year the company evaluates ongoing projects and generates new initiatives aimed at benefiting the communities in which it operates.

According to current CSR policies, "projects and initiatives are prioritized" after prior consultation with "stakeholders (national, departmental and local governments, society and the community)" and based on this "they are formulated and structured in a rigorous manner as an integral part of the Company's environmental plans to make operations viable" (ECOPETROL, 2021, p. 341). In other words, there is a clearly established procedure for defining the Colombian oil company's social investment projects.

Pemex has four social investment strategies, namely: a) donations; b) community and environmental support program (PACMA); c) integrated exploration and production contracts (CIEP); and d) mutual benefit works (OBM) (PEMEX, 2021, 2020). The following is a brief description of these strategic lines of action.

Within PACMA, the company "promotes actions in the areas of infrastructure, health, public safety and civil protection, productive projects, environmental protection, education and sports" (PEMEX, 2021, p. 141). On the other hand, the so-called integrated exploration and production contracts "are service contracts that include a sustainable development clause in which Pemex's contractors are obliged to execute" certain works "in the area where the project is being developed". According to the CSR policies of this company, the purpose of these actions "is to mitigate the impacts that the oil industry could cause in the community and the environment" (PEMEX, 2020, p. 110). And the works of mutual benefit (OBM), "are actions of construction, improvement or rehabilitation of road infrastructure for the service of the communities, as well as to cover the needs for the operation of the company" (PEMEX, 2020, p. 110). According to the four reports consulted, from 2018 to 2021, the highest percentage of social investment is always destined to the donations axis, which refers to products (for example, gasoline or other oil derivatives) that the company donates, through contracts, to different localities or regions of the country, according to the needs of the moment.

Finally, PETROBRAS, the company with the highest profits of the three, is the one that allocates the lowest percentage of its profits to social investment. The oil company's strategic

lines are: i) social and environmental incentives; ii) cultural and sports sponsorships; and iii) business, science and technology sponsorships. The latter focuses both on promoting small companies and sponsoring innovation projects in science and technology. This company has three strategic pillars: safety, environment and health, and works on each of them, seeking both internal and societal benefits.

We will now analyze the commitment of companies to the issue of climate change and environmental sustainability. For this purpose, the tons of greenhouse gases that each company discharges annually have been identified. Thanks to the pressure exerted by international organizations, oil companies must report, within their sustainability report, the tons of CO_2 produced in their operations. Emissions from the last four years have been taken into account for this study, as shown in the following table.

Table 3

CO_2e emissions MMt

COMPANY	2018	2019	2020	2021
ECOPETROL	11.19	11.14	10.24	10.3
PEMEX	46.3	48.0	65.8	71.1
PETROBRAS	61.4	58.8	55.5	61.4
Total	118.89	118.08	131.54	142.8

According to the data collected, it can be deduced that the company that has achieved the greatest effectiveness in reducing greenhouse gas emissions is ECOPETROL. PEMEX and PETROBRAS, on the other hand, instead of decreasing, have increased the tons of CO2 they emit (directly) in all their operations. When making an overall balance, adding the emissions of the three oil companies, the outlook is discouraging, going from 118.89 million tons in 2018 to 142.8 million tons in 2021. This may be due to increased oil extraction and production, or to technological deficiencies in the control systems, or negligence on the part of the companies.

However, in addition to greenhouse gas emissions, another factor to analyze is the willingness of companies to invest in renewable energies or in projects directly related to environmental protection. In this regard, ECOPETROL has signed cooperation agreements with international entities, such as Water Mandate, Water Action Hub and with national organizations such as Coalición Agua para Colombia. Additionally, this company has a specific division of Biodiversity and eco-systemic services, through which it manages projects related to conservation areas and planted trees or actions aimed at avoiding deforestation, among others (ECOPETROL, 2021).

On the other hand, in 2021, "161 voluntary conservation agreements were managed for the fulfillment of environmental obligations (...). With other actions, these agreements led to the conservation of another 111 ha in 2021 and to the Company having conserved or restored 5,549 ha" (ECOPETROL, 2021, p. 211). In the same year, the company, through one of its subsidiaries (Cenit), inaugurated the San Fernando Solar Ecopark, "in the department of Meta (Colombia), with an installed capacity of 61 MWp". In this park, "more than 113,000 panels with bifacial technology to capture energy on both sides" (ECOPETROL, 2021, p. 232) have been put into operation.

PETROBRAS also has several projects related to climate change and biodiversity protection. In fact, in its Corporate Social Responsibility policies, within the framework of environmental sustainability and actions against climate change, the company has defined three strategies: i) Carbon quantification and transparency; ii) Value and resilience of the fossil fuel position in the transition to low carbon emissions; iii) Strengthening skills to create low carbon value. In addition, the oil company is an active member of the *Oil and Gas Climate Initiative* (OGCI). In the same vein, the company expresses its interest in seeking options to operate within a low-carbon energy matrix. In 2021, for example, specific actions were carried out that contributed to the recovery and conservation of more than 175,000 hectares of forests and natural areas in several areas of the country (PETROBRAS, 2022).

Thirdly, according to its CSR reports, PEMEX shows less interest in environmental issues than the other two oil companies analyzed here. In its 2021 sustainability report, it states that the company "is a decentralized organization whose priority function is to carry out exploration, exploitation and other activities required for the operation and strategic management of the oil industry", and additionally emphasizes that "activities related to renewable or alternative energies represent a minor segment within the line of business". (PEMEX, 2022, p. 43)

However, PEMEX has contributed for several years to the government program called Areas Voluntarily Designated for Conservation (ADVC), which are "a mechanism for voluntary certification of properties, focused on the preservation of their ecosystems by private individuals, ejidos and communities" (PEMEX, 2022, p. 48). A similar program also exists in Colombia. In 2002, the Mexican oil company "certified the first property (...) corresponding to the "Parque Ecológico Jaguaroundi", located in Coatzacoalcos, Veracruz". In addition, since that year, the company "periodically evaluates the park's biodiversity to monitor its conservation status through field sampling [conducted] by specialists" (PEMEX, 2022 p. 48).

Evidence from Digital Newspapers

As noted above, in order to avoid possible false or unsubstantiated news, we mainly consulted the website of the Business and Human Rights Information Center (www.business-humanrights.org/es/).

In this search, which is admittedly not exhaustive, news about the three companies were found, although mainly about ECOPETROL and PEMEX. The following is a brief description of the main news related to human rights (social sustainability) and environmental impacts involving these companies.

In relation to the Colombian oil company, the most relevant news were the following:

a) The Casanare court determined that Ecopetrol must compensate the environmental damages caused in this department, especially to the community affected by the Cupiagua project. This news item is dated April 4, 2023. Very recent.
b) In January 2023, the public is informed that the indigenous communities are opposed to 32 oil contracts that the government is apparently seeking to reactivate.

c) According to the consulting firm Mongabay Latam, between January 2015 and June 2002, there have been 2133 environmental incidents caused by oil spills in Colombia, 67% of which correspond to Ecopetrol.

With respect to PEMEX, the following news items were found to be the most relevant:

a) On November 4, 2022 it is published that fishermen from Salina Cruz, in La Ventosa Bay, denounce that in 40 days there have been 4 oil spills in the area.
b) On April 25, 2022, a digital newspaper reported that several PEMEX workers denounced that the company has been violating their labor rights, since the agreements reached in previous years have not been complied with.

As for PETROBRAS, no news related to the issues in question were found. The only news reported on the website has to do with an alliance between the oil company and two other companies (Total and Total Eren) to analyze the possibility of jointly developing projects related to solar and wind energy in Brazil.

Discussion

From the point of view of economic sustainability, ECOPETROL and PETROBRAS show a positive and rising net profit performance, especially the Brazilian oil company. Ecopetrol went from generating earnings of $2.49 billion in 2018 to $3.6 billion in 2021, an increase of 44%, although with a significant blip in 2020, the year of the COVID-19 pandemic. Petrobras, on the other hand, in 2018 earned a net profit of over US$11 billion and in 2021, the profit was above US$33.7 billion, which translates into an increase of 204%. Pemex, for its part, went from having a loss of US$10.09 billion in 2018 to a loss of US$16.5 billion in 2021, which is equivalent to a negative difference of 63.5%. PEMEX's financial performance is surprising because it is a company that has been showing negative results for ten years in a row, yet it continues to operate. This cannot be positive for the company, nor for the country, nor even for the oil industry. This is a situation that needs to be investigated further.

In summary, ECOPETROL and PETROBRAS present healthy financial statements that, in principle, guarantee their economic sustainability in the short and medium term. The same cannot be said of PEMEX. However, the fact that oil is a non-renewable natural resource and that world reserves are dwindling should not be overlooked. In this scenario, if these companies do not seek other business alternatives, they may perish in the long term. Ecopetrol and Petrobras seem to have it clear.

In terms of social sustainability, the three companies show a clear interest in the subject with projects and actions that have a positive impact on the communities where they work and even with others outside their territory. One aspect on which the three companies agree is the support they give to educational projects, especially in terms of equipment for students and infrastructure for educational centers. At least from what they report in their sustainability reports, they do not seek to impact educational quality as such. In a comparative analysis, of the three companies, Ecopetrol is the one that offers the clearest and most detailed structuring of its social investment plans and projects.

Thirdly, in terms of environmental sustainability, the results shown by Latin American oil companies are still far from what is expected and necessary to meet the goals of the 2030 Agenda. Of the three companies analyzed, Ecopetrol is the one that has made the greatest progress in reducing greenhouse gas emissions. Pemex and Petrobras, on the other hand,

have continued to increase the tons of CO_2 emitted directly into the atmosphere. It is clear that these companies must redouble their efforts in order to make an effective and significant contribution to the fight against climate change.

However, it should be noted that all three companies develop actions aimed at mitigating the impact of their operations on the environment. However, in this sense, Pemex also presents a less proactive scheme than the other two oil companies. Both Ecopetrol and Petrobras, in addition to working to restore some ecosystems and protect biodiversity, have a clearly defined division within their companies that is basically dedicated to designing and executing environmental sustainability projects. In the case of Pemex, at least from what we read in its sustainability reports, it is not so clear.

As for the news consulted, it is evident that at least ECOPETROL and PEMEX have presented important incidents in the last few years related to environmental damage, especially the Colombian oil company. PETROBRAS has apparently been more careful in this regard. Given that the issue of environmental care is becoming increasingly important and arouses greater sensitivity, it is natural that large companies, such as oil companies, want to show a positive image of environmental responsibility to society, which is evident in the reports consulted, but not so much in the news found. For this reason, a more rigorous search for news in national newspapers involving any of the three oil companies is suggested.

On the other hand, it is worth noting that, in the preliminary search carried out in the development of this research, no news about internal problems, that is, with workers, were found, which confirms the generalized idea that oil companies usually offer fair and even above-average salaries, and also treat their employees well. Nevertheless, this is a subject that is worth exploring in depth and carrying out another comparative study, within the framework of CSR, but focused on this particular aspect.

Conclusions and Recommendations

The challenges currently facing humanity in meeting the objectives of sustainable development and, in particular, in the fight against climate change, are enormous. As determined in this article and as pointed out by numerous authors, oil companies have a large share of responsibility in this task (Grasso, 2019). Unfortunately, based on the results obtained so far, at least in the case of Latin American oil companies, the outlook is not very encouraging. The evidence (see Table 3 and the reported news) shows that much remains to be done on this issue to reverse the negative effects of fossil fuel exploitation and production on climate change.

Based on the Corporate Social Responsibility reports analyzed, Ecopetrol, Petrobras and Pemex are clear about the importance of the three dimensions of sustainability, and proof of this is that these reports are structured based on the three lines of action established by the Global Reporting Initiative, i.e. economic, social and environmental. However, the latter still deserves more attention from the three Latin American oil companies.

Based on the financial results consulted, Ecopetrol and Petrobras can be qualified as economically sustainable companies in the medium term, while Pemex has been showing substantial losses for several years. In terms of social sustainability, although companies invest a very small percentage of their profits (or losses, in the case of Pemex), it is clearly an important topic in their annual sustainability reports, as evidenced by the fact that each

company has well-defined action plans to contribute to achieving greater social justice and equity in the countries where they operate.

As for the most relevant news, according to the web portal of the Business and Human Rights Information Center, both ECOPETROL and PEMEX have had situations that have put at risk some of the ecosystems where they operate, and therefore the environment, in some of the areas where they develop their oil exploration and extraction operations. However, for future research, a more in-depth analysis of the news related to the positive and negative actions of oil companies in Latin America is recommended. Likewise, it is suggested to investigate in more depth, using quantitative and/or qualitative methods, about the environmental projects developed by each company and their impact on the ecosystems where they develop their activities of exploitation, extraction and production of crude oil.

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FORMULATION OF A NEW ELECTRICAL SAFETY MANAGEMENT SYSTEM AND ASSESSMENT OF ITS IMPACT THROUGHT A CASE STUDY IN CHILEAN LARGE-SCALE MINING

FORMULACIÓN DE UN NUEVO SISTEMA DE GESTIÓN DE SEGURIDAD ELÉCTRICA Y LA EVALUACIÒN DE SU IMPACTO MEDIANTE UN ESTUDIO DE CASO EN LA GRAN MINERÍA DE CHILE

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ABSTRACT

Currently, internationally electrical regulations like, IEEE and NFPA, and legislation in various countries require management of electrical safety, but there is no existing system for its implementation. Therefore, a system for electrical safety management was designed based on the requirements of ISO 45001 standard and technical norms such as NFPA 70E and IEEE 3007.2. First, an investigation of national and international regulations regarding electrical safety was conducted, and the electrical safety management system was designed. Based on the proposed electrical safety management system, diagnostic audits were performed on companies from various economic sectors to assess their electrical safety management. The results of these audits indicated that all the audited companies were taking specific actions, but there was no management of electrical safety. Subsequently, the electrical safety management system was applied to one of the audited companies, and after the system was

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implemented, a follow-up audit was conducted. Finally, an analysis of the obtained data was carried out, which allowed us to demonstrate the positive impact of the system, as it showed benefits such as increasing compliance with legal regulations, reducing accidents involving individuals, lowering costs related to equipment and facility damages, and optimizing operational costs. This was aimed at promoting the safe and efficient use of electrical energy.

RESUMEN

Palabras clave:
sistema de gestión, seguridad eléctrica, riesgos industriales, indicadores de seguridad, riesgos de accidentes.

Actualmente la normativa eléctrica internacional como, la IEEE y la NFPA, y la legislación de diversos países exigen realizar gestión sobre la seguridad eléctrica, pero no existe un sistema para su implementación. Por ello, se diseñó un sistema de gestión en seguridad eléctrica con base en los requerimientos de la norma ISO 45001 y normas técnicas como la NFPA 70E y la IEEE 3007.2. Primero, se realizó una investigación de las normativas nacionales e internacionales en lo que respecta a la seguridad eléctrica y se diseñó el sistema de gestión de seguridad eléctrica. Con base en el sistema de gestión de seguridad eléctrica propuesto, se realizaron auditorías de diagnóstico a empresas de diversas actividades económicas para evaluar su gestión de seguridad eléctrica. Los resultados de estas auditorías indicaron que todas las empresas auditadas realizaban acciones específicas, pero no se hacía gestión de seguridad eléctrica. Posteriormente se aplicó el sistema de gestión de seguridad eléctrica a una de las empresas auditadas y a la que, después de implementado el sistema se le realiza una auditoria de seguimiento. Finalmente, se realizó un análisis de los datos obtenidos donde se pudo demostrar el impacto positivo del sistema ya que mostró beneficios al aumentar el cumplimiento de la normativa legal, además de reducir los accidentes a las personas, reducir los costos por daños a los equipos e instalaciones y optimizar los costos operacionales, buscando el uso seguro y eficiente de la energía eléctrica.

Introduction

Currently, international electrical safety standards such as IEEE 3007.3 and NFPA 70E, have been demanding greater awareness of the real cost of electrical injuries and learning to appreciate the risks related to electricity, which is why countries such as the United States, Costa Rica or Colombia have required them in their national standards and countries such as Spain, Australia or Canada have used them as a reference (Crow et al., 2018). Given this, the National Fire Protection Association (NFPA, 2021) and the Institute of Electrical and Electronics Engineers (IEEE, 2012), recommend the employer implement and document an electrical safety program that mandates appropriate activities for risks related to electrical hazards.

In countries such as Costa Rica, Colombia and Mexico, electrical safety and electrical safety programs have already been included as a specific standard based on NFPA 70E criteria. Therefore, although it has become a legal requirement for companies to have an electrical safety program, there is still a general lack of knowledge on how to implement it. Currently, the regulatory bodies of different countries, such as the Superintendency of Electricity and Fuels (SEC) in Chile, through the Regulation of consumer electrical installations DS 8, requires companies that general electrical installations must comply with the basic requirements for operation and maintenance as defined in DS 8 - RIC 17: "Operation and Maintenance. This document establishes that each company must implement and document an electrical safety program (PSE) in accordance with the company's occupational risk management system, either through universally used standards (ISO, OHSAS, ANSI) or through specific risk prevention programs implemented by the company.

Like Chile, other countries such as the U.S. and Canada have also been affected. The US, Colombia, Mexico and Peru, within their legal requirements, demand the incorporation of technical standards such as the National Electrical Code (National Executive Committee), the electrical safety standard in the workplace (NFPA 70E), the National Electrical Safety Code (NESC), among others. There are also other recognized standards and guides that contain electrical safety information that can be referred to in a legal case such as the IEEE and NETA standards, however, the same problem of not having an electrical safety management system in place is present.

Another difficulty is the tendency of organizations to implement management systems that do not consider the complexities of electrical risks, nor the benefits that their reduction can bring to operational continuity and efficiency. This added to the absence of a clear and consensual definition of what electrical safety implies, which generates confusion by carrying out isolated activities to solve specific problems, but not systematized to be able to make measurements and take actions to improve the independence of electrical safety management of the productive activity where it is implemented, without considering the variables and conditions of each sector or industry.

These factors limit the ability of organizations to ensure effective electrical safety management that protects workers, improves operational performance and contributes to sustainable development. Therefore, there is a need to design and implement a specific management system for electrical safety that considers its particularities and benefits, and that adapts to the characteristics and needs of each organization.

To comply with this, a key requirement for any installation internationally, is that good design practices are followed; that new systems are installed in accordance with NFPA

70E, the NEC and/or other applicable technical codes and standards; and that any changes to the electrical system are properly documented. (Drewiske and Kalcec, 2020). Other countries such as Mexico and Colombia, for example, include in their regulatory requirements that companies engaged in the production, transformation, transmission and distribution of electrical energy must have an asset management system to ensure the integrity of electrical installations, in accordance with the standards of the International Organization for Standardization, specifically ISO 55000.

Despite all these legislative efforts, false safety and worker comfort increase, which transforms into small failures turning into serious accidents (Lee et al, 2019). Electrical hazards are very different from non-electrical hazards, as they are very difficult to deal with. It is apparently very difficult to foresee the level of risk associated with an electrical circuit just by a simple visual inspection of the circuit. It is also noted that, in most cases of dangerous occurrences, the worker who performed an unsafe act was not the victim of the injury, but rather it was a member of his or her team who relied on his or her aptitude and was therefore injured. (Sarkar, 2021).

According to on-site audits conducted as part of this study, there was low compliance with national and international regulations. In this sense, most of the audited companies have electrical safety programs and comply with the recommendations, but they are not systematic or structured processes, rather they are isolated activities that seek to solve a problem or comply with a specific regulation being NFPA standard 70E, which defines electrical safety program as a documented system consisting of electrical safety principles, policies, procedures and processes that governs the activities appropriate to the risk associated with electrical hazards. In other words, the NFPA standard requires the implementation of a safety management system and not a program of isolated activities or activities for a specific circumstance.

In this sense, the problem that emerges from the evaluation of the audits carried out is that programs of activities focused on electrical safety are implemented, but no management is implemented to support electrical safety and allow for the continuous improvement of this management.

In accordance with the stated problem, the objective of this work was to propose an electrical safety management system and to show the benefits of implementing such a system. The system is based on 3 fundamental principles: People, electrical equipment/facilities and operational continuity that allows the company to identify needs, implement controls seeking to reduce incidents, comply with legal and/or corporate regulations and ensure operational continuity, which in turn, reduces harm to people, costs due to damage to equipment and costly operational losses caused by undesired events that cause the use of electricity.

Management System

The term management Lopez Cachero (1998)defined it as the methodical order of interdependent activities and related procedures that make possible the good work of an organization. Therefore, a management system is an integrated set of interacting processes and tools used by an organization to develop a strategy in order to develop operational actions, monitoring and improving the effectiveness of both (Kaplan y Norton, 2008).

If the concept is expanded a little further, a risk management system consists of constructing the minimum information that makes it possible to calculate the risk to be

assumed and to foresee the reserves that would allow survival under appropriate conditions (Lavell, 2001).

The objective of the safety management system is to prevent work-related injuries and health impairment and to provide safe and healthy workplaces; consequently, it is of critical importance for the organization to reduce hazards and eliminate risks by taking effective preventive and protective measures (ISO, 2018).

Electrical Safety Program

Annually, the average number of work-related fatalities in Chile exceeds 200 workers, of which between 10 and 13% are of electrical origin (Electro Industria, 2016). Particularly, the electrical industry presents accident rate indicators below 2%, i.e., 2 workers per 100 are injured, being the country average in 2013 of 4.3%. However, "the Mortality Rate is notoriously higher, being 3.5% in the companies that are members of the Mutual Societies and 6.4% in the total number of companies".

Electro Industria (2016) relates how a report on electrical accidents carried out by the ACHS between 2009 and 2012 found that about 17% of electricity-related work accidents are considered to be serious. Although this figure appears to be low in absolute terms, it is important to note that these few incidents account for almost 80% of the days lost due to medical leave. Of these cases, 72% are related to the electric shock effect, while the remaining 28% are due to electric arc, according to the ACHS expert.

According to NFPA (2021), an electrical safety program is a documented system consisting of electrical safety principles, policies, procedures, and processes governing activities appropriate to the risks associated with electrical hazards.

In this sense, the goal of the PES is to systematically, proactively and preventively address electrical hazards in the workplace, which is a more effective approach than reacting to injuries and fatalities caused by those hazards.

IEEE 3007.3 (2012), for its part, indicates that an electrical safety program is a plan designed so that neither workplace conditions nor the actions of individuals expose personnel unnecessarily to electrical hazards. Establishing an electrical safety program and making sure employees follow it can be a great tool against accidental injury or death due to electrical incidents.

If one considers the requirements and definitions given to the concept of electrical safety program in the various standards, what the standards require is an electrical safety management system, even though the term used does not explicitly define it. Since companies are unfamiliar with the concept and there is no defined electrical safety management system that they can implement, in the best of cases, they apply isolated actions to try to comply with the requirements of these regulations.

When implementing an electrical safety management system, the principles of the system should be identified and taught to employees as a key component of improving the electrical safety culture (Eastwood et al., 2002)as a key component of improving the electrical safety culture. This is achieved by aligning the objectives of the electrical safety program with the organizational objectives of each company.

The goal of electrical safety programs was established to address unsafe work practices and unsafe installations (Becker y Davis, 2015)it is easy to focus on the technical aspects of the program (Crow et al., 2018), such as facility maintenance, leaving aside the document management, which is what demonstrates that the planned actions have been

carried out. However, electrical safety has not been well defined (Liggett, 2006). Identifying incidents that can cause injury to electrical workers helps prevent these types of injuries from occurring (Anderson, 2019).

Those responsible for implementing and monitoring the electrical safety program should be informed about the evolving knowledge of leading indicators and assist those responsible for training management in establishing a balanced scorecard of metrics that can more effectively serve the organization in identifying and controlling the risk of electrical hazards. The main indicators should be closely related to electrical safety. For example, an organization with a leading indicator that measures overall safety and health management/leadership needs to add a metric that measures electrical safety management/leadership (Landis, 2022). Electrical injuries, compared to other types of industrial injuries, represent a relatively small percentage, however, in terms of the number of injuries with serious and fatal results it ranks first. Therefore, the utmost attention should be paid to the indications of the technical regulations with regard to electrical safety (Lebedev, 2021).

Method

The research approach was based on a methodology of documentary analysis of information and statistical analysis, where the identification and compilation of documentation was carried out through the analysis of available information. For confidentiality reasons, this article reserves the right to name and/or identify the audited companies, due to the possibility of non-compliance with national or international regulations, otherwise company 1 (E1), company 2 (E2) and so on are named.

Data Collection

In the first instance, research was carried out on current national and international standards, such as ISO 45001; ISO 31001, NFPA 70E (NFPA, 2021) and IEEE 3007.2. As a result of this research, checklists were prepared and used to collect data for diagnostic audits or gap verification.

Subsequent to this, an electrical safety audit was designed based on ISO 19011 (ISO, 2018). The audit evaluated 7 topics which are: general installations, electrical rooms, fire fighting system, safety equipment and PPE, safety procedures, documentation and electrical training. Details of each of these topics are included in the checklists used for data collection. The data collected from these audits were evaluated on a scale ranging from 0 to 5, with 0 being total non-compliance with regulations, 3 being minimum compliance with regulations and 5 being full compliance with regulations, best practices and innovation in implementing electrical safety management. For this purpose, matrices were developed that incorporate specific indicators applicable to each situation. These indicators cover all stages of the electrical safety management process, and are detailed in Table 1 and Table 2. The purpose of these indicators is to accurately measure each of the topics to be audited, which allows for a subsequent impartial and objective analysis of the results obtained in the audit.

Table 1
Acceptance criteria for operational variables

		Does not comply	Does not comply	Does not comply (by very little)	Minimum compliance	Complies with best practices	World Standard
Variables	**Standard**	**0**	**1**	**2**	**3**	**4**	**5**
General electrical installations	▪ SD 132 ▪ DS 08 ▪ NFPA 70E ▪ IEEE 3007.3	No type of control is defined	Significant shortcomings with respect to expectations	Minor shortcomings compared to expectations	Updated without implementing recommendations	Updated and systematized studies	Practices above expectations
Maintenance management	▪ SD 132 ▪ DS 08 ▪ NFPA 70B	No type of control is defined	Significant shortcomings with respect to expectations	Minor shortcomings compared to expectations	The requirement is effectively fulfilled	Effective and systematized compliance	Practices above expectations
Equipment and PPE	▪ SD 132 ▪ DS 08 ▪ DS 40 ▪ NFPA 70E	No PPE for electrical use is defined	Electrical PPE is not enough	Shock PPE is delivered, but not arc PPE	It is available for arc and electric shock and is monitored and reset	It is effectively complied with. Systematized delivery and replenishment	Practices above expectations
Fire protection systems	▪ SD 109 ▪ SD 132	No fire protection systems	Do not comply with legal requirements	They exist, but there is no control of periodic inspections and maintenance	They exist and are inspected and maintained periodically.	It is effectively complied with. Systematic testing and inspection	Practices above expectations

Table 1 shows the acceptance criteria for operational variables, where the variables considered and the associated score are shown. The variables consider several aspects based on legal regulations, which are explained in more detail below:

- General electrical installations: Seeks to provide safe working environments with no or minimal exposure to electrical hazards, while complying with current legislation, technical regulations and manufacturer's guidelines. The design should consider aspects such as electric shock and arc flash protection, fire protection measures, adequate lighting, workspace layout and design considerations.
- Maintenance management: Seeks to carry out proper maintenance of electrical systems to preserve their original condition. This is done through measurement (predictive maintenance) and scheduled maintenance (preventive maintenance) programs to avoid unexpected failures. Pre-planning, detailed documentation, and implementation by qualified personnel are essential to achieve this objective.

- Equipment and PPE: It includes the selection of elements and personal protective equipment (PPE) for people exposed to electrical hazards. This is verified by reviewing the electric shock PPE, which must be insulating, considering the voltage to which people will be exposed, and for the electric arc PPE, which must be flameproof, taking into account the incident energy that could be generated in the event of an electric arc.
- Firefighting systems: It focuses on the existence and maintenance of fire protection systems in electrical installations.

Table 2

Acceptance criteria for documentary variables

		Does not comply	**Does not comply**	**Does not comply (by very little)**	**Minimum compliance**	**Complies with best practices**	**World Standard**
Variables	**Standard**	**0**	**1**	**2**	**3**	**4**	**5**
Projects and Technical Documents	■ SD 132 ■ DS 08	They do not have any type of document	The documents submitted are outdated	Minor shortcomings compared to expectations	The requirement is effectively fulfilled	Effective and systematized compliance	Practices above expectations
Security documents	■ SD 132 ■ DS 08 ■ NFPA 70E ■ IEEE 3007.3	No document backup	Procedure does not meet all requirements	Procedure is delivered, but comprehension is not evaluated	Procedures are provided and understanding is evaluated, but it is not systematized	Monitoring and measurement of document compliance is systematized	Practices above expectations
Training and qualification	■ SD 132 ■ DS 08 ■ NFPA 70E	No training	Only occasional training is provided	Training is provided and on-site training is conducted	It is delivered, trained and authorized, but the process is not systematized	Monitoring and measurement of compliance with qualifications. It is systematized	Practices above expectations

Similarly, variables were defined for the acceptance criteria for documentary variables as follows:

- Projects and technical documents: Verify the projects and technical documents, which are tools that detail the technical specifications of the electrical installations. These consist of drawings and descriptive memories that are created for the purpose of illustrating the design of the electrical installation and the amount of materials required.
- Security documents: Reference is made to various documents, such as work authorizations, inspections, audits, hazard identification, risk assessment, procedures, regulations, talks, checklists, guidelines and action plans for non-conformities.

- Training and qualification: Training is essential to protect all personnel, including contractors, who face electrical hazards. This verifies that an effective strategy is in place to ensure the safety of workers and also to raise awareness of electrical safety. Its objective is to enable workers to identify electrical hazards and reduce their exposure to them.

Finally, on-site audits were carried out at various mining companies in Chile and a surface graph was made with the data obtained, which facilitated the analysis of the data to justify the problem for this stage.

Population and sample

For this research, electrical safety audits were carried out on a sample of 15 large mining companies in Chile, since this is one of the most developed and regulated areas with respect to electrical safety. This is due to the fact that the companies selected for this study are international corporations, which means that not only the national regulations must be complied with, but also those of their country of origin, making them more demanding. Among these, one of them was selected as a case study for analysis. The case study data are as follows:

- Economic Activity: Large copper mining. Chile.
- Number of workers: 900 of our own and an average of 3,100 contractor workers.
- Electrical workers: 60 of our own and an average of 250 contractor workers.

Formulation of the System

This system was developed based on the structure of the Deming cycle (Fisher et al., 2005), with a theoretical basis extracted from the ISO 45000 standard (ISO, 2018) and the recommendations of the NFPA 70E (NFPA, 2021) and IEEE 3007, highlighting the addition of a context evaluation to the cycle and the continuous improvement applied transversally throughout the system.

It began with an assessment of the context of the organization. This was aimed at identifying internal and external factors that could influence the achievement of the objectives and the attainment of the desired results for the system. The context assessment addressed both internal company information and external information affecting its implementation.

The planning design then proceeded. In this phase, the complete structure for the management of the proposed system was created. This involved conducting an analysis of the safety and maintenance aspects that would be relevant, as well as establishing organizational aspects such as the scope and responsibilities of the roles. The design and creation of specific documented procedures for the proposed system was carried out, and the activities and requirements to be fulfilled were established.

In the implementation, the decision was made to establish a system based on process management. This involved defining the necessary management, complying with the essential requirements of reference standards (ISO 45000, ISO 31000) and widely recognized technical standards, such as NFPA 70E and IEEE 3007.1. Management focused on areas such as work authorization, inspection, maintenance, hazard identification and risk assessment, as well as the creation of procedures, among other aspects.

The system verification stage was based on the objectives and goals previously defined during the planning phase. To carry out this verification, the actions and processes

requiring monitoring and measurement were established, which included legal aspects and other requirements, activities related to electrical hazards and risks, progress towards the achievement of objectives, effectiveness of controls, among others.

The evaluation and follow-up of the proposed system involved comparing the information gathered in the initial evaluation with the results obtained after the implementation phase. This was proposed to be achieved by conducting an audit or applying other management indicators.

Application of the Electrical Safety Management System

Based on the diagnostic audits, one of the initially audited companies, which provided the facilities to carry out the study, was taken and a process of implementation of the proposed electrical safety management system was developed. Subsequently, a second audit was carried out to evaluate the improvement in security management.

An analysis was also made of the incidents, caused by electrical energy, that occurred in this same company before and after the implementation of the electrical safety management system.

Analysis of Results and Profitability

The information from the initial audit is presented in an area graph. Subsequently, the implementation and actions taken by the company to improve its processes. And then, a surface graph corresponding to a final audit is presented, showing the progress made in implementing the management system.

Finally, the diagnostic audit versus the follow-up audit was compared and a comparative table was made with the initial evaluation versus the final evaluation of the case study, showing how much the evaluation improved and how this affects the company.

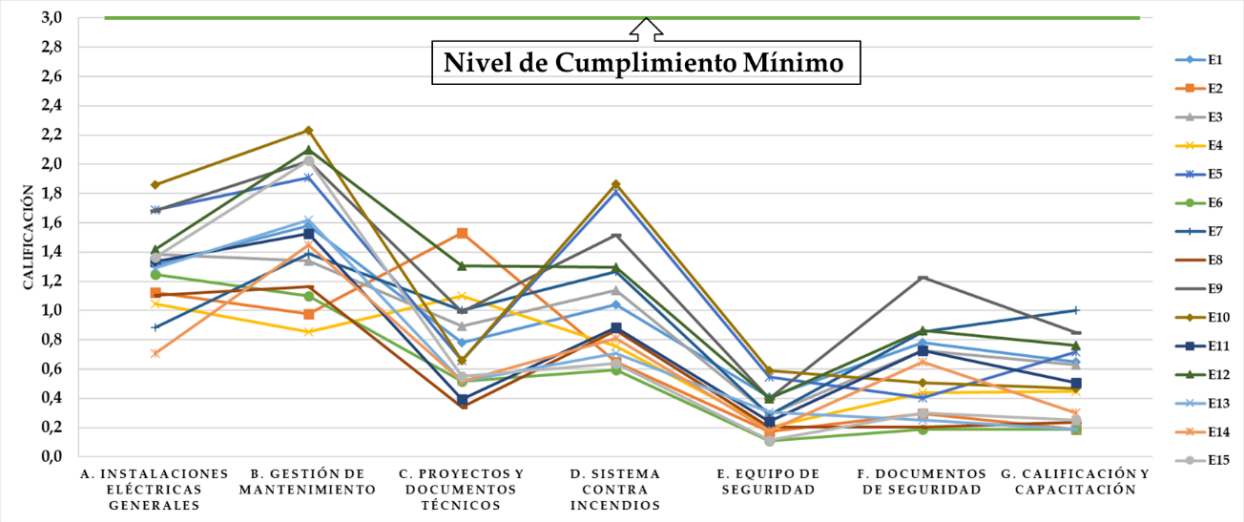
Results

Data collection Analysis

The audits carried out in different mining companies were grouped in Figure 1, which shows the similarities in the shortcomings and their best evaluated points.

Through the audits it was possible to detect legal non-compliance, loss of resources, incidents caused by electricity, among other undesirable findings resulting from lack of knowledge of the regulations and/or poor application of electrical safety management. Of the 15 companies audited, all were engaged in electrical safety activities. However, none of them had an electrical safety management system in place. It was also found that management depended solely and exclusively on the leadership of the person in charge, which is exactly what a management system tries to avoid. What is even worse, in several of these companies, the entire management was the responsibility of the superintendence or electrical department, and these programs were not included in the company's OHS management.

Figure 1
Results of diagnostic audits



Management System

By analyzing the problem, the most common shortcomings among all the companies were identified and an electrical safety management system was developed to improve the poorly evaluated processes. The proposed system was developed based on the Deming cycle, which is a method of proven effectiveness worldwide in most organizations (Azadeh et al., 2014; Roldán-Molina et al., 2021; Rungtusanatham et al., 2003). It is composed of five major stages (Figure 2), which are planning, implementation, verification, evaluation and continuous improvement, which can be carried out at each stage of the cycle.

Figure 2
Graphical representation of the proposed electrical safety management system

In addition, to start the cycle proposed by the system, the context assessment is considered, in which an analysis of the internal and external context of the organization is

carried out, and the policies and objectives concerning electrical safety are established, thus starting the planning stage.

The first stage of the system is planning, where all the schematization and structuring of the management system is developed. For this purpose, an analysis of occupational safety and maintenance aspects is performed, organizational aspects such as scope, roles and responsibilities are also established, and then the identification of hazards and electrical risk assessment is performed in order to establish preventive and mitigating control measures for the associated risks.

Next, in the implementation stage, the documentation of the proposed system is prepared. This documentation must be prepared based on compliance with the basic requirements demanded by the reference standards (ISO 31000, ISO 45000), also considering the applicable legal and technical regulations. As a minimum, an electrical safety management manual should be prepared, which contains all the general, technical, electrical risk prevention and maintenance management documentation, in the form of procedures and instructions, focused on the operation of the electrical safety management system. In addition, it considers all actions arising from the planning.

In the verification stage, the actions implemented are followed up at a frequency established in the planning. This is done through the execution of a specific audit for the electrical safety management system, which focuses on several objectives, including verification of compliance with legal and regulatory requirements, evaluation of the effectiveness of the electrical safety management system, identification of risks and prevention measures, promotion of continuous improvement and promotion of an electrical safety culture. This audit covers seven key aspects: electrical safety management, design and engineering of safe work areas, maintenance of electrical installations, condition of electrical enclosures, regulatory documentation and procedures, electrical-related fire systems, training and qualification of personnel exposed to electrical hazards, as well as the condition of personal protective equipment and available electrical protection systems.

The evaluation establishes the level of compliance with the planned actions versus the implemented actions, being able to determine the gaps and good practices through the analysis of the results of the verifications carried out; finally, at this point, recommendations are given on the findings and the new cycle begins, planning the actions to correct the gaps detected.

Continuous improvement is placed at the center of the cycle, to demonstrate that this improvement can be made at any stage of the cycle, where the deviation is detected, and not having to wait until the verification and evaluation stages to make a new planning. On the contrary, at the stage where the deviation is detected, we return to planning and then correctly implement and, consequently, verify and evaluate the proposed improvement.

Case Study

From Figure 1, company N°8 (E8) was selected for an implementation and follow-up study to evaluate the impact of the implementation of an electrical risk management system.

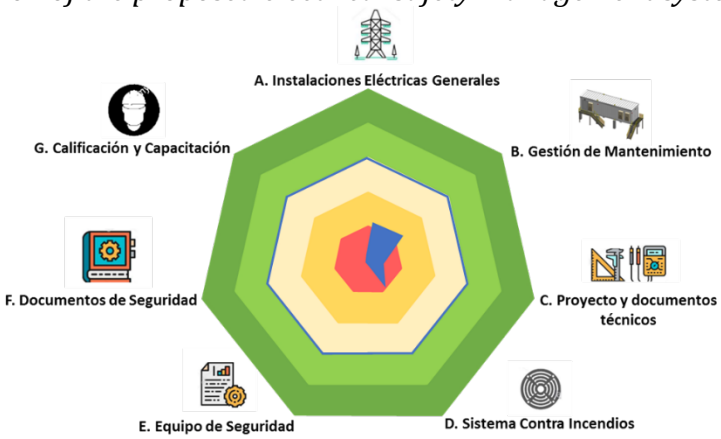
Context Evaluation

The initial audit (Figure 3) shows the results of the evaluation of the different topics prior to the implementation of the management system developed in the case study. Such is the case of extreme topics, such as the best evaluated topic, which is the electrical rooms.

Here it shows an evaluation of 1.2 pts. In contrast, the worst evaluated point is the documentation of the electrical system, with an evaluation of 0.2 points, not to mention that it shows the minimum legal compliance level indicated with the green line.

Figure 3

Graphical representation of the proposed electrical safety management system



On the other hand, through the initial audit, conducted in 2019, in the documentary analysis it was established that there have been 3 accidents and 5 incidents without harm to people. Subsequently, the case study (the company E8 shown in Figure 1), provided the facilities to implement the electrical safety management system and set up an electrical safety committee that will be responsible for implementing the different stages defined in the management system, which also defined: objectives, scope and plans of the working groups, meeting schedules, work plans, methods for evaluating the results of the management system, among others.

Planning

The key factors for the success of this implementation is the support of senior management and the support of experienced personnel with up-to-date knowledge. According to electrical safety standards, the minimum requirements to be met are:

- Establishment of roles and responsibilities of those in charge of managing and implementing the system such as representatives, an electrical safety committee or coordinators.
- Design and maintenance of installations by means of a procedure for the engineering and construction conditions of electrical installations and a standard for the maintenance of electrical equipment and installations was developed.
- Identification of hazards and evaluation of electrical risks based on the activities present in the tasks of the organization's personnel, both specialists and users of electrical energy.
- Inspection and evaluation of electrical equipment through documentary reviews and field inspections.
- Elaboration of general and specific procedures and work permits required for electrical safety. This may include manuals, audits, procedures for performing specific tasks, among others.

- Development of a personnel training and qualification model for implementation in organizations.
- Design of electrical safety emergency procedures for operational emergencies. This was developed in conjunction with emergency, medical, electrical and SSO personnel, an electrical emergency procedure, as well as training on the rescue of victims related to electrical accidents.

Implementation

Some of the actions implemented to reinforce and improve the processes were as follows:

- Senior management considered the integration of OHS requirements into the electrical safety management system processes, in addition to the mission, vision and electrical safety policy.
- Elaboration of an electrical safety regulation in accordance with the legal regulations and technical standards applicable to electrical safety.
- Implementation of maintenance plans which contain the actions, procedures, resources, methods and time necessary for the development and systematization of tasks through software such as SAP.
- Studies of electrical systems such as power, short circuit, protection coordination and incident energy.
- Electrical risk assessment through the development of a specific method that includes probability, consequence and human factor, as well as the appropriate control measures respecting the hierarchy of controls.
- Application of qualification and authorization processes for electrical personnel and training of electrical energy users regarding the electrical risks to which they are exposed by developing a model which includes general and specific inductions, training and training related to electrical safety and evaluations.

Verification and Evaluation

A follow-up audit was conducted to verify the implementation process. This audit provided results of the implementation of the electrical safety management system (Figure 4). In this case, although the values obtained do not reach legal compliance (green line marked in note 3), all the topics evaluated are very close to achieving it. The gap decreased considerably, with documentation increasing from 0.2 to 2.8.

A comparative table (Table 3) was made between the results of the initial audit versus the results of the follow-up audit. This table shows the decrease in the gaps in each of the evaluated topics, as opposed to the low evaluation obtained in the initial audit.

Figure 4

Surface chart showing the results of the monitoring and evaluation audit of the implementation of the electrical safety management system

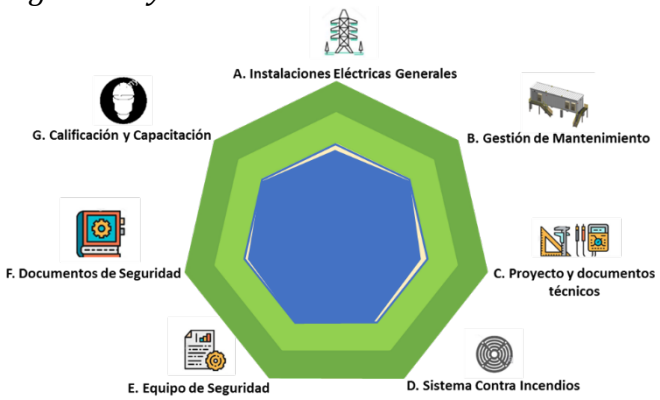


Table 3

Comparative table between the results of the initial audit vs. the final audit

Topics evaluated in the audits	Initial	Final
General electrical installations	1.1	2.8
Maintenance management	1.2	3.0
Project and technical documents	0.3	2.8
Fire protection system	0.9	2.9
Safety equipment	0.2	2.9
Security documents	0.2	2.8
Qualification and training	0.2	3.0

Discussion and Conclusions

Data Interpretation

In Figure 1, it can be seen how the different audits show a negative trend in the evaluation, which allowed to determine management failures or vulnerabilities existing in the organization (Biler, 2017)the best evaluated points are always the general installations, the electrical rooms and the electrical equipment , and even so, their evaluations do not achieve the minimum requirements to comply with the regulations. On the other hand, the worst evaluated points are safety procedures, documentation and electrical training, which do not achieve a score of 1, which means that the performance in these areas was more than deficient, demonstrating administrative shortcomings, failure in follow-up, lack of systematization of processes in risk assessments and lack of knowledge of the minimum requirements of the regulations in force, due to the lack of an electrical safety management system.

A management system provides efficient solutions to solve the problems of organizations through dynamic, forward-looking, holistic and contingent principles, in addition to giving them the opportunity to develop better strategies for the survival of organizations by taking advantage of more regular and logical methods (Gholizadeh et al., 2021). Therefore, to solve the problems raised in the study , a management system was

developed to solve the problems identified (Figure 2), which consists of a series of steps that after an initial action of context evaluation corresponding to the analysis of the initial state of the company, proceeds to follow a cycle of stages, which consists of planning the necessary measures to improve the shortcomings, the implementation of these measures, the verification of the effectiveness of the system and the final evaluation and taking contingency actions if these were necessary.

Implementation of the Management System

A case study was conducted to implement and demonstrate the effectiveness of the electrical safety management system. The study reviewed in this section provides an overview of some aspects of the integration of the proposed management system into the occupational health and safety management of the company where it was implemented and, more specifically, the benefits and difficulties of having it in place (Simon et al., 2012). According to the electrical safety management system developed, in the first instance a context assessment is carried out; an initial audit was performed at this stage (Figure 3), which shows deficiencies of the company studied, and as shown in Figura 1, is not very far from the deficiencies shown by most of the companies previously audited.

Continuing with the stages of the electrical safety management system, we proceeded to the planning stage where we formulated an implementation plan with actions such as improving the electrical infrastructure, maintenance plans, systematization of documentation systems, safety procedures, electrical training, among others, since the electrical safety management system is based on a comprehensive approach that covers all the factors that influence safety, not only administrative controls and PPE. If it is limited to just that, then the electrical safety effort will not see a significant change (Liggett, 2006). Subsequently, we proceed to implement what was proposed in the previous stage.

The effectiveness of management systems can be evaluated and measured by analyzing a wide variety of factors that together constitute the input to electrical safety management (Acosta-Palmer and Troncoso-Fleitas, 2011). Therefore, in order to verify the effectiveness of the proposed management system, a second audit was carried out to collect progress data and thus quantify the improvement achieved (Figure 4).

Recognition of Benefits

The implementation of electrical safety management benefits all employees and, above all, the company that implements it (Lavell, 2001). This is demonstrated in the comparative table between the initial audit versus the follow-up audit (Table 3), which shows an improvement in all the topics evaluated, but despite these great results, the minimum compliance evaluation is still not achieved. Even so, among the numerous advantages provided by the implementation of an electrical safety management system, we were able to recognize:

- Potential reduction in the number of accidents and incidents in the workplace.
- Potential reduction of downtime and associated costs.
- Demonstration to all stakeholders of commitment to occupational health and safety. Stakeholders include workers, personnel and prevention delegates, labor authorities, etc.
- Potential reduction of costs associated with medical expenses.

- It allows to obtain a privileged position in front of the competent authority by demonstrating compliance with the legislation and regulations in force and the commitments acquired.
- Ensures credibility focused on electrical safety control. Greater bargaining power is obtained with insurance companies thanks to the reliable backing of the company's risk management.
- Better management of electrical safety risks now and in the future.

Limitation of the Method

Although the positive results are evident, it is still not possible to meet all the requirements for compliance with current regulations, since the implementation time of an electrical safety management system such as this one requires at least 3 years to meet the planned objectives. While administrative controls are possible to implement in the short term, actions such as standardization of facilities, formulation of maintenance plans, electrical studies and others will require more time because long-term investment plans may even have to be formulated.

Another important limitation is the current safety culture, that of evaluating electrical safety in a similar way to how all safety processes are evaluated, given that electrical safety is regulated by legal and technical standards, which according to the evaluations carried out in most cases are not taken into account.

Recommendations

Given that the results obtained are consistently positive, the implementation of the proposed electrical safety system integrated to the safety and occupational health management system of the company that implements it is recommended, since the benefits that the proposed system provides have been demonstrated. In addition, the systematization of management increases the efficiency and effectiveness of the processes considered in the electrical safety management system.

Projections

Although the results are based on a single company, the electrical safety management system is being implemented in 5 companies included in the initial audits. The results of the implementation processes are not included in this study because it was not possible to perform the follow-up audit, due to the restrictions of the current COVID-19 pandemic, the implementation has been delayed. It is expected that from the publication of the results of the implementation processes of this and the other companies that are implementing it, more companies will be interested in implementing it, since electrical safety in the different countries is one of the most regulated safety processes, both by legal regulations and technical standards. Precisely, one of the objectives of the proposed management system is to comply with both legal and technical regulations, depending on the company that implements it and the country where it is implemented, especially if it is considered that all the proposed practices are easily integrated into the usual Occupational Health and Safety management.

The main conclusions derived from this research are as follows:

- In conclusion, based on the results obtained from the initial audits, the problem raised in this study has been demonstrated. In other words, the companies

analyzed do not apply an electrical safety management system, mainly due to a lack of knowledge of this concept or because there is no system to implement.

- With the implementation of the proposed management system, the electrical safety standards necessary to comply with current regulations are achievable, since there is an improvement in the culture and education about electrical safety, the facilities are improved, maintenance becomes a preventive and efficient control, a systematization of document management also facilitates the qualification and authorization, which translates into better and specific procedures, training and training, which ultimately improves the protection systems and prevention of electrical incidents in the company that implements the system.
- These improvements mean a series of tangible benefits such as the protection of electrical equipment, reduction of costs caused by operational interruption and reduction of incidents, not to mention the intangible benefits such as an increase in the workers' sense of security, better training, etc.
- Finally, it was demonstrated that the proposed system is based on the principles of electrical safety, which translates into reducing accidents to people, reducing costs due to damage to equipment and facilities, and optimizing operational continuity by seeking the safe and efficient use of electrical energy.

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