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Editorial

This issue of MLS Project Design & Management reinforces the academic and scientific multidisciplinary participation of our collaborators in the design, development and implementation of tools and instruments applicable to strategic management, resource optimization and sustainable innovation in engineering projects. Innovation in scientific and 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 8 articles selected for their methodological rigor and practical contributions in different professional areas. The research addresses contemporary challenges ranging from the methodological transition in construction and the detection of financial risks in Mexico, to the viability of renewable energies in tourist environments and heritage conservation techniques using ancestral materials. In the organizational area, strategies of digital and traditional companies are contrasted, leadership models for agile environments are modernized and adaptive management for projects in uncertain contexts is proposed.

The first article proposes the implementation of Building Information Modeling (BIM) as a strategic solution to strengthen hospital resilience in Guatemala. Through interviews, surveys and case studies, we demonstrate how this methodology mitigates risks in critical infrastructure during health emergencies and natural phenomena, offering an applicable model in the absence of mandatory national plans.

The research presented in the second article designs a comprehensive urban mobility plan for Panama that addresses the shortcomings of selective public transportation. The proposal integrates subway, feeder buses (MetroBus) and a new system of cabs with a single card and fixed salaries, improving safety, efficiency and sustainability to make the city a regional benchmark.

The research in the third article analyzes 1,805 global documents on project management, revealing through tools such as Atlas.ti that agile and hybrid methodologies outperform traditional approaches (Six Sigma, Waterfall) in terms of flexibility and effectiveness, especially in dynamic environments that demand rapid adaptation.

The fourth article in this issue demonstrates a method for accurately combating money laundering using a method based on data mining and customer segmentation that outperforms traditional systems. Reduces false alerts and classifies risk with variables adapted to the Mexican context and applying international standards.

Through a quantitative study of 37 large companies, the fifth article identifies that personnel competence and effective audits are key factors in reducing inventory costs, validated by multiple linear regression as a priority solution in supply chains.

The sixth article, analyzing the strategies and tools of digital versus traditional; provides key strategies to survive in competitive environments, the authors contrasted strategies of digital (agile, technological) and traditional (relational, practical) companies and through an analysis and research of improvements provide the 6 essential strategies identified to enhance innovation and sustainable growth in any of the two models that your company works.

The research focused on solar energy in Playa del Carmen includes indicators of feasibility, savings and opportunity, and tests the sustainability of solar energy in tourist destinations. This seventh study shows a positive impact: users report 30-50% savings in electricity and carbon footprint reduction. They analyzed the potential, incentives and the need for educational campaigns to massively adopt them.

Finally, the eighth article details a heritage restoration procedure using ancestral materials (lime, mud, cactus mucilage) for cracked adobe walls. The experimental methodology—validated in the recovery of mechanical resistance—includes unpicking, mortar injection, and reinforced wooden keys, ensuring authentic conservation. The findings presented provide applicable tools for strategic decision making in project engineering, enhancing environmental sustainability, operational efficiency and resilience in complex contexts. MLS Project Design & Management welcomes contributions that reflect the scientific and committed innovation of its authors.

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
Editors in Chief

IMPACT OF NATURAL DISASTERS ON HOSPITAL INFRASTRUCTURE IN GUATEMALA AND ITS MITIGATION THROUGH THE USE OF BIM
IMPACTO DE LOS DESASTRES NATURALES EN LA INFRAESTRUCTURA HOSPITALARIA EN GUATEMALA Y SU MITIGACIÓN MEDIANTE EL USO DE BIM

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	ABSTRACT
Keywords: hospital infrastructure, BIM methodology, natural disaster mitigation, resilience.	Guatemala is a country located in position 10 of the countries with the highest risk of natural disasters in the world. Likewise, COVID-19 highlighted the need to strengthen the resilience of hospitals in the face of health emergencies, because they simultaneously continued to provide care during outbreaks of infectious diseases, social, financial and other crises. This creates the need for buildings that have the capacity to adapt to such natural phenomena so that people can use their facilities and that they are functioning. In this sense, the use of Building Information Modeling BIM is proposed as a work methodology to design and build complex buildings and can be used for the design, construction, maintenance and demolition of hospitals. Because there are still no plans or programs for the mandatory use of BIM in Guatemala, it was decided to carry out an exploratory investigation with its primary exploration methods; through interviews and a secondary survey; collecting information from previous uses of BIM use cases, answering questions about what, why and how the development of hospital infrastructure would be carried out, the impact of natural disasters on said infrastructure and its mitigation through the uses of BIM. According to the discussions and conclusions of the results obtained in the interview, surveys and data obtained on secondary researches, it is possible to mitigate the impact of natural disasters on hospital infrastructure through the use of the BIM methodology in Guatemala.
	RESUMEN
Palabras clave:	Guatemala es un país ubicado en la posición 10 de los países con mayor riesgo de desastres naturales en el mundo. Asimismo, el COVID-19 puso de manifiesto la necesidad de fortalecer la resiliencia de los hospitales frente a emergencias de salud, porque

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infraestructura hospitalaria, metodología BIM, mitigación de desastres naturales, resiliencia.

simultáneamente estos continuaron brindando atención durante brotes de enfermedades infecciosas, crisis sociales, financieras y otros. Esto crea la necesidad de construcciones que tengan la capacidad de adaptarse ante tales fenómenos naturales para que las personas puedan hacer uso de sus instalaciones y que éstas se encuentren funcionando. En ese sentido, se propone la utilización de Building Information Modeling BIM como una metodología de trabajo para diseñar y construir edificaciones complejas y puede utilizarse para el diseño, construcción, mantenimiento y demolición de hospitales. Debido a que aún no hay planes ni programas de uso obligatorio de BIM en Guatemala, se optó por realizar una investigación exploratoria con sus métodos de exploración primaria; a través de entrevistas y una encuesta y secundaria; recopilando información de casos previos de uso BIM, respondiendo las preguntas sobre qué, porque y cómo se llevaría a cabo el desarrollo de infraestructura de hospitales, el impacto de los desastres naturales en dicha infraestructura y su mitigación mediante el uso de BIM. Según las discusiones y conclusiones de los resultados de las entrevistas, encuesta y datos obtenidos y presentados en la investigación secundaria es posible mitigar el impacto de los desastres naturales en la infraestructura hospitalaria a través del uso de la metodología BIM en Guatemala.

Introduction

Due to its physiographic and geotechnical characteristics, Guatemala is prone to natural disasters such as hurricanes and tropical storms, floods, earthquakes, volcanic eruptions and landslides that have caused economic, social and welfare impacts on the Guatemalan population (Barillas, 2022). In this regard, according to the National Coordinator for Disaster Reduction (CONRED) (2021) "the Republic of Guatemala ranks 10th among the countries with the highest risk of disasters in the world".

According to the Pan American Health Organization/World Health Organization PAHO/WHO (2023a) indicates that:

The COVID-19 pandemic highlighted the need to strengthen the resilience of hospitals to health emergencies and disasters, not only because they have been the backbone of the response, but also because they simultaneously continued to provide care during all types of disasters, infectious disease outbreaks, social, financial and other crises (para. 1).

In this regard, as part of the programs for the implementation of hospital infrastructure resilient to health emergencies and natural disasters in Guatemala, CONRED indicates that the Executive Secretariat of the National Coordinator for Disaster Reduction together with representatives of WHO and PAHO, as well as the Ministry of Health and Social Assistance MSPAS met to learn about the Protocol for the Application and Certification of Standards for Disaster Reduction (NRD) that establishes safety guidelines in buildings, both in new designs and remodeling or repairs of existing work in order to prevent all kinds of damage to the integrity of the people who occupy it and to the infrastructure itself and to work on a Manual or Protocol for Safe Hospitals in the country (2013, para. 1 to 4).

As a result of the above, Guatemala has addressed the issue of reducing the impact of natural disasters on hospital infrastructure by means of a manual of protocols and standards. Consequently, this research proposes the use of the Buiding Information Modeling (BIM) methodology in the design for the construction of hospitals in Guatemala. Authors such as Meléndez et al., (2019, pp. 153-157) states that:

BIM... is a working methodology that generates and manages the data of a building project from the very beginning of the design process, optimizing documentation and project management... is a data creator and manager to design and construct large building works, considering the project geometry and additional data... in a three-dimensional way and in real time... can be used to illustrate the complete building process, maintenance and even demolition.

The above is an indication that BIM methodology can be a valuable tool in hospital construction, in addition to what Bustos & Sosa (2021a, pp. 91 and 92) state:

Hospitals being built in the State of California...involve building systems and processes integrated with BIM [shaping] resilient buildings capable of remaining in operation even during an earthquake measuring 9.0 or higher on the Richter scale. [Performing] space clearance simulations... [allowing] to identify problems such as dimensions and circulation distributions, correct and then, bring them to reality. [Avoiding] tragedies. The benefits of BIM do not end with the delivery of the work, they continue during its management and even in the case of a possible remodeling or demolition... by means of the digital model and with the support of specialized software, energy analysis, natural lighting analysis, ventilation analysis, interior temperature analysis, sunlight and radiation analysis can be performed.

The previous work that can be done during the design of a construction with BIM methodology is noteworthy, since it is possible to anticipate the construction development by performing functional tests of the infrastructure to be built and observe in the BIM model created the behavior before certain events, thus saving lives and guaranteeing the resilience of the building to be developed, up to the demolition and even the reuse of recyclable materials in the mentioned infrastructure, hence the importance of the benefits of the use of BIM for hospital infrastructure design projects as mitigation against natural disasters that constantly affect Guatemala.

In this sense, a research instrument was designed which consists of a closed dichotomous survey, designed by the author of this research and once it was carried out, it was reviewed, corrected and validated in its content by two architects, the first designer, consultant and supervisor related to hospital infrastructure and the second specialist in hospital design, both with knowledge in BIM methodology.

In summary, the questions asked to the participants and contained in the aforementioned research instrument are as follows: 1. Do you develop hospital projects in Guatemala? 2. Do you know of any hospital construction projects using BIM methodology in Guatemala? 3. Do you know of any BIM implementation plan or program for infrastructure development in the country? Do you consider it possible to mitigate the impact of natural disasters on hospital infrastructure through design and construction using BIM methodology? 5. Do you consider it important to implement the BIM methodology in the construction of hospitals in Guatemala?

Method

Design

Since there are still no mandatory programs for the implementation of the BIM methodology for hospital design in Guatemala, an exploratory research was conducted with its primary and secondary exploration methods answering the questions of what is needed, why it is needed and how the development of hospital infrastructure using the BIM methodology would be carried out locally. Is BIM methodology being implemented in hospital design and construction in Guatemala? Are there institutions that offer technical and professional training based on formal education on BIM methodology in the country? Is it possible to develop design and construction projects, as well as to give continuity to hospital infrastructure already built with BIM methodology in Guatemala?

Participants

Primary research was carried out through interviews with a first group of eight expert designers of hospital infrastructure in the areas of architecture, civil and mechanical engineering, electrical and plumbing (MEP) to extract information on the use of BIM in the design and construction of healthcare infrastructure and its positive impact on natural disasters and general recommendations that the experts could provide.

In the second group, seven experts in general infrastructure design were interviewed in order to determine the development and use of BIM models in Guatemala, team or collaborative work with this methodology and its results, as well as the implementation of BIM in the country and the use of simulation programs by specialty associated with this methodology, among others.

On the other hand, with a third group, a closed dichotomous survey was conducted with modelers, designers and executors of infrastructure in general and of health care centers to answer questions about the use of BIM, whether or not they consider it

important to develop construction projects in general using the aforementioned methodology and whether they have or are developing hospital infrastructure projects with BIM.

Finally, as secondary research, information was collected from previous cases in Guatemala on the use of BIM in the design and construction of hospitals or infrastructure in general in the country.

Research Instrument

A research instrument was designed consisting of a closed dichotomous survey for which 15 people were selected from a population of 50 BIM modelers, students, teachers, developers and/or designers, design and construction project managers in general and hospital project managers. However, it is important to mention that a pilot test of the survey, test or questionnaire was carried out, in order to subsequently carry out the final test.

To define and validate the population and the sample, we approached representatives of companies and educational entities, both related to design and construction, as well as BIM knowledge. Those involved in the survey were given a written informed consent document, indicating that the data and opinions obtained will be kept confidential and strictly confidential, and will not be associated with any particular opinion.

Validity and Reliability

The research instrument was designed by the author of this research and once it was completed it was reviewed, corrected and validated in its content by two architects, the first a designer, consultant and supervisor related to hospital infrastructure and the second a specialist in hospital design, both with knowledge in BIM methodology. These experts have given their opinion on the objectivity of these questions and have validated their understanding of the formulation of the questions or queries and their delimitation in terms of critical aspects for the data analysis procedure and, therefore, the results of the same.

Research Development Process

Four steps were developed for the development of the research process of this work, as shown in Figure 1 below.

Figure 1
Steps for the development of this research
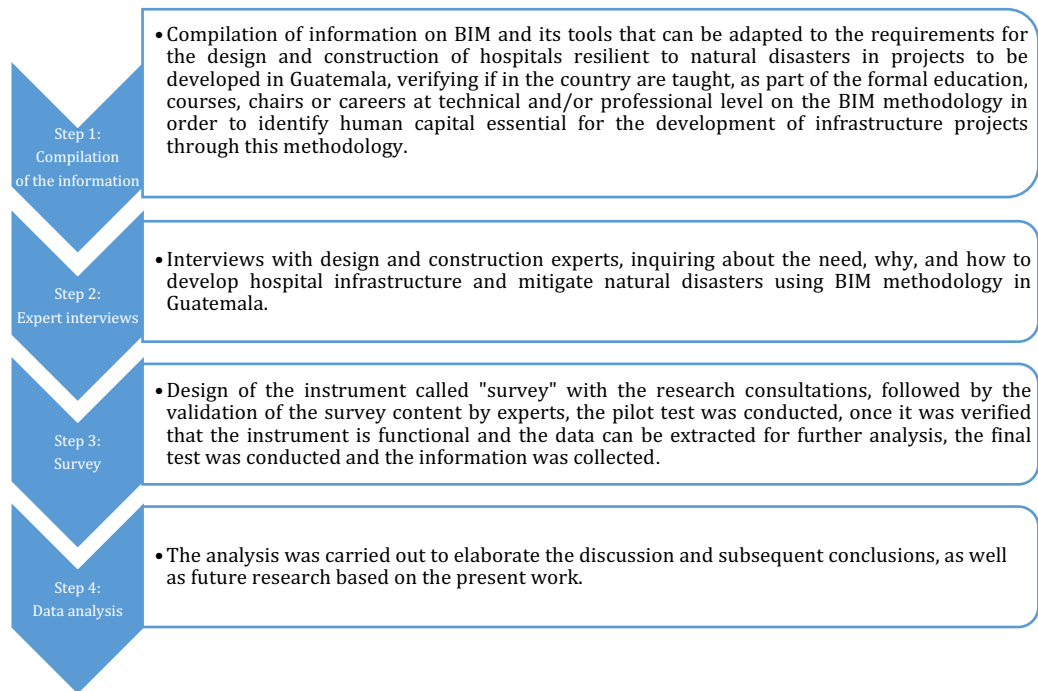
Figure No. 1 shows the work in interviews with professionals in the area and the design of the instrument called "survey", in the interviews the experience of working on projects with the BIM methodology and/or with programs aimed at making hospitals resilient to natural disasters and the results that they have obtained, the survey is oriented to closed dichotomous answers on the knowledge of the methodology and/or the aforementioned programs developed in Guatemala.

Procedure and Data Analysis

In accordance with the approaches taken and with the information gathered, it is possible to answer these questions, which are as follows:

1. Why implement design projects for the construction of disaster resilient hospitals in Guatemala using BIM methodology?

To that end, WHO/PAHO (2023b) states:

The growing need for Resilient Hospitals in the face of health emergencies and disasters in the Region of the Americas is also based on scientific evidence that demonstrates the importance of these hospitals being resilient, sustainable (SMART), inclusive, flexible and adaptable, in order to learn from experiences and recover in a timely and efficient manner (para. 2).

In fact, health care centers in the regional area are affected by natural disasters, requiring buildings that can withstand and provide services to the population in need and according to Bolaños (2020a), Guatemala was affected in November 2020 by tropical depression ETA, reporting 21 deaths, 103 missing persons, 3,125 people at risk, and 27,129 evacuations. Hurricane Mitch hit in 1998, catalogued by the Hurricane Center of Miami, USA as one of the worst hurricanes in the last quarter century, with official figures of 268 deaths and an economic impact of 1,061.4 million US dollars in losses. In 2005, as a result of tropical storm Stan, a landslide caused the disappearance of the community of Panabaj (para. 1-12).

As a result, the country has suffered great devastation from tropical depressions. Regarding disasters caused by volcanic eruptions in Guatemala, Bolaños (2020b) mentions that in 2010 the Pacaya volcano made a strong eruption and at the same time tropical storm Agatha made landfall on the Atlantic coast of the country, between both events the primary population affected was 104,052 people affected, 159,882 evacuated, 110 missing, 92 injured and 193 dead, as well as 74,214 sheltered. In 2018 the Volcán de Fuego erupted leaving 201 people dead and 229 missing (para. 19-22, 35-39).

Also, in addition to natural disasters caused by volcanoes and storms, there has been damage caused by earthquakes in the country, according to Bolaños (2020c), the population of San Marcos recorded two earthquakes, the first in 2012 and the other in 2014, causing losses of about 128.5 million US dollars, reporting for the second earthquake about 50 deaths and multiple damaged houses and buildings. In 2017 an earthquake was recorded causing damage in San Marcos, Huehuetenango, Quiche, Quetzaltenango, Totonicapán and Suchitepéquez, reporting 3,518 people affected, 81 victims, 4 injured, as well as 81 houses affected, 5 buildings, 3 roads and 1 bridge damaged (para. 26-29, 33-34). Note the series of catastrophes of different kinds suffered by the Guatemalan population.

In this sense, natural disasters have impacted the infrastructure of hospitals in Guatemala and to mitigate such impact, the use of BIM is proposed for the hospital construction process, taking into account, when designing, functionality tests of alternative areas to attend massively affected patients, as happened with COVID 19, the reduction of costs of services such as electricity, reduction of greenhouse gas emissions, better access to drinking water and other benefits offered by the design for the construction of hospitals through BIM, i.e., an integral design is proposed until the end of the life cycle and the recycling of materials used in the construction of hospital infrastructure.

2. What is needed to implement design projects for the construction of disaster resilient hospitals in Guatemala using BIM methodology?

On the subject, WHO/PAHO (2010, p. 1 and 2) that; in Guatemala, the project "Strengthening communities through safer health facilities in Central America: Safe Hospital Program with a local perspective" ...to evaluate the safety of health facilities through the training of professionals...related to the topic of disaster risk management; also, the application of the Hospital Safety Index (ISH) in selected health facilities, the evaluation and analysis of results, and...the implementation of some improvement actions in the evaluated facilities. [The] project started on October 1, 2008 and ended on February 28, 2010.

To this effect, the Ministry of Public Health and Social Assistance MSPAS (2022) points out that an evaluation program was carried out using the ISH of Safe Hospitals from 2015 to 2022 in 45 hospitals of the network evidencing these 2 hospitals in category A (Have little threat and adequate security), 33 hospitals in category B (Has threats and medium security) and 10 hospitals in category C (Has many threats and little security), the evaluators were accredited by the Risk Management Unit, General Coordinator of IGSS Hospitals, DECAP, Guatemalan Red Cross and PAHO, creating short and medium term improvement plans, presenting the results to Ministerial authorities and authorities of the evaluated hospitals (pp. 4, 5, 16 y 17).

In addition to describing, the experts interviewed point out that from the history of evaluations and recommendations to the current hospital infrastructure, it is necessary to implement the design methodology through BIM for the design and construction of health care centers, since with this it is possible to apply tests and verify results by

observing the behavior in the generated 3D model, from the terrain for construction, performance tests in natural disasters such as earthquakes, landslides, mudslides, simulations of use, to the behavior of the infrastructure over the years, being possible to determine the optimal use of such facilities and their maintenance until their demolition and recycling of its elements.

In this regard, the experts also point out that COVID-19 forced them to improvise the use of certain areas of hospitals for the care of affected patients, being able to foresee from the design stage the change in the use of these areas, something that would be possible with the use of BIM in this process.

3. Is BIM methodology being implemented in hospital design and construction in Guatemala?

The interviews with the experts also revealed that they have no knowledge of hospital infrastructure development programs using BIM in Guatemala, although they mentioned that some companies dedicated to infrastructure development have begun the transition to BIM design and modeling on their own. Two experts mention that they are collaborating with a hospital design through the methodology, but that although it is Guatemalan, it is not being designed in the country.

4. Are there institutions that offer technical and professional training based on formal education on BIM methodology in the country? On this matter, the Technical Institute of Training and Productivity INTECAP indicates on its official web page https://www.intecap.edu.gt/centros/ that it is a national reference institution with 33 study centers in five national regions and within its training offer announced in https://intecap.edu.gt/ctms/tecnico-en-modelado-y-administracion-de-proyectos-bim/ it offers the BIM Modeling and Project Management Technician course.

Similarly, only in the curriculum of Architectural Civil Engineering of the Universidad del Valle de Guatemala UVG of the year 2024 is the BIM Project Management Course and it can be consulted in its official website https://www.uvg.edu.gt/carreras/civil-arquitectonica/ in addition, some national universities offer BIM master's degrees, such is the case of the Universidad del Istmo de Guatemala UNIS, in its official web page https://unis.edu.gt/facultad-de-arquitectura-y-diseno/maestria-en-building-information-modeling-bim/ offers the Master in Building Information Modeling (BIM) and likewise the UVG offers in its official website https://www.uvg.edu.gt/uvgmaster/posgrado-en-modelado-bim/ a postgraduate degree in BIM modeling.

Indeed, according to interviews with experts in BIM technical and professional training programs, there has been a low influx of students and this may be due to many causes, mainly to the lack of BIM implementation policies at the national level.

5 Is it possible to develop design and construction projects, as well as to give continuity to hospital infrastructure already built with the BIM methodology in Guatemala?

Linked to the concept, the experts interviewed indicate that it is possible to give continuity to hospitals designed and built with the methodology through the BIM Dimensions and by giving continuity to the 3D model of the infrastructure in reference to the changes made in the infrastructure being transferred to the BIM model mentioned. Regarding hospitals already built, they indicate that it is not possible to design a BIM model of an existing infrastructure because the design collisions and their resolution would be unknown, therefore, it would not be a model designed with the methodology as such and the analysis would not be accurate.

In that sense, they mentioned that the programs for simulation of construction processes by specialty, especially the pay-per-use ones, are already linked to BIM, but that

because this methodology is not yet widespread in the country and is not commonly used, they have rarely or never used the software links in question. It is important to note what the experts indicated, there are pay-per-use and free-to-use software in the BIM methodology.

6. How would the development of designs for the construction of hospital infrastructure be carried out using the BIM methodology in Guatemala?

Within this framework, according to the experts, the benefits of the use and implementation of the BIM methodology should be made known at the national level by creating dissemination policies, implementing rules and regulations for its use and encouraging the institutions in charge of the design, development and maintenance of this type of infrastructure to have the profiles required by the methodology through the Guatemalan authorities who are in charge of the decision to act and implement programs of this type.

A structural engineer mentions that for him the most important thing when using BIM in hospital designs is to be able to simulate the behavior of the structure in the 3D model with all its specialties in the face of certain natural phenomena such as floods and earthquakes, which makes it possible to detect the behavior of concurrent piping from different engineering fields such as plumbing, medical gases, electricity, weak signals, among others, avoiding collapses, since with the traditional method of 2D plans it is impossible to observe and anticipate failures or collisions between the elements described.

As a complement, since it is necessary that the centers dedicated to the health of the population are resilient to the aforementioned disasters so that people can go and make emergency use of these facilities and that these are in good condition, the tools of this methodology should be analyzed and among them are the BIM dimensions and according to what was stated by Estruga (2021) and Vitorino (2021) the following compilation was made:

Table 1

BIM dimensions as an adjuvant for resilient infrastructure development

BIM DIMENSION	PRODUCT OR DEVELOPMENT
First dimension or 1D	Concept or definition of the idea or origin of the project; includes location, initial infrastructure conditions, feasibility studies, estimates, analysis of applicable laws and standards to assess the feasibility of the project.
Second dimension or 2D	Vectorization of the project plan or sketch; it may include the development of a two-dimensional plan elaborated in CAD or computer aided design, it must be the basis for the following dimensions working with a software compatible with BIM modeling, it includes contract issues, definition of collaborative scope and sustainability schemes of the project object.
Third dimension or 3D	Three-dimensional modeling or object-oriented model; represents geometric information of the project in an integrated manner including parameterization of the components, mainly the architectural design and each of the engineering required for the development of the project, which will allow updating the model in three dimensions during the life cycle of the project, making the coordination of the disciplines of architecture, structures and facilities or MEP Mechanical, electrical and plumbing.
Fourth dimension or 4D	Planning or timing; achieved by integrating the schedule of activities and work into the developed model
Fifth dimension or 5D	Cost; includes the determination of the budget, cost control and cost estimation, all oriented to improve the profitability of the project, associated to input quantities, including materials, equipment and personnel. Additionally, organize and budget operating costs for the use and maintenance phase, which may include costs and quantities of inputs such as purchases, orders, salaries, administrative and general expenses, among others. It must be linked to the three-dimensional model developed in 3D by means of variables that allow the construction of the budget so that it can be considered in this fifth BIM dimension.
Sixth dimension or 6D	Energy sustainability or Green BIM; this includes simulations that allow energy sustainability analysis in order to visualize the energy performance of the project before important decisions are made and the construction of the project starts in order to optimize processes in real time such as future inspections, remodeling, among others. This dimension deals with the sustainable design of the project and the concept of Value Engineering, which consists of optimizing the construction systems and installations, so that by making strategic modifications, costs are significantly reduced in the construction phase and future operations without the project losing its essence.
Seventh dimension or 7D	Monitoring and maintenance or management of the project life cycle; This dimension or phase involves the use of models to foresee or carry out maintenance and operation activities of the project life cycle through its management, as well as associated services, adding the logistic and operational control of the project during the use and maintenance of the useful life, optimizing processes such as inspection, repair, maintenance, among others. By correctly applying this dimension it is possible to apply Asset Management, which corresponds to the management of assets based on principles such as knowledge, planning, organization and integrated management contained in ISO 55000 and ISO 55000-1, optimizing the performance of these assets, minimizing costs and improving the service offered, referencing the analysis of strategies during the life cycle of the building, as well as the future reforms of the construction from the 3D model made, this model is useful for the visualization and simulation of the operation and maintenance of the asset, with this it is possible to establish the objective of knowing what, when and how much.

Eighth dimension or 8D	Construction Safety; safety related information is added to the geometric model, by adding this information to the model it is possible to predict the risks in the construction process by identifying the activities that when applied will improve safety at work and prevent accidents.
Ninth dimension or 9D	Lossless construction; in this dimension it is oriented to optimize and speed up all the steps of the construction phase of a project, through the digitalization of the processes
Tenth dimension or 10D	Industrialization of construction, aims to industrialize and make the construction sector more productive by implementing technology and integrating physical, commercial and environmental data, among others.

In this sense, the designed facilities built, based on the BIM Dimensions are generated in a three-dimensional model in which a series of tests and solutions between concurrent architectural and engineering specialties have been performed to it (third BIM dimension), perform energy sustainability analysis to the construction (sixth BIM dimension) and even being able to continue the BIM work on the infrastructure through the maintenance of the same (seventh BIM dimension), meanwhile, states WHO/PAHO (2018 p. 113):

The Health Facilities Initiative...based on the ISH...bridges the gap between environmental performance, climate resilience, hazard resilience and disaster risk reduction in health facilities. (A higher standard will be set in design and construction, as well as in energy and water use and service provision to help withstand expected climate variability and change). The expected impact of the Smart Health Facilities Initiative is to build or remodel facilities to be climate adapted and resilient to disasters affecting the Caribbean.

It is noteworthy that WHO/PAHO has indicated the construction of health facilities that have the capacity to adapt to the climate and are resilient to natural disasters with flexibility in terms of infrastructure performance testing

Linked to the concept, another important tool is the "Level Of Development LOD" which defines the level of development or maturity of information that an element, construction system or infrastructure assembly has within the BIM methodology and according to the BIMnD Team (2013), Imasgal (2022) and Sanchez (2016) the following compilation was made:

Table 2
LOD Development Level used for modeling according to BIM methodology

LOD	DESCRIPTION
LOD 100 Symbolic representation	It is the elementary model of the project; it is represented graphically with a symbol or other generic and schematic representation.
LOD 200 Generic System	The element is represented graphically within the model as a generic object with an approximate quantity, size, shape, position and orientation.
LOD 300 Specific System	The element is represented graphically within the model as a specific system, in which the object has specific quantity, dimension, shape, position and orientation. Geometric elements are also linked to non-graphic information, which is more detailed than that possessed by the previous level.
LOD 350 Interference detection	LOD 350 is equivalent to LOD 300 but includes the detection and solution of interferences between different elements, referred to projects involving several disciplines or specific project disaggregation. It affects the analysis, programming and coordination of the project. Sometimes the cost per item and as a whole,
LOD 400 Manufacturing	The element is graphically represented within the model as a specific system, in which the object has specific dimensions, position, shape and spatial orientation with details for its fabrication and installation. Geometric elements are linked to non-graphic information that is more detailed than that presented in the previous level.
LOD 500 Verified on-site representation	The model element is a site-verified representation, in terms of size, shape, quantity, position and orientation, the final graphic information is linked to the geometric elements of the system.
LOD 600	The G202 document of the American Institute of Architects AIA indicates the possibility of creating new LOD levels, among them the LOD 600, the object does not have a detailed geometric definition, but it does have conditions of recycling, material properties, toxicity, useful life, basic manufacturing properties, distance to the point of manufacture/recycling, weight, volume, ways of transportation and disassembly, among others. It has non-graphical information linked to the element.

Consequently, the use of LOD 350 in infrastructure developments is important, as it enables the detection and solution of interferences between concurrent specialties, especially and according to experts, in hospital facilities, in addition to architecture, structural, sanitary, mechanical, electrical, electronic and computer engineering, among others, are involved. With respect to hospitals and their contribution to the environment when designing health center infrastructure, the provisions of the LOD 600 on recycling of materials once the life cycle of the project has been completed should be taken into account. According to the research, it is possible to develop design projects for the construction of hospitals using the BIM methodology and its tools as an alternative to mitigate the natural disasters that affect Guatemala.

Results

Results of the Interviews of the First Group of Participants
Interviews were conducted with a first group of eight expert designers of hospital infrastructure: 3 architects, 2 civil engineers, 1 electrical engineer, 1 mechanical engineer

and 1 electromechanical engineer. These were individual, personal, by telephone or by means of applications such as WhatsApp, notes were taken and, at the request of the interviewees, no recording was made of the interviews, which were conducted to extract information on the use of BIM in the design and construction of health infrastructure as a mitigation alternative to natural disasters affecting the area and general recommendations that the experts could provide.

In this sense, the interviewees indicated having knowledge of BIM, but only 2 architects, 1 civil engineer and the electrical engineer indicated having participated in at least one hospital infrastructure design and construction project developed with this methodology, indicating the difficulty of the project development, they indicate the difficulty of the project development, both for the use of software and hardware (that all of them had recent model computers with the software installed and running), the use of communication channels between all involved (definition of the software to be used and access to it) and the definition of profiles to develop the project, that the experts involved, both architects and engineers, had BIM knowledge in their areas.

With reference to this, the experts interviewed with BIM knowledge mentioned that it is possible to give continuity to hospitals designed and built with the methodology through the BIM Dimensions and giving continuity to the BIM model of the infrastructure, referring to the changes made in the infrastructure being transferred to the BIM model mentioned. Regarding hospitals already built, some of the interviewees indicated that they cannot work with the methodology because they do not know the conditions of construction and changes made to the infrastructure in question. In other words, it is not possible to design a BIM model of an infrastructure, since the design collisions and their resolution would be unknown, therefore, it would not be a model designed with the methodology as such and BIM tests could not be applied in their entirety.

Within this framework, all the interviewees indicate that they are not aware of any public or private regulation in the country, of mandatory use of the BIM methodology and that the efforts for its implementation have been individual, as for the acquisition of knowledge about BIM, some institutions have provided it to their workers, but mainly at a personal level, they have gone to educational institutions paying to obtain practice and theory of the methodology.

In addition to this situation, they mention that policies and programs should be created at the national level to disseminate the topics of "BIM methodology", "hospitals with resilience to natural disasters" and "implementation of BIM at the national level" in Guatemala, especially to institutions dedicated to the development of hospital infrastructure projects.

Likewise, it is recommended that the institutions in charge of developing such projects in their design, construction and maintenance stages, whether public or private, should ensure that their work teams are trained in BIM, since for such implementation it is recommended to have among their personnel, the different profiles that make up the working groups for the development of constructions through the methodology.

Results of the Interviews of the Second Group of Participants

In the second group, seven experts in general infrastructure design were interviewed (3 architects, 2 civil engineers, 1 engineer specializing in plumbing and 1 electrical engineer) in order to determine the development and use of BIM models in Guatemala, team or collaborative work with this methodology and its results, as well as the implementation of BIM in the country and the use of simulation programs by specialty associated with this methodology, among others.

In this sense, all the experts indicate having knowledge of the BIM methodology, indicating that they have participated in the development of infrastructure in general with this methodology in the country and, like those interviewed in the first group, they are not aware of any mandatory regulations or laws in Guatemala on the use of BIM. Regarding the development of projects with BIM, they mention that they have been developed mainly with collaborative work, people have demonstrated knowledge and practice in BIM acquired individually. Experts mention that some companies, especially foreign ones, are requesting their designs for construction with BIM.

On the other hand, the experts coincide in indicating that the simulation programs in their specialty already include a link to BIM, although their use is for a fee and not all the experts interviewed have used them. The Hydrosanitary expert interviewed indicates that he has not used simulation programs linking them with BIM, but he makes his design with simulation tests and exports it to the BIM model.

Similarly, the experts interviewed mentioned that it is possible to give continuity to hospitals designed and built with the BIM methodology through the BIM Dimensions, as well as to the changes made in the mentioned infrastructure once they are transferred to their BIM model. Regarding the existing infrastructure, the interviewees indicated that they cannot work with the methodology because they do not know the conditions and changes made to the infrastructure in question. In other words, it is not possible to design a BIM model of an existing infrastructure, since the design collisions and their constructive resolution would be unknown, therefore, this is not advisable.

It is noteworthy that the interviewees indicate that in Guatemala there are educational institutions that offer BIM courses and technical and professional careers, mentioning INTECAP and KINAL, among the universities mentioned are UNIS and UVG.

Survey Results

As part of this research, a closed dichotomous survey was also conducted and within a population of 50 health care infrastructure modelers, designers and implementers, a random sample of 15 professionals was selected, being 4 hospital architecture modelers, 4 hospital construction project managers/supervisors, 2 architecture students supporting hospital architecture modelers, 2 MEP designers for health care infrastructure, and 3 BIM experts oriented to hospital infrastructure designs to answer the questions presented in Table 3.

As a follow-up to this activity, the survey was carried out with a Google Form that was validated in its content by an architect, designer, consultant and supervisor related to hospital infrastructure and an architect specialized in hospital design and expert in Safe Hospitals according to WHO/PAHO terminology, authorization was also requested from the companies and authorization from the ethics committee of said companies to which some of the surveyed participants belong and a letter of informed consent was given to the participants before filling out the survey.

It is also important to mention that all interviewees and respondents were persons of legal age who were previously informed and asked for their support to participate in such events and that the Google Form only saved the answers for the privacy of the participants. The interviews and survey were conducted between May 2023 and February 2024 in Guatemala.

Table 3

Results of the survey instrument

ITEM	YES	%	NO	%	DESCRIPTION
1	14	93%	1	7%	Do you develop hospital infrastructure projects in Guatemala?
2	11	73%	4	27%	Do you know of any hospital construction projects using BIM methodology in Guatemala?
3	6	40%	9	60%	Do you know of any BIM implementation plan or program for infrastructure development in the country?
4	15	100%	0	0%	Do you consider it possible to mitigate the impact of natural disasters on hospital infrastructure through design and construction using BIM methodology?
5	11	73%	4	27%	Do you consider it important to implement the BIM methodology in the construction of hospitals in Guatemala?

Below are the figures representing the quantities obtained based on the closed dichotomous responses to the survey and an analysis of the results, comparing these results with those indicated by experts who participated in the two interviews conducted, both in infrastructure development in general and in hospital infrastructure.

Figure 2

Question 1. Do you develop hospital projects in Guatemala?
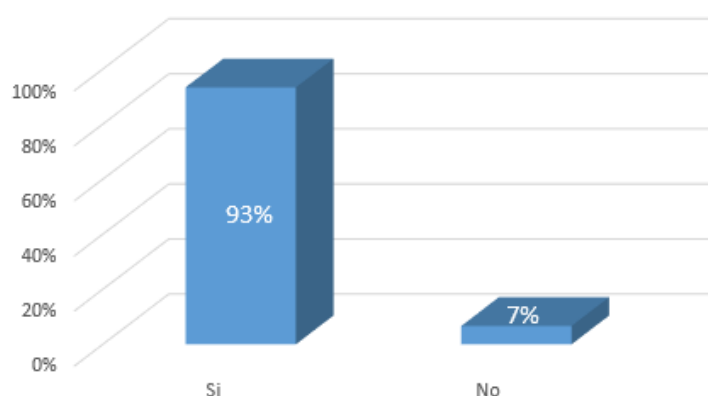
In this regard, it is interesting to note in Figure 2 that 93% of those interviewed are currently involved in the development of hospital infrastructure projects in Guatemala, while 7% of those interviewed are not developing this type of project. This provides a valid and favorable opinion regarding health center construction projects, since most of the respondents are involved in this type of project.

Figure 3
Question 2. Do you know of any hospital construction projects using BIM methodology in Guatemala?
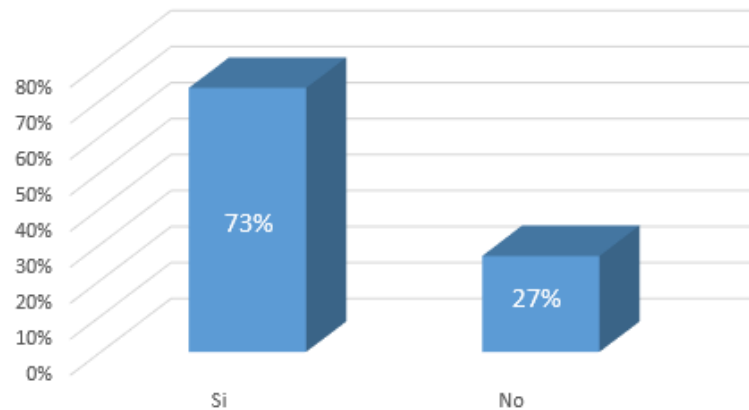
On the other hand, it is possible to observe in Figure No. 3 that 73% of the interviewees indicate that they have knowledge of some hospital construction project developed with the BIM methodology in Guatemala and 27% indicate that they have not used it or have no knowledge of this type of project; it is possible that they are not dedicated to the development and design of infrastructure for hospitals and do not have BIM knowledge or are not interested in it.

Figure 4
Question 3. Do you know of any BIM implementation plan or program for infrastructure development in the country?
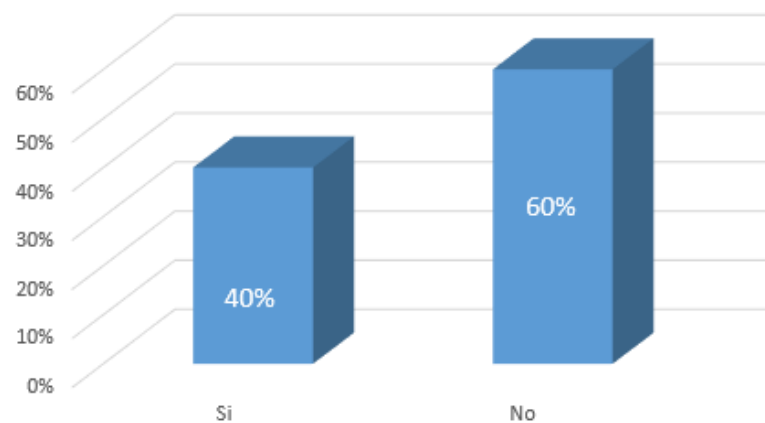
Among the professionals who responded to the survey and according to Figure No. 4. Forty percent indicated having knowledge of a plan or program to implement BIM in the development of infrastructure in Guatemala, while 60% said they had no knowledge of this, while the interviewees indicated that they were unaware of any plan or program to implement BIM in Guatemala, this may be due to the fact that there are companies dedicated to the development of infrastructure construction that have regulations within their lines of work oriented to the use of BIM for these projects.

Figure 5

Question 4. Do you consider it possible to mitigate the impact of natural disasters on hospital infrastructure through design and construction using BIM methodology?
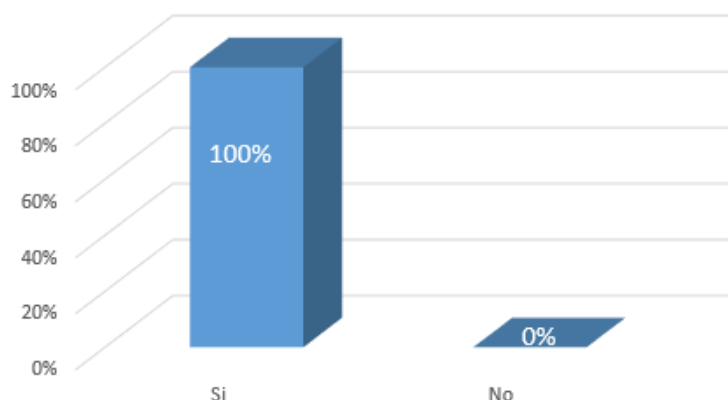
According to Figure 5, 100% of the respondents indicate that it is possible to mitigate the impact of natural disasters on hospital infrastructure through design and construction using BIM methodology, which is in agreement with what was indicated by all the professionals interviewed.

Figure 6

Question 5. Do you consider it important to implement the BIM methodology in the construction of hospitals in Guatemala?
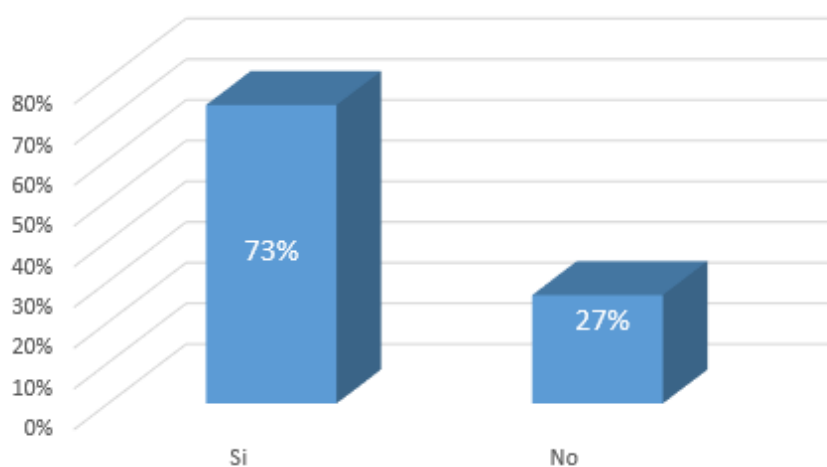
According to the survey, 73% of the participants indicated that it is important to implement the BIM methodology in the construction of hospitals in Guatemala and 27% indicated that it is not important. The results obtained were generated through a contrast between the interviews, the survey and the documentary research.

Discussion and Conclusions

Based on the results obtained (period May 2023-February 2024) it is possible to affirm that the implementation of BIM methodology is of utmost importance as a mitigation measure in the design and construction of hospital infrastructure in the face of

the natural phenomena that affect Guatemala and according to the documentary research, interviews and the survey conducted it can be concluded that:

1. Do you develop infrastructure projects with BIM methodology in Guatemala?

   Ninety-three percent of the professionals surveyed mentioned being involved in the development of hospital infrastructure, while 7% were not involved in this type of project. For their part, the experts interviewed in the two groups mentioned that they are working on the development of projects for the construction of health care centers in the country, unlike before the pandemic, there were few hospital development projects, from which it can be deduced and concluded that there is a boom in hospital construction processes in the country and that the answers given in the survey indicate that most of them correspond to people developing hospital infrastructure.

2. Do you know of any hospital construction projects using BIM methodology in Guatemala?

   The results of the survey indicate that 73% of the people surveyed indicate that they have knowledge of hospital construction with BIM methodology, and consulting with the professionals interviewed, they indicate that they have also developed projects of this type of infrastructure with BIM. However, the experts in BIM methodology interviewed in the first group indicate that in Guatemala they have worked in the development of hospital projects, mainly in remodeling or expansions, and they mention four professionals who are working on accompanying a hospital design with the methodology, but this is being carried out by an international firm.

   As a complement, the indicated agrees with the answers of the previous question, that, the majority of respondents have developed infrastructure projects with BIM including hospitals. Regarding the percentage, both in the survey and the professionals interviewed who indicate that they have not used it or have no knowledge of this type of projects with BIM, it is possible that they are not dedicated to the development and design of infrastructure for hospitals and that their projects are developed in a traditional manner, without the use of the methodology.

3. Do you know of any BIM implementation plan or program for infrastructure development in the country?

   Forty percent of the respondents indicated that they were aware of any BIM implementation plan or program in the development of infrastructure in Guatemala, while 60% said they were not aware of any BIM implementation plan or program in Guatemala, which may be due to internal regulations or those of certain companies. Unlike the experts interviewed in the first and second groups, who indicate that they are not aware of any public or private plan, program or regulation in the country for the mandatory use of the BIM methodology and that the efforts for its implementation have been individual, they also indicate that some companies, especially foreign ones, request their designs for construction with BIM. In this regard, the documentary research indicates that there are no policies or mandatory dissemination and implementation programs for the design and construction of hospitals using BIM in Guatemala, but some companies, on their own initiative, are in the process of transitioning to the use of this methodology; within the working groups of the different institutions there are personnel who have been trained by their own means.

4. Do you consider it possible to mitigate the impact of natural disasters on hospital infrastructure through design and construction using BIM methodology? How will the impact of natural disasters on Guatemala's hospital infrastructure be reduced?

    To this effect, 100% of those surveyed and interviewed indicated that it is possible to mitigate the impact of natural disasters on hospital infrastructure through design and construction with BIM methodology. This is in agreement with the secondary research conducted, since it is possible to test the 3D model, analyze the behavior and solve problems before construction, and there are programs or software to perform functional tests in the various specialties, whether architecture or engineering, with a link to the BIM methodology, which can reduce the impact of natural disasters on hospital infrastructure in Guatemala. The experts interviewed in the first and second group of participants indicate that it is important to have previous studies of the site and based on this to make a final model to which performance tests are made in the face of various phenomena, the behavior is analyzed and solved in the model generated prior to the construction process, it is also affirmed that it is possible to give continuity to any construction designed and built with BIM through what is indicated in the BIM Dimensions and giving continuity to the BIM model of the infrastructure in reference to the changes made in the infrastructure being transferred to the aforementioned model. Regarding infrastructure already built, the interviewees indicated that they cannot work with the methodology because they do not know the conditions and changes made to the infrastructure in question. It is important to mention that one of the interviewees indicated that it was possible to give continuity with BIM to remodeling projects, but concluded that it only applies to environments built with the methodology.

5. Do you consider it important to implement the BIM methodology in the construction of hospitals in Guatemala?

    It is noteworthy that 73% of the survey participants indicated that it is important to implement the BIM methodology in hospital construction in Guatemala and 27% indicated that it is not important. In this regard, the experts interviewed in both groups mentioned that policies and programs should be created at the national level to disseminate the topics of BIM and hospitals that are resilient to natural phenomena, and that the public or private institutions in charge of developing such projects should ensure that their work teams are trained in BIM methodology, with a view to creating the different profiles for the development of construction using the methodology.

Recommendations and Proposal for Continuity

1. It was documented that due to the disasters caused by natural phenomena that have occurred and continue to occur in Guatemala and have left heavy losses both human and material and due to the need to build infrastructure for resilient health care centers, as well as the reduction of costs of services such as electricity, reduction of greenhouse gas emissions, better access to drinking water, among others, it is advisable to implement BIM in the design and construction of hospitals in the country, since the 3D models generated make it possible to simulate the behavior of the infrastructure in the face of the aforementioned natural phenomena and to solve before building with much

more detail than with only 2D plans, making it possible to build hospitals that are resilient to disasters caused by the phenomena described.

2. Evidence based on documentary research, interviews and surveys indicates that in order to implement hospital construction projects using the BIM methodology in Guatemala, programs and dissemination policies are needed, and it is important to publicize the short, medium and long-term goals, as well as the social and institutional commitments generated at the national level through the implementation of BIM in the design and construction of hospitals in Guatemala.

3. Based on interviews with BIM experts, it is not possible to give continuity through BIM to all infrastructure that was not built with the methodology. If the design and construction development is carried out with BIM, it is possible to give it continuity, even up to its demolition and recycling of materials, through the methodology tools, as well as to give continuity to extensions or remodeling designed and built with the methodology.

4. Based on the primary and secondary research presented, it is possible to indicate that in order to carry out the development of hospital infrastructure using BIM, it is necessary to develop mandatory standards and regulations for its use in the construction of centers dedicated to the health of the population. Likewise, the institutions in charge of developing such projects in their design, construction and maintenance stages, whether public or private, must ensure that their work teams are trained in the terminology and application of the methodology, as well as develop and train personnel to form work teams with the profiles required by this methodology.

5. For future research from the present work, one can mention the selection of pay-per-use or free-to-use software for BIM development in the country for healthcare facility project development, BIM use software recommended for each concurrent specialty involved, BIM software for green hospital infrastructure development, bIM hospital infrastructure development through the use of building materials that can be recycled, BIM hospitals and the environment during their life cycle, BIM dimensions and self-sustainable hospital infrastructure, BIM technical and professional profiles for the development of infrastructure and maintenance of hospitals in Guatemala, updating the BIM model beyond the construction of infrastructure, among others.

Acknowledgments

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COMPREHENSIVE SUSTAINABLE URBAN MOBILITY PLAN FOR THE CURRENT MASS TRANSPORTATION SYSTEM FOR THE METROPOLITAN AREA OF PANAMA WITH METROTAXIS
PLAN INTEGRAL SUSTENTABLE DE MOVILIDAD URBANA AL SISTEMA ACTUAL DE TRANSPORTE MASIVO PARA EL ÁREA METROPOLITANA DE PANAMÁ CON LOS METROTAXIS

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	ABSTRACT
Keywords: metrotaxis, integrated, mobility, transport.	This research seeks to design a comprehensive urban mobility plan to address the problems caused by poor selective public transport service, considering factors of effectiveness, efficiency and social impact, with the aim of improving the quality of life of residents and guaranteeing a safe, efficient and sustainable public transport system in Panama City. It seeks to develop short-term strategies and action plans, considering various components of the current urban mobility system. The current system initially consisted of the first two subway lines. Immediately the feeders were attached to reach the places that geographically the subway could not access, which were called MetroBus. The way the city is structured makes it even more difficult for buses to access, so the need to add another system to the current mass transportation is appropriate due to: places that, due to the structure of the roads, it is not feasible for a MetroBus to access, for security reasons that current taxis are used as camouflage to commit robberies or that they are victims. This last one being integrated (compensated), and the single integrated system would use the same access card without the need to use cash and likewise, drivers with a fixed base salary. The goal of this research is to offer innovative solutions that improve the transportation network and provide reliable and safe tools to achieve an organized city recognized as a benchmark in urban mobility.

	RESUMEN
Palabras clave:	La presente investigación tiene como objetivo diseñar un plan de movilidad urbana integral para abordar las problemáticas causadas por

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metrotaxis, integrado, movilidad, transporte.	el servicio deficiente de transporte público selectivo, considerando factores de eficacia, eficiencia e impacto social, con el propósito de mejorar la calidad de vida de los habitantes y garantizar un sistema de transporte público seguro, eficiente y sostenible en la ciudad de Panamá. Se busca desarrollar estrategias y planes de acción a corto plazo, considerando diversos componentes del sistema actual de movilidad urbana. El sistema actual consistió inicialmente en las dos primeras líneas de metro. Inmediatamente se le anexaron los alimentadores para llegar a los lugares que geográficamente no podía acceder el metro la cual se denominaron MetroBus. La manera como se encuentra estructurado la ciudad, dificulta aún más el acceso de los buses por lo que la necesidad de anexar otro sistema al actual de transporte masivo es lo adecuado debido a: lugares que, por la estructura de las vías, no es factible que acceda un MetroBus, por temas de seguridad que los taxis actuales sean utilizados como camuflaje para cometer robos o que los mismos sean víctimas. Este último al ser integrado (indemnizado), ya el sistema integrado único utilizaría la misma tarjeta de acceso sin la necesidad de utilizar dinero en efectivo y de igual modo, los conductores con un salario base fijo. La meta de esta investigación es ofrecer soluciones innovadoras que mejoren la red de transporte y aporten herramientas confiables y seguras para lograr una ciudad organizada y reconocida como referente en movilidad urbana.

Introduction

Within the structure of large cities, selective public transport plays an essential role. One of the greatest challenges facing public administrations in Panama City, which also includes the district of San Miguelito, is to achieve a system that meets the needs of the inhabitants. Efficient public transport will not only improve the quality of life of citizens, but will also facilitate sustainable and economic development adapted to the needs of the population (Arévalo, 2016).

Figure 1
Nomenclature Sectors for the Districts of Panama and San Miguelito
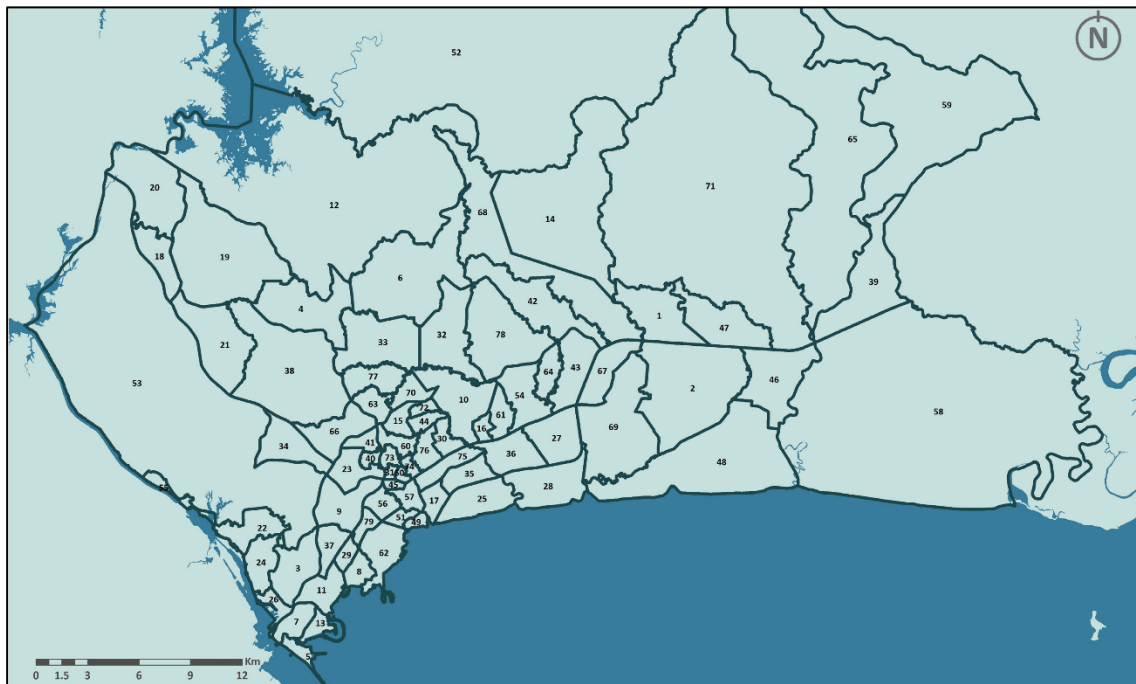
Note. Adapted from *Nomenclature System for the District of Panama* (p. 16), by Steer Davies, 2018, Manual of Graphic Standards.

Table 1

Sectors of the District of Panama and San Miguelito

ID	Name	ID	Name	ID	Name	ID	Name
1	December 24 North	21	Chilibre South	41	Los Andes 2	61	San Antonio
2	December 24 South	22	Clayton	42	Mañanitas North	62	San Francisco
3	Albrook	23	King's County	43	Mañanitas Sur	63	San Isidro
4	Mayor Diaz	24	Corozal	44	Hand of Stone	64	San Joaquin
5	Amador	25	East Coast	45	Monte Oscuro	65	St. Maarten
6	Bachelor	26	Diablo	46	Pacora Center	66	Bahai Temple
7	Balboa	27	Don Bosco	47	Pacora North	67	Tocumen Downtown
8	Bella Vista	28	Don Bosco South	48	Pacora South	68	Tocumen North
9	Betania	29	The Crab	49	Panama Viejo	69	Tocumen South
10	Brisas del Golf	30	The Crucible	50	Paradise	70	Torrijos Carter
11	Calidonia	31	The Hammer	51	Lefevre Park	71	Utivé
12	Long Causeway	32	Ernesto Cordoba Campos East	52	Chagres National Park	72	Urracá Valley
13	Historic Center	33	Ernesto Cordoba Campos West	53	Sovereignty Park	73	Veranillo
14	Cerro Azul	34	Rod Carew Stadium	54	Pedregal	74	Villa Guadalupe
15	Cerro Batea	35	Olympic Garden	55	Pedro Miguel - Paradise	75	Villa Lorena
16	Cerro Viento	36	Juan Diaz	56	Pueblo Nuevo	76	Villa Lucre
17	Chanis	37	The Locería	57	Rio Abajo	77	Villa Zaíta
18	Chilibre Center	38	Las Cumbres	58	Rio Chico	78	Villalobos
19	East Chilibre	39	Las Garzas	59	Indian River	79	Vista Hermosa
20	Chilibre North	40	Los Andes 1 - 9 de Enero	60	Samaria		

Note. Adapted from *Nomenclature System for the District of Panama* (p. 16), by Steer Davies, 2018, Manual of Graphic Standards.

The development of Panama's metropolitan area has experienced poorly planned growth, driven mainly by the real estate market and with deficient legislation in terms of planning, execution and control tools. During the last 60 years, development has been explosive and discontinuous, which has generated a linear structure in three different directions, with residential uses predominating in the periphery and labor activities concentrated in the center of the metropolitan area. This situation has resulted in complicated mobility for inhabitants, with long commutes to work and study centers, congestion on the few roads available, and high urban land costs (Metro de Panamá, 2016).

In recent years, specific projects have been carried out to improve mobility conditions in the metropolitan area, focusing in particular on Panama City, which also includes the district of San Miguelito. One of the main advances has been the implementation of the MetroBus system, along with the first two Metro lines, which are part of the city's current mass transit system (Metro de Panamá, 2016).

The way the city is structured makes bus access even more difficult, so the need to add another component to the current mass transportation system is appropriate due to: places where, due to the structure of the roads, it is not feasible for a MetroBus to access, also due to insecurity issues that the current cabs are used as camouflage to commit

robberies or that the cabs themselves are victims of robberies. The latter, when integrated (indemnified), would allow the use of the same multimodal access card for the current components of the mass transit system, both MetroBus and Metro de Panama, without the need to use cash. Similarly, that drivers have a fixed base salary (Metro de Panamá, 2016).

The difference of this project with respect to the various studies carried out on the cab system would be that apart from being part of an integrated system with the Metro and MetroBus, the fleet of Metrotaxis would first be well identified and labeled in accordance with the corporate image of the system.

In order to support the contribution of the research, we mention, among others, some previous studies where solutions to a similar need were presented in such a way that gaps in previous research can be raised to justify the objectives of the research.

Table 2
Previous investigations

Previous studies	*Disadvantages or peculiarities*
Economic Commission for Latin America and the Caribbean (ECLAC). Following successful examples in several cities around the world, a first effort to improve public transportation systems was undertaken in Latin America. This was achieved through the construction of rail systems in large cities, with the objective of counteracting the disadvantages and negative effects of conventional transportation that had prevailed in the region (Pardo, 2009).	These rail systems represented a significant improvement in the quality of transportation services in several Latin American cities. However, this improvement was limited to the specific routes where they were established, leaving the other traditional public transportation routes in the city untouched (Pardo, 2009).
The Andean Development Corporation (CAF) launched the Urban Mobility Observatory (OMU) in Latin America to address the lack of up-to-date and reliable information on transportation and mobility in the region. The project began with the analysis of 15 metropolitan areas in 9 countries in the region and showed that Panama City is not the only one facing these challenges (Fonseca, 2012).	The OMU found that the private transportation model predominates in the 15 cities studied, as a result of the irregular concession of services. The vehicles that use the road system most intensively are cars and individual cabs, accounting for 85% of total trips according to the CAF report (Fonseca, 2012).
To address the growing need for urban mobility in the city of Maracaibo municipality, Zulia state, the Presidential Transportation Commission in Maracaibo, Venezuela, implemented a policy aimed at introducing a collective transportation system that is in line with transportation and urban policies (Velásquez, 2015).	As a result of this initiative, the development of the Maracaibo Metro began, with the objective of offering an effective solution to the mobility challenges facing the city. The insertion of the subway in the city is currently positioned as a scenario that evidences a disarticulation between the policies of intervention of the desirable public space and the development models of the means of transportation that facilitate its mobility. The impact, as a good practice for transportation planning, was minimized by not considering diversity, accessibility

	and qualification of its public spaces, as indicators for mobility management (Velásquez, 2015).

Method

Design

The type of study carried out in the research was based on the construction of a theoretical and practical frame of reference. The main objective is to become familiar with a novel topic, so an exploratory or formulaic approach was used. This approach served as a starting point for further in-depth studies (FUNIBER, 2020).

The type of study proposed has little precedent in terms of its theoretical model or practical application, since no other studies have been conducted on the subject. Therefore, a theoretical compilation was sought due to the absence of a specific model related to the research problem. This work could serve as a basis for further research in the future (Vásquez, 2005).

To achieve the proposed objectives related to the variables to be measured, the collection of two types of information was considered: primary information and secondary information. The primary information was based on a series of field studies previously conducted by Metro Panama and financed by the Inter-American Development Bank. Secondary information included data from the latest Population Census (2023), the Economic Census prepared by the National Institute of Statistics and Census (INEC), and city databases with information related to population, household size, family income, among others. These data were combined with the surveys to estimate generation rates and trip matrices (Metro de Panamá, 2015 - 2016, p. 7).

It should be noted that initially secondary information was collected from textbooks, followed by field research with interviews that provided primary and updated information on the object of study.

The surveys were carried out with the support of the collaborators. The information obtained was then processed manually, starting with tabulation, graphs, analysis and interpretation of the results.

Once the information was collected, it was processed and analyzed to generate the necessary inputs to build the supply and demand models, as well as the transportation model.

Research Hypothesis

H_1: carrying two or even three different races or people on the same trip affected the time of the user boarding the vehicle in the first instance, as well as his or her safety.

H_2: the distribution of cab operation certificates indiscriminately by the competent authority exceeded the ratio between the number of inhabitants.

H_3: The fact that there are different cab owners from the same cab stand has caused vehicle races and accidents and congestion at the stops, in order to get to the passenger first.

Population and Sample

To determine the sample size, the formula for infinite population was used (Fernandez, 2010), since being a place where the greatest demand is concentrated, a survey was applied to the sample population, in this case, the metropolitan region of Panama City which also includes the district of San Miguelito, which according to

information from the National Institute of Statistics and Census (INEC) of the Comptroller General of the Republic of Panama, of the amount of 1,311,075 inhabitants it comprises, we will take 1.1%, which includes 14,461 inhabitants that are equivalent to a population of 10 years of age and older living in private households that, due to their activity, have a monthly household income of less than USD 1000.00 per month (US dollar), taking into account that the current average minimum wage is USD 769.00 per month (Hernández, 2023). To generate the sample, criteria such as the activities developed in the area, the potential for attracting and producing trips and the accessibility to the stations of the Metro Lines were used, seeking to generate the optimization of the users' way to the different transportation systems. Applying the formula, we obtain the following representative sample of 171 people, equivalent to 20% of the selected population (Office of the Comptroller General of the Republic of Panama, 2023).

The following formula was used to calculate the sample:

$$n = \frac{N * Z_\alpha^2 p * q}{d^2 * (N - 1) + Z_\alpha^2 * p * q} \qquad (1)$$

Where:

n = sample size = 171 persons
N = total population = 14,461

1. **Zα** = 1.645 squared (if safety is 90%)
2. **p** = expected proportion (in this case 20% = 0.20)
3. **q** = 1 - p (in this case 1-0.20) = 0.80
4. **d** = margin or precision (5% = 0.05)

$$n = \frac{14461 * (1.645)^2 * 0.20 * 0.80}{(0.05^2 * 14461 - 1) \quad + \quad (1.645^2 * 0.20 * 0.80)} \qquad (1.1)$$

$$n = \frac{14461 * 2.7060 * 0.16}{(0.0025 * 14460) \quad + \quad (2.7060 * 0.16)} \qquad (1.2)$$

$$n = \frac{6261.03456}{36.15 + 0.43296} \qquad (1.3)$$

$$n = \frac{6261.03456}{36.58296} \qquad (1.4)$$

$$n = 171 \qquad (1.5)$$

Variables

The following were considered:
1. Historical research: establishment of background of previous studies similar to this research.

2. Satisfaction analysis: deepening in the impact factor that gave rise to the problem of dissatisfaction with the transportation service and showing recommendations that achieve safety, commitment, comfort and punctuality of the user and the efficiency of Metrotaxis in their integration to the current mass transportation system.
3. Investments and service adjustments: the external and internal thresholds with the greatest impact on the problem of dissatisfaction with the cab transportation service for users in Panama were determined.
4. Transportation alternative: an investigation was carried out on the positions of the carrier and the user regarding the selective public transportation service provided.
5. Adaptations and operating capacity: the current situation of the cab sheds, administration area, service operations and cab fleet were evaluated in detail.

Table 3
Data collection

Variables	Instruments
Historical research	Observation
Satisfaction analysis and transportation alternative	Survey
Service adequacy and operating capacity	Observation

Research Instrument

Having clear objectives in order to obtain better results, the computer and specialized programs were used as tools according to the particular variable of data collection that was required. In accordance with the nature of the data collected, both quantitative and qualitative research instruments were used.

In order to measure variables and analyze trends, the questionnaire was used to conduct surveys and subsequently evaluate the questions to ensure their reliability. Initially, in the case of the surveys, this was done by coding, and in the case of the quantitative results, by tabulation (Parra, 2023).

Similarly, regarding service adequacy and operating capacity as a proposal for operational planning, direct observation took place where the service will operate, which was a useful method for identifying inefficiencies or bottlenecks. The daily activities within the service were observed, which allowed the identification of operational problems such as delays, misused resources and redundant processes.

After submitting the collation instruments to consultation, in the opinion of the experts, it met two quality criteria, both in terms of validity and reliability. Content validity was frequently determined in two main contexts. One of them was related to the design of the test, while the other concerned the validation of an instrument that has undergone translation and standardization processes, with the purpose of adapting it to different cultural meanings (Robles, 2015). The validation of the instruments by the experts was based on the report of the Integral Plan for Sustainable Urban Mobility (PIMUS), specifically adjusted to this research, which at the time focused on selective public transport type cab however, the project was not implemented. Panel of experts composed of Metro de Panamá S.A., the Transit and Land Transportation Authority, the Municipality of Panama and the consulting group (Cal y Mayor Asociados - IBI Group).

1. Primary sources: in addition to the in-depth survey, techniques used included participant and non-participant observations. This allowed us to know the information provided by the users of the selective public transportation

system, obtaining valuable information with this data (Secretaría de Desarrollo Urbano y Ecología, 2022) as well as to observe directly how the service operates and is carried out. Observations on operational aspects, efficiency, interaction with users, and other relevant factors.

2. Secondary sources: secondary data were obtained through magazines, books, demographic databases, websites and articles related to the topic of urban mobility in the metropolitan area of Panama (Manrique, 2004).

Results

At present, the platform does not intend to compete directly with the already known commercial and private houses, but seeks to further integrate a system under the same common single payment umbrella. The choice of an appropriate transportation model required the evaluation of several aspects, such as: the scale of the policy-making environment, the problem being addressed, the degree of precision and level of detail, both spatial and analytical of the expected results, the availability of data and the resources that were available for its own development.

Satisfaction Survey and Data Analysis

With respect to the analysis of satisfaction and transportation alternative, the data were processed and analyzed in two ways:

1. Data processing: in the case of quantitative results, this was done by tabulation, followed by the use of statistical tables.
2. Data analysis: the research process on the integrated urban mobility plan for the current mass transit system was developed using a mixed approach. A qualitative approach was used to discover and refine the research questions, while the quantitative approach was used to collect and analyze data to answer the research questions and test previous hypotheses (Sampieri, 2003), relying on the extraction of conclusions and meanings from unstructured and heterogeneous data that are not extracted in a quantifiable or numerical form to accurately establish patterns of behavior in a population. The reproduction of a large number of data sources, of different origins and formats, makes it very often necessary in this research to analyze qualitative data using special techniques and tools such as observation and surveys. To facilitate statistical analysis, the questions were closed. We used software that facilitated the task of analyzing massive data from heterogeneous sources in digital format, such as the SurveyMonkey Internet tool. This tool allowed us to feasibly extract data patterns that could answer the questions of our analysis.

The data obtained were grouped, classified, and organized in tables and statistics showing the results in order to facilitate analysis, including brief notes on the finding. The surveys were used to analyze the attitudes of carriers and users regarding the selective public transportation service provided.

Question 1

How many different routes of public transport, either selective and/or collective, do you use per day to move around the city?

Table 4

Different public transportation routes, whether selective and/or collective, used daily to move around the city

Responses	Selection	Percentage
One	57	33%
Two	87	51%
Three	16	9%
More than three	11	6%
Total	**171**	

Findings and data analysis: the majority voted that they use approximately two routes per day, including transfers.

Question 2

Approximately how long does it take you to travel on selective public transportation units per day?

Table 5

Travel time on selective public transport units for daily commuting

Responses	Selection	Percentage
Less than one hour	44	26%
One hour	91	53%
Two hours	25	15%
Three hours	11	6%
More than three hours	0	0%
Total	**171**	

Findings and data analysis: we can observe that people can take hours on selective public transport and it is for this reason that improvements should be made to get people to their destinations faster.

Question 3

Have you used any mobile application for selective public transport use?

Table 6

Use of mobile application for selective public transport use

Responses	Selection	Percentage
Yes	13	8%
No	158	92%
Total	**171**	

Findings and data analysis: the question was very loose on whether or not they use applications for public transportation, but where NO with 92%, i.e., people do not download applications on the mobile because all those that are, are bad and / or deficient.

Question 4

How would you rate the city's selective public transportation system, where 1 represents the lowest score and 5 the highest.

Table 7

Rating you would assign to the city's selective public transportation system

Responses	Selection	Percentage
1	101	59%
2	23	13%
3	25	15%
4	13	8%
5	9	5%
Media	**1.9**	
Total	**171**	

Findings and data analysis: in the question we want to know how people who use selective public transport rate the system, which earns a 1.9 which means how deficient it is.

Question 5

What aspects do you consider to be the most important for the provision of a selective public transportation service in Panama City?

Table 8

Aspects considered to be the most important for the provision of selective public transportation services in the city

Responses	Selection	Percentage
Security	122	71%
Punctuality	43	25%
Cleaning	2	1%
Cost	4	2%
Total	**171**	

Findings and data analysis: what people would value most about transportation is security, either because of fewer robberies or because women would feel safer when riding selective public transportation. Secondly, it is punctuality, i.e., the time in which it arrives or the time in which we arrive at our destination. Thirdly and fourthly, cleanliness is extremely important now in times of pandemic, as well as the price we are paying is fair for the service provided by the transport.

Question 6

Would you be willing to install an application on your cell phone to help you make better use of selective public transportation in the city, where you can optimize time and money?

Table 9

Willingness to install an application on the cell phone that helps to better use selective public transportation in the city, where time and money can be optimized

Responses	Selection	Percentage
Yes	125	73%
No	46	27%
Total	**171**	

Findings and data analysis: people are willing to download an application on their cell phone as long as it is good and efficient, with 73% of the respondents saying YES.

Question 7

What do you consider to be the most important aspect that a mobile application should include, focused on selective public transportation in the city?

Table 10
Aspect to consider as the most relevant to be included in the mobile application aimed at selective public transport in the city

Responses	Selection	Percentage
Routes	35	20%
Schedules	112	65%
Location	7	4%
Passage	17	10%
Total	**171**	

Findings and data analysis: again we can see how timetables are so important for people e.g. the Metro tells us what time the next car will arrive, but for cabs it is non-existent. Routes and passage took into account also important. As all my respondents are Panamanians and live in the capital city or San Miguelito, location is not so important to them, but for a tourist it is and that is why it was not taken into account in this survey.

Question 8

From where you live, how efficient is selective public transportation?

Table 11
Efficiency of selective public transport

Responses	Selection	Percentage
Excellent	7	4%
Good	56	33%
Neutral	88	51%
Malo	15	9%
Lousy	5	3%
Total	**171**	

Findings and data analysis: in this question my concern is how good the transportation is and so neutral wins with 51% and with 9% bad which is good news, since not for many people the efficiency of transportation is lousy or inaccessible, and that for most it is quite good.

Question 9

For what reason do you use selective public transport?

Table 12
Reason for which selective public transportation is used

Responses	Selection	Percentage
Job	96	56%
Studies	57	33%
Leisure	14	8%
Another	4	2%
Total	**171**	

Findings and data analysis: the majority use transportation to commute to the workplace at 56%. The others are studies and recreation (leisure) among the most voted.

Question 10

Have you been satisfied with selective public transport?

Table 13
Level of satisfaction with the use of selective public transport

Responses	Selection	Percentage
Yes	20	12%
No	151	88%
Total	**171**	

Findings and data analysis: as a last question I wanted to know if they were satisfied with selective public transportation and by a wide margin they win that they are NOT satisfied with transportation.

Mobile Application

In terms of accessibility, Panama City is making a considerable effort to strengthen its public transportation system, achieving positive results compared to other areas in the Central American region. Although there is still much work to be done, the initiative to digitize the transportation network is an important step. This will allow users to have real-time access to the arrival of Metrotaxis, know the location of nearby stops and plan their trips with detailed route information, among other conveniences.

The implementation of the MetroTaxi application is a project integrated in the "open data" policy. In other words, it is a tool designed with reliable information obtained directly from the transportation system. Users can access this application directly or by easy registration through their email, Google account or Facebook social network profile (Alcalde, 2014).

The operation of the MetroTaxi application is similar to that of many other private service applications available on the market. The user enters the address, requests the cab and waits for the nearest cab driver to accept the ride, then meets and begins the journey.

The current application aims to address several of the key issues associated with taking a cab, safety being foremost among them. With this application, we are certain to know the identity of the driver who will transport us (Trujillo, 2013).

As in many countries, the application has an emergency button, located at the top right of the interface, with the main objective of improving safety conditions for occupants. This emergency button consists of an always visible siren. When pressed, either by the driver or the user, the position of the transport unit is notified to the corresponding authorities through the GPS system. In case it is proven that the button

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was pressed intentionally and not by mistake, either by the user or the driver, penalties will be applied.

Given that the existing applications lack control and monitoring by the transit authority, and considering their potential usefulness for planning and control, the following is an analysis that addresses the application's weaknesses, opportunities, strengths and threats.

Table 14
SWOT analysis of the application

Weaknesses	Opportunities
• The applications do not monitor that cab drivers, in order to avoid traffic jams, do not accept rides, which does not improve the current situation of access to the service during rush hours. • The apps do not monitor that cab drivers comply with being "unavailable" while they are providing a service. • The use of apps while the cab driver is driving generates accident risk. • It depends a lot on the technology of the smart phone.	• Generation of information on trip generation and attraction points. • Real-time demand monitoring to optimize cab supply. • Decreased response time to service requests. • The special zones constitute an area of high demand during peak hours. • Integration of selective transport with other means of transport. • The applications have the possibility of compulsorily assigning races to the vehicle unit according to its availability status and geographic position. • Information is generated in the cloud that can be used for urban planning and development processes.
Strengths	**Threats**
• It is faster to order cabs by app than by radiotelephone. • Eliminates intermediaries in the cab supply and travel demand market. This may represent a reduction in some operating costs. These savings could be used to improve other aspects of the service. • Allows greater monitoring of the location of each unit. • It is safer to order a cab through an app than to take one on the street.	• Not having a radio phone (a cab driver who only works with apps) may imply greater insecurity for the cab driver since support networks are often triggered by this channel. • The handling of the information provided by the passenger can be used by cab drivers after the ride to threaten the person.

According to the latest reports of the National Institute of Statistics and Census of the Comptroller General of the Republic of Panama, the number of active cell phones in the country increased from 5,141,768 to 5,709,163 in the last five years (Instituto Nacional de Estadística y Censo, 2020).

As more people deal with various demands, they are turning to their smartphones to perform various tasks including secure mobility from one place to another. Based on this, we can conclude that the demand for using selective public transportation through a single digital medium would not be a limitation and could even increase due to the security it would represent for the user and the confidence of knowing the fare collection in advance.

While it is true that requesting a MetroTaxi unit requires no more than using the mobile application, the MetroTaxi charge would be coupled to the single card of the current integrated system that also includes both the Panama Metro and the MetroBus. The user would be required to register his or her integrated transportation system card under a unique identification number in the application.

Finally, the application will provide the route that the MetroTaxi unit will follow so that the user can see it on our smart phone. In addition, there will be no extra charges for cabs that want to take us on the longer route to charge us more.

It will be in operation for now in Panama City and the district of San Miguelito, although expansion plans consider other cities as access to both the Panama Metro and MetroBus is developed in the different areas.

Cards and Their Role in the MetroTaxi System

Like the Panama Metro and MetroBus, the MetroTaxi fare collection system will be operated by a company that, apart from integrating both systems, also has experience in the implementation of these types of systems, which in the case of the public transportation system includes, among others:

1. Areas designated as yards or piqueras will be equipped with Concentrators for automatic transaction downloading and balance validators. These elements will help streamline the process for users when recharging their MetroTaxi cards, as well as for accessing Metro de Panama and Metro Bus services.
2. A communications network will be established to facilitate the transfer of transactions from the concentrators or computers to the equipment installed with the central Clearing systems. This involves the creation of a system designed so that when transactions arrive at terminals equipped with a hub (computer), either via wireless or wired connection, the corresponding transactions are automatically downloaded. The main objective of this flow of operations is to ensure the efficient continuity of the collection process.
3. Daily transaction processing capacity for use and loading.
4. Secure antennas distributed in commercial networks will be implemented, thus facilitating the recharging of integrated public transportation system cards.
5. Transport system users will be provided with web access to consult movements and recharge their integrated public transport system card.

With the implementation of MetroTaxi, the aim is once again to integrate the system with a single card. The card will have the same special benefits and denomination for retirees, senior citizens, pensioners and disabled persons, and students.

Figure 2
Integrated public transportation system card proposal

Rates

The proposal recommends implementing fare and operational integration between the Metro, MetroBus and MetroTaxi systems. From the tariff point of view, the same card will continue to be used for payment of both systems, but users will pay a fraction of the individual tariffs if they combine services and/or systems. This fare integration starts operating simultaneously with Metrotaxis. For this purpose, the proper functioning of the collection system, including cards, recharge points, etc., must be guaranteed.

Current cab fares are managed according to the zonal and sectorial division that exists in Panama City and the District of San Miguelito. Taking into account that $1 U.S. Dollar is equivalent to B/.1 Panamanian Balboa.

Table 15
Rate between Zones

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
Zone 1	B/. 1.20	B/. 1.60	B/. 2.00	B/. 2.40	B/. 2.80	B/. 3.20	B/. 3.60
Zone 2	B/. 1.60	B/. 1.20	B/. 1.60	B/. 2.00	B/. 2.40	B/. 2.80	B/. 3.20
Zone 3	B/. 2.00	B/. 1.60	B/. 1.20	B/. 1.60	B/. 2.00	B/. 2.40	B/. 2.80
Zone 4	B/. 2.40	B/. 2.00	B/. 1.60	B/. 1.20	B/. 1.60	B/. 2.00	B/. 2.40
Zone 5	B/. 2.80	B/. 2.40	B/. 2.00	B/. 1.60	B/. 1.20	B/. 1.60	B/. 2.00
Zone 6	B/. 3.20	B/. 2.80	B/. 2.40	B/. 2.00	B/. 1.60	B/. 1.20	B/. 1.60
Zone 7	B/. 3.60	B/. 3.20	B/. 2.80	B/. 2.40	B/. 2.00	B/. 1.60	B/. 1.20

Note. Adapted from *Autoridad del Tránsito y Transporte Terrestre de Panamá.* (https://www.transito.gob.pa).

Table 16
Tariff South sector

	Sector A	Sector B	Sector C	Sector E	Sector F	Sector G	Sector H	Sector I	Sector J	Sector K
Sector A	1.20 - 1.80	B/. 1.80	B/. 2.10	B/. 3.65	B/. 3.95	B/. 4.25	B/. 4.55	B/. 4.85	B/. 8.20	B/. 8.50
Sector B	B/. 1.80	1.20 - 1.80	B/. 1.80	B/. 3.35	B/. 3.65	B/. 3.95	B/. 4.25	B/. 4.25	B/. 7.90	B/. 8.30
Sector C	B/. 2.10	B/. 1.80	1.20 - 1.80	B/. 1.80	B/. 2.40	B/. 3.65	B/. 3.95	B/. 3.65	B/. 7.55	B/. 7.90
Sector E	B/. 3.65	B/. 3.35	B/. 1.80	1.20 - 1.80	B/. 1.80	B/. 2.10	B/. 3.65	B/. 3.65	B/. 6.05	B/. 6.35
Sector F	B/. 3.95	B/. 3.65	B/. 2.40	B/. 1.80	1.20 - 1.80	B/. 1.80	B/. 3.35	B/. 3.35	B/. 5.75	B/. 6.05
Sector G	B/. 4.25	B/. 3.95	B/. 3.65	B/. 2.10	B/. 1.80	1.20 - 1.80	B/. 2.40	B/. 3.65	B/. 5.45	B/. 5.75
Sector H	B/. 4.55	B/. 4.25	B/. 3.95	B/. 3.65	B/. 3.35	B/. 2.40	1.20 - 1.80	B/. 3.65	B/. 5.15	B/. 5.45
Sector I	B/. 4.85	B/. 4.25	B/. 3.65	B/. 3.65	B/. 3.35	B/. 3.65	B/. 3.65	1.20 - 1.80	B/. 6.05	B/. 6.35
Sector J	B/. 8.20	B/. 7.90	B/. 7.55	B/. 6.06	B/. 5.75	B/. 5.45	B/. 5.15	B/. 6.05	1.20 - 2.40	B/. 1.80
Sector K	B/. 8.50	B/. 8.20	B/. 7.90	B/. 6.35	B/. 6.05	B/. 5.75	B/. 5.45	B/. 6.35	B/. 1.80	1.20 - 2.40

Note. Adapted from *Autoridad del Tránsito y Transporte Terrestre de Panamá.* (https://www.transito.gob.pa).

Table 17

North sector tariff

	Sector A	Sector B	Sector C	Sector D	Sector E	Sector F	Sector H	Sector I	Sector J	Sector L
Sector A	1.20 - 1.80	B/. 1.80	B/. 2.10	B/. 3.65	B/. 3.95	B/. 4.25	B/. 5.75	B/. 7.85	B/. 8.45	B/. 12.40
Sector B	B/. 1.80	1.20 - 1.80	B/. 1.65	B/. 2.05	B/. 2.50	B/. 2.50	B/. 2.90	B/. 4.85	B/. 7.25	B/. 10.90
Sector C	B/. 2.10	B/. 1.65	1.20 - 1.80	B/. 2.40	B/. 2.70	B/. 2.70	B/. 3.15	B/. 4.55	B/. 6.05	B/. 9.70
Sector D	B/. 3.65	B/. 2.05	B/. 2.40	1.20 - 1.80	B/. 1.80	B/. 1.80	B/. 2.10	B/. 3.35	B/. 5.45	B/. 9.10
Sector E	B/. 3.95	B/. 2.50	B/. 2.70	B/. 1.80	1.20 - 1.80	B/. 2.10	B/. 1.65	B/. 2.40	B/. 4.85	B/. 8.45
Sector F	B/. 4.25	B/. 2.50	B/. 2.70	B/. 1.80	B/. 2.10	1.20 - 1.80	B/. 2.40	B/. 3.05	B/. 5.45	B/. 7.85
Sector H	B/. 5.75	B/. 2.90	B/. 3.15	B/. 2.10	B/. 1.65	B/. 2.40	1.20 - 2.40	B/. 2.40	B/. 4.25	B/. 7.25
Sector I	B/. 7.85	B/. 4.85	B/. 4.55	B/. 3.35	B/. 2.40	B/. 3.05	B/. 2.40	1.20 - 3.00	B/. 3.05	B/. 4.85
Sector J	B/. 8.45	B/. 7.25	B/. 6.05	B/. 5.45	B/. 4.85	B/. 5.45	B/. 4.25	B/. 3.05	1.20 - 3.00	B/. 3.65
Sector L	B/. 12.10	B/. 10.90	B/. 9.70	B/. 9.10	B/. 8.45	B/. 7.85	B/. 7.25	B/. 4.85	B/. 3.65	1.20 - 3.00

Note. Adapted from *Autoridad del Tránsito y Transporte Terrestre de Panamá.* (https://www.transito.gob.pa).

Table 18

Rate between Sectors and Zones

	Sector A	Sector B	Sector C	Sector D	Sector E	Sector F	Sector G	Sector H	Sector I	Sector J	Sector K	Sector L
Zone 1	B/. 4.60	B/. 4.90	B/. 5.20	B/. 5.80	B/. 6.70	B/. 7.00	B/. 7.30	B/. 7.60	B/. 9.15	B/. 11.25	B/. 13.65	B/. 16.40
Zone 2	B/. 4.20	B/. 4.50	B/. 4.80	B/. 5.40	B/. 6.30	B/. 6.60	B/. 6.90	B/. 7.20	B/. 8.70	B/. 10.85	B/. 13.25	B/. 16.00
Zone 3	B/. 3.75	B/. 4.05	B/. 4.35	B/. 4.95	B/. 5.85	B/. 6.15	B/. 6.45	B/. 6.80	B/. 8.30	B/. 10.40	B/. 12.85	B/. 15.55
Zone 4	B/. 3.35	B/. 3.65	B/. 6.95	B/. 4.55	B/. 5.45	B/. 5.75	B/. 6.05	B/. 6.35	B/. 7.85	B/. 10.00	B/. 12.40	B/. 15.10
Zone 5	B/. 2.90	B/. 3.20	B/. 3.50	B/. 4.10	B/. 5.00	B/. 5.30	B/. 5.65	B/. 5.95	B/. 7.45	B/. 9.55	B/. 12.00	B/. 14.70
Zone 6	B/. 2.50	B/. 2.80	B/. 3.10	B/. 3.70	B/. 4.60	B/. 4.90	B/. 5.20	B/. 5.50	B/. 7.00	B/. 9.15	B/. 11.55	B/. 14.30
Zone 7	B/. 2.05	B/. 2.35	B/. 2.65	B/. 3.30	B/. 4.15	B/. 4.50	B/. 4.80	B/. 5.10	B/. 6.60	B/. 8.70	B/. 11.10	B/. 13.85

Note. Adapted from *Autoridad del Tránsito y Transporte Terrestre de Panamá.* (https://www.transito.gob.pa).

In order to guarantee the profitability of the service, a management approach will be followed that is aligned with the zonal and sectorial division present in Panama City and the District of San Miguelito. Pricing will be based on traffic volume and time of day, which implies that the fare will be variable depending on the availability of Metrotaxis drivers at that time. As with the mobile application, users will also be able to check fares through the web in any sector where Metrotaxis operate. These tariffs will be strategically

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adjusted to meet the needs of the population and compete effectively with existing platforms in the market.

Figure 3
Areas of Panama City and the district of San Miguelito
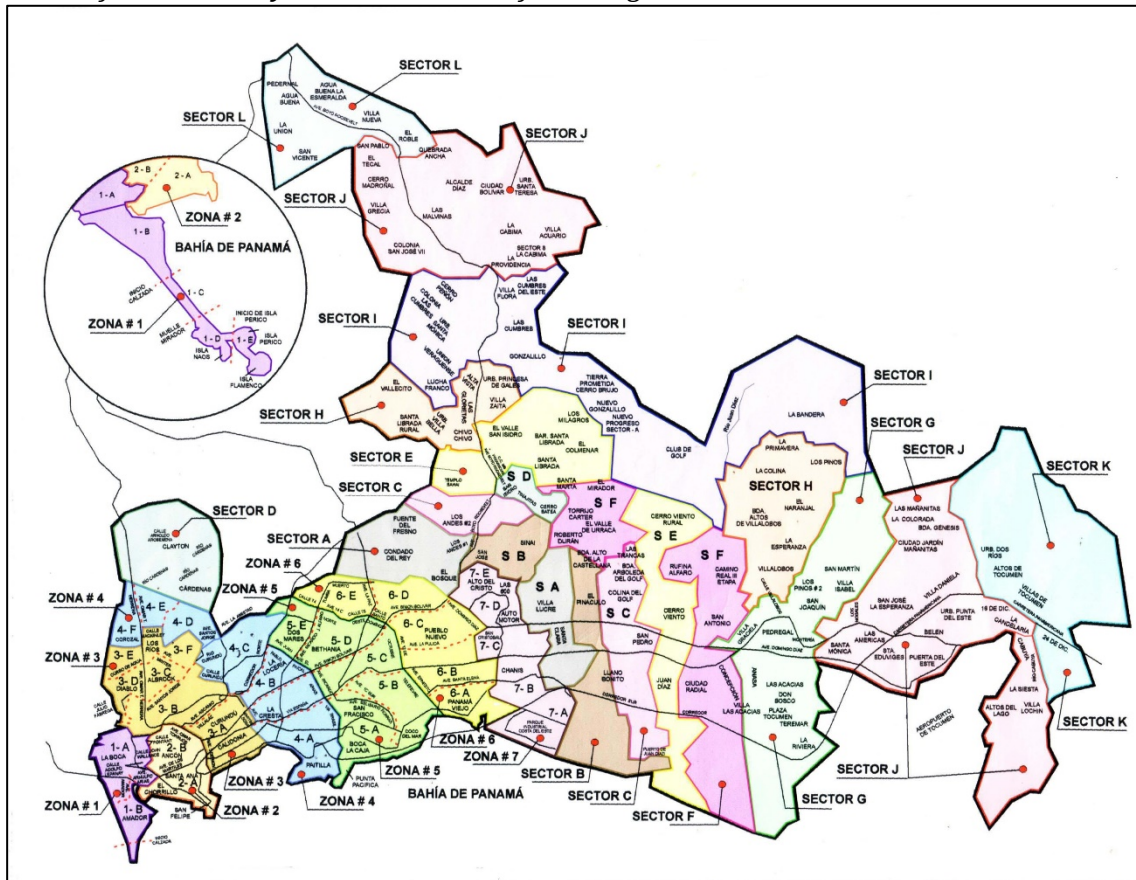
Note. Adapted from *Autoridad del Tránsito y Transporte Terrestre de Panamá.* (https://www.transito.gob.pa).

Yards for Operation: Paid Zones

For practical purposes, the same location of the current MetroBus Pay Zones within Panama City and the San Miguelito District will be used.

Figure 4
Current Paid Zones Locations
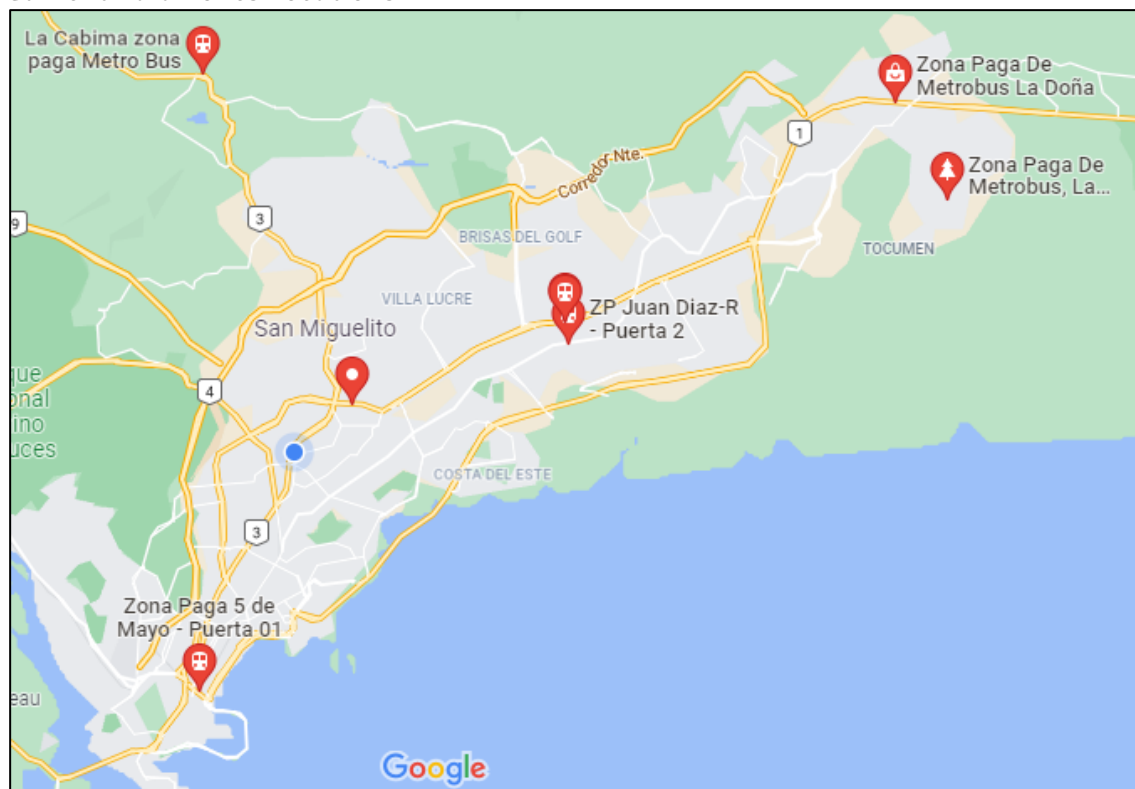
Note. Adapted from Current Pay Zone Locations, Google Maps.

The current Zonas Pagas of the MetroBus will be adapted for MetroTaxis where they will also be used as stops where passengers will form a dedicated line to board the MetroTaxi. They would maintain modern facilities for the operation and maintenance of the vehicles with state-of-the-art technology for efficient and safe operation of the fleet.

In addition to Paid Zones, Special Zones will also be designated areas on the public roadway, and may be located either on the vehicular roadway or in existing bays. These areas will be delimited with temporary parking spaces for individual passenger transportation vehicles, known as "cabs". In these zones, with prior authorization from the Panama Metropolitan Area Transit Authority, cabs may park temporarily while waiting to be requested, and the public may come to hire their services.

In the context of the special zones, the collection of vehicles is contemplated, which implies the physical presence of Metrotaxis waiting for the demand of the service, either on site or through reservations. It should be noted that the special zones will be exclusively reserved for the use of Metrotaxis.

For the purpose of establishing guidelines and detailing the functions of the special zone system, the following sections of this document present detailed information on the requirements, characteristics and conditions of the parking zone network for Metrotaxis.

Figure 5
Horizontal signaling special zone on the road
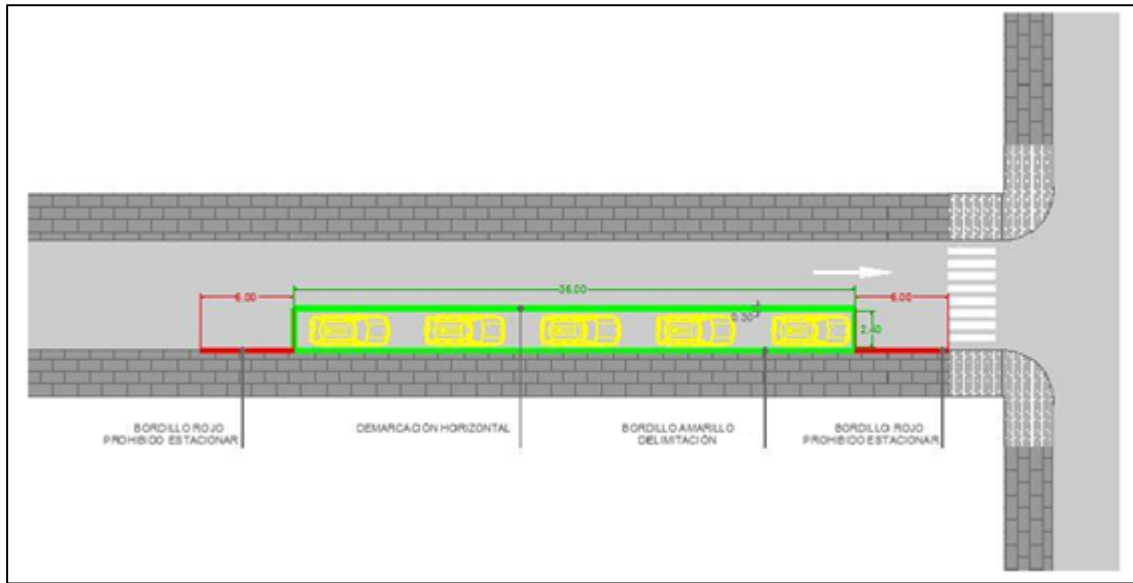
Note. Adapted from *Metro de Panamá*, by Cal y Mayor y Asociados, 2016, Plan Integral de Movilidad Urbana Sustentable - PIMUS.

Case study

The preliminary design of the special zones was based on the selection of a sector. A region was chosen based on the area of influence of the Metro Line 1 stations, where unauthorized piqueras were identified occupying a lane of the track to wait for users, affecting mobility in the area of the stations. The chosen sector includes the Iglesia del Carmen station and the Via Argentina station, both located in Panama City, as shown in the following figure:

Figure 6
Pilot zones

Note. Adapted from Current Pay Zone Locations, Google Maps.

At the end of the research, the following results were obtained:

1. A plan for the integration of Metrotaxis to the current mass transportation system, in order to reduce the participation of selective public transportation based on the understanding of different aspects such as the intelligent way to reduce the unnecessary consumption of hydrocarbons and the optimization of routes that achieve safety, punctuality and user comfort.
2. A platform that seeks to integrate even more, a system under the same umbrella of single payment in common and by different means.
3. A proposal for the development of special zones with proper signage, in demarcated areas of public roads with temporary parking spaces for taxi-type passenger transportation vehicles, where services can be requested through the mobile application and where the public can also go to hire them.

Discussion and Conclusions

It can be assumed that the authorities have not been able to approach the problems correctly and, therefore, adequate solutions to the problem of public transport, especially selective transport, have not been found.

The definition of the special zones seeks to address the problems of inefficiency in the provision of selective public service, inadequate use of road infrastructure, inefficient

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operation of individual public transportation, increased operating costs and insecurity for drivers and passengers.

A main factor that could contribute to the efficient use of the integrated system by users is related to the transshipment item, triggered by several reasons: agility, fast mobility throughout the city and finally the economic factor. The current transportation system requires a feeder network, which can transport a large volume of users from their communities to the main roads and stations of the Panama Metro and the MetroBus and vice versa, becoming a branch of the latter.

According to the surveys, the system's problems are focused on three main points: route frequency, travel time and safety, causing distrust and fear among users.

Current development standards should encourage development around integrated transportation systems, including homes and businesses. This action will strengthen the components that make up the integrated transportation system and facilitate the establishment of urban centers away from the center to reduce the daily flow of people to urban centers. To curb the proliferation of single-function development projects, especially the so-called "dormitory cities" in remote areas, action must also be taken at the same time, because these projects are neither sustainable nor compatible with development.

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GLOBAL TREND OF PROJECT MANAGEMENT METHODOLOGIES
TENDENCIA MUNDIAL DE LAS METODOLOGÍAS DE GESTIÓN DE PROYECTOS

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	ABSTRACT
Keywords: project management, agile methodologies, hybrid methodologies, traditional methodologies	This study addresses the evolution and trends in project management methodologies globally, emphasizing the increasing importance of project management across various industries due to the need for adaptability and efficiency in the business world. The research was based on an analysis of 1,085 documents to provide a comprehensive overview of emerging practices and techniques in this field, focusing on agile, hybrid, and traditional methodologies. The research methodology employed is non-experimental, documentary, and cross-sectional, using secondary data analysis and both theoretical and empirical research techniques to break down, analyze, and synthesize information. An integrated approach was used that combines theoretical analysis with empirical techniques such as documentary analysis, employing tools like Atlas.ti for data coding and analysis. The results showed that agile and hybrid methodologies are highly effective and popular, particularly in contexts that require high flexibility and rapid adaptation to changes. Traditional methodologies such as Six Sigma and Waterfall were found to be less flexible and with limited applicability to specific contexts. The study concludes by emphasizing the importance of selecting project management methodologies that align with the specific needs of the project and the organization, highlighting the trend toward more flexible and adaptive practices in modern project management.

	RESUMEN
Palabras clave: gestión de proyectos, metodologías ágiles, metodologías híbridas, metodologías tradicionales	El presente estudio aborda la evolución y tendencias en las metodologías de gestión de proyectos a nivel global, destacando la importancia creciente de la gestión de proyectos en diversas industrias debido a la necesidad de adaptabilidad y eficiencia en el mundo empresarial. La investigación se basó en un análisis de 1805 documentos para ofrecer una visión integral de las prácticas y técnicas emergentes en este campo, enfocándose en metodologías ágiles, híbridas y tradicionales. La metodología de investigación

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empleada es no experimental, documental y transversal, utilizando análisis de datos secundarios y técnicas de investigación teóricas y empíricas para descomponer, analizar y sintetizar información. Se utilizó un enfoque integrado que combina el análisis teórico con técnicas empíricas como el análisis documental, empleando herramientas como Atlas.ti para la codificación y análisis de datos. Los resultados mostraron que las metodologías ágiles e híbridas son altamente efectivas y populares, particularmente en contextos que demandan alta flexibilidad y adaptación rápida a cambios. Metodologías tradicionales como Six Sigma y Waterfall se encontraron menos flexibles y con aplicabilidad limitada a contextos específicos. El estudio concluye subrayando la importancia de seleccionar metodologías de gestión de proyectos que se alineen con las necesidades específicas del proyecto y la organización, resaltando la tendencia hacia prácticas más flexibles y adaptativas en la gestión de proyectos moderna.

Introduction

In an ever-changing business world, project management has emerged as an essential discipline in a wide range of industries, where adaptability and efficiency are critical to project success. This study delves into the most current trends in project management methodologies, highlighting how innovations in the field are reshaping the way organizations approach project planning and execution globally. By comprehensively analyzing 1085 documents, it aims to provide a comprehensive overview of the most effective practices and emerging techniques in project management.

As we move into the information and technology age, project management methodologies are challenged to keep up with rapid technological changes and the increasing demands of organizations and their customers for flexibility and efficiency. This article examines how agile, hybrid and traditional techniques are adapting and transforming in response to the needs of the global environment, and what implications they have for the future of project management in sectors as varied as engineering and construction.

The research is supported by an in-depth review of academic literature, analysis of recent survey data, and detailed case studies. Through these elements, it seeks to provide a detailed understanding of how project management methodologies are evolving to meet the challenges of the 21st century, including both theoretical and empirical considerations. Methods such as analytical-synthetic and inductive-deductive are used, together with documentary analysis techniques, to decompose, analyze and synthesize the information, thus allowing a deeper understanding of the interrelationships and internal dynamics of the phenomena studied.

The study also includes the codification and analysis of secondary data obtained from various sources, with the support of tools such as Atlas.ti and Mendeley to organize and analyze the documents, which facilitates the identification of patterns, contextualizations and deductions about the variables and goals proposed. With an integrated approach, the research ensures a rigorous assessment of the current and future situation of project management, providing effective solutions and clear guidance for the engineering and construction field.

Method, Techniques and Analysis

The research presented was non-experimental, documentary and cross-sectional, focused on addressing practical problems and proposing the implementation of new knowledge in organizations that manage projects. The methodology included the analysis of secondary data obtained from various sources such as books and surveys, relying on techniques such as data collection, coding and analysis.

The research methods were divided into two main categories: theoretical and empirical. At the theoretical level, analytical-synthetic, inductive-deductive, historical-logical and systemic-structural-functional methods were used. These methods made it possible to decompose, analyze and synthesize the information to formulate a solid theoretical and methodological basis, facilitating the understanding of the interrelationships and internal dynamics of the phenomena studied (Rodríguez Jiménez and Pérez Jacinto, 2017; Torres-Miranda, 2020).

At the empirical level, techniques such as documentary analysis were used. This included the modification of documents to facilitate their access and subsequent analysis (Falcón and Serpa, 2021).

This integrated methodological approach allowed for a deep and multifaceted understanding of project management at a global level, specifically addressing the practices and dynamics of communication in this field. The combination of theoretical and empirical analysis facilitated a rigorous and detailed assessment, essential for developing effective solutions tailored to the engineering and construction field.

The methodological framework applied included the exhaustive review of existing literature, the analysis of recent surveys, and the evaluation of case studies, all selected to reflect both the global reality and the particularities of diverse international contexts. This strategy allowed us to identify international best practices in project management, focusing on the unique needs and challenges faced in diverse markets.

In addition, the methodology incorporated a systematic analysis of the communication tools used in engineering and construction projects, evaluating their effectiveness in different cultural and organizational contexts. It analyzed how cultural differences affect communication and collaboration practices within project teams, and how these practices could be improved to increase efficiency and effectiveness in project management.

The implementation of advanced data coding and analysis techniques, using software such as Atlas.ti and Mendeley, allowed for a meticulous organization and synthesis of the information, facilitating the identification of trends, patterns and gaps in current practices.

Overall, this methodological approach not only deepened the understanding of global project management dynamics, but also established a robust framework for proposing and implementing changes that effectively respond to the challenges and opportunities of the engineering and construction sector in international contexts.

The research was conducted through the review, analysis, comparison and deduction of existing documents, data, surveys and records in order to establish patterns, contextualizations and deductions of the variables and goals proposed. An important part of this phase was carried out through the codification of 1805 documents, with the help of the Atlas.ti and Mendeley tools. Figure 1 outlines the methodology used.

Figure 1
Methodological outline for the study of the project management system of world reference companies.
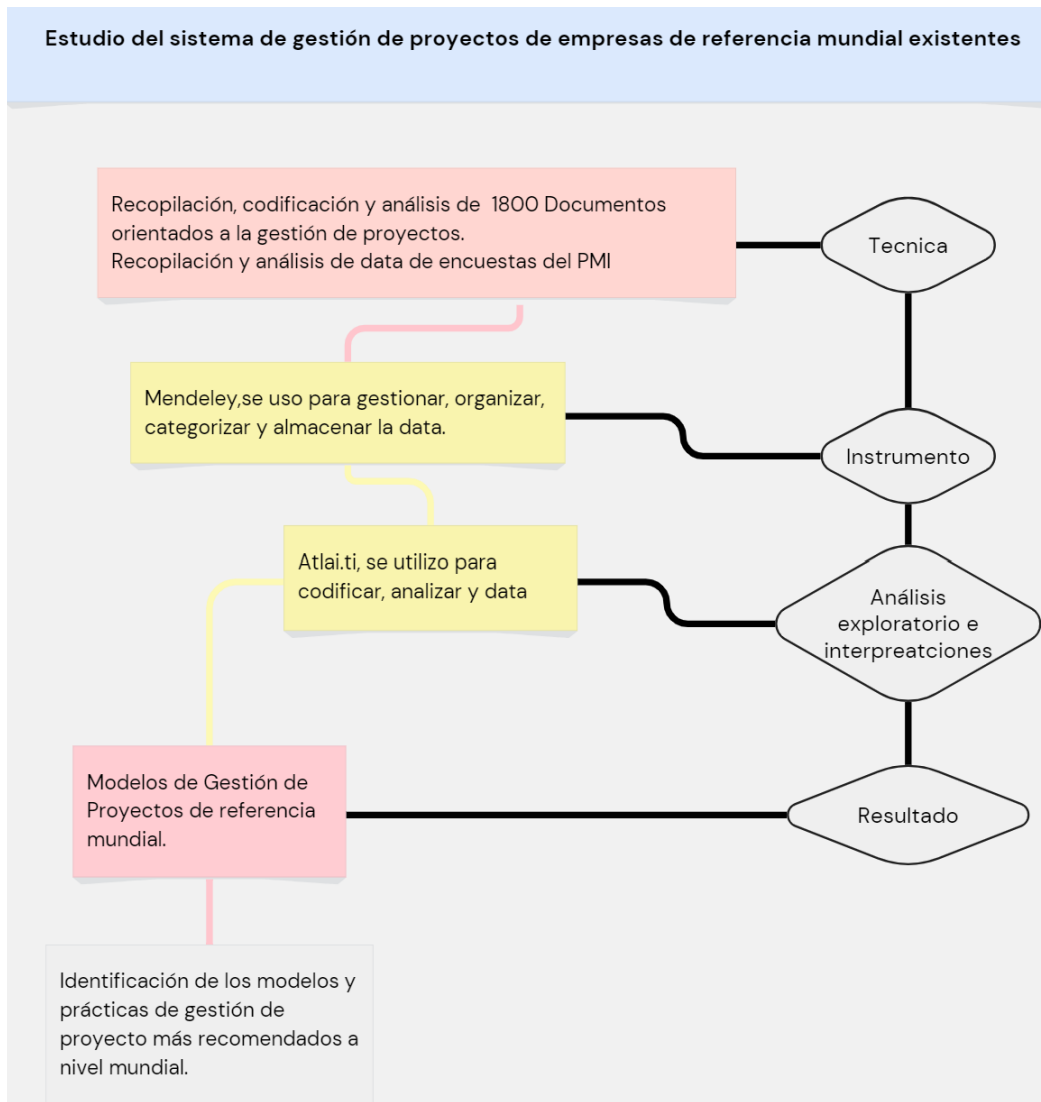
Document Selection

It was decided to use Mendeley as the main tool for reference management in this research, given its ability to organize and facilitate access to a large number of academic documents. Mendeley is a bibliographic reference management software that allows to store, organize and categorize research in an efficient way, which was essential in this project given the magnitude of the review.

In this case, 1,805 documents related to project management were stored in a Mendeley database. These documents included studies, articles, books and other academic materials. The software allowed documents to be categorized according to a number of key attributes, such as:

- Title: Each document was labeled with its full title, which facilitated its identification.
- Author: Authors' names were recorded to allow quick and proper reference in the research.

- Editorial and Source: These data made it possible to trace the origin of each publication and the level of credibility of each source.
- Date: Sorting the papers by date helped to identify the most recent papers, ensuring that the research included the most current findings.

The criteria for selecting the documents that were incorporated into Mendeley focused on specific topics relevant to project management. The main inclusion criteria were:

- Project management methodologies: Studies that analyzed different approaches and methodologies (such as Agile, Prince2, Six Sigma, among others).
- Standards and practices in project management: Documents discussing standards and best practices applied in project management, such as PMBoK or ISO.
- Project management models and approaches: Studies on different models used to manage projects in various industries.
- Statistics on project efficiency and success: Research presenting quantitative data on project performance and efficiency under different methodologies.

The use of Mendeley not only facilitated the efficient organization of a large number of documents, but also helped to discover recent research in the field of project management. Mendeley has features to suggest relevant articles based on the stored readings, which increased access to new sources of information that could be useful for the research.

Mendeley served as a central tool in the reference management process, ensuring that the 1,805 documents were logically organized and accessible to the research team. This not only facilitated the quick and efficient retrieval of information, but also allowed the tracking of the most recent and relevant literature on project management methodologies and practices.

Import of Documents

The documents collected in the Mendeley platform were transferred to Atlas.ti for further qualitative analysis. This process included the import of 1805 documents related to project management methodologies, which had previously been organized and stored in Mendeley. At this stage, each document was tagged with specific metadata, which allowed a precise structuring of the information within Atlas.ti, optimizing both the organization and the search for relevant documents during the analysis.

The use of this metadata greatly facilitated the organization of documents in Atlas.ti, allowing researchers to efficiently navigate through a large amount of information. Instead of performing extensive manual searches, researchers could quickly filter documents using the assigned tags, which significantly accelerated the analysis process. In addition, labeling provided the ability to identify patterns or relationships between studies of the same author, a specific time period, or with a particular focus on a methodology.

Thanks to the metadata-based organization, the search for documents during the thematic analysis was more agile and accurate. This allowed the researchers to directly access the most relevant studies for each phase of the analysis or for each aspect of the project management methodologies. For example, if at one point in the analysis, recent studies on the adoption of agile methodologies were needed, documents labeled by "date" and "type of methodology" could be easily located and analyzed in depth.

Detailed metadata tagging in Atlas.ti not only allowed efficient organization and access to documents, but also optimized the analysis process by facilitating the search for accurate information. This was key to handling a large number of documents in a systematic way and ensuring that maximum value was extracted from the available information, providing a solid basis for a detailed qualitative analysis of project management methodologies.

Data Coding

Coding in this study was conducted using a mixed approach, meaning that it combined both deductive coding and inductive coding to capture the complexity of the project management systems used by the companies. This approach allows both the application of predefined codes and the discovery of new topics as documents are examined.

Deductive Coding: In deductive coding, codes were created before starting the analysis, based on concepts already known from the project management literature. These predefined codes represented the parameters already expected to be found in the analysis, such as high performance, profit, efficiency, success, and productivity. For example, if existing studies indicated that an agile approach favors high performance, a code for "high performance" would be created and applied to text segments that mention or discuss this idea.

Inductive Coding: In parallel, as the documents were reviewed, new themes or patterns emerged that had not been anticipated. This is the process of inductive coding, in which new codes are created to capture these unexpected findings. For example, if an emerging theme emerged during the document review, such as the influence of organizational culture on the choice of methodology, a new code was created to reflect that theme. This inductive approach made it possible to enrich the analysis by better reflecting the specific reality of the companies' project management systems.

Coding is a central process in the analysis of qualitative data, and in this case, Atlas.ti software was used to perform the analysis in a structured and efficient manner. The coding process is explained in detail below:

- Text Encoding: The first step was the selection of text segments within the documents that discussed key parameters such as high performance, profit or efficiency. For example, if a document described how a particular methodology increased the efficiency of a project, that segment of text was identified as relevant to the analysis.
- Creation of Codes: Each key parameter was represented by a code. These codes may have been previously defined (deductive) or created during the analysis (inductive). For concepts that were repeatedly mentioned in the literature (such as "profit" or "productivity"), codes were created to organize and group all the fragments related to these topics.
- Code Assignment: Once the codes were created, they were applied to the relevant text segments. This means that every time a document referred to one of the parameters, that text fragment was "tagged" with the corresponding code. For example, if a section talked about how a methodology contributed to the success of the project, the code "success" was assigned to that text segment.

The ultimate goal of this coding process was to organize the qualitative analysis in a way that would allow for the identification of key patterns and themes in the documents reviewed. This facilitated the analysis of the relationships between the different parameters (such as high performance or profit) and the project management

methodologies used. In addition, coding made it possible to compare the use and effectiveness of different methodologies quantitatively, based on the frequency with which certain themes or parameters are mentioned and how they correlate with each other.

The parameters of the study of global project management trends were established as shown in Table 1, while the codes used are reported in Table 2.

Table 1
Parameters used in Atlas.ti

Parameter	Description
High Performance	It measures the ability of the methodology to achieve superior results in terms of effectiveness and compliance with objectives. It is focused on evaluating the overall effectiveness of an approach to achieving outstanding performance, including the ability to exceed expectations and industry benchmarks.
Benefit	Evaluates the direct and indirect impact of the methodology on the generation of economic gains or competitive advantages for the organization. This parameter focuses on both tangible and intangible financial returns and benefits.
Efficient	Measures the optimization in the use of resources within a project, minimizing waste and maximizing productivity. This parameter considers how the methodology facilitates more efficient use of time, money, and human resources.
Successful	Evaluates the degree to which the methodology facilitates the satisfactory achievement of project objectives. It considers the effectiveness of the approach in achieving the established goals, both in terms of final results and in terms of meeting deadlines and budgets.
Productivity	Refers to the improvement in quantity and quality of the work produced under the application of the methodology. Analyzes the ability of equipment to do more work in less time, increasing efficiency without compromising the quality of the end result.
Negative	Measures the adverse effects or disadvantages that could arise from adopting a specific methodology. This parameter evaluates potential risks or contraindications in certain contexts or projects, helping to identify potential drawbacks before implementing an approach.
Practice	Evaluates the actual and practical implementation of the methodologies in concrete real-world situations. It examines the applicability and effective execution of an approach, considering how it adapts to different circumstances and how viable it is in various operating environments.
Approach	Analyzes the underlying philosophy or approach of the methodology to project management. It includes the evaluation of how projects are planned, executed and evaluated under this approach, highlighting

	the coherence and alignment with the organization's objectives and values.
Project	Measures the structure and management of specific projects implemented under the methodology. It focuses on the methodology's ability to organize and carry out projects effectively, ensuring cohesion and coordination between the different stages of the project.
Management	Evaluates the effectiveness of the methodology in overall project management. It covers aspects such as decision making, resource management and progress monitoring, assessing how these elements contribute to the overall success of the project.
PMI	Investigates the adoption and application of Project Management Institute (PMI) standards in actual practice. It includes the evaluation of how best practices and management techniques aligned with PMI certifications are integrated into projects.
PMBoK	It focuses on the implementation of the Project Management Body of Knowledge (PMBoK) guide and its congruence with the standards recommended by the PMI. Evaluates the ability to adapt these practices to specific projects and contexts, ensuring their effectiveness and relevance in different situations.

Table 2
Table of codes used in Atlas.ti

Codes	Codes	Codes
○ Agile	○ Kanban	○ Project Management
○ Approach	○ Improve	○ Project
○ Benefit	○ Methodology	○ Performance
○ Wellness	○ Negative	○ Scrum
○ Efficiency	○ PMBoK	○ Six Sigma
○ Success	○ PMI	○ Waterfall
○ Management	○ Positive	○ Communications
○ Good	○ Practice	○ Spain

○ Hybrid	○ Prince2	○ Software
○ IPMA	○ Productivity	

Data Analysis

The analysis of the documents in the study was performed using Atlas.ti, a qualitative data analysis software. The analysis tools provided by Atlas.ti were instrumental in identifying patterns and relationships among the key concepts extracted from the 1805 documents reviewed. Two key techniques were used for this analysis: Cooccurrence Analysis and Semantic Networks.

Cooccurrence Analysis is a technique that made it possible to identify which codes (themes or concepts) appear together frequently in the documents. By tagging text segments with codes such as "high performance," "efficiency," "profit," and "productivity," this analysis allowed us to see which themes tend to be associated with each other. For example, if "high performance" and "efficiency" frequently appear together, this suggests that in the documents studied there is a relationship or dependence between the two concepts.

This analysis was instrumental in uncovering relationships between different aspects of project management, showing how certain factors (such as the use of a particular methodology) are linked to specific outcomes, such as productivity or success. It also made it possible to identify connections that were not obvious on the surface, providing a deeper insight into how the different components within a project are interrelated.

In addition to the cooccurrence analysis, semantic networks were generated to visualize the relationships between the different codes. These networks allow to graphically visualize the connections between codes, showing how concepts are related in the context of project management. Each code is represented as a node in the network, and the links between nodes show the frequency or strength of the connections.

The semantic networks provided a clear view of patterns and structures in the data, helping to identify which themes were most central or interrelated. For example, if "productivity" is directly connected to many other concepts such as "high performance" or "profit", this indicates that productivity is a central theme in project management.

The combined use of co-occurrence analysis and semantic networks allowed not only to quantify the presence of certain concepts in the documents, but also to understand how these concepts are interconnected within the practice of project management. This holistic view facilitated the identification of patterns that would not be evident through superficial analysis, providing a deeper framework for understanding the dynamics at play in project management and helping to identify key areas for improving efficiency and performance in business projects.

Data Visualization

Atlas.ti, as an advanced qualitative analysis tool, was used not only to manage and analyze large volumes of data, but also to visualize the findings in a way that made them easily understandable and accessible. Two of the main visualization functionalities used in the analysis were Word Clouds and Code Maps, each with distinct but complementary purposes.

Word Clouds are visual representations that highlight the most frequent terms in a set of documents. In this case, Atlas.ti generated word clouds to highlight the themes and concepts that appeared most frequently in the project management documents. The most

common words were displayed with greater size and prominence, while less frequent terms were represented in smaller sizes.

- Purpose: The use of word clouds helped the researchers to quickly identify the key terms that predominated in the analyzed documents. This provided an immediate overview of the most recurring themes in the project management literature, such as "efficiency", "profit", "productivity" or "agile methodologies". This functionality is particularly useful for detecting initial patterns without the need to perform an in-depth analysis from the beginning.
- Advantage: The word clouds not only facilitated the identification of dominant themes, but also helped to visualize how concepts were organized within the content, which gave clues as to which topics were most relevant or were being discussed with greater emphasis.

Code Maps, another key feature of Atlas.ti, were used to graphically show how specific topics (or codes) were distributed throughout the document set. These maps are visual representations that show the relationship and connections between different themes coded in the analysis. Each code or topic is presented as a node, and the links between nodes indicate the co-occurrence or strength of the relationship between those topics.

- Purpose: The code maps were essential to understand the interconnections between the different themes present in the documents. For example, in an analysis of project management methodologies, a code map might show how "efficiency" connects to other codes such as "high performance" or "profit". This made it possible to clearly and directly visualize how the different aspects of project management interact and are distributed in the documents.
- Advantage: This tool helped identify deeper and more complex patterns that word clouds alone could not show. The code maps revealed relationships between themes and helped researchers understand not only which themes were prevalent, but how they were related to each other within the contexts discussed in the literature.

The combination of word clouds and code maps in Atlas.ti made it possible to present the findings in a visually intuitive and understandable way. While word clouds facilitated the detection of the most recurrent themes, code maps provided a more detailed view of the relationships and connections between those themes. Together, these visualizations helped the researchers interpret the data more fully, identifying both the central themes and underlying structures in the project management documents

Results

Using the "concept" and "cloud" functionalities in Atlas.ti, a preliminary view of the predominant terms in the 1805 documents analyzed was generated, as illustrated in Figure 2. This word cloud visualization reveals key terms such as management, projects, culture and approach (including mentions such as agile approach and agile methodologies), as well as other important terms such as success and enterprise.

The word cloud highlights the most frequently discussed topics in the papers, providing a quick and clear view of the predominant concepts in the project management literature. Terms such as "management" and "projects" underline the centrality of these

themes in the studies analyzed, while concepts such as "culture" and "approach" reflect how agile methodologies are being adapted and adopted in different organizational environments. This suggests a trend towards aligning management methodologies with local practices or industry-specific characteristics.

Terms such as "success" and "enterprise" also appear frequently, indicating a strong correlation between the implementation of certain methodologies and the achievement of positive project results, in addition to their impact on the overall performance of organizations. This frequency highlights the perceived value of project management methodologies as key tools for improving operational efficiency and achieving organizational success.

Figure 2
Visualization of word clouds obtained from the analysis of 1805 documents

Based on this visualization, a more detailed coding of the documents was carried out. Specific codes were used to represent the key concepts that emerged from the analysis, allowing a systematic categorization of the data. Codes such as High Performance, Profit, Efficiency, Success, and Productivity were applied to relevant passages within the documents. In addition, additional codes were created for specific methodologies such as "Agile", "Scrum", "PMBoK" and "Six Sigma", which facilitated the analysis of the differences between them.

The citation generation process allowed the extraction of text segments that were labeled with the relevant codes, which facilitated the analysis of frequencies and patterns. These citations not only provided references for the key concepts, but also offered concrete evidence on how the methodologies are discussed and applied in different contexts.

Figure 3 provides a visual representation of these codes and citations through a network of codes, which shows how the topics are connected to each other in the documents. This network helps to identify the most prominent relationships and

connections between concepts, providing a clear view of how themes are distributed throughout the analysis.

Figure 3

General display of the project from the analysis of 1805 documents

Tables 3 and 4 present the results of the code co-occurrence analysis, where the interactions between different codes are examined to better understand how the methodologies and key parameters are related. For example, the co-occurrence between High Performance and PMBoK indicates a significant correlation in the literature, suggesting that the practices recommended by PMBoK are closely linked to the achievement of outstanding project performance.

In contrast, the low frequency of co-occurrence between High Performance and Six Sigma suggests that this methodology is not perceived as particularly effective in achieving outstanding performance, highlighting the limitations of Six Sigma in certain contexts.

The use of Atlas.ti allowed not only to organize and analyze the data efficiently, but also to quickly identify the most relevant issues and their interrelationships. This provided a solid basis for assessing the strengths and weaknesses of each methodology and offering guidance on selecting the most appropriate approach for the specific needs of projects and organizations.

Table 3

Code co-occurrence analysis of the 1805 document analysis (part 1)

Parameter	High Performance Citations=622	Benefit Appointments=745	Efficient Appointments=125	Successful Appointments=1407	Citation Productivity=53	Negative Citations=86
Agil+Scrum+Kanban+Hibrido Citas=283+62+22+65	3	128	26	128	8	2

Parameter	High Performance Citations=622	Benefit Appointments=745	Efficient Appointments=125	Successful Appointments=1407	Citation Productivity=53	Negative Citations=86
Agil Citas=283	2	85	18	85	5	1
Scrum Quotes=62	1	16	5	9	1	0
Kanban Quotes=22	0	5	2	4	0	0
Hybrid Appointments=65	0	22	1	30	2	1
Prince2 Citations=543	0	143	14	117	4	6
Six Sigma Quotes=10	0	6	0	3	0	0
Waterfall Appointments=43	0	10	2	16	0	0
IPMA Citations=11	0	4	0	3	0	0
PMBoK Citations=85	1	28	3	30	4	1
PMI Citations=70	1	24	2	30	3	0

Table 4

Code co-occurrence analysis of the 1805 document analysis (part 2)

Parameter	Methodology Citations=1399	Practical Appointments=414	Approximation Appointments=946	Project Appointments=3472	Appointment Management=4104	PMBoK Citations=85	PMI Citations=70
Agil+Scrum+Kanban+Hibrido Citas=283+62+22+65	270	102	199	429	425	34	26

66

Agil Citas=283	159	70	123	280	279	20	16
Scrum Quotes=62	51	15	28	62	60	5	3
Kanban Quotes=22	20	2	8	22	22	0	0
Hybrid Appointments =65	40	15	40	65	64	9	7
Prince2 Citations=543	497	62	65	543	515	10	11
Six Sigma Quotes=10	2	1	2	10	5	1	1
Waterfall Appointments =43	33	15	23	43	43	5	1
IPMA Citations=11	2	3	2	11	10	1	4
PMBoK Citations=85	38	23	28	85	84	0	28
PMI Citations=70	32	16	22	70	70	28	0

Discussion and Conclusions

The analysis of 1805 documents on project management methodologies provides valuable information on the preferences and effectiveness of different approaches according to sector and project characteristics. Through the use of qualitative analysis tools such as Atlas.ti, significant patterns in the adoption of these methodologies were identified, providing a deeper understanding of their applicability in specific contexts.

Agile methodologies, which include Agile, Scrum, Kanban and their hybrid combinations, stand out for their flexibility and adaptability. With 128 quotes on the parameters of high performance and profit, these methodologies are particularly useful in sectors that undergo rapid change and require an agile response to market fluctuations. This is the case in financial services and information technology (IT), where the ability to adjust project approaches in real time is essential to remain competitive. Agile methodologies enable continuous iteration, facilitating frequent delivery of value and rapid adaptation to changes in customer requirements or market conditions.

This agile approach is highly valued for its ability to maintain operational efficiency while navigating uncertain environments, making it a preferred choice in volatile industries where flexibility is crucial to success.

In contrast, Prince2 is a highly valued methodology in projects that require structure and rigorous control. With 143 citations in profit and 117 in high performance, this methodology excels in sectors such as construction and manufacturing, where the management of complex, large-scale projects requires detailed planning and tight control of risks and resources. Prince2 is distinguished by its ability to divide a project into clear and manageable phases, which facilitates better resource management and ensures that each phase meets its objectives before moving on to the next.

This methodology is particularly appreciated in regulated environments, where it is mandatory to follow a well-defined process to ensure that all regulations and quality standards are met. Prince2 provides a systematic approach that minimizes risk and helps organizations achieve clear, measurable results.

Although PMBoK and PMI do not reach the same level of popularity as agile methodologies in terms of performance and benefit, their structure and standardization are highly valued in environments that demand consistency and alignment with international standards. With 30 citations in high performance and profit, PMBoK and PMI are frequently used on projects where predictability and compliance with global standards are critical.

These approaches provide a solid foundation for managing projects that require a meticulous approach aligned with industry best practices, making them ideal for large-scale projects that need to meet strict standards and have a high degree of control.

Traditional methodologies such as Six Sigma and Waterfall show less flexibility compared to agile methodologies, but are still useful in projects where a sequential and predictable approach is preferable. Six Sigma, with 6 quotes on profit and efficiency, focuses on process optimization and defect reduction, being particularly relevant in sectors such as manufacturing, where quality and continuous improvement are essential.

Waterfall, with 10 quotes in profit and 16 in high performance, is appreciated in projects with clear requirements from the beginning, such as in construction or traditional software development. However, its lack of flexibility and less ability to adapt to changes make it less suitable for more dynamic environments, where project needs may evolve over time.

The analysis also reveals how the adoption of methodologies varies considerably by sector and region. In sectors such as IT and financial services, agile methodologies are the most prevalent due to their ability to adapt quickly to change. On the other hand, in sectors such as construction and manufacturing, traditional methodologies such as Waterfall and Six Sigma are still relevant, although less popular than Prince2 and PMBoK due to their structured and predictive approach.

The choice of project management methodology should be based on a thorough assessment of project needs and operating conditions. Agile methodologies are ideal for projects that require adaptability and rapid response to change, while Prince2 and PMBoK offer structured and predictable solutions, suitable for contexts that demand rigor and control.

Traditional methodologies, although less flexible, continue to play an important role in industries where sequentiality and predictability are essential for success. This analysis provides project managers and organizations with the information needed to make informed decisions, maximizing operational efficiency and ensuring success in a competitive environment.

In addition, understanding the differences in the adoption of methodologies by industry and region allows organizations to adapt their management practices to improve project effectiveness and increase job satisfaction in a variety of industry contexts.

To continue advancing in the analysis of project management methodologies, it is suggested that a series of complementary research studies be carried out to delve deeper into key aspects not covered in this initial analysis. These are some proposals for continuity:

- Comparative Analysis of Hybrid Methodologies: Given the increase in the adoption of hybrid methodologies in Europe and other regions, it would be interesting to carry out a more in-depth comparative analysis between pure agile and hybrid methodologies. This study could explore how organizations are customizing their project management practices, combining the flexibility of Agile with the structure of Prince2 or PMBoK, and how these variations impact project efficiency and success in different industries.

- Impact of Methodologies on Team Satisfaction and Sustainability: A future line of research could examine how different project management methodologies influence team satisfaction and job well-being. In addition, it would be interesting to study how agile, Prince2, or PMBoK approaches contribute to operational sustainability within organizations, both in terms of human resources and the use of material and technological resources.
- Detailed Sector Research: Although the current analysis reveals differences in the adoption of methodologies between sectors such as IT, financial services, construction, and manufacturing, more specific research exploring the peculiarities of each sector could help identify what factors determine the choice of a particular methodology. This could include regulatory aspects, size of companies, types of clients, and project complexities.
- Adoption of New Technologies in Project Management: In the era of digital transformation, it is important to analyze how new technologies such as artificial intelligence (AI), machine learning, and blockchain are influencing project management methodologies. A study investigating the integration of these technologies into traditional or agile methodologies could provide valuable insights into how project management will evolve in the coming years.
- Performance of Methodologies in SMEs versus Large Corporations: It would be useful to compare how small and medium-sized enterprises (SMEs) and large corporations adopt and use different project management methodologies. This analysis could identify which methodologies are most effective depending on the size of the organization and what adaptations are required for them to be successful in different types of companies.
- Evaluation of the Cost-Benefit of the Implementation of Methodologies: Finally, it would be relevant to conduct an exhaustive cost-benefit analysis associated with the implementation of different project management methodologies. This would include the costs of training, implementation, and maintenance of the methodologies, in contrast to the benefits generated in terms of efficiency, quality, and customer satisfaction.

These proposed studies would not only advance knowledge of the effectiveness and applicability of project management methodologies in different contexts, but would also provide organizations with more precise tools to choose the methodology that best suits their needs. In addition, they could contribute to the continuous improvement of existing methodologies or to the development of new approaches that integrate the flexibility and structure needed to meet today's project management challenges.

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CLIENT SEGMENTATION AND DETECTION OF UNUSUAL OPERATIONS CLASSIFIED INTO RISK DEGREES FOR THE PREVENTION OF MONEY LAUNDERING WITH DATA FROM A FINANCIAL INSTITUTION IN MEXICO BY 2023

SEGMENTACIÓN DE CLIENTES Y DETECCIÓN DE OPERACIONES INUSUALES CLASIFICADOS EN GRADOS DE RIESGO PARA LA PREVENCIÓN DE LAVADO DE DINERO CON DATOS DE UNA INSTITUCIÓN FINANCIERA EN MÉXICO A 2023

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	ABSTRACT
Keywords: data mining, money laundering prevention, unusual transactions, segmentation methods.	The research develops and validates a quantitative method using data from a financial institution in Mexico, with the objective of obtaining a better understanding of the clients, detecting the possible misuse of the institution in crimes related to the integration and dispersion of illicit financial resources, taking the international recommendations established by the Financial Action Task Force (FATF) and with the provisions in Mexico. Data mining techniques are used, as well as instruments to collect, analyze and use information on the inherent and transactional characteristics of customers. A descriptive statistical analysis is presented and, to achieve adequate segmentation, classification methods based on mobile centers and Ward's hierarchical classification are combined, along with factorial methods, which allows for the identification of changes in behavioral patterns of the variables and the analysis of possible unusual operations, explaining the degree of risk associated with each segment. The results offer a classification of medium and high risk, contrasting with the scoring model currently used, which classifies customers as low risk. In addition, this approach facilitates the suspicion of unusual operations by reducing the number of false alerts. One of the contributions this research offers is the incorporation of qualitative variables for segmentation adapted to the context of Mexico, considering best practices in Colombia and the FATF.
	RESUMEN
Palabras clave: minería de datos, prevención de lavado de dinero, operaciones	La investigación desarrolla y valida un método cuantitativo utilizando datos de una institución financiera en México, con el objetivo de obtener un mejor conocimiento de los clientes, detectar el posible uso indebido de la institución en delitos relacionados con la integración y dispersión de recursos financieros ilícitos

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inusuales, métodos de segmentación.	atendiendo las recomendaciones internacionales establecidas por el Grupo de Acción Financiera Internacional (GAFI) y con las disposiciones en México. Se emplean técnicas de minería de datos, así como instrumentos para recolectar, analizar y utilizar la información sobre las características inherentes y transaccionales de los clientes. Se presenta un análisis estadístico descriptivo y, para lograr una segmentación adecuada, se combinan métodos de clasificación basados en centros móviles y la clasificación jerárquica de Ward, junto con métodos factoriales, lo que permite identificar cambios en patrones de comportamiento de las variables y analizar posibles operaciones inusuales, explicando el grado de riesgo asociado a cada segmento. Los resultados ofrecen una clasificación de riesgo medio y alto, contrastando con el modelo de puntaje actualmente utilizado, que clasifica a los clientes como de riesgo bajo. Además, este enfoque facilita la sospecha de operaciones inusuales reduciendo el número de alertas falsas. Uno de los aportes que ofrece esta investigación es incorporar variables cualitativas para la segmentación adaptada al contexto de México considerando mejores prácticas en Colombia y de GAFI.

Introduction

One of the international priorities is the fight to prevent money laundering and the financing of terrorism because they represent a high risk to peace, security, stability and the economic development of countries. The effect of not being properly managed, on the one hand, is an increase in the number of victims due to crimes committed by individuals or organizations and, on the other hand, according to BASEL (2022) investors and financial institutions may decide to withdraw or not to start a business in a country that is assessed as high risk for money laundering to avoid exposure to non-compliance, operational and reputational risks.

There are several international organizations to combat it, one of which is the FATF, which periodically reviews money laundering techniques, strengthens its standards and monitors countries to ensure that they fully and effectively implement its 40 recommendations. FATF data is a primary source of information on a country's commitment. Mexico partially complies with some recommendations, in accordance with the evaluation process carried out between 2017 and 2018 (GAFILAT,2023).

Another organization is BASEL, which, among other actions, annually measures "the risk of money laundering and terrorist financing (ML/FT) in jurisdictions around the world"(BASEL, 2023, p. 5). Risk is defined as vulnerability to ML/FT and its counteracting capabilities. The index considers 18 indicators, which differ in focus and scope and are classified into five domains. The score is based on data from publicly available sources, such as the FATF, World Bank, World Economic Forum and Transparency International. In 2022 and 2023, Mexico is assessed at medium risk.

The Mexican Government, derived from the international commitments adopted as a member of the FATF, issues for financial institutions, among various laws and regulations, the general provisions referred to in Article 115 of the Law of Credit Institutions to prevent and detect these acts, which establishes that the "Entities, based on the measurement of the Risks they carry out, must classify their Clients in different Risk Grades that allow them to differentiate them significantly" (SHCP, 2022, p. 67).

On the other hand, the National Banking and Securities Commission (CNBV) in its supervisory work identifies several recurring findings, among which the following stand out: "The model of classifying customers by degree of risk does not consider all criteria, factors and inherent or transactional characteristics of customers" (2020, p. 9).

The financial institution develops and uses a point rating model for compliance purposes. Since its application, it presents results with a concentration of low-risk clients, which have heterogeneous characteristics. The limitations of this model are considered to be:
- It is static, so it does not adjust to changes in customer behavior.
- Generates a high number of false positives.

It is highlighted that ML/FT benefits from the use of artificial intelligence as it significantly improves the processing of large volumes of data in real time, facilitating the accuracy of the results to identify atypical operations (FATF, 2021, p. 35; Martinez et. al., 2022, p. 78).

FATF (2021, p. 38) mentions that ML/FT prevention is favored by segmentation, since by forming homogeneous groups of individuals it is possible to find association between them by knowing their usual behavior and from this identify unusual operations, compared to their segment that may be linked to suspicious behavior of crimes associated with ML/FT.

Therefore, the general therefore, the general objective of this article is to use a segmentation method that allows classifying and detecting the unusualness of customer operations considering data from 2022 and 2023 in order to have more elements to know it, classify it in a risk grade and if necessary suspect ML.

The research questions posed are: How could the financial institution in Mexico segment customers to achieve homogeneous groups within and heterogeneous among them; does customer segmentation allow explaining the degree of risk that their inherent and transactional characteristics expose the financial institution in Mexico to be used for money laundering; and could the financial institution in Mexico detect and suspect unusual operations of its customers that represent a risk of money laundering with the support of segmentation?

To do so, we initially collected and analyzed several articles, such as the one published by (Jovel, 2020) who segmented the members of a savings and loan cooperative in Colombia using quantitative variables. It relies on R software, Cross Industry Standard Process for Data Mining (CRISP DM) and three partitioning-based clustering techniques: K-means- PAM, Fuzzy C-Means, and a technique based on density models: Dbscan. He concludes that the planned objectives are met by identifying the same groups by the different methods applied, however, the associates of the "group obtained by PAM differ from those obtained by K-means, since the former is based on the medoid, while the latter is based on the centroid" (p. 84).

Castro and Castro (2020) develop a proposal with the objective of "identifying homogeneous and heterogeneous groups between segments based on quantitative variables of the associates in an employee fund in Colombia" (p. 10). It is supported by the Rstudio tool. They perform a principal component analysis and conclude that by applying the segmentation method with the k-means algorithm in line with the object of study, the result of this clustering determined three groups and identifies warning signs.

On the other hand, Perez (2020) presents a segmentation methodology for two Colombian financial institutions using the K-Means algorithm and comparing the results in different indexes to validate the optimal selection of the number of clusters and cluster membership. It uses the following variables: Frequency of transactions, city of origin, sector or natural person, years of seniority and transactions, with the support of R Software and the NbClustm package. It concludes that adequate segmentation is obtained.

As for background in Mexico, there is an article by Camacho et al., (2021) in which they deal with ML/FT detection by means of neural networks and an anomaly indicator. The proposed methodology involves the use of fuzzy logic to obtain risk metrics, uses four unsupervised algorithms (Strict Competitive Learning, Self-Organizing-Map, C-Means and Neural Gas) to form groups and identify the one with the highest risk, and finally applies an anomaly indicator to detect any unusual behavior. The model succeeds in reducing the false positive rate and lowering the company's costs.

It can be observed that the articles will be developedmainly in Colombia with quantitative variables different from the present article, due to the requirements of the regulatory entities; most of the previous researches use data mining with the support of the CRISP DM methodology, segmentation techniques and the R software with satisfactory results.

Method

The research is non-experimental quantitative type because variables are not deliberately manipulated, but are observed as they occur in their natural context to

analyze them, likewise, it is longitudinal panel type because three measurements are made over time, one for the last semester of 2022 and two semesters for the year 2023 to analyze the changes and evolution of the variables of active customers and considers a hybrid segmentation algorithm using factorial methods and Ward's method, which according to GAFILAT (2021, p. 52) is the most widely used in money laundering methodologies. 52) is the most widely used in money laundering methodologies, likewise, it is supported by data mining using the CRISP-DM methodology for the structure and process of understanding, preparation, modeling and evaluation of data, organized in:

Step 1.- Understanding the business:

The purpose of the financial institution is to contribute to economic growth by promoting the public and private sectors that generate foreign exchange in the country. These activities are carried out through the granting of credit directly or indirectly through the granting of guarantees on loans that commercial banks grant to the private sector, as well as in the financial markets through the money market desk integrated by repurchase transactions.

Step 2.- Understanding and preparing the data:

In order to ensure completeness, consistency and accuracy, the following activities are carried out:

Data Collection

Data on customers' inherent characteristics are collected by analysts and recorded in a system. The information entered in the system coincides with the information found in the physical identification file, since it is validated by the money laundering prevention area. Transactional data is obtained by extracting information from transactional applications. In order to verify the quality of the data, the external auditor's favorable opinion of the review performed for fiscal years 2022 and 2023 is considered.

Data Selection

The risk factors required by Mexican regulations that explain how and to what extent each customer represents a money laundering risk are considered:

1. Type of person: the National Risk Assessment 2020 (SHCP, 2020, p. 50) mentions that the required information may be hindered by the operation of front companies, complex legal structures, trusts and other legal agreements that allow a separation of legal ownership and the use of intermediaries, since the most complex schemes or mechanisms could allow operations with resources of illicit origin; companies and trusts are considered high risk and the rest are considered low risk.
2. Type of Politically Exposed Person (PEP): a person who performs or has performed prominent public functions in a foreign country or in Mexican territory in accordance with the provisions and who, in the case of a foreigner, is considered a high risk.
3. Seniority of the person: the typology issued by the Financial Intelligence Unit considers young persons and newly created entities as the most common mode of operation for money laundering.
4. Economic activity risk.

5. Geographical location: organized crime and drug trafficking often use the economy to launder money and bribe authorities, thus increasing crime rates and corruption in different geographical areas.

6. Product used: may increase the risk considering: The type of person with whom it can operate, the type of currency, the jurisdictions involved in its operation, the complexity of the product, the participation of financial intermediaries in its operation and whether the operation could be carried out jointly with other development banks.

7. Destination of the resource: indicates whether it is a credit in local currency (MN) or in US dollars (USD) related to the client's economic activity.

8. Origin of the resource: indicates whether it is domestic or foreign related to the client's economic activity, as these may increase the risk considering: The ease of identification of third parties involved, whether or not it allows the placement or receipt of resources in foreign currency, whether or not it allows the mobility of resources to or from abroad, and the type of process (face-to-face or non-face-to-face that gives rise to the channel's operations).

9. Number of operations: this is the sum of operations carried out in the six-month period by the type of person in the product used.

10. Amount of operations.

11. Counterparty number: indicates the number of bank accounts of different counterparties to which the funds will be deposited, considering more than five accounts as high risk.

12. Fund transfers: shows the country to which the transfer is made in order to analyze its profile and behavior.

Data Cleansing

Exploratory analysis is carried out to find and eliminate incomplete, inaccurate or incorrect records, "because hierarchical methods have no solution with missing values and outliers deform the distance and produce unit clusters" (Perez, 2013, p. 279). Table 1 below shows the number of records eliminated:

Table 1
General summary of deleted data

Customers with transaction	2022 2S	2023 1S	2023 2s
Total number of records	730	961	553
Total records deleted	3	37	19
Percentage of representation of deleted records	0.41%	3.85%	3.44%
Total clean records	**727**	**924**	**534**

Note. The table shows the total number of records and the elimination of records for inaccuracy in the heap records due to inaccuracy in the heap. The percentage of elimination is low with respect to the total number of records and therefore does not affect the result of the investigation.

Step 3.-Execution:
Phase I.- Data Exploration

A descriptive analysis was performed with the support of R software. It is identified that 53.95% are companies and 37.41% are agencies or entities; only one is assimilated foreign PEP; of the 324 economic activities, the majority are low risk: 20% Investment companies, 9% foreign financial institutions and 7% private and mixed multiple banking services, among others; the average age is 22 years, with a maximum of 123 years; the geographic location is concentrated in Mexico City and Nuevo Leon; the

origin and destination of funds is mainly in Mexican pesos and 3.5% of transfers are to the United States. One to two counterparties are used to disperse resources. As for the number of operations, the minimum is one and the average is between three and four. With respect to the amount of operations, a positive bias can be observed, since the amounts recorded up to the third quartile are lower than the maximum.

Phase II.- Segmentation of the Factors Customers, Products, Channels and Geographic Location: Segmentation Technique and Identification of Factors

The classification suggested by Pardo (2020) is considered, which, based on what has been reviewed in previous research, strengthens the quantitative method in order to expect better segmentation results:

- Step 1: the corresponding principal axis analysis is performed, using on the one hand the simple correspondence method for the segmentation of products, channels and the integral segmentation of the four factors; the objective of the simple correspondence analysis is to describe the associations between the row and column variables in order to have a view of the data for its interpretation; on the other hand, the multiple factor analysis for the geographic and customer segmentation, considering that the data table is multivariate. The segmentation analysis is performed through a classification based on the coordinates of the first axes obtained from the factor analysis. These segments are formed in such a way that the elements within each segment are as similar as possible and that the elements of different segments are as different as possible. The concept of inertia or total variance of the elements to be segmented is very important in the analysis. This inertia is divided into intraclass or intragroup inertia (variance of the members of the same segment) and interclass or intergroup inertia (variance between the centers of each of the segments).

- Step 2: the number of axes for the classification is selected considering several options, on the one hand, by analyzing the variances of the main dimensions with the eig function, the eigenvalues correspond to the amount of information retained by each dimension; on the other hand, by observing the eigenvalue plot of the variances ordered from highest to lowest with the fviz_screeplot function of the Factoextra package in which visually allows to select the dimensions by observing the curvature in the bar "called elbow"; For the case of the product and channel factors, it is further supported by the quality of representation of the cosine squared rows and columns; the graphical representation of the cosine squared row and column points with the Corrplot package and the contribution of the rows and columns in order to explain the variability in the data set. In the case of the customer and geography factors, to confirm the number of dimensions, we use the Factoextra package, which provides a list of matrices containing all the results of the active variables (coordinates, correlation between variables and axes, cosine squared and contributions) and the quality of the representation of the variables in the cosine squared factor map with the Corrplot package.

- Step 3: hierarchical classification is performed using Ward's method on the "individuals" of the previous step. This method again requires the selection of a concept of similarities, dissimilarities or distances. Additionally, the selection of a distance between segments is required. To determine which individuals join first, it is necessary to calculate the matrix of distances between all pairs

of individuals. Joining the first pair results in a partition of n-1 (where n is the number of individuals to be segmented) segments, one of them with two individuals. It is required to calculate the distance between the new segment and the remaining individuals. By joining the two closest individuals we have a new distance matrix of size (n-1 ,n-1). On this matrix, the nearest pair is selected again and the algorithm continues in this way until a single segment containing all the individuals is reached.

- Step 4: the number of classes is decided and the tree is cut, using hierarchical classification. The dendrogram represents a series of embedded segments, where the number of segments decreases as the height of the tree grows. To obtain a particular number of segments, a cut is made in the tree. This tree is constructed starting from the global set of individuals (top-down classification) and making successive divisions until reaching each individual.
- Step 5: a consolidation K-means is performed starting from the centers of gravity of the partition obtained by cutting the tree.
- Step 6: the segments obtained are characterized by comparing the descriptive statistics within them with the statistics of the classified population. For continuous variables, the mean within the segment is compared with the overall mean. The profiles of each segment are accompanied by descriptive statistics (mainly the mean and standard deviation) as well as descriptive statistics of the illustrative variables of the individuals belonging to each segment.

For the customer factor, the data established by the provisions for inherent risk are as follows: Type of person, PEP, seniority of the type of person and risk of the economic activity; by its transactional characteristics: Destination and origin of the resource, number and amount of operations carried out in the six-month period, number of counterparties and country in which the funds were transferred.

For the product factor, the binary table prepared by the product development staff in conjunction with the financial institution's money laundering prevention staff and validated by the external auditor was obtained, in which they indicated with one if the product presents a risk and zero if it does not. Risk considering: The type of person with whom it can operate, the type of currency, the jurisdictions involved in its operation, the complexity of the product, the participation of financial intermediaries in its operation and whether the operation could be carried out jointly with other development banks in Mexico.

For the channel factor, the financial institution disperses and receives financial resources from its clients in five ways. The binary table previously prepared by the cash flow personnel in conjunction with the money laundering prevention personnel and validated by the external auditor was obtained, in which they indicated with one if the channel presents a risk and zero if it does not. Risk considering: The ease of identification of third parties involved, whether or not it allows the placement or receipt of resources in foreign currency, whether or not it allows the mobility of resources to or from abroad, and the type of process (face-to-face or non-face-to-face that gives rise to the channel's operations).

The segmentation of the geographic location factor is carried out considering all the states that make up Mexico, since transactions are carried out from any state. The risk indicators used for segmentation are: Homicide being the number of victims of intentional homicide per 100,000 persons; violent crime being the number of violent crimes per 100,000 persons, include: Robbery, assault, sexual violence, and violence within the

family; and organized crime, which is composed of extortion, major crimes, retail drug crimes, and kidnapping or human trafficking ;(IEP, 2023).

The indicators are on a scale of one to five, with one representing the most peaceful score and five the least peaceful. Organized crime and drug trafficking often use the economy to launder money and bribe the authorities, thus increasing the crime rate and corruption and consequently the likelihood of being sentenced. On the other hand, the state competitiveness index is considered. Competitiveness is the state's capacity to generate, attract and retain talent and investment, which translates into productivity and well-being for its inhabitants and investors.

Phase III.- Risk Measurement and Classification Considering an Abnormality Indicator:

The risk level indicates how critical the customer is considering the different threats involved in each factor. To measure it, a matrix is prepared with the result of the segmentation, in which a value of one is considered for low risk, two for medium risk and three for high risk.

Table 2 shows the results in which it is observed that the factors: Customers are at low and medium risk levels; all products are classified as medium risk; channels and geographic location have high and medium risk levels.

Table 2
Customer Risk Grades by semester

Factor	Period 2022 second semester	Period 2023 first semester	Period 2023 second half
Customer segment 1	2	1	1
Customer segment 2	1	2	2
Customer segment 3	2	1	2
Customer segment 4	2	1	1
Product segment 1	2	2	2
Product segment 2	2	2	2
Product segment 3	2	2	2
Product segment 4	2	2	2
Channels segment 1	2	2	2
Channels segment 2	3	3	3
Channels segment 3	2	2	2
U. Geographic segment 1	2	2	2
U. Geographic segment 2	3	3	3
U. Geographic segment 3	3	3	3
U. Geographic segment 4	2	2	2

Risk classification is fundamental to effectively allocate the financial institution's available resources to mitigate ML/FT risk. In order to classify the client by the degree of risk in each six-month period, the sum of the value assigned in each risk factor is added, so that a high risk level has an upper limit of 12 and a lower limit of 11; for medium-high risk the upper limit is 10 with a lower limit of nine; medium risk has an upper limit of eight and a lower limit of five; and for low risk it is equal to 4. Table 3 shows a summary of the results showing a higher concentration of medium-risk clients.

Table 3

Concentration of customers in risk grades by semester

Period	Risk under	Risk medium	Risk medium high	Risk high
2022 second half	0	326	401	0
2023 first half	0	850	74	0
2023 second half	0	437	97	0

Segmentation integrates homogeneous individuals allowing the identification of atypical individuals within the segment. To analyze abnormal behavior it is common to use in risk management two standard deviations of the average amount traded; therefore, it is applied in the research considering that it is the one used in the current model of the financial institution. An integral segmentation of the four factors is carried out, creating groups that are homogeneous inside and heterogeneous outside, in order to subsequently generate a table with the operations of maximum amount, average amount and average amount plus two standard deviations per client in the three periods to compare the amount of the average operation plus two standard deviations and the maximum operation carried out by the client with that of the segment and thus be in a position to suspect an unusual operation.

Results

For the customer factor, the result is five segments for 2022, four for the first and second half of 2023, as an example, for the second half of 2023, Figure 1 shows the first factorial plane in which the conformation of four associated groups can be observed and Figure 2 shows the dendrogram with four segments according to the analysis performed together with the eigenvalues/variance of the principal components, the values plot with the elbow technique and the correlation plot of variables. The Ttable 4 shows the result of the hierarchical classification with Ward's method and optimization of the classes with K-means.

Figure 1
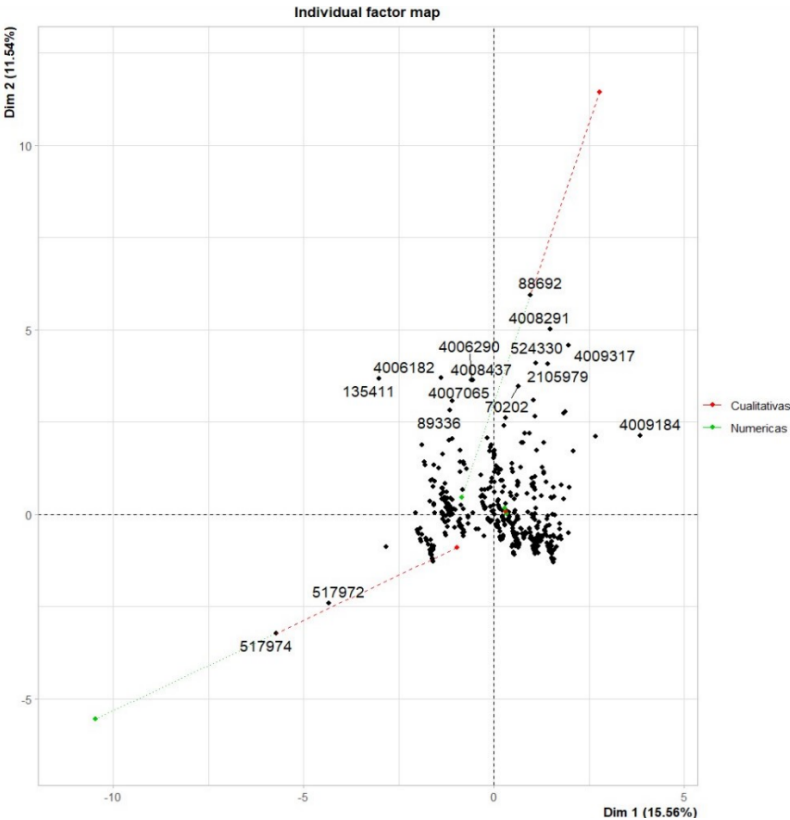*Graphical representation of data in two dimensions*

Figure 2
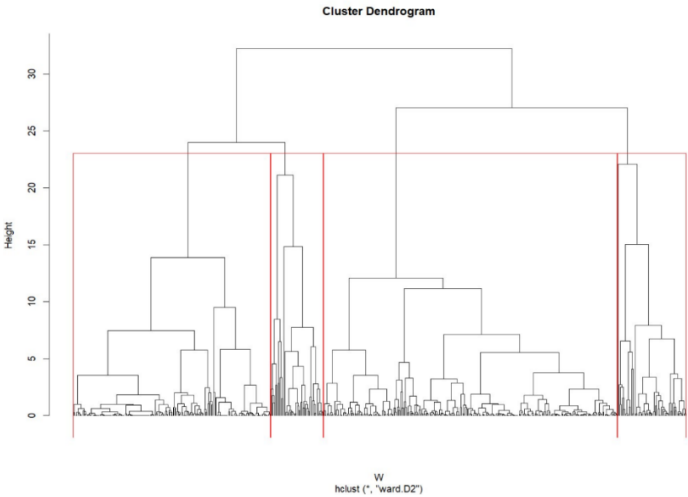*Graphical representation of the dendrogram*

Table 4

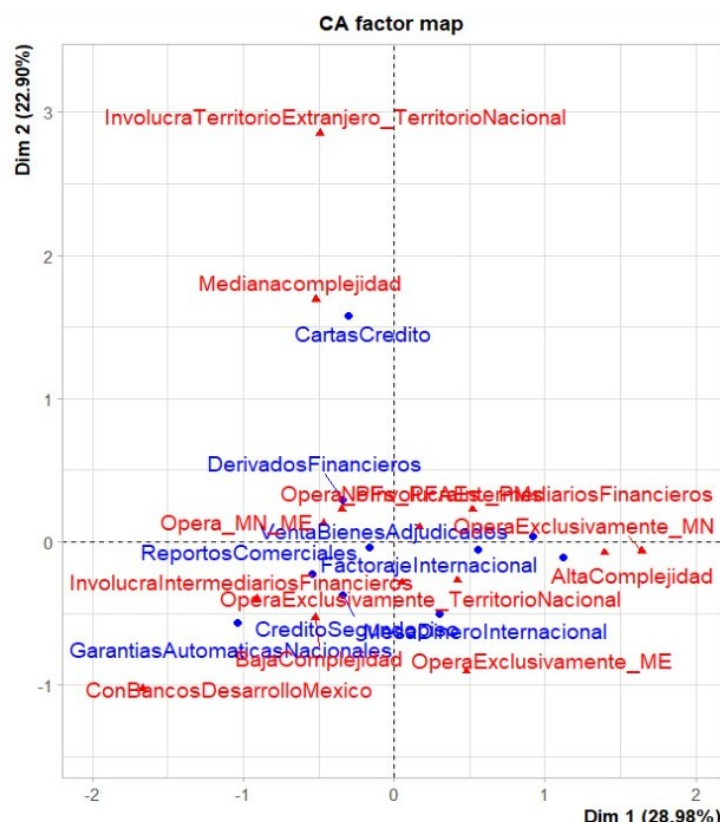*Hierarchical classification with Ward's method and optimization with K-means*

Method	Segment one	Segments two	Segment three	Segment Four
Ward	256	60	46	172
K-means	248	59	39	188

The clients that are grouped in the different segments in the three semesters are similar inside and different outside, this is corroborated by the descriptive statistics that, for example, in the first segment groups 46.44% of the total number of clients in the second semester of 2023 95.17% are companies with 57% of the origin of the national resource and 100% of its destination in national currency; the risk of the economic activity is medium; the minimum number of operation is one and its maximum 23; the average amount of its operations goes from $1 to $ 3,949,492,386 (MN) and the third segment with 35.21% of the clients being 91.44% dependencies and entities with 68% of the origin of the foreign resource and 100% of its destination in national currency; the risk of the economic activity is low; its minimum number of operation is one, but its maximum is 14 and the amount of its operations goes from $5,000 to $286,160,000,000 (MN). Customers in the second segment have almost similar characteristics to those of the first segment, differing mainly in the number and amount of transactions; the same is true for the third segment and the fourth segment.

For the segmentation of the products, the factorial plane in Figure 3 shows that letters of credit have different risks with respect to the others; as well as, that of domestic automatic guarantees and international money desk, the quality of the rows is obtained in which it turns out that nine of the eleven products are well represented up to the fifth dimension by bringing their sum close to one and only two: second floor credit and commercial repo are far away; the row dot plot in five dimensions of the cosine squared which shows that their highest values are found within the first four dimensions and the table of the contribution of the product rows in percentage, which shows the products with the highest value and which are the ones that contribute most to the definition of the dimensions, being in the first dimension trust services and domestic automatic guarantees and in the second dimension letters of credit; as for the table of the quality of the columns, which shows whether a risk is well represented by the five dimensions if the sum is close to one, it turns out that 12 out of 14 are well represented and only two are well represented: operates in MN and ME; and operates exclusively ME are little far from one and with the plot of the column points in five dimensions of the cosine squared showing all the products in which it can be observed that their highest values are within the first three dimensions and the result by the mixed algorithm are five segments obtained in accordance with what was observed in the first factorial plane and in the histogram together with the eigenvalues/variance of the main dimensions and with the elbow technique.

Figure 3
Factorial foreground of the attributes of the product variable

With the result of the hierarchical classification with Ward's method and optimization of the classes with K-means, the products contained in two of the segments are as similar as possible, differentiating them from the three products that formed one segment each based on the analysis performed. The possibility of forming four segments is evaluated in which it is observed that the product of national automatic guarantees is part of the first segment, affecting the quality of the rows.

For channel segmentation, the factorial plane in Figure 4 shows that correspondent payment channels in pounds, Euros and USD do not facilitate identification, that payments and credits in MN do not allow mobility abroad and are not face-to-face, and that correspondent payments in pounds, Euros and USD and payments and credits in USD facilitate customer identification. The table of the cosine squared of the rows channels is obtained, which shows whether a product is well represented by the three dimensions if the sum is close to one, resulting that all are well represented, also, the graph of the row points in five dimensions of the cosine squared that shows all the products within the three dimensions, the table of the contribution of the row channels in percentage, which shows the channels with the highest value and which are the ones that contribute the most to the definition of the dimensions, being in the first dimension subscription and payment in MN and in the second dimension subscriptions in correspondent; the quality of the columns is obtained using the same techniques.

Figure 4
Factorial foreground of the attributes of the carcass variable
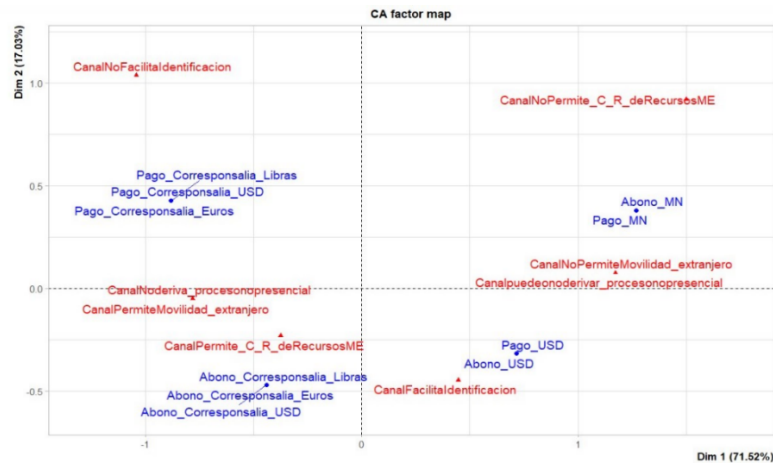

With Ward's method and K-means class optimization, the channels contained in the three segments are as similar as possible on the inside and differentiated on the outside based on the analysis performed. The possibility of forming two segments is evaluated in which the first segment consists of payments and credits in MN and USD and the second segment consists of payments and credits in correspondent, the latter is divided into two in the proposal; observing the symmetrical diagram of the factorial plane, the payment and credit in USD are closer to the credit in correspondent, so it would be assumed different groupings to those obtained, but analyzing the contribution and quality of the rows and columns in three dimensions it is concluded that it is the best option.

The Figure 5 shows the factorial plane of the geographic location that allows us to observe the conformation of four groups, which were corroborated by obtaining the eigenvalues/variance, the graph of values ordered from highest to lowest and the graph of points in the cosine squared dimensions which shows that the highest values of the numerical variables are found in the first and even the fourth dimension for the qualitative variable and with the result of the hierarchical classification with Ward's method and optimization of the classes with K-means the geographic locations contained in the four segments are as similar as possible in their interior differentiating themselves in their exterior based on the analysis carried out. The highest risk segments are the second, comprising the states of Baja California Sur, Coahuila, Jalisco, Nuevo León and Querétaro, which are characterized by a high competitiveness index; and the third segment, comprising the states of Campeche, Colima, Guanajuato, Hidalgo, Michoacán, Morelos, Puebla, San Luis Potosí, Estado de México, Tabasco, Veracruz and Zacatecas. They are characterized by having a medium-low competitiveness index and this is supposed to be caused by being one of the states with the highest perception of crime and insecurity; it integrates Mexico City with a very high competitiveness index.

Figure 5
Factorial foreground of the attributes of the variable geographic location
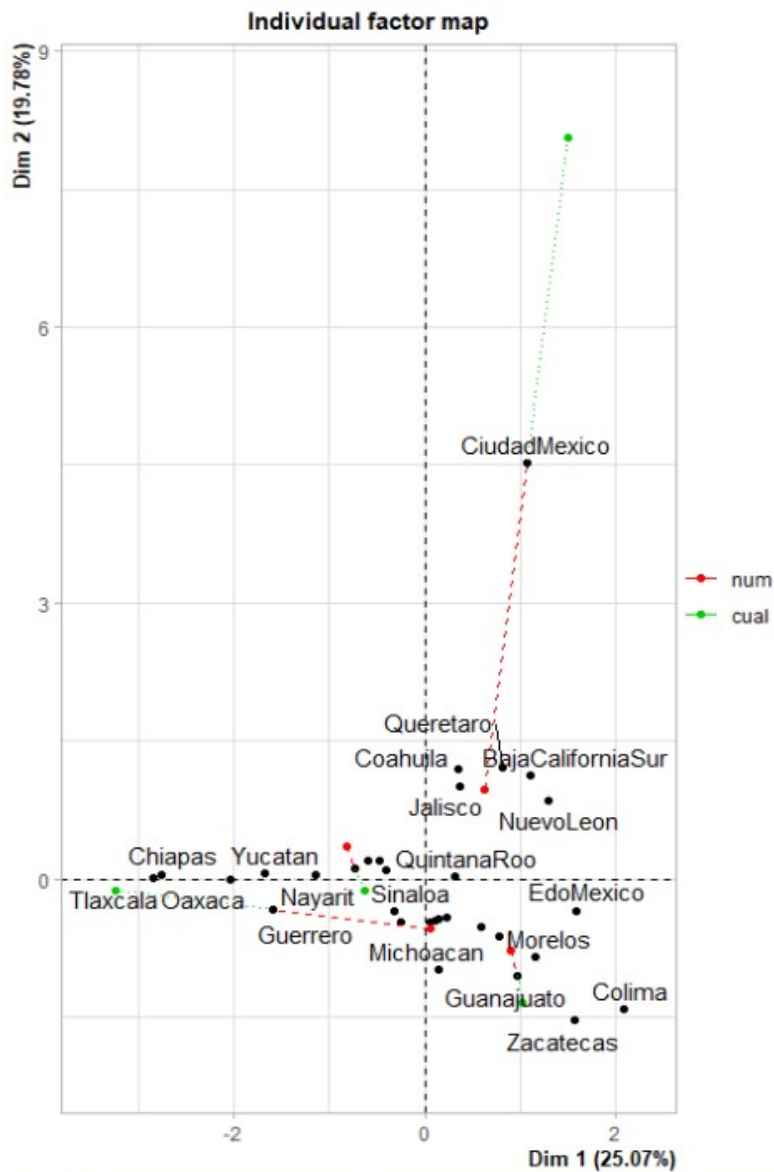
To conclude, the segmentation of the four factors for each semester is integrated by applying a correspondence analysis Figure 6 shows the factorial plane obtained in which the concentration of the cloud of points in four groups can be observed, the blue points and numbers represent the clients, while the red ones represent the location of the risk factors. These results were validated with the histogram were validated with the histogram together with the eigenvalues/variances of the main dimensions and their plot with the elbow technique and with the result of the hierarchical classification with Ward's method and optimization of the classes with K-means.

Figure 6

Factorial close-up of the four segments in the second half of 2023
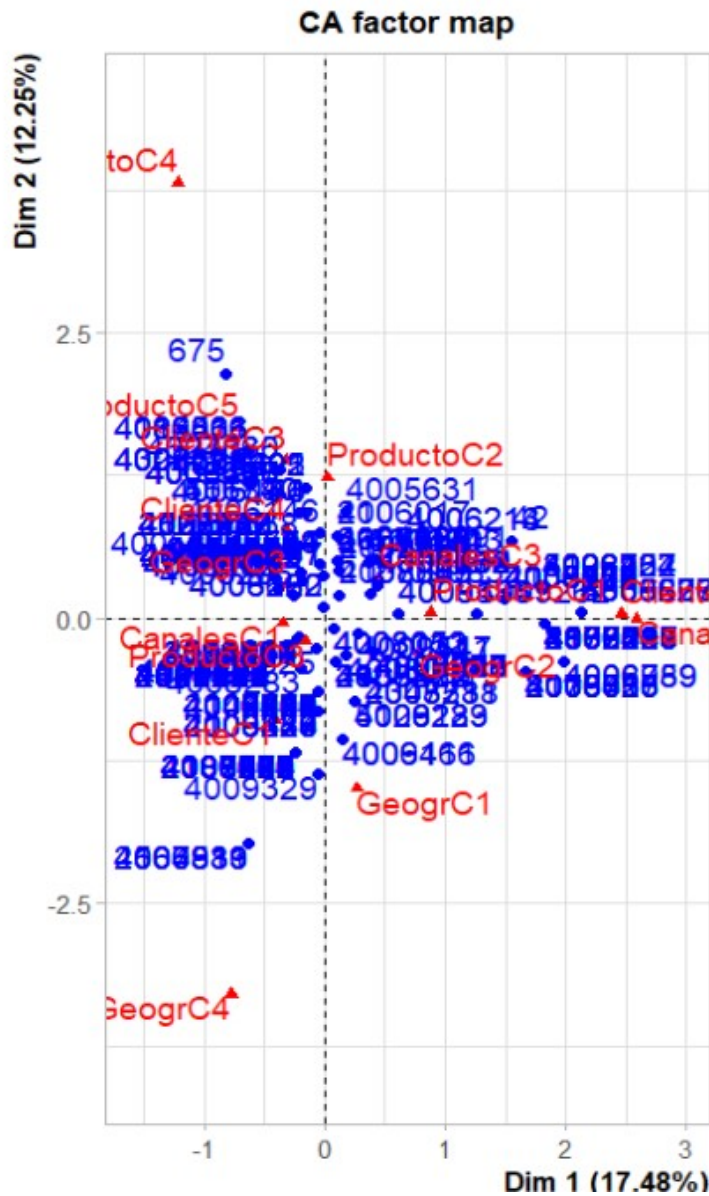
Table 5 shows the results of the clients that presented an alert shows the results of the clients that presented an alert and that considering the grouped amounts of the segmentation, a threshold of the maximum amount of operations is established in comparison with those of the client in that period and previous periods, which allows to know the client's transactionality and to accept or reject the alert and thus reduce false positives.

Table 5

Clients with alerts

Period	Total	With alert	Confirm the alert	Medium risk alert	Alert medium high risk
2022 second half	727	1	0	0	1
2023 first half	924	518	14	13	1
2023 second half	534	183	15	6	9

Discussion and Conclusions

In conclusion, Mexico, according to BASEL, faces a medium risk situation in relation to ML/FT and, therefore, requires strengthening its prevention, control and detection strategies.

For criminal organizations, financial institutions are useful and of interest, since their international connection allows them to operate large amounts of money throughout the world and thus facilitate their actions, hence the importance and responsibility of financial institutions to act in an effective and timely manner in their preventive management (Guevara and Flores, 2021, p. 5).

The objective and research questions posed are met, since the segmentation technique suggested by Pardo (2020) allows grouping, explaining and validating the homogeneous integration inside and heterogeneous integration outside, as well as to measure and explain the degree of final customer risk. With the data collected during the three periods together with the values grouped in each segment, it is possible to establish a threshold and buy the transactionality of the customers in order to have more knowledge, comparability and elements to determine the abnormality of the operations and thus decide in a better manner unusual transactions with a risk-based approach and perform a more specific knowledge management of customers.

The results of the proposed segmentation method reflect a medium and high risk profile of the financial institution's clients in terms of money laundering, as opposed to the method currently used, which concentrates on low risk. This is explained by Mexico's geographic position and the risks derived from its proximity to other jurisdictions (Ministry of Finance and Public Credit, 2020) and the indicators taken from IEP (2023), as well as by the risks grouped in the factors of products and channels used together with the inherent and transactional characteristics of the customers.

This article proposes a model that considers the recommendations described in FATF reports, best practices and national provisions; as well as variables that had not been included in previous studies, assigning a degree of risk and thresholds for the identification of suspicious transactions and therefore improving it.

One of the limitations of the model is the dependence on data quality, so it is recommended to carry out the cleaning process and; establish and adequately maintain the quality of the data to be in a position to prevent the proper functioning of the Method, likewise, is the absence of data from confirmed clients in money laundering to know and validate the behavior of the model.

It is worth recalling the BASEL (2020) guidelines in which it is essential that financial institutions understand and document the normal and expected banking activity of their customers. This will make it possible to establish effective mechanisms to detect operations that deviate from the usual pattern of banking activity.

For future research, it is suggested that indicators of the country's economic activity be incorporated to compare it with the behavior of the client and the segment and to assess whether the increases or decreases are consistent with each other in order to improve the method.

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MODEL DETERMINATION FOR THE REDUCTION OF INVENTORY COSTS IN AUTO PARTS MANUFACTURING COMPANIES
DETERMINACIÓN DE MODELO PARA LA DISMINUCIÓN DEL COSTO DE INVENTARIO EN EMPRESAS MANUFACTURERAS DE AUTOPARTES

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	ABSTRACT
Keywords: inventories, supply chain, costs.	The supply chain is the set of processes that develop from the request for the product until it is delivered to the final customer, one of the main components of this is the warehouse area, Inventory as a current asset in the balance sheet is a concern for organizations. Because of the above, this research aims to determine a model for reducing inventory costs, based on the identification of factors that influence it. The study is quantitative, non-experimental and cross-sectional; to collect data a measurement instrument was applied to 37 large enterprises, for analysis of the data a multiple linear regression was used, and it was found that, If the staff is competent and appropriate inventory audit policies are applied for the organization, inventory costs will decrease.
	RESUMEN
Palabras clave: inventarios, cadena de suministro, costos.	La cadena de suministro es el conjunto de procesos que se desarrollan desde que se hace la solicitud del producto hasta que se entrega al cliente final, uno de los principales componentes de esta, es el área del almacén, el inventario al ser un activo corriente en el balance general es motivo de preocupación de las organizaciones. Debido a lo mencionado esta investigación tiene como objetivo determinar un modelo para disminuir los costos del inventario, a partir de la identificación de los factores que influyen en este. El estudio es cuantitativo, no experimental y transversal; para recabar los datos se aplicó un instrumento de medición a 37 empresas grandes, para el análisis de los datos se usó una regresión lineal múltiple y se encontró que, si el personal es competente y se aplican políticas de auditorías de inventario adecuadas para la organización, los costos de inventario disminuirán.

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Introduction

The Importance of Inventory Management in the Supply Chain

Supply chain management is a term that has emerged in the last 60 years, covering all activities related to the flow and transformation of goods, from the raw material stage to the end user, as well as the information flows related to the handling and management of demand (Ballou, 2004).

The supply chain is comprised of facilities, inventory, transportation, procurement, demand planning, customer service, as well as pricing.

As mentioned above one of the areas of the supply chain is inventory management; these are material goods found in the supply chain and can be found as raw material, in-process product and finished product (Chopra & Meindl, 2013).

Inventory management consists of determining the quantity to order in order to avoid incurring unnecessary costs, such as obsolescence, damaged material, as well as costs generated by inventory management. On the other hand, inventory management within the warehouse consists of securing stock within the warehouse, avoiding having discrepancies in inventory that could affect production, and thus incurring material dispatch costs (Chang, 2017) (Chase, 2009).

Inadequate inventory management and valuation can contribute to business failure, while good inventory valuation, management and control contribute to business success. Until the 1980s, holding large volumes of inventory was interpreted as a sign of economic strength and good management, and sometimes the strength of a company was even measured by the amount of inventory it was able to store. The economic benefits that can be derived from reducing inventories are clear just by looking at the following statistics: in the United States, the average cost of an inventory represents between 30 and 55% of its value. These costs are derived from obsolescence, insurance, opportunity costs and others (Duque Roldán, Osorio Agudelo, & Agudelo Hernández, 2010).

Izar (2011), focused on identifying a model that would decrease inventory costs, in his research he posed two questions: How much of a given item should be ordered when placing a new order? When is it time to place a new order? to solve these questions I use the hybrid method, which considers the economic quantity of the order and the discounts for buying larger volumes of items, in addition to considering the financial opportunity cost of having inventories in the warehouses that do not generate any profit and in turn the cost of the shortage that they defined as that which is not earned by not having the item in stock, on the other hand the cost that they did not consider was associated with the quality; in the research concluded that the quantity and time of order significantly influence the reduction of inventory costs.

On the other hand, for inventory management already in the warehouse, policies should be established for the classification of materials according to their importance, according to the literature this classification is usually in three ABC categories, where class A are very important because they represent 80% of inventory costs, class B are moderately important, representing 15% and class C represent 5%, it can be said that they are the least important, however, they should be audited, to avoid affecting production by the loss of them, in case they have not yet been marked as obsolete (Park, 2014) (Sucky, 2005).

The inventory classification policy is in turn supported by cycle counting policies, which are designed to guarantee the accuracy of the inventory. The frequency of these audits is based on how it is established in the organization, some organizations state that it is necessary to audit Class A materials four times a year, Class B materials three times a year and Class C materials once a year (Kok & Shang, 2014) (Wiffels, Giannikas, Woodall, McFarlane, & Lu, 2016).

The Auto Parts Manufacturing Sector in Nuevo León

The population selected for this research was the large auto parts manufacturing companies; this is because they are firmly established and are generally the ones that invest in strategies and technologies to make their processes efficient.

According to INEGI (2023), the automotive industry is delimited as follows: branch 3361 manufacture of cars and trucks, branch 3362 manufacture of bodies and trailers, branch 3363 manufacture of parts for motor vehicles, and branch 3369 manufacture of other transportation equipment.

It can be noted that according to figures from the monthly manufacturing industry survey (2019), Mexico's northern border accounts for 50.6% of Mexico's auto parts manufacturing industry, while the Bajío accounts for 29.8%.

By the year 2022, Nuevo Leon was the third entity with the largest automotive investment, generating 7689 jobs and a construction area of 259,332 square meters during the year mentioned (Cluster Industrial, 2023).

Research Objective

The population selected for this research was the large auto parts manufacturing companies; this is because they are firmly established and are generally the ones that invest in strategies and technologies to make their processes efficient.

Justification of the Study

Due to the importance of inventories and their costs, this research addresses the problem of inventory cost from a perspective that evaluates the perception of the leaders of the organizations with respect to the identification of the variables that have an impact on the management and cost of the inventory, as mentioned in the previous section, Nuevo Leon was selected because it is one of the main states that is dedicated to the mentioned sector.

Theoretical Framework

Due to the cost importance of inventory management, numerous studies have been conducted to determine which factors have an impact on inventory management.

Demand Management

To reduce the costs associated with inventories, it is necessary to have a correct demand management, which consists of developing activities that allow managing the sources of demand between customer and supplier, in order to buy what is necessary and thus stop incurring inventory management costs (Vollman, Matzke, Grunewald, & Spengler, 2013).

Demand management for production can vary according to the organization, mainly the demand for the final product (independent demand) must be known, in other words, the one that will be sold to the target market, and from there request the materials according to the bill of materials (independent demand) (Leal & Olivia, 2012) (Gutierrez & Vidal, 2008). After identifying the dependent and independent demand, it is determined which method will be used for the correct inventory planning, which can be a simple rolling forecast, batch by batch production, economic order quantity, simple linear regression or only producing what is needed; the latter with the objective of reducing the costs generated by inventories (Bustos & Chacon, 2012).

Information Technology

On the other hand, other authors indicate that the use of information technologies such as Enterprise resource planning, material requirements planning, warehouse management

system, radio frequency identification, bar code or qr code, have a savings of 16% in the cost generated by the handling of materials in the supply chain (Byrne & Heavey, 2006).

Human Resource Competence

Similarly, other authors indicate that employees are considered as the source of value creation in inventory management, but for this to happen it is necessary to mention the concept of competence focused on inventory management (Palsaitis, Ciziuniene, & Vaiciute, 2017).

Qualitative studies have also been carried out focused on the analysis of the just-in-time methodology, where a survey of a total of 30 items was applied to managers and engineers. The survey aimed to analyze the impact between human resources and production processes, the impact of human resources and inventory management, the impact of human resources and economic performance, as well as inventory and its impact on economic performance, the impact of production processes on inventory and economic performance. To conduct the research, structural equations were used and it was determined that there is an impact by the human resource on production processes, inventory management and organizational performance (Garcia, et al., 2015).

Operationalization of Variables and Hypotheses

Table 1 shows the definitions of the variables that will be used in this research.

Table 1
Types of Variables

	Variable	Definition	Author
X1	Competence of the human resources involved in inventory management.	A competency is a set of skills to be developed.	Palsaitis, Ciziuniene, & Vaiciute, (2017)
X2	Information systems involved in inventory management.	Information systems not only support the flow of information, but also improve the performance of the supply chain.	Garcia, et al., (2015)
X3	Demand management	It consists of optimally determining the production of external demand and the quantity of materials to be ordered.	Vollman (2013)
X4	Inventory audit policies	These tools are intended to ensure the accuracy of the inventory.	Wiffels, Giannikas, Woodall, McFarlane, & Lu, (2016)
Y1	Inventory Costs	Refers to all costs incurred in maintaining inventory.	Gutierrez & Vidal , (2008)

Hypothesis

According to the literature presented in the introduction and in the theoretical framework, it can be highlighted that there are four variables that have an impact on the reduction of inventory management costs. The following are the hypotheses of the research that will be tested by means of multiple linear regression in order to establish the model mentioned in the research objective. The decision was made not to place the direction of the impact on the hypotheses, since it is known that a negative impact would generate a recommendation as well as a positive one; Figure 1 shows the interaction of the hypotheses.

-     Inventory audit policies have an impact on inventory costs.
-     Demand management has an impact on inventory costs.
-     Information technology has an impact on inventory costs.
-     Human resource competency has an impact on inventory costs.

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Figure 1
Graphical model of the hypotheses
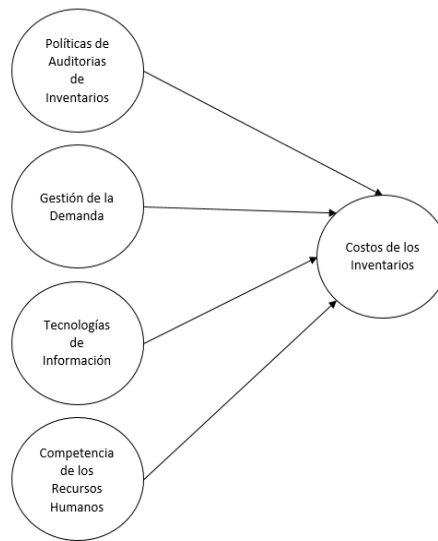
Method

The selected population were the large auto parts companies, which according to INEGI (2018) are those with more than 250 workers having as a result 47 companies in Nuevo León Mexico. To carry out the application of the measurement instrument, a 95% confidence level was used, which indicates that there is a 5% margin of error, with the result that the survey should be applied to 31 companies. The type of sample was not probabilistic since the companies to which the instrument was sent were selected by the authors.

The type of research for this study is qualitative, correlational, explanatory, non-experimental, cross-sectional and causal.

Following the literature review presented in the introduction and in the theoretical framework, a measurement instrument was developed called "Variables that impact inventory costs from the perspective of supply chain leaders", the measurement instrument was divided into two sections, where the first section was questioned by data such as gender, age and schooling of the person answering the questionnaire, this in order to give a description of the subject of study; the second section, composed of 36 items, consisted of the questionnaire that would gather the information for the elaboration of the model with the variables that have an impact on the costs generated by inventory management. Table II shows the type of variable, how it is measured, as well as the number of items per variable and the scale used, which in this case was a Likert scale of 1-7.

Table 2
Types of Variables

Dependent / Independent Variable	Variable	Type of Variable.	Measurement	Items
X1	Human Resource Competence	Ordinal Variable, Discrete	Likert scale 1-7	CRH1 - CRH11.
X2	Information Technology	Ordinal Variable, Discrete	Likert scale 1-7	SI12- SI17
X3	Inventory audit policies	Ordinal Variable, Discrete	Likert scale 1-7	PAI18- PAI23
X4	Demand Management	Ordinal Variable, Discrete	Likert scale 1-7	GD24 - GD30
Y1	Inventory Costs	Ordinal Variable, Discrete	Likert scale 1-7	CI35 - CI41

Pilot Test

On the other hand, to check the reliability of the study, which refers to the degree to which its repeated application to the same individual or object produces the same results (Hernández, 2014). To evaluate the reliability of the measurement instrument, Cronbach's Alpha was used, obtaining the results shown in Table III, where it can be noted that the variables meet the aforementioned requirement.

Table 3
Cronbach's Alpha Analysis

Variable	Cronbach's Alpha
Competencies of the Human Resources involved in inventory management.	0.856
Information Systems involved in inventory management.	0.743
Inventory Audit Policies.	0.796
Demand Management	0.766
Cost of Inventories	.741

As mentioned above, the multiple linear regression method was used to analyze the data collected through the survey, which allows us to determine the correlation between the independent and dependent variables (Montgomery, 2004).

Results

The study consisted of 42 surveys conducted to large companies dedicated to the manufacture of auto parts in the metropolitan area of Monterrey; According to INEGI (2018) a large industry is one that has more than 250 workers; Of these 42 companies only 37 surveys were considered for the study, because when analyzing them in the IBM SPSS 21 software five of them were answered in an atypical way.

Table IV shows the distribution by sex of the leaders who answered the measurement instrument; 64.864% are men and 35.13% are women.

Table 4
Gender distribution of the surveyed sample. Inventory Cost

Sex	Quantity	%
Women	13	35.13
Men	24	64.864
Total	37	100%

Multiple Linear Regression with Sample Data.

The type of research for this study is qualitative, correlational, explanatory, non-experimental, cross-sectional and causal.

As mentioned above, multiple linear regression was used for data analysis, which is a statistical technique used to study the relationship between independent and dependent variables. On the other hand, multiple linear regression must meet the following assumptions: linearity, independence, homoscedasticity, and normality (Baños, Torrado, & Alvarez , 2019).

The IBM SPSS Statistics 21 software was used for the data analysis, where the method by successive steps was chosen, this technique consists of analyzing each independent variable and introducing it in the equation if its probability of F is sufficiently small, in case there are variables already introduced in the equation and the F is large, they are eliminated. The process ends when there are no more variables to be included or eliminated (IBM, 2023).

For this research, several analyses were carried out, in which atypical cases or outliers were detected, which are those observations that have significantly different characteristics from the others. The main problem with outliers is that they are elements that are not representative and can distort the result of the investigation. The outliers located were surveys 14, 23, 34, 26 and 38. For the five outliers eliminated, it can be observed that those who answered the surveys did not have extensive experience as leaders in the supply chain.

In order to test the adequacy of the model in Table V, it can be observed that an R square of .567 was obtained, which indicates that 56.7% of the variability in the dependent variable can be explained by the independent variables in the proposed model, while the rest is due to other causes not explained in the model.

Similarly in Table V, the Durbin Watson is used to test the independence of the data, this indicator has allowed values between 1.5 and 2.5, for this study a value of 1.509 was obtained, which indicates that there is no auto correlation between the residuals.

Table 5
Summary of models with 37 data

Model	R	R^2	Standard error	Durbin Watson
1	.753	.567	.6628	1.509

According to the summary of the ANOVA analysis of variance presented in Table VI, we can observe the significance of the model p<0 and an F of 22.26, which means the contrast of the null hypothesis that the population value of R is zero and, therefore, allows us to decide if there is a significant linear relationship between the dependent variable and the set of independent variables.

Table 6
ANOVA

Model	Sum of Squares	Degrees of Freedom	Mean square	F	Significance
Regression	19.56	2	9.783	22.267	.000
Residual	14.937	34	.439		
Total	34.503	36			

On the other hand, the T student analysis was carried out, where it can be highlighted that of the four variables presented, two of them have a significant impact on the inventory cost variable, this information can be observed in Table VII, where the variable human resource competencies and inventory audit policies are the variables that have significance in the research problem, it is necessary to clarify that this significance can be negative as in the case of human resource competencies, and positive as in the case of inventory audit policies.

Table 7
Model coefficients

	B	Standard Error.	Standard Beta Coefficient	T	Sig.
Constant	.106	.110		.968	.340
Inventory Audit Policies	1.137	.173	1.127	6.586	.000
Human Resource Competence	-.675	.159	-.726	-4.242	.000

Finally, the model resulting from the research is presented in Figure 3. Where X1 is the competence of the human resources used for inventory management, X3 is inventory audit policies and Y2 is inventory cost.

Figure 2
Model proposed in the research
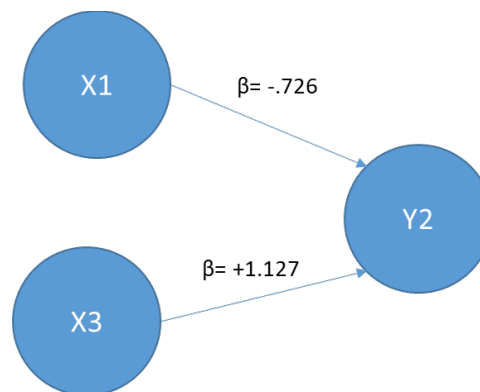
Equation 1 shows the multiple linear regression model. Where Y1 is the dependent variable inventory cost, and the independent variables are X1 Human resource competencies, and X3 Inventory audit policy with an estimated error of .110.

$$Y1 = .110 - .726X1 + 1.127X3. \quad (1)$$

Hypothesis testing.

As can be seen in Table VII, two of the four proposed variables are accepted according to the literature.

Table 8
Acceptance or Rejection

Variables		Beta	T student	P value	Accept or Reject
Competence	of	-0726	-4.242	0.00	Accept
human resources					
Information Systems					Rejects
Inventory	Audit	1.127	6.586	.00	Accept
Policies					
Demand		-	-	-	Rejects
Management					

Discussion and Conclusions

As can be seen, inventory costs are a major concern in the supply chain. Good inventory management will help to avoid expenses that are not planned by the organization, such as expedited materials, handling of obsolete inventory and surplus inventory. According to the literature analyzed, four variables that impact inventory costs were presented: human resource competencies, demand management, information technology and inventory auditing policies. In this research, based on the statistical analysis of the data collected, it was determined that the variables that have an impact on the problem are the inventory audit policies and the competencies of the human resources, the former having a positive impact and the latter a negative impact, which means that if the organization establishes a policy for inventory management within the warehouse, costs will be reduced, in contrast to the variable of the competencies of the human resources, which had a negative impact. In the case of the variable that had a negative impact, it is considered that it should be developed in greater depth and according to the characteristics of the subject of study, in order to determine which specific competencies would have a positive impact, since each manufacturing sector is different, and it is also necessary to mention that the greater the manipulation by the human resource, the more errors there may be in the processes.

On the other hand, according to the analysis performed, two variables had no impact on the research problem. These variables were information technology and demand management, even though the literature mentions that they are fundamental to inventory management.
It is considered that the subject of the study, having a market with a stable demand, since most of the suppliers have their requirements firm at least two months in advance, makes the opinion of the subject of the study inclined to consider that the demand management variable has no impact; however, if this study is carried out in another market, it could have another perception and thus consider new lines to deepen on this variable and its impact on the cost of inventories. Similarly, information technologies will become relevant with the incorporation of Industry 4.0 in manufacturing practices, not only in the inventory area but also in the entire value chain of

organizations, being key to deepen this variable under different perspectives for future work that will be beneficial for decision making in organizations.

We will seek to develop this topic in specific branches of manufacturing, with the intention of exploring whether companies share organizational factors or whether the nature of these factors makes a difference when it comes to improving their value chains; this work will make it possible to establish a possible path for organizations to improve the performance of their key indicators.

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APPROACHES IN TRADITIONAL AND DIGITAL COMPANIES FOR BUSINESS DEVELOPMENT: SYSTEMATIC LITERATURE REVIEW
ENFOQUES UTILIZADOS EN LAS EMPRESAS TRADICIONALES Y DIGITALES PARA EL FORTALECIMIENTO EMPRESARIAL: REVISIÓN SISTEMÁTICA DE LITERATURA

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	ABSTRACT
Keywords: strategy, digital, traditional, company, entrepreneurship	Business strategies are a combination of actions taken to analyze financial, market and performance data in order to impact an organization's bottom line. Given the diversity of approaches to business strengthening and the multiple alternatives for entrepreneurship, this research focused on comparing the strategies employed by digital and traditional companies. The former show a strong dependence on technology to respond with agility to the global market, while the latter are characterized by conventional practices and face-to-face relationships. The main objective was to identify and analyze the key strategies proposed for both types of companies, based on a literature review of articles published between 2020 and 2023. For this purpose, a search was carried out in Scopus and Web of Science, following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Subsequently, 20 relevant articles were selected, after elimination of duplicates and studies unrelated to the object of research. The analysis included the evaluation of similarities and differences in organizational practices, allowing the establishment of a comparative framework for business development. The findings revealed six relevant strategies: three for digital companies and three for traditional companies, providing practical tools for consultants, teachers and entrepreneurs. Likewise, these results can guide governmental decision-making in the definition of public policies, fostering competitiveness, innovation and sustainable growth in both types of organizations.

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RESUMEN	
Palabras clave: estrategia, digital, tradicional, empresa, emprendimiento.	Las estrategias empresariales son una combinación de acciones adoptadas para análisis de datos financieros, de mercado y de rendimiento con la finalidad de impactar en los resultados de una organización. Dada la diversidad de enfoques para el fortalecimiento empresarial y las múltiples alternativas de emprendimiento, esta investigación se centró en comparar las estrategias empleadas por empresas digitales y tradicionales. Las primeras muestran una marcada dependencia tecnológica para responder con agilidad al mercado global, mientras que las segundas se caracterizan por prácticas convencionales y relaciones presenciales. El principal objetivo fue identificar y analizar las estrategias clave propuestas para ambos tipos de empresas, basándose en una revisión bibliográfica de artículos publicados entre 2020 y 2023. Para ello, se llevó a cabo una búsqueda en Scopus y Web of Science, siguiendo los lineamientos PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Posteriormente, se seleccionaron 20 artículos pertinentes, tras la eliminación de duplicados y estudios no relacionados con el objeto de investigación. El análisis comprendió la evaluación de similitudes y diferencias en las prácticas organizacionales, permitiendo establecer un marco comparativo para el desarrollo empresarial. Los hallazgos evidenciaron seis estrategias relevantes: tres para empresas digitales y tres para empresas tradicionales; aportando herramientas prácticas para consultores, docentes y emprendedores. Asimismo, estos resultados pueden orientar la toma de decisiones gubernamentales en la definición de políticas públicas, fomentando la competitividad, la innovación y el crecimiento sostenible en ambos tipos de organizaciones.

Introduction

Digital and traditional companies represent two distinct paradigms in the business world, each with unique characteristics that reflect the trends and technological advances of their time. A digital company is defined by its reliance on and use of information and communication technologies to operate, grow and compete in the marketplace. These companies base their business model on online platforms, massive data, automation and a strong presence in the virtual environment (Cáceres, 2022).

The importance of digital companies lies in their ability to adapt quickly to market changes, leverage data analytics for decision making and reach global audiences efficiently. Their agility and focus on innovation allow them to explore new business models and respond dynamically to the demands of the contemporary consumer (Lemanowicz, 2015).

In contrast, traditional companies are those that have developed their operations and strategies without a predominant reliance on digital technology. Often, these organizations have established business models rooted in conventional practices and face-to-face relationships. The importance of traditional companies lies in their experience, consolidated relationships and in-depth knowledge of local markets (Varela, 2014).

The differences between these two categories are evident in their operational structures, marketing strategies and ways of interacting with customers. While digital companies tend to be agile, decentralized, and user experience oriented, traditional companies can be more hierarchical, slow to adapt, and focused on long-term relationships (Delfin & Acosta, 2016).

Despite these differences, the two categories share similarities in their pursuit of profitability, sustainability and customer satisfaction. In today's era, a successful business strategy can integrate elements of both approaches, capitalizing on the strength of digital and the stability of traditional to create a hybrid model that optimizes efficiency and innovation (Solaimani et al., 2022).

With respect to the strategies identified, there is evidence of proposals aligned with Varela's (2014) perspective, which are immersed in the constant search to identify and cultivate the fundamental competencies in their personnel to successfully achieve their strategic objectives. (Alvarez & Jimenez, 2020)) indicate that this process involves not only recognizing the current skills of employees, but also actively working on their development and improvement. Varela (2014) suggests that this proactive approach to competency management contributes significantly to the company's adaptability and responsiveness to the changing challenges of the business environment.

On the other hand, (David, 2016) provides a valuable perspective by highlighting that business strategy involves both systematic and intuitive approaches. The combination of these approaches facilitates the objective measurement of results and the evaluation of the impact of the strategies adopted for the analysis of financial, market and performance data, among others. Likewise, efficient resource management and strategic asset allocation benefit from data-driven decision making, maximizing operational and financial efficiency as evaluated through business plans (Rivera Rodriguez & Gonzalez Rodriguez, 2020). Systematic strategic planning, according to (David, 2016) involves the creation of detailed blueprints and structured processes that guide progress toward strategic objectives. This rigorous and structured planning translates into greater consistency and monitoring of the strategy over time.

Finally, with respect to strategies for strengthening traditional companies, the action plan is presented as a fundamental aspect of strategic management. This plan becomes an effective means of breaking down objectives or goals into specific, measurable tasks. The sequential and coordinated execution of these tasks is presented as the catalyst for the successful achievement of these objectives. Thus, the action plan emerges as a practical guide for strategic decision making, providing a clear structure that guides the company toward the efficient achievement of its strategic goals (Thompson et al., 2015).

On the other hand, the strategies for strengthening digital companies are framed in digital enterprises, are framed in the first instance in the agile methodology of design for business modeling, known as *Canvas Model,* presented by (Osterwalder & Pigneur, 2010a), stands out as an essential tool for structuring ideas and strengthening ventures. Its visual and collaborative approach facilitates the efficient conceptualization of the key components of a business, allowing entrepreneurs and companies to quickly adapt to market dynamics.

Likewise, the *Lean Startup,* developed by (Ries, 2013) represents a revolution in innovation and product development for new companies. Advocating iterative and rapid construction, this approach prioritizes the creation of a Minimum Viable Product to validate hypotheses and reduce risks, standing out for its flexibility and ability to continuously learn from user feedback.

In the same way, the *Customer Development*, devised by (Blank & Dorf, 2012a) redefines business creation by putting the customer at the center of the process. With its four stages, from discovery to the construction of the company, this methodology seeks to reduce risks through constant validation of the value proposition, representing a fundamental shift towards prioritizing attention to the customer's real needs.

These agile methodologies such as *Canvas*, *Lean Startup* and *Customer Development*, are intertwined to offer entrepreneurs and digital companies, solid and complementary tools, transforming the conception, development and management of business in a dynamic and competitive business environment.

Method

This systematic review was carried out following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Page et al., 2021) (Page et al., 2021) with the purpose of identifying and analyzing the strategies employed for business empowerment in digital and traditional companies.

Eligibility Criteria

We selected published studies that analyzed strategies used to strengthen digital and traditional companies, without discriminating by company size or industry sector. The studies included had to detail the characteristics of the strategies, provide information on their effects on business performance, or contribute knowledge on the implementation of these strategies in different organizational contexts. Articles that did not focus on business strategies for digital and traditional companies or that did not have the full text available were excluded.

Search Strategy

The search strategy focused on identifying studies published between January 2020 and December 2023, in Spanish or English. A search was performed in the Scopus and Web of Science databases, using English descriptors: *entrepreneurship*, *digital*, *business* and *strategy*, combined by means of Boolean operators: *entrepreneurship AND digital AND business AND strategy*.

To gain an in-depth understanding of the subject, a review protocol was designed that not only synthesizes the empirical results, but also allows for a critical and comparative analysis of the selected literature. This protocol was structured around the following research questions:

1. What are the strategies for strengthening traditional and digital companies?
2. What are the differences and similarities in the main strategies of digital and traditional companies?

Selection of Studies

The identified bibliography was managed to eliminate duplicates and organize relevant information. Two independent reviewers screened the titles and abstracts of the articles according to the established eligibility criteria. Subsequently, the selected manuscripts were evaluated in detail to verify their inclusion in the systematic review. Any disagreement regarding compliance with the inclusion criteria was resolved by discussion among the reviewers.

Data Extraction

Using an instrument developed by the authors, the researchers extracted data from each selected article. The data extracted included the year of publication, the type of company (digital or traditional), the strategies employed for business strengthening, and the characteristics of these strategies. In addition, the focus of the study and the organizational context were recorded. All data were reviewed and verified by both reviewers to ensure the consistency and accuracy of the information extracted.

Results

General Characterization

A total of 20 studies were included in this systematic review, following a process that involved initial identification of 371 publications, elimination of duplicates, screening of abstracts, and detailed evaluation of full texts. The complete flow of this process is detailed in Figure 1, following the guidelines of the PRISMA diagram.

Figure 1

PRISMA flow chart
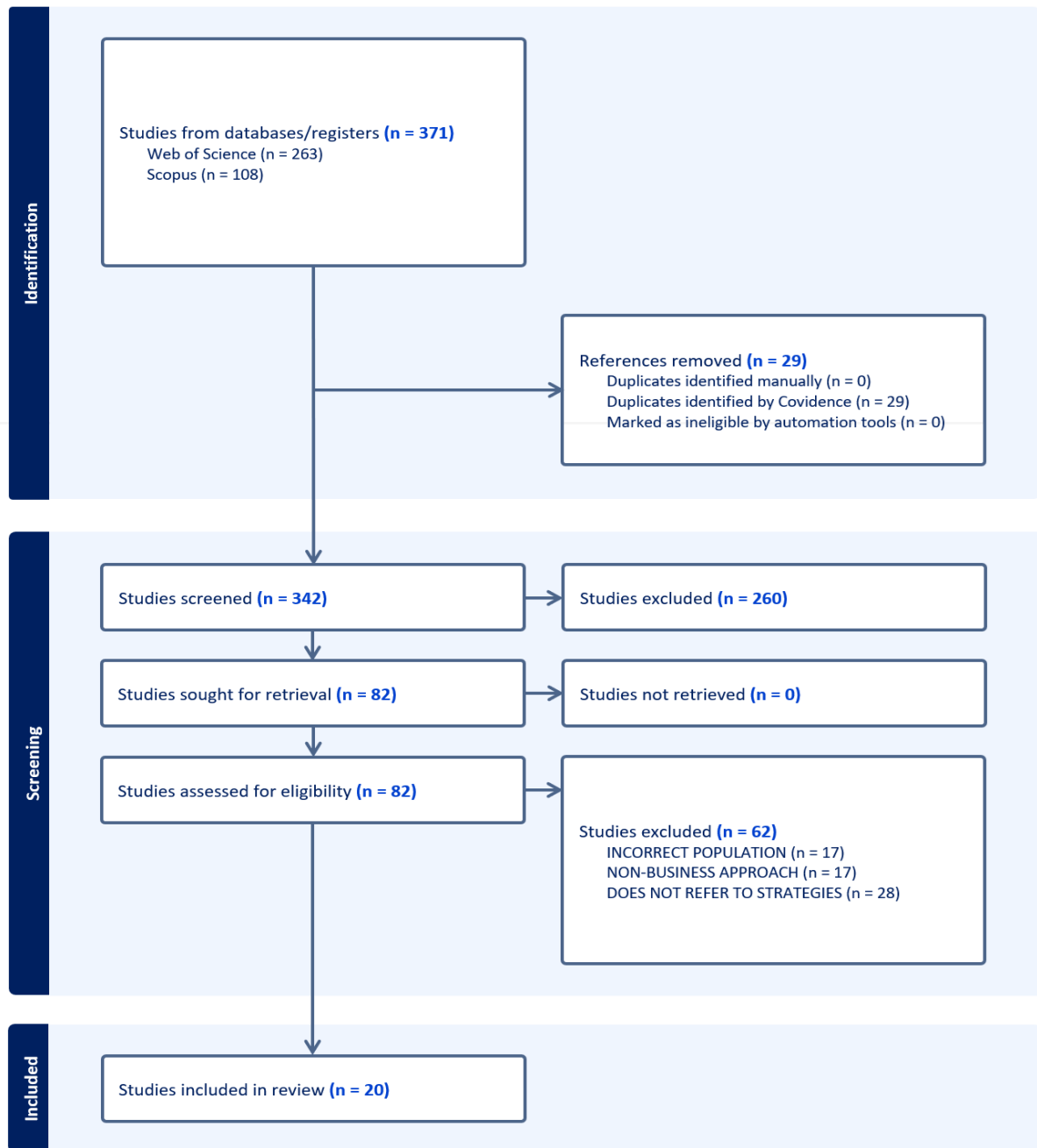
The selected articles addressed business strategies in digital and traditional enterprises, detailing specific approaches and categories of business strengthening. Of these, 60% (n=12) focused on digital strategies, while 40% (n=8) addressed traditional strategies. The main findings are summarized in Table 1.

Among the most common digital strategies were the adoption of digital technologies (n=8), the transformation of business models (n=5), and the implementation of Lean Startup methodologies (n=4). On the other hand, the most representative traditional strategies included the development of business plans

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(n=6) and market analysis for decision making (n=4), underlining the focus on conventional practices for business consolidation.

The predominant methodological designs of the studies included qualitative approaches (65%), followed by single case studies (25%) and structured literature reviews (10%).

Table 1

Analysis of articles related to business strategies

Author/Year	Title	Approach	Category	Types of strategy by category	Object of study	how was it done?	Finding
(Vrontis et al., 2022)	*Adoption of Digital Technologies by SMEs for Sustainability and Value Creation: Moderating Role of Entrepreneurial Orientation*	*Lean Start Up*	Digitals	Effective adoption and integration of digital technologies such as artificial intelligence, *IoT, blockchain, big data analytics.*	The research seeks to understand how the adoption of different digital technologies affects the creation of economic and social value in SMEs and how it influences their performance.	*Partial least square structural equation modeling* (PLS-SEM) was used to analyze the data and validate the conceptual model. This method was chosen because it is suitable for exploratory studies and can handle data that are not normally distributed.	The adoption and effective integration of digital technologies such as artificial intelligence, *IoT, blockchain, big data analytics,* among others, can synergistically create value for SMEs and differentiate them in the market. In addition, the use of these technologies can improve the effectiveness and efficiency of business practices and increase productivity and performance in SMEs.
(Cueto et al., 2022)	*Digital Innovations in MSMEs during Economic Disruptions: Experiences and Challenges of Young Entrepreneurs*	Business competencies	Traditional	Market analysis and marketing plan development, as well as development of entrepreneurial skills	To provide information on digital innovations in SMEs during economic disruptions and the experiences of young entrepreneurs in the digital age.	The qualitative research approach. The study is based on in-depth interviews with young entrepreneurs in the Philippines to understand their experiences and perspectives on SME digitization during the COVID-19 pandemic.	One of the main findings is that the COVID-19 pandemic has accelerated the adoption of digital innovations in SMEs, as companies have had to adapt to changing consumer habits and market conditions. The study also highlights the importance of digital skills and training for employers and their employees, .
(Zhang et al., 2022)	*Start-Up's Road to Disruptive Innovation in the Digital Era: The Interplay Between Dynamic Capabilities and Business Model Innovation*	*Canvas Model*	Digitals	Transformation of the business model through innovation.	Identify the key pillars that support the path to innovation in the digital era, such as digital technology, dynamic capabilities and business model innovation. In addition, they present the research design, reveal the findings of the case company analysis.	The exploratory and longitudinal single case research method is adopted to deepen the case and unfold the dynamic evolution process of the investigated phenomenon over time, and the path of compliance can be summarized. The analysis of a single case is conducive to building a chain of causal evidence.	Dynamic capabilities and business model innovation are critical to the success of disruptive innovation in *startups* in the digital age. The study shows how *startups* can develop and improve their dynamic capabilities and innovative business models to gain a competitive advantage in the marketplace. In addition, the study highlights the importance of alignment between dynamic capabilities and the business model to achieve sustainable disruptive innovation
(Bachmann and Jodlbauer, 2023)	*Iterative business model innovation: A conceptual process model and tools for incumbents*	Business Plan	Traditional	Development of a business plan.	It is the process of business model innovation in traditional companies. Business model innovation is crucial for established companies.	structured review of the existing literature on the business model innovation process in incumbent companies. Forty-seven publications presenting business model innovation process models were analyzed.	The main finding of the research is that the business model innovation process in incumbent companies is incremental, iterative, recursive and reflexive. This means that companies must build on their existing business models, adjust them incrementally, iterate in the process as they gain new insights.
(Ferreira et al., 2022)	*Knowledge strategies and digital technologies*	*Lean Start Up*	Digitals	*Lean Startup* implementation. Focused on	To investigate the influence of knowledge strategies and the	The method used in the research is a quantitative analysis based on a sample of small companies.	The main finding of the study was that external and internal coding strategies have a positive and significant impact on firm

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Author/Year	Title	Approach	Category	Types of strategy by category	Object of study	how was it done?	Finding
	maturity: effects on small business performance			learning, knowledge, testing and measuring	maturity of digital technologies on the performance of small businesses.	Four knowledge strategies were identified: external coding, internal coding, external customization and internal customization.	performance, especially when considering the level of digital technology maturity and knowledge intensity.
(Cavallo et al., 2023)	*Business model scaling and growth hacking in digital entrepreneurship*	*Lean Start Up*	Digitals	Implementation of *marketing* techniques: High impact *growth hacking*.	The objective of the study was to investigate how digital companies can scale their business model and the role of *growth hacking* in this process.	The method used in the research was a methodology called *Dynamic Business Modeling* (DBM) *for Scaling,* which combines the adapted business model canvas with system dynamics modeling.	The main finding of the research is that *growth hacking* can be an effective strategy for scaling digital businesses. By implementing *growth hacking* strategies, companies can experience exponential growth in their customer base and generate additional revenue.
(Katsikeas et al., 2020)	*Revisiting international marketing strategy in a digital era Opportunities, challenges, and research directions*	Business Plan	Traditional	Market analysis and development of a marketing plan.	Examine the role of digital technologies in international *marketing* strategies.	The method used in the research is a review of existing literature in the field of international *marketing* strategy and digitization.	The main finding of the research is that the right combination of digital technologies and traditional international *marketing* strategies can result in a successful and valuable relationship with customers.
(Centobelli et al., 2022)	*The undigital behavior of innovative startups: empirical evidence and taxonomy of digital innovation strategies*	*Lean Start Up*	Digitals	Adoption and use of different infrastructures and digital tools inside and outside the organizations.	Conceptualize the digital behavior of *startups* and examine emerging behaviors in terms of digital strategies of Italian companies enrolled in the Startup Act policy initiative.	The method used in the research is empirical analysis, and an analysis of the adoption of intra- and inter-organizational digital infrastructures in the total population of 6,178 Italian companies registered in the Register of Innovative *Startups* was carried out.	The main finding of the study is the proposal of a taxonomy that brings together four digital behaviors for the adoption of digital technologies in *startups*: digital follower, technical influencer, social influencer and digital leader. These behaviors are based on the adoption and use of different digital infrastructures inside and outside organizations.
(Chaturvedi and Karri, 2022)	*Entrepreneurship in the Times of Pandemic: Barriers and Strategies*	Business Plan	Traditional	Establish *marketing*, digitalization and networking strategies.	Investigate the challenges that the COVID-19 pandemic has posed to entrepreneurs and the strategies that organizations can adopt to survive and grow.	a mixed-method approach was used. An empirical analysis of the factors that have affected smaller firms during past economic downturns was conducted. This was done through descriptive analyses.	The main finding of the study was the identification of the main factors affecting companies during the pandemic. These factors include organizational readiness, government infrastructure support, technological inadequacy and financial crisis.
(Jafari-Sadeghi et al., 2021)	*Exploring the impact of digital transformation on technology entrepreneurship and technological market expansion: The role of technology readiness,*	Business Plan	Traditional	Digital transformation strategies, such as ICT investments	The objective of the study is to investigate the effects of digital transformation on value creation through technology entrepreneurship and technology market expansion.	Relevant data from 28 European countries over a 7-year period (2009-2015) were analyzed to formulate and investigate a new perspective on digital entrepreneurship driven by the concepts of digital transformation and entrepreneurship. Descriptive analyses were performed and	The main finding of the study was the identification of significant relationships between key constructs related to digital transformation. For example, ICT investments and Internet access were found to have a positive impact on technology entrepreneurship and technology market expansion. It was also observed that R&D investment and the number of R&D

Author/Year	Title	Approach	Category	Types of strategy by category	Object of study	how was it done?	Finding
	exploration and exploitation					data analysis techniques were used.	researchers have a positive relationship with technological entrepreneurship.
(Ghezzi and Cavallo, 2020)	*Agile Business Model Innovation in Digital Entrepreneurship: Lean Startup Approaches*	*Lean Start Up*	Digitals	Implementation of *Lean Startup and Agile Development* strategies	The objective of the research was to identify and analyze the business strategies and agile methodologies used by *startups* in the lodging industry.	The study used a qualitative research methodology based on in-depth interviews conducted with founders and executives of lodging *startups*.	The main finding of the research is that hosting *startups* use a combination of Lean *Startup* and *Agile Development* methodology to enhance growth and innovation. In addition, several successful business strategies used by *startups* were identified.
(Ritala et al., 2021)	*Digital strategy implementation: The role of individual entrepreneurial orientation and relational capital*	Business competencies	Traditional	Development of internal and external relational capital	The objective of the research is to analyze the role of individual entrepreneurial orientation and relational capital in the implementation of digital strategies in a European manufacturing company.	The authors conducted an empirical study using data from 256 employees of a European manufacturing company. They used regression analysis to assess the relationship between individual entrepreneurial orientation, relational capital and digital strategy performance.	The study findings show that both individual entrepreneurial orientation and relational capital have a positive effect on digital strategy performance. In addition, the authors found that relational capital acts as a moderator between individual entrepreneurial orientation and digital strategy performance,
(Lee, 2022)	*Challenges to the Export-Led Growth Strategy in the Digital and Global Era: An Empirical Investigation of South Korea's Experience*	Business competencies	Traditional	Strategic collaborations, enhance training and skills development, and create a culture of innovation and experimentation	The objective of the study was to identify and analyze the challenges faced by small and medium-sized enterprises (SMEs) during the COVID-19 crisis in relation to the adoption of digital transformation.	The authors conducted an exploratory study using survey data from 152 SMEs in various sectors in the United Kingdom. Descriptive statistical analysis and hypothesis testing were used to assess respondents' perceptions of the impacts of the COVID-19 crisis on the digital transformation of their companies.	The authors found that SMEs experience significant challenges in adopting digital transformation during the COVID-19 crisis. Lack of resources and skills, technology implementation and cultural resistance are the main areas of challenge they face. To overcome these challenges, companies can seek strategic collaborations, improve training and skills development, and create a culture of innovation and experimentation
(Cavallo et al., 2021)	*Competitive intelligence and strategy formulation: connecting the dots*	Action Plan	Traditional	Strategic analysis of the environment and the market.	The object of study of the research is the relationship between competitive intelligence (CI) and the company's strategy formulation process.	used a qualitative approach and the method of data analysis was thematic analysis. The authors analyzed semi-structured interviews with leaders of four private companies located in Brazil in different industries.	The main finding of the research is that IC can be a key enabler in the formulation of business strategies through the exploration of opportunities and threats in the business environment. In addition, the research suggests that CI infrastructure and information literacy
(Stallkamp et al., 2022)	*Scaling, fast and slow: The internationalization of digital ventures*	*Customer development*	Digitals	Exploration of new international markets with growth metrics.	It discusses how digitization can enable rapid international expansion and scalability in business, but also mentions some limitations	NA	The internationalization of digital companies is not homogeneous and can be influenced by factors such as heterogeneous demand and the need for complementary non-digital resources. Digital companies focused on the B2C market tend to have a lower probability and proportion of international sales.

Author/Year	Title	Approach	Category	Types of strategy by category	Object of study	how was it done?	Finding
(Guo et al., 2022)	*Inside the black box: How business model innovation contributes to digital start-up performance*	*Canvas Model*	Digitals	Strengthen the business model, unique value proposition and marketing strategy through innovation.	Analyzes how innovation in value proposition, value creation and value capture affect the performance of digital startups.	quantitative study involving regression analysis to examine the relationships between different variables. Since the excerpts provided refer to several different studies, it is possible that the method used may vary according to the specific study referred to.	The importance of innovation in the business model and its impact on the performance of emerging companies. The relationship between the financial competence of founding teams and the growth of start-ups. The influence of strategic alliances on the success of an emerging company.
(Buck et al., 2023)	*Digital transformation in asset-intensive organisations: The light and the dark side*	Business Plan	Traditional	Creating customer value and improving operational efficiency through process digitalization	Digital transformation in asset-intensive organizations, and how these organizations can make the most of the opportunities offered by digitalization.	The method used in the research was a combination of in-depth interviews with key informants and an analysis of relevant documents. A qualitative research approach was used to gain a detailed understanding of perceptions and experiences	The main finding of the research was that digital transformation can be an important source of competitive advantage for asset-intensive organizations, but that it also presents unique challenges that must be addressed. Several strategies and recommendations were identified to help organizations make the most of the opportunities.
(Zahoor et al., 2022)	*International open innovation and international market success: an empirical study of emerging market small and medium-sized enterprises*	*Lean Start Up*	Digitals	Application of Open Innovation and Agile methodologies	The object of study is the impact of international open innovation on the international market success of small and medium-sized enterprises (SMEs) in emerging markets. The study focuses on the importance of intercultural competencies and digital alliance skills in this context.	The method used in the research is a theoretical and empirical analysis. A review of the existing literature on the subject was conducted and an empirical study was carried out using an online survey of 200 SMEs in the United Arab Emirates.	The main finding of the research is that international open innovation has a positive impact on the international market success of SMEs in emerging markets. In addition, intercultural competencies and digital alliance skills were found to moderate this relationship. In other words, SMEs that are better able to work with international partners and adapt to different cultures are more likely to succeed in the international market.
(Cenamor, 2021)	*Complementor competitive advantage: A framework for strategic decisions*	Business Plan	Traditional	Market research and marketing plan development	It is the competitive advantage of complementors in platform ecosystems.	The method used in the research is a review of the existing literature on the subject.	The heterogeneity of complementors is critical to attract end users to platform ecosystems and that cost leadership strategy and differentiation strategy are two of the generic business strategies identified by Porter (1980)
(Miroshnychenko et al., 2021)	*Absorptive capacity, strategic flexibility, and business model innovation: Empirical evidence from Italian SMEs*	Action Plan	Traditional	Development of action plans.	The relationship between absorptive capacity, strategic flexibility and business model innovation in Italian small and medium-sized enterprises (SMEs).	Survey method through a questionnaire that was developed and piloted by the authors. A random sample of 1300 Italian companies with up to 250 employees and total annual revenues between 1 and 50 million euros was drawn.	The main finding of the research is that absorptive capacity and strategic flexibility are key factors for business model innovation in Italian SMEs. In addition, potential absorptive capacity was found to have a stronger effect on business model innovation than realized absorptive capacity.

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Description of Strategies for Business Strengthening

According to the articles analyzed, Table 2 presents the strategies, models or methodologies related to the traditional and digital business approach.

Table 2
Strategies, models and approaches for business strengthening

Author	Strategy / model / methodology	Approach	Articles (n=20)
Varela, 2014	Business competencies	Traditional	3
David, 2016	Business Plan	Traditional	6
Thompson et al., 2015	Action plan	Traditional	2
Osterwalder and Pigneur, 2010	*Canvas* business model	Digital	2
Ries, 2012	*Lean Startup*	Digital	6
Blank and Dorf, 2012	*Customer development*	Digital	1

Business Competencies

The conceptual model of competency-based business development focuses on identifying and cultivating key skills, such as leadership, communication, and problem solving, and aligning them with organizational strategic objectives. This approach includes stages such as entrepreneurship training, idea evaluation, business planning, and sustainable growth (Varela V., 2023). The implementation of these competencies uses tools such as 360-degree feedback and performance analysis (Ortega et al., 2020). These strategies promote the alignment between individual skills and organizational objectives (Fuentes García & Sánchez Cañizares, 2021).

Among the selected publications, Cueto et al. (2022) apply this model by analyzing how business skills helped SMEs adapt to digital innovations during the COVID-19 pandemic, highlighting the importance of digital training for leaders. Ritala et al. (2021) highlight the role of relational capital development to enhance the implementation of digital strategies in European manufacturing companies. On the other hand, Lee (2022) addresses the development of strategic competencies in SMEs to face digital transformation challenges, prioritizing interpersonal and cultural skills. These publications demonstrate how competency development can be an essential pillar in diverse business contexts, strengthening both adaptability and organizational competitiveness.

Business Plan

The business plan model combines systematic and intuitive approaches to manage the complexity of the business environment. Systematic approaches focus on the detailed analysis of financial, market and performance data, enabling the creation of structured plans to assess feasibility and viability, optimizing resource allocation and decision making (David, 2016; Segarra Ciprés et al., 2017). On the other hand, the intuitive approach, based on experience and creativity, enables quick decisions in contexts of uncertainty, fostering innovation and differentiation in the marketplace (Canh et al., 2019; Wheelen & Hunger, 2013). This model reflects a balance between quantitative analysis and emotional market insight, integrating data and judgment for effective decision making in dynamic environments (Fred R., 2017).

Among the selected publications, Bachmann and Jodlbauer (2023) highlight how traditional companies apply iterative and reflective business plans to incrementally innovate their operating models. Katsikeas et al. (2020) investigate how the combination of digital technologies and traditional business plans optimize international marketing strategies, strengthening customer relationships. Chaturvedi and Karri (2022) discuss the

use of business plans to mitigate financial and operational challenges during the COVID-19 pandemic, emphasizing strategic planning as a survival tool. Jafari-Sadeghi et al. (2021) explore how ICT investments and digital transformation, supported by structured business plans, drive technology entrepreneurship in Europe. Cenamor (2021) applies the business plan in platform ecosystems, highlighting its usefulness in exploring competitive advantages through market research. Finally, Buck et al. (2023) show how business plans guide digitization in asset-intensive organizations, improving operational efficiency and creating customer value.

Action Plan

The action plan organizes strategies into objectives, broken down into measurable and sequential tasks that enable the achievement of organizational goals (Thompson et al., 2015). This approach provides clarity and structure, improving business competitiveness and profitability through resource optimization and cost minimization (Thompson et al., 2012a). The strategy can also take a proactive approach, anticipating opportunities to improve financial performance, or a reactive approach, adjusting to competitors' strategies (Briones Veliz et al., 2021; Thompson et al., 2012)

Among the selected publications, Miroshnychenko et al. (2021) explores how action plans foster innovation in business models through absorptive capacity and strategic flexibility, highlighting their application in small and medium-sized Italian companies. Cavallo et al. (2021) identifies how competitive intelligence, structured through action plans, facilitates the formulation of organizational strategies by analyzing opportunities and threats in the business environment.

Canvas Business Model

The *Canvas* business model, developed by Osterwalder and Pigneur (2010), organizes the business strategy into nine key blocks: value proposition, customer segment, communication channel, customer relationship, revenue stream, costs, key resources, key activities and partners (Osterwalder & Pigneur, 2010). This agile and visual approach answers fundamental questions about the structure and monetization of business models, being especially useful for digital enterprises seeking flexibility and differentiation in competitive markets (Reynier Israel et al., 2021). Among the selected publications, Zhang et al. (2022) apply the *Canvas* to analyze the transformation of business models and their alignment with dynamic capabilities in digital startups, promoting disruptive innovation. Guo et al. (2022) highlight how innovation in proposition and value creation, based on the Canvas, improves the performance of startups, integrating strategic alliances and monetization strategies.

Lean Startup

The Lean Startup model, developed by Eric Ries, is an agile methodology that transforms the approach to innovation and product development in startups (Ries, 2013). Based on iterative Build-Measure-Learn cycles, it prioritizes the creation of a Minimum Viable Product (MVP) before full launch, allowing rapid adjustments through real feedback, minimizing risks and maximizing success in dynamic business environments (Grisales Ocampo, 2020). Among the selected publications, Vrontis et al. (2022) highlight how Lean Startup drives the integration of advanced technologies, such as artificial intelligence and big data, for value creation in small and medium-sized enterprises. Ferreira et al. (2022) analyze its impact on learning, testing and measurement strategies in small companies, improving organizational performance. Cavallo et al. (2023) explore

the application of Lean Startup combined with marketing techniques such as Growth Hacking, facilitating the scalability of digital business models. Centobelli et al. (2022) investigate the adoption of this methodology in Italian startups, proposing a taxonomy of digital behaviors related to its implementation. Ghezzi and Cavallo (2020) integrate Lean Startup with agile methodologies, demonstrating how startups in the lodging industry employ both approaches to accelerate innovation and growth. Finally, Zahoor et al. (2022) address the application of Lean Startup together with international open innovation, showing its effectiveness in small and medium enterprises in emerging markets to boost international success.

Customer Development

The Customer Development model, developed by Blank and Dorf, shifts the traditional product-centric approach towards the prioritization of customer needs, being structured in four interconnected stages: discovery, validation, customer creation, and business building (Blank & Dorf, 2012). In the discovery stage, we seek to understand the customer's problem; in validation, we confirm the proposed solution through testing; in customer creation, we focus on acquiring and retaining customers; and in business building, we ensure expansion and optimization. This approach highlights direct interaction with customers from the outset, promoting rapid learning, adaptability and continuous adjustments to minimize risks and maximize business success (Fernández-Salinero & de la Riva, 2014; Kahn, 2018).

In this context, Stallkamp et al. (2022) apply the customer development model to analyze how digital companies explore new international markets. The research highlights the use of growth metrics to assess demand in heterogeneous markets and how companies adjust their strategies based on customer feedback. In addition, they emphasize that, although digitization allows for rapid international expansion, it also faces challenges such as the need for complementary resources and the diversity of cultural demands.

Applicability of Business Models

The analysis of the business models identified key similarities and differences in their approach, usefulness and prevalence. Among the models analyzed, the Business Plan stood out as the most frequent in traditional companies due to its ability to structure detailed strategies, make financial projections and guide decision making. On the other hand, in digital companies, Lean Startup stood out as the most widely used model, thanks to its iterative approach and focus on customer feedback, which facilitates innovation and adaptation in dynamic environments.

Similarities

Structured strategies: Both traditional and digital models are based on defined structures that guide business development. Models such as the Business Plan and Canvas Model provide detailed planning for achieving objectives, while approaches such as Lean Startup and Customer Development integrate iteration and continuous learning.

Focus on value creation: All models prioritize the generation of value, although they differ in the way they conceptualize it. In traditional models, value is derived primarily from efficient resource planning and allocation, while in digital models the focus is on innovation and customer experience.

Strategic relevance: The six models seek to offer competitive advantages, either through market differentiation, resource optimization or adaptation to changing environments.

Differences

Sector applicability: In the case of the traditional models, the Business Plan was the most frequent (n=6), standing out for its emphasis on detailed planning, market analysis and financial projections. This model provides a robust structure that facilitates strategic decision making in consolidated companies. The Action Plan complements this methodology by breaking down strategies into specific and measurable tasks, allowing for a more operational and practical implementation. Business Competencies focused on the development of individual and organizational skills, prioritizing aspects such as training, leadership and the alignment of competencies with organizational objectives. As for digital models, Lean Startup was the most used (n=6), characterized by its iterative approach based on continuous learning cycles and customer feedback, which minimizes risks and fosters innovation. The Canvas Model, on the other hand, was positioned as a visual and agile tool for conceptualizing business models, highlighting key elements such as the value proposition and customer segments. Finally, Customer Development placed the customer at the center of business development, structuring its methodology in stages of discovery, validation and expansion to ensure business sustainability.

Level of flexibility: Traditional models tend to be more rigid and detailed in their initial implementation, making them ideal for established companies that require extensive planning. In contrast, digital models are more dynamic and allow for quick adjustments to respond to market changes, being especially relevant in startups and technology sectors.

Strategic approach: While digital models prioritize direct interaction with the customer, which allows them to respond quickly to their needs and demands, traditional models focus on the optimization of internal processes and the efficient use of organizational resources.

Discussion and Conclusions

This study highlights how traditional and digital companies adopt different business models, reflecting their particular characteristics and the dynamics of the markets in which they operate. The business strategies identified show a clear segmentation according to the type of company, with emphasis on structured planning for traditional companies and iterative adaptability for digital ones.

The Business Plan was consolidated as the most frequent model among traditional strategies, confirming its relevance as a robust tool for market analysis, financial projections and strategic decision making. This model, applied in publications such as Bachmann and Jodlbauer (2023) and Katsikeas et al. (2020), reaffirms its usefulness in stable contexts, where companies seek to minimize risks through exhaustive planning. However, the limitations of this model in terms of flexibility highlight the need to complement it with more dynamic tools, such as the Action Plan, which allows the translation of strategies into concrete and measurable tasks, as observed in the findings of Cavallo et al. (2021).

In contrast, digital models, led by the Lean Startup, reflect a more innovation and customer-centric approach. The publications of Ferreira et al. (2022) and Centobelli et al. (2022) highlight how this model facilitates rapid iteration and continuous validation of hypotheses, crucial aspects in highly competitive and changing markets. This approach finds a complementary application in the *Canvas* Model, used to visualize in an agile and

structured way the key elements of a business, as shown in the studies of Zhang et al. (2022) and Guo et al. (2022). On the other hand, Customer Development, although less frequent, stands out for its focus on direct interaction with customers from the early stages, as evidenced by Stallkamp et al. (2022) in the context of international expansion.

The comparison between traditional and digital models also highlights significant differences in their level of flexibility and strategic focus. While traditional models tend to be more rigid, prioritizing the optimization of internal resources, digital models are inherently dynamic, allowing for quick adjustments and prioritizing the customer experience. These results are aligned with previous research, such as Blank and Dorf (2012) and Ries (2013), which emphasize the importance of adaptability in digital startups.

However, one of the main observations of this study lies in the areas of opportunity for hybridizing approaches. For example, although traditional models, such as the Business Plan, stand out for their structure and completeness, their integration with agile methodologies such as Lean Startup could increase their responsiveness to rapid changes in the business environment

market. Similarly, digital companies could benefit from incorporating more detailed strategic planning elements typical of traditional models to ensure sustained growth.

In addition, this study highlights certain regional and contextual differences. While the adoption of Lean Startup is consistent with international trends, the lower presence of approaches such as Customer Development in some markets may reflect limitations in the adoption of customer-centric methodologies. This suggests that local dynamics and cultural barriers may influence the implementation of certain models, which requires further research to better understand these discrepancies.

As a proposal for continuity, it is recommended that the analysis be expanded by incorporating specific case studies and evaluating the effectiveness of hybrid models in different economic sectors. In addition, future research could explore how global trends, such as digitalization and sustainability, are reshaping companies' preferences and needs when choosing business models. This would allow for a more comprehensive and contextualized approach to strengthen organizational development in a constantly evolving global marketplace.

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Conflict of Interest

The authors declare that they have no conflicts of interest that may have influenced the results or interpretation of this study.

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USE OF SOLAR PANELS IN PLAYA DEL CARMEN MEXICO
USO DE PANELES SOLARES EN PLAYA DEL CARMEN MÉXICO

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	ABSTRACT
Keywords: solar energy, sustainability, solar panels, environment.	Given the growing demand for energy in Playa del Carmen as a result of the growth that the international tourist destination has had in recent years, interest in renewable energies has been promoted, especially solar energy. This study analyzes and proposes the implementation of solar panels in the region and its environmental and economic impact, as well as the domestic viability of the use of this technology. Solar panel installation has increased by 40% since 2019, with most users reporting a 30-50% reduction in their electricity bills. Furthermore, 70% of respondents were willing to recommend this technology to others, highlighting its contribution to reducing the local carbon footprint. The results show that the use of solar panels is not only viable, but also beneficial for the local economy and the environment. Government incentives and the high solar potential of the region are key factors that encourage their adoption, however, there has been a lack of knowledge in some sectors about the use of this technology, which in the face of previous stereotypes has slowed down its use, educational and dissemination campaigns are therefore required to inform about its benefits, its uses and procedures in addition to the facilities that allow recovering the initial investment and promote the use of technology in the home environment.
	RESUMEN
Palabras clave: energía solar, sostenibilidad, paneles solares, medio ambiente.	Ante la creciente demanda de energía en Playa del Carmen producto del crecimiento que el destino turístico internacional ha tenido en los últimos años, se ha impulsado el interés por las energías renovables, especialmente la solar. Este estudio analiza y propone la implementación de paneles solares en la región y su impacto ambiental y económico, así como la viabilidad doméstica del uso de esta tecnología. La instalación de paneles solares se ha

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incrementado un 40% desde 2019, la mayoría de los usuarios reportaron una reducción del 30-50% en sus facturas eléctricas. Además, el 70% de los encuestados mostró disposición para recomendar esta tecnología a otros, destacando su contribución a la disminución de la huella de carbono local. Los resultados evidencian que el uso de paneles solares no solo es viable, sino también benéfico para la economía local y el medio ambiente, Incentivos gubernamentales y el alto potencial solar de la región son factores clave que fomentan su adopción, sin embargo, ha existido un desconocimiento en algunos sectores sobre el uso de esta tecnología, lo que ante estereotipos anteriores ha desacelerado su uso, se requieren entonces campañas educativas y de difusión que informe sobre sus beneficios, sus usos y trámites además de las facilidades que permitan recuperar la inversión inicial y promover el uso de la tecnología en el ámbito doméstico.

Introduction

In this article an extensive analysis of secondary sources was carried out to generate a cross-sectional descriptive documentary research, initially giving a context that goes from the general to the particular of renewable energy as well as its concept, current situation and benefits; based on the documentary research, the feasibility of the use of solar panel energy in the Riviera Maya, in the city of Playa del Carmen in the municipality of Solidaridad Quintana Roo, Mexico, is analyzed.

The inertia of constant change seems to have no end before the immensity of the universe, the constant discoveries and research, as well as the new theories, the knowledge accumulated over time and the constant innovation in all areas, not only evolve day by day, but second by second, perhaps as a response to the immensity previously mentioned, since, as Francis Bacon points out, the human being enters into a dynamic of participative evolution that allows giving order to scientific research and theories, developing them to solve the unknowns of our universe; of course, the curiosity of the human being has always been the ambitious engine of such evolution (Bacon, 1779). However, at times, paradoxically, we see omissions of previous knowledge or theories, some significantly basic, that seem to disappear with the passage of time or intentionally and that would allow us to return to the basics, giving a greater context to the present and the future.

Concepts or postulates conveniently disappear or are lost in time if they favor some interests and in some cases knowledge and theories or practices of the optimal use of natural resources that have been accumulated over time have significant omissions, again in favor of the interests of a few, although it is also convenient to point out that not always all common practices promote common benefits; human beings seem to have, among several of their differences with other beings, the capacity to convert into a communicable experience every experience they get from the reality that surrounds them, but the weight of generational or personal interests can stop the evolution in search of a common welfare (Cordón, 1991).

It would be convenient then to think that in order to achieve the closest thing to a balance in the use of resources it is vital of course to understand and not forget the past, but also to have a deep knowledge of the present and adapt all the knowledge poured throughout the history of humanity in favor of it towards the future, thus promoting a mix of asymmetric and timeless time thinking (Stokes, 2016). A thinking that allows to obtain the best of the past, including the most representative mistakes, to adapt incessantly to the present, but always considering the future and detonating actions that transcend in time beyond today, taking into account the aspects that the environment, in time, will bring with it, but also, in an essential way, always keeping in mind the premise that resources "ARE NOT INFITIMATE".

On the benevolent side of the application of knowledge in favor of the common good, we can say that, as of 2015, global renewable energy consumption has increased by an average of 2.3%, which allowed for stable carbon emissions as a consequence of relatively stable energy consumption and economic growth. According to the International Energy Agency (2017), the cited effects are linked to an increase in renewable energy (RE) penetration in addition to improvements in energy efficiency.

Method

Importance of Renewable Energy

Recognition of the importance of renewable energy and energy efficiency has been permeating the planet thanks to globalization, highlighting their role as key strategies to combat climate change, in addition to the generation of new economic opportunities and the social function that provides access to energy to millions of people who lack modern energy services; in 2014, the United Nations General Assembly issued a declaration calling for a decade of sustainable energy for all (SE4ALL), encouraging the quest to increase the share of renewable energy sources in the energy system from 18% in 2010 to 36% in 2030. (Ballesteros, 2016)

According to the International Renewable Energy Agency (IRENA) it has been estimated that RE grew approximately 19.3% of global energy consumption in 2016; renewable energy sources such as biofuels, wind energy, solar photovoltaic, hydroelectricity and solar thermal are the most used resources for cooking or heating in some remote or rural areas in developing countries and only 10.2% of these sources are considered as renewable energy (REN21, 2017).

Canada, Denmark, Germany, Spain, the United Kingdom and Brazil have undertaken actions focused on the development of technologies that enable the use of a large number of renewable resources to produce energy; analyzing this international experience it is possible to glimpse that renewable energy becomes a priority in the energy agenda and not only in developed countries but in those that are on that path, even in all those countries that have emerging economies since the positive impact on the environment and society and therefore the economy is undoubted (Olabi, 2016).

Context of Renewable Energies in the World

In the scientific context and in the quest for new discoveries, research has been carried out dating back to the nineteenth century, the idea of harnessing energy in the environment dates back to 1838 where the French physicist Alexandre Edmond Becquerel conducted experiments that allowed him to discover that through the use of sunlight using two metal electrodes was possible to generate electricity and for the year 1866 the French researcher Augustin Mouchot would create the first parabolic solar collector, which by capturing solar rays that were concentrated by a set of mirrors heated the water in a boiler, at the time of boiling generated steam that powered a motor. It is evident that the resources of other times have been consumed and today scientific efforts concentrate their projects on the postulate that conventional energy sources are no longer as profitable compared to alternatives, this as a result of increased cost competitiveness; today renewable energies are more frequent and used and their profitability is being increasingly recorded in rural areas that are generally likely to have limited access, which strengthens their role in the provision of essential energy services and support to the productive sector (Robles and Rodriguez, 2018).

Renewable energies are thus a pillar in the clean energy transitions that have increased due to their deployment in the heat and transportation energy sectors, which is one of the main enablers of keeping the increase in average global temperatures below 1.5°C; in the Net Zero Emissions scenario, it is proposed that by 2050, renewable energies will enable almost complete decarbonization of electricity generation. Meanwhile, renewable transport fuels and renewable heat contribute to significant emission reductions in transport, buildings and industry.

Consistent with what was described at the beginning of this article, it is pertinent to point out that renewable energies have advantages and disadvantages, some of which

are shown in the following table:

Table 1
*Renewable energies advantages and disadvantages*

Renewable energies	
Advantages	**Disadvantages**
They are considerably clean and are valued as fundamental tools against climate change since they do not emit Greenhouse Gases.	Some renewable energy sources are intermittent (solar, wind) and there is no operational control because they operate when the resource is available (i.e. they require other support sources to guarantee continuous production, sometimes these support alternatives can be fossil fuels or hydroelectric power plants).
Due to their nature of being inexhaustible resources, they strengthen the energy independence of the regions.	Some renewable energy sources require construction of considerable dimensions that affect the ecosystem where they are implemented, such as wind farms, which can modify the environment and produce vibrations or noise.
When biomass is produced, it is decentralized, which can support the reduction of external dependence on primary fossil fuels, since it has a high degree of technological development and its long-term supply is reliable, allowing the development of small and modular projects distributed geographically.	The shadow effect of wind turbines, like the rest of the tall structures, will cast a shadow on neighboring areas when the sun is visible, which can alter the ecosystem or even affect the performance of a solar energy source if it is to be used.
By 2040, solar and photovoltaic energy are expected to provide more than half of the additional electricity generation under the current scenario of established policies and sustainable development.	Wind turbine structures and turbine rotors can affect the habitat and fauna, changing their habits or even causing accidents when they collide with them.
Offshore wind energy has a high technical potential to meet the current and future electricity demand, it has great advantages such as the maximum use of higher wind speeds with less variability.	Designing materials that can withstand extreme marine conditions is perhaps one of its main challenges, in addition to subsequent maintenance.
They are sources of employment in the localities where they are used, and have also reduced their costs,	It is not possible for them to be available in every type of territory and sometimes it is not possible to

making them more competitive.

change their location, there is no standardization and each region has a different availability of natural resources that allow their use, which causes a variation from one source to another in obtaining energy.

In a context of preservation, the growth rates of renewable energies in the world have grown gradually, it is true that some regions and companies continue with environmentally unfriendly practices, enriched with information to carry them out that is transmitted as mentioned globally; however, the pressure of the common good even if not forcefully seems to influence more and more allowing the rates of growth rates of renewable energies to grow gradually and diversify in the different alternatives to make use of it as we see in Figure 1 that compiles information during the period 2007-2012 (REN21, 2015).

Figure 1
Annual growth rate of renewable energies (2007-2012)
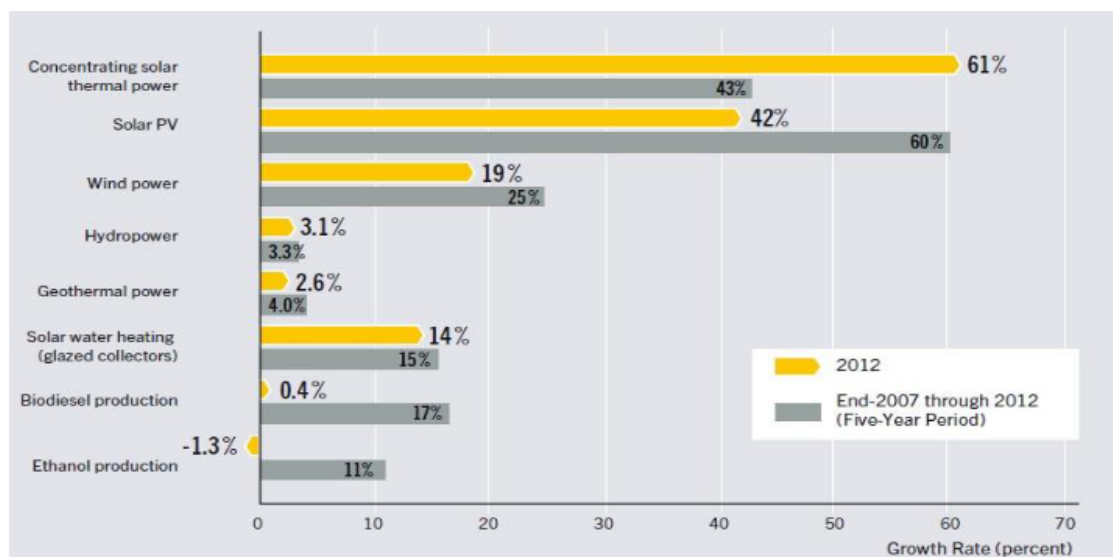
Note. Wind and photovoltaic are the types of renewable energy that have shown the greatest acceptance and use in the period from 2007 to 2012. Taken from RENEWABLES 2015 GLOBAL STATUS REPORT, https://www.ren21.net/wp-content/uploads/2019/05/GSR2015_Full-Report_English.pdf

86% of power generation capacity in Europe is attributed to renewable energy sources, particularly wind and photovoltaic (REN21, 2017). In 2014, Germany's share increased to 24% from 10.5% in 2010; on the other hand, renewables are responsible for about half of Scotland's electricity production (REN21, 2015).

The U.S. renewable energy sector contributed to more than 15% of electricity generation, wind and photovoltaics produced electricity significantly, but bioenergy generation remained stagnant (REN21, 2017).

Brazil for its part occupies the first position in new installed renewable energy capacity in Latin America and the Caribbean, with 2.5 GW of generation capacity with wind power by 2014 (REN21, 2015), while Uruguay is the country that has added the highest wind power generation capacity per capita. By 2016, wind energy accounted for 22.8% of the country's total electricity consumption (REN21, 2017).

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The installed capacity of renewable energy is the largest in Asia, China is the country with the largest solar, wind and hydropower production capacity while Thailand has already surpassed European countries in solar power production and Pakistan in addition to the Philippines have significantly increased their wind power capacity (REN21, 2015).

With 59% of Australian electricity generated by hydropower plants and 32% by wind power, Australia has the largest share of renewable electricity capacity in the Oceania region (REN21, 2017) and Africa has seen an increasing number of renewable energy installations, in fact currently, South Africa is undertaking the first wind power installations and has secured its place in the top 10 solar power markets, ahead of India. and that Kenya having more than half of the world's installed geothermal capacity (REN21, 2015).

The challenges facing renewable energies mainly concern the electricity sector, which continues to be the sector with one of the most sustained growth rates, based on solar photovoltaic and wind energy, which have grown significantly in recent years, clearly taking advantage of the already significant contribution of hydroelectric energy; however, electricity represents only one fifth of global energy consumption and finding a more important role for renewable energy sources in transportation and heating remains fundamental for the energy transition.

Renewable energies are a resource with a much broader and to some extent inexhaustible use and consumption scheme compared to fossil fuels, promote self-sufficiency in the country's energy matrix, are less harmful to the environment and support the reduction of climate change; therefore, the complex interconnection of sustainability and energy is today the basis for transformation processes that seek to change the way societies behave as well as global goals, the environmental crisis can only be addressed by reaching a deep and meaningful agreement between nature and humanity, while seeking to reverse the effects caused by pollution and disproportionate anthropogenic global warming. The seriousness of the problem poses a global mobilization factor for society and opens the door to other forms of environmental and cultural assessment (Perino et al., 2021).

Types of Renewable Energy

The UN defines renewable energies as energies derived from natural sources that can be replenished faster than they can be consumed, such as wind and sunlight, which are considered to be relatively abundant sources of self-renewal in certain ecosystems. Generating renewable energies produces a considerable lower amount of emissions compared to burning fossil fuels, which is why switching to renewable energies is essential to influence the crisis caused by climate change (UN, 2024).

Table 2 shows the general characteristics of each of the types of energy, where it is evident that their generation and classification is related to the source or natural resource from which they obtain the engine that drives them:

Table 2
Types of renewable energy.

Bioenergy	This energy is obtained from biomass, i.e. organic matter such as forestry, agricultural or livestock waste, rapidly rotating forest plantations, energy crops, organic components of municipal solid waste and other organic waste (Edenhof, 2011).
Solar energy	It comes from the sun and the electromagnetic radiation it produces is used directly with technologies developed to capture such radiation by means of cells, photoelectric cells, solar collectors or heliostats (Vivanco, 2020).
Geothermal energy	It is obtained from the heat available in the earth's interior. The steam output from the planet's interior is used to drive turbines. The required groundwater temperature has to be above 150°C (Schallenber, 2018).
Hydropower	It generates electricity by storing water in reservoirs or lakes and as the water moves at lower elevation levels over a period of time, the moving water produces kinetic energy, which is then converted into electrical energy through its flow in a hydroelectric power plant.
Wind energy	It is the energy produced by the movement of air masses or wind, thanks to which turbines, blades or devices that eventually produce energy move. During the day, the lack of density causes the air masses to heat up and rise, which contrasts with the cold air of the oceans and lakes, causing movement and winds (González et al., 2022).

America and Mexico in Renewable Energies

The Latin American and Caribbean region is one of the richest sources of renewable natural energy in the world where non-conventional renewable energy has great potential, in fact, it is estimated that the region could meet the energy demands of the economic growth of the entire area if it used only a small portion of its non-hydroelectric renewable capacity (Centro Mexicano de Derecho Ambiental, 2017), and although the region continues to rely on fossil fuels and hydropower Latin America and the Caribbean is experiencing a strong silent and complex movement in the renewable energy sector is slow progress (Tejeda et al., 2007).

In addition to renewable energy, countries continue to explore non-renewable technologies such as hydraulic fracturing to take advantage of oil and gas reserves with an estimated expenditure of more than 40 billion dollars to subsidize fossil fuels in the region, which shows that traditional energy sources will not disappear very soon in the Americas or in other parts of the planet (WWF, 2014).

However, the renewable energy market is growing rapidly as the region has great potential, Costa Rica, Uruguay, Brazil, Chile and Mexico represent efforts in the region to accelerate the necessary paradigm shift, according to the World Wildlife Fund, only 6% of the region's energy comes from modern sources, including solar energy, wind energy, biomass energy and geothermal energy, yet this figure is expected to reach 20% by 2050 (WWF, 2014).

Latin America is currently a fast growing region for renewable energies and there is a growing interest in developing this type of resource as its context is framed by a constant high electricity prices in most regions and on the other hand the increase in demand with some export potential, which provides a fertile ground for the use of renewable energy technologies, let us not forget that the region has a long history of hydroelectric generation, which drives support in policies and laws, i.e. power generation is the area that receives the most attention in renewable energy policy and legislation promoting its use by establishing renewable electricity production targets, tax incentives, grid access provisions and financing services and tariff reduction policies, (Robles and Rodriguez. 2018). Currently, most countries in the region already have legislation in the renewable energy sector, with the exception of Bolivia, Guyana and Suriname, which do not yet have programs in this sector (Robles and Rodriguez, 2018).

The establishment of national renewable energy targets provides a clear picture of the status of renewable energy development and the government's planned timeline. Targets can be expressed in a variety of formats, such as capacity in MW or MWh relative to generation or relative numbers, an example of this according to data from REN21 (2015), is that Ecuador had a target of reaching 90 RE in 2017 and a hydroelectric generation target of 4.2 GW in 2022.

This type of energy is still in its initial stages in Mexico, and although the regulatory and institutional framework is good, there are still obstacles to overcome that make it impossible to deploy renewable energies and expand their use. The country is undergoing an energy transition that is consistent with a change in the direction of the energy sector, seeking to diversify primary energy sources and increasing the participation of renewable energies as the main source of energy in the national territory, the main reasons for this transition are the excessive dependence of the Mexican economy on hydrocarbons, as well as the negative environmental impact of the use of conventional energy and the guarantee of energy security (Zúñiga et al., 2017).

In line with the objectives and strategies established in the National Development Plan 2007-2012, the Energy Sector Program 2007-2012 aims, among other things, to balance the portfolio of primary energy sources, promote the use of renewable energy sources and biofuels, and address the energy issue, to attack alleviate the increase in greenhouse gas emissions and to achieve these objectives, PROSENER defines a medium-term strategy and script.

Discussion on the Relevance of Solar Energy and Solar Panels

The photoconductivity of selenium was discovered by the Englishman Willoughby Smith, who in his experiments noticed how the conductivity of selenium rods increased exponentially when exposed to intense light, which led his compatriots Richard Evans Day and William Grylls Adams to create the first selenium photovoltaic cell, the amount of light we receive from the sun is undoubted and its use since then has attracted the attention of scientists; The amount of energy that reaches the Earth from the Sun per year is 175.the amount of energy that the human being consumes is 17 TW, but only if we take advantage of the energy of this star.

In this context Mexico is a great place for renewable energies since there are regions where the radiation is 130 watts per square meter, Germany is one of the main nations that generates more electricity through photovoltaic systems in the world, although it receives half the solar irradiation of Mexico, the electricity production in Mexico is less than that of Germany, a few years ago this production was only about 100 MW and is currently estimated at 2,015 MW which shows a considerable growth (s.a., September 14, 2023).

From 2007 to 2012, the total installed capacity in the world for some renewable energy sources increased significantly and rapidly wind energy increased installed capacity by just over eight times, while geothermal energy has increased by just over a third compared to 2001 however solar energy increased it by 38 times (Upton & Snyder, 2017).

In this order of thought, we find that solar energy is undoubtedly one of the fastest growing technologies not only in the aforementioned period but also in 2012, with global efforts in research and development in this field (Manzano et al., 2014). Further evidence of solar PV progress is provided in Table 3, which shows the global capacity for solar PV over the period 1995 to 2012 (Mercure et al. 2011).

Renewable energy has been gradually replacing conventional fuels in five different markets: electricity generation, water heating, space heating, transportation fuels, and power supply in off-grid rural centers (Tsai et al., 2017). Table 3 identifies the advantages and disadvantages of photovoltaics.

Table 3
Advantages and disadvantages of photovoltaic solar energy.

Photovoltaic solar energy	
Advantages	Disadvantages
Clean, renewable, infinite and silent	Large initial investment
Economically remunerated to production for sale to the grid	Difficult to store
Subsidies	Complex and costly module manufacturing process
Short energy pay-back	Not competitive with other energies at present
No moving parts and modular	Variable production according to climate and time of year

Note. Photovoltaic Solar Energy. (2007, December). Official College of Telecommunications Engineers: https://www.coit.es/sites/default/files/informes/pdf/energia_solar_fotovoltaica.pdf

As mentioned above, photovoltaic solar energy is received through panels or solar cells of which there are up to four generations, the first of silicon, the second of thin film and the third of copper, gallium and selenium, where efficiency is similar, the last generation of photovoltaic cells are the organic ones.

The third and fourth generation cells can be used in windows, suitcases and clothing, the difference between these devices and the first generations is that the latter absorb light and have equipment that can charge mobile devices. The next generation of solar cells is intended to be more efficient, since most modern organic cells, in addition to being flexible and semi-transparent, are already created by design and the challenge is to make them stable so that they can be easily replaced if they fail.

In 2003 the cost of producing solar energy was seven dollars per watt, so the return on investment was long term, in addition to the need for backup or storage for night and day use, i.e. the area of opportunity lay in the storage capacity of the energy generated, the weakest point of photovoltaic systems. The production of one watt in pesos was 75.53 pesos, as a consequence of the exchange rate, while the cost of solar panels in the United States was US$3.50 per watt and in Mexico it was US$6.65 per watt.

Evidently with this information it was to be expected that there were important budgetary limitations that made this type of energy generators which meant that it was

restrictive and only available to some, but in the last three years, the cost of solar panels has dropped about 60%, so that the average price of 1.81 dollars per watt was reduced to 0.7 dollars per watt, the cost per watt between 22.9 pesos in 2007 and 8.8 pesos in 2010 evidently the variation also responded to the exchange rate of the US currency at that time.

The use of solar panels has made it possible to document their benefits and highlight some good practices in various parts of the world, among which we can mention Freiburg, Germany, which is a global benchmark in the use of solar energy and urban sustainability, since the city has integrated solar panels in public and private buildings, maximizing solar collection and thanks to local policies, new developments must include photovoltaic systems or comply with energy efficiency standards, thus achieving a significant reduction in carbon emissions through a combination of renewable energy and sustainable transportation where residents actively participate in solar cooperatives, sharing the energy generated and reducing costs. Power, G. (2016, August 31) Isabel. (2024, December 18).

Another notable example is San Diego, United States, which is a leader in the use of solar energy in North America with energy equity programs, "San Diego Solar Equity Program" that facilitates access to solar panels for low-income families, covering up to 100% of the cost of installation, in addition to offering subsidies and financing for residential solar installations, which has driven its massive adoption, San Diego is one of the cities with the highest installed capacity per capita in the U.S., thanks to local policies that encourage the energy transition. Ini, L. (2022, 12 August), Admin. (2024, October 3)

Singapore and Barcelona are 2 other examples that have made a successful implementation in the use of solar energy, Singapore on the other hand combines urbanization with sustainability, due to limited space, makes use of building integrated solar panels (BIPV), such as photovoltaic windows and green roofs with solar systems, in addition to implementing floating solar projects to maximize the use of water as an energy generating surface. GetSolar. (2024, 4 July), Granda, C. (2024, 14 June). Barcelona, Spain has had a mandatory regulation since 2006, which requires the installation of solar thermal panels in new buildings and major renovations as well as encouraging collective projects where communities share the energy generated by common solar systems. (S/f). Sotysolar.es. evoconfort. (2025, January 13).

In Mexico, participation in projects related to this type of energy has increased in photovoltaic energy generation in states such as Sonora, Baja California, Baja California Sur, San Luis Potosí, Guanajuato, Chihuahua, Coahuila, Yucatán, Jalisco and Morelos.

Now, talking about this type of energy in a domestic environment we can find that, in the United States, a solar system for a house cost between $15,000 and $29,000 depending on the user's consumption, it also represented more than half of the average household income, so the government applied fiscal policies to help the dynamism of the solar sector and the panel market.

Previously, the cost of producing one watt of solar energy was $1.7 in 2017, so the supply has increased and the costs in the market are lower, i.e., companies, industries and families are increasingly opting for the installation of photovoltaic systems thanks to the reduction of costs and government support, with the cost of solar production being 32.16 pesos per dollar.

For 2019, the cost of solar energy was US$0.244 per watt and the average annual exchange rate was 19.24 pesos per dollar, meaning that better prices can be offered for their photovoltaic systems. The payback period for the investment in solar energy can be reached in 3 years, taking into account the price, the cost per watt in Mexico was 2.23 pesos in 2020, in the last 20 years, the cost of solar panels has gone down, making them

affordable for families and their domestic use. In addition, storage batteries are no longer necessary.

The solar panel has a 20-year warranty, if there are no faults in the solar panel after installation, the supplier company will no longer need to contact the customer; however, some companies offer additional services after installation, such as monitoring the photovoltaic system to see at what times of the day it is producing more solar energy or simply indicating that the system is working properly.

The management in Mexico with the Federal Electricity Commission (CFE) has changed since 2014 with the National Program for the Sustainable Use of Energy (PRONASE), which together with the Special Program for Climate Change 2014-2018 authorizes the installation in the home or business its own Distributed Generation Power Plant and Distributed Clean Generation of less than 0.5 MW, through its management makes an interconnection contract with CFE Basic Services Supplier. In order to make the request for the interconnection contract for a power plant with a capacity of less than 0.5 MW that were published in the Official Gazette of the Federation on March 7, 2017, the following is requested:

- Interconnection Request.
- Map of the geographic location of the Power Plant and geographic coordinates.
- One-line diagram of the Power Plant and Load Centers that will share the same Interconnection/Connection point.
- Technical data sheet of the generation used (generator technology).
- Data sheet and certificate of the power inverter or current matching system
- Copy of the last receipt, without debts.

Once the solar energy panels are installed, a bidirectional meter is installed, which is basically a meter with similar characteristics to the conventional ones, the difference is that it supports two sources of electricity supply, the bilateral connection allows the user to consume energy from the CFE in the event that it does not generate the amount of energy required for its consumption, it should be noted that in the case of generating more energy than the user needs, this is sent to the CFE and the bilateral meter makes the record so that you get a credit balance.

Below is an image of how the installation could look in a house, taking into account that the wiring is hidden over the electrical spaces for the light installations of the house (Figure 2).

Figure 2
Example of installations in a house

Results

Conclusions

It is evident that the use of solar energy in the domestic sphere is one of the markets with the greatest potential in Mexico. The current costs, as well as the policies and administration of this type of energy alternative allow more and more users to select it as an alternative that not only has less impact on the environment but also promotes savings and eventually the recovery of the investment is relatively short depending on the user's consumption. In Mexico there are several institutions that finance and promote photovoltaic systems for the housing sector, MSMEs and agribusinesses, these institutions have lists of reliable suppliers, which are verified through third parties or by the institution itself.

The presence of more than 600 companies that have entered the distributed photovoltaic generation market in Mexico was identified, but the information reported in these portals does not necessarily reflect the total universe of companies with participation in the Mexican market, there are at least 28 national and foreign companies that manufacture photovoltaic panels that are certified with the FIDE seal.

A registry of 563 project development companies was created by FIRCO, an institution that has supported the installation of photovoltaic systems in agribusiness, the states with the highest concentration of companies are Sonora, Jalisco, Nuevo Leon, Chihuahua, Sinaloa, Mexico City, State of Mexico and Baja California (Gerardo, 2023).

Today the costs of storing generated energy have also changed in price, technology has improved and this has allowed greater efficiency, Table 8 presents the solar energy storage options we can find.

Table 8
Solar photovoltaic energy storage options

Battery type	Cost	Charging time	Typical capacity	Number of cycles	Annual maintenance cost
Lead-acid	$1,000 - $3,000	8 to 10 hours	50 to 200 Ah	300 to 500 cycles	$500 a $2,000
Nickel-cadmium	$2,000 - $8,000	3 to 5 hours	20 to 100 Ah	500 to 1000 cycles	$1000 a $2,500
Nickel-metal hydride	$3,000 - $9,000	4 to 6 hours	50 to 200 Ah	500 to 2000 cycles	$500 a $2,000
Lithium ion	$5,000 - $15,000	2 to 3 hours	50 to 100 Ah	4000 to 10000 cycles	$1000 a $4,000
Gel	$4,000 - $12,000	8 to 10 hours	50 to 200 Ah	1200 to 1500 cycles	$500 a $2,000
Nickel-iron	$5,000 - $13,000	6 to 8 hours	20 to 100 Ah	2000 a 3500	$300 a $1,200

Note. Characteristics of batteries for isolated photovoltaic systems in rural areas of the department of Santander, Colombia. (n. d.). Santander Technical Units.

Regarding the types of panels we can find great diversity that adapts to the budget and needs of each user, for example:

Flexible solar panels

Probably one of the most pointed out disadvantages of the cost for solar panels are their dimensions, but today this has not been an impediment to promote their innovation, since currently portable flexible solar panels have been developed, whose sales proposal includes their use in:

- Start-up of recreational vehicles and automobiles
- Solar battery chargers
- In homes due to its low cost
- Outdoor expeditions or activities where there are no power plants.
- These are considered to be the best solar panels to be used on maritime vessels as they can be used for are fully waterproofed, which allows them to withstand salt water from the sea

Flexible panels have the following characteristics:

Polycrystalline flexible solar panel

Composed by the union of silicon crystals, they have a fast manufacturing process and are more economical because they use less materials in the production process, they are currently the most known worldwide, they are ideal for use in residential areas and their heating process is very agile and fast, they have a dark navy blue color when they are receiving sunlight.

Flexible monocrystalline solar panel

Their cells are manufactured with high purity silicon crystals, they are blackish in color and have rounded edges, one of the disadvantages is that their manufacture is very slow and their energy expenditure is higher, however, they are characterized because they have a fairly high performance in low light areas, their useful life can be up to 50 years, they are more efficient, but equally, they are more expensive.

Flexible crystalline solar panels

Their cells are manufactured with the same silicon as conventional panels, they are the most common with the only detail that their photovoltaic cells are flexible.

Semi-flexible solar panel

They are quite efficient, usually use 12v batteries, are ideally used to carry out trips both on land and at sea, usually domestic, taking advantage of the lightness they have since they do not weigh more than 2 kilos, they are more expensive than rigid solar panels.

Thin film flexible solar panels

It is a new technology that works by printing the photovoltaic material and then adhering it onto a thin surface, however they are considered to have a shorter lifetime as they lack the protection of silicon.

Costs:

- Flexible solar panel kit. It exceeds $500 and has a range of up to 248 degrees.
- Extremely flexible 12v solar panel. it is around $200 but has the ability to be installed on the curved roof of an air flow
- Flexible solar panel 120w 4. is close to $600 and has a crystal with high light transmission anti-reflective properties,
- Flexible solar panel 200w. costs 170 dollars approximately and has a 10 A current controller.
- Flexible solar panel 300w. its price is around 1000 dollars and has a maximum power in STC (Pmax) of 100w and a maximum voltage of 1000 V DC.
- Flexible solar panel 400w. priced at $450, it offers a high quality silicon material that allows for greater reliability and stability.
- Flexible solar panel 500w. its cost is less than $ 90 has a life of up to 20 years and has a double monocrystalline silicon.

Regardless of the alternative for the user's physical and economic environment, the use of alternative energy generation not only benefits the planet and the user's economy, but it can also gradually make the user independent of energy consumption and payment by using adequate storage sources, in economies of such dizzying growth as the case of Playa del Carmen, located in the Riviera Maya, Quintana Roo and recognized as an international tourist destination that attracts millions of visitors and therefore thousands of people seeking work each year and has generated a growing demand for energy, which has led the region to face significant challenges in terms of sustainability and environmental management, the use of solar panels could impact the dependence on traditional sources of energy, such as fossil fuels, which not only increases energy costs, but also contributes to pollution and therefore climate change.

A testimony of the impact on the acquisition of this type of energy can be found in the case of the Vera family who established their residence in Playa del Carmen 10 years ago and until a few months ago they acquired a house that they rented, the new house is significantly larger than the apartments where they lived and the cost they paid for electricity was around $1500 Mexican pesos bimonthly, with peaks in hot seasons that reached up to $2400 pesos, however, the new house represented new challenges, since it has 3 floors, for the moment they acquired 3 air conditioners, 2 of 8000 btu British thermal unit that can cool a room of between 4 and 8 square meters each and another air conditioner with a capacity of 16000 btu that cools twice as much, on each floor an air conditioner was installed and with the experience they had had they decided to acquire solar panels; as part of the requirements established by the CFE to install the bidirectional meter, an initial billing is required, so the first payment they made without panels was $4495.61 and with the use of solar panels their payment today is $63. The family says that even when they have the technology they take care of their consumption, however they feel less pressure to receive high bills, the investment in solar panels was worth it.

The use of solar panels is presented as an innovative and effective solution to mitigate costs, solar energy is a renewable source that uses solar radiation to generate electricity, and its implementation in Playa del Carmen has gained momentum in recent years. Thanks to its warm and sunny climate throughout most of the year, the region has ideal conditions for maximizing the efficiency of photovoltaic systems. The adoption of solar panels not only represents an environmentally friendly and sustainable alternative, but also offers considerable economic benefits; the initial installation costs are being offset by savings on electricity bills and government incentives that encourage the use of renewable energy. In addition, it is estimated that each PV system installed contributes significantly to the reduction of greenhouse gas emissions, helping to combat climate change.

As more residences, hotels and local businesses opt for this technology, Playa del Carmen is positioning itself as a leading example in the transition to a more sustainable energy model. This trend not only improves the quality of the local environment, but can also positively influence the tourist attractiveness of the destination by aligning with the growing expectations of environmentally conscious travelers. In addition, the economic benefits of savings are significant, and although they depend on the average consumption, they give us an idea of the significant savings and return on investment, in this context it should be noted that the cultural environment also plays a role, i.e. not by having panels you will spend more than what you are used to spending.

Returning to the case presented and comparing the billings before and after the use of solar panels, we see that this home on average spent 1355 (kwh) bimonthly without solar panels, which is equivalent to $4495.61 Mexican pesos per bimonth, if it continued with its average consumption, which is unlikely given the hot periods where there are

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consumption peaks, annually would be paying $26,973.66 Mexican pesos, that is, if the price per kilowatt were to remain the same, i.e. his annual consumption would be around 8,130 (kwh); today that same household by using 5 solar panels is having a registered bimonthly consumption of 330 (kwh), equivalent to $63 Mexican pesos, about $378 Mexican pesos per year, if we take into account that this consumption has a surplus in favor of the energy generated with the panels and that accumulates to the following period, if we consider that the cost of the panels and installation was $50,000 Mexican pesos, the house is recovering its investment in approximately 22 months, which is totally sustainable in the medium term.

Within the promotion of the use of this type of technology in the state of Quintana Roo, initiatives and public policies have been carried out as well as several projects and efforts where we can include the State Plan for the Promotion of Energy Efficiency and the Use of Renewable Energy Sources (PLANFEER), which promotes not only the use of solar energy but also the efficient design of urban housing and a decrease in deforestation as well as a reduction of waste and energy production with waste; another initiative is the second state-promoted call for Quintana Roo companies to benefit from a financing fund of 15 million dollars to be used in the installation of photovoltaic systems that will allow them to save around 30% of their current invoicing, ensuring that there is no initial investment and obtaining an incentive of 6 months of free energy production. An agreement has also been established with the Word Resources Institute (WRI) to implement energy efficiency measures and update construction regulations, and the Renewable Energy Laboratory (NREL) of the United States has conducted research in the Yucatan Peninsula to enable the transformation of the electricity sector. Joaquín, P., & Joaquín, P. (2021, October 30). The Quintana Roo Welfare Secretariat (Sebien) has awarded Energain de México a contract that will allow 405 solar panels to be installed in 221 homes in the municipality of Solidaridad, where Playa del Carmen is located. Pantoja, H. (2024, 12 August). In summary, the use of solar panels in Playa del Carmen already represents a key strategy to address current energy challenges and promote a more sustainable future, the combination of abundant natural resources and a growing commitment to continuous and persevering private and governmental green practices would put this city on the path to a greener and more sustainable economy (Guevara, 2023).

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STRUCTURAL REINFORCEMENT TECHNIQUES IN HERITAGE BUILDINGS FOR ADOBE MASONRY FOR A CORRECT INTERVENTION
TÉCNICAS DE REFORZAMIENTO ESTRUCTURAL EN EDIFICACIONES PATRIMONIALES PARA MAMPOSTERÍAS DE ADOBE PARA UNA CORRECTA INTERVENCIÓN

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Keywords: mortars, mucilage, lime, wooden staples, mud injection	**ABSTRACT** This research presents a structural reinforcement method suitable for heritage structures featuring adobe walls compromised by fissures. The intervention involves the employment of traditional materials and techniques including: lime, clay, wild grass, and nopal mucilage for mortars and grouting. The applied methodology follows a quantitative approach, focusing on an experimental design, and was implemented in this structural reinforcement to restore masonry affected by cracks caused by settlements, seismic movements, or material fatigue within the wall, leading to a reduction in its mechanical resistance properties, such as compressive, flexural, and tensile strength. This indicates the need to restore the original mechanical properties of the masonry. The structural reinforcement was carried out following these steps: damage assessment of the wall, including an investigation to determine the presence of any mural paintings on the plaster. As no valuable paintings were present, the plaster was removed to expose the underlying damage, revealing a crack traversing the entire width of the wall. The crack's dimensions were measured, and the materials comprising the structure were identified. The preceding steps informed the choice of intervention and materials for the structural reinforcement. The work involved the disassembly and reassembly of the masonry, injection of mortar, and installation of wooden dowels reinforced with steel rods. Following these parameters, the result was a successful strengthening of the damaged masonry, achieving a faithful architectural restoration.

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	RESUMEN
Palabras clave: morteros, mucilago, cal, llaves, inyecciones.	Esta investigación muestra un procedimiento de reforzamiento estructural aplicable a edificaciones patrimoniales con muros de adobe afectados por fisuras, la intervención se realiza mediante el uso de materiales y técnicas tradicionales como: cal, barro, paja de monte y mucilago de nopal para morteros e inyecciones. La metodología que se aplicó tiene un enfoque cuantitativo que se focaliza en un diseño experimental y se aplicó en este reforzamiento estructural para recuperar los mampuestos afectados por fisuras producidas por asentamientos, movimientos sísmicos o fatiga de los materiales en el muro, provocando que este pierda su capacidad de resistencia mecánica, como: la compresión, flexión y tracción, esto indica que se debe devolver las características mecánicas originales del mampuesto. Para este reforzamiento estructural se realizaron los siguientes pasos: verificar el daño que afecta al muro, luego se investigó la presencia o no de pintura mural sobre los enlucidos, en este caso no se encontró pintura de valor, lo que permitió retirar el aplanado para determinar el tipo de afectación, se localizó una fisura que cortó todo el ancho del muro, debiéndose verificar su longitud y profundidad. Luego se identificaron los materiales con los que está construida la estructura. Estos pasos determinaron el tipo de intervención y materiales que se utilizaron para realizar el reforzamiento estructural; en este caso se procedió a ejecutar el descosido y cosido de la mampostería, inyección de mortero y colocación de llaves de madera reforzadas con varillas de acero. Bajo estos parámetros se ejecutó un correcto reforzamiento de la mampostería afectada, cumpliéndose una apropiada restauración arquitectónica.

Introduction

This study seeks to typify methods and systems of structural reinforcement for heritage buildings. The importance of this research lies in establishing the feasibility of the correct use of methods and techniques to recover the structures and perform an adequate intervention. Traditional materials that are similar to the originals are used to carry out the intervention techniques. In addition, traditional construction techniques are used so that, as far as possible, they help to maintain the values of the heritage building.

The reinforcement methods and techniques analyzed in this research have been applied in structures located in Quito, a city with a very important Historic Center, with an extension of 376 hectares and where a large part of its colonial architecture is located, such as the buildings of La Ronda Street (Fig.1). There are about 130 monumental buildings. As for religious buildings, there are 40 churches and chapels, 16 convents and monasteries such as the convent of Carmen Bajo (Fig.2), in addition there are civil constructions such as palaces and buildings that have a style that can be admired, from baroque to the most classic gothic (Universidad de Las Américas, 2016).

Figura 1
Image of La Ronda street - Quito

Figura 2
Image of Carmen Bajo convent, Main façade view

The city of Quito was declared a World Cultural Heritage Site by UNESCO in 1978. The Historic Center, the largest in the Americas, has an unparalleled wealth of colonial architecture. In each of its stones is written the history of the city.

The beginning of the restoration activity in the city of Quito dates back to 1988, due to several earthquakes that caused structural damage to major religious monuments. Structural damage was mainly caused by the March 1987 earthquake. This major natural disaster was caused by a series of earthquakes, whose epicenters were located in the vicinity of the Reventador volcano. (Boxes, 2016)

The earthquakes severely damaged the historic heritage and, to a lesser extent, affected buildings constructed with contemporary materials. In most cases, there was cracking of the masonry and breakage of the masonry, as well as detachment of the eaves and coverings.

It can be determined in these colonial constructions that in certain aspects of their composition the materials are fatigued and structurally present the risk of future collapse. In order to maintain the safety of the inhabitants and the architecture intact, these buildings must undergo structural reinforcement without altering their composition, i.e., traditional materials and construction techniques must be used to safeguard the heritage.

This research aims to explain the correct use of traditional materials and construction techniques that should be used for the proper recovery of heritage, thus giving way to the recovery of knowledge of the benefits and peculiarities of traditional materials (lime, clay, stone, wood, thatch and cactus mucilage). This will show the effectiveness of these elements to be used in the structural reinforcements to be applied in the field of restoration of the built heritage.

Pacají Ruiz et al. (2015) stated that intangible cultural heritage is characterized by preserving the integrity and authenticity of cultural expressions and customs.

It is therefore important to preserve and rescue the knowledge of traditional construction techniques. In this case, for structural reinforcements it is necessary to use the expressions, knowledge and techniques related to ancestral buildings, as part of the use and training of specialized labor. In other words, this is a way to promote the rescue of social memory, the craft and knowledge of ancestral construction systems and materials.

Methodology

This research is supported by the experiences of the field work that has been carried out in different architectural restoration interventions. The aim is to disseminate the different types of damage and reinforcement interventions in adobe buildings, which will serve as a basis for further analysis and classification.

From these interventions, images are recorded of the types of damage that have occurred in the different types of masonry, and the degrees of degradation have been established. These can be determined by fatigue of its elements, by structural failure processes and by seismological phenomena. On the other hand, this in turn indicates the type of intervention to be applied to the affected parts.

Research Design

The methodology used is of a research type, with the purpose of establishing structural reinforcement methods for colonial structures. These reinforcements are characterized by the use of traditional materials that are compatible with the original components of the structures involved, i.e., the use of traditional techniques and materials such as adobe, brick, stone and wood and, as joint elements for mortars and injection of reinforcement, lime, mud and mucilage[2] of nopal are rescued.

In the Historic Center you can see buildings that still maintain the vernacular construction techniques that characterize colonial constructions. Due to their temporary nature and the type of materials used, these structures suffered structural damage caused, in some cases, by the fatigue of their components, time and the seismic movements supported by the structures, a situation that encourages them to be recovered, thanks to their compatibility, with the use of traditional materials.

Types of Effects

With the purpose of verifying and classifying the damages that have mainly deteriorated the adobe structures, which could reach a state of collapse, the following are

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[2] Organic substance of viscous texture, similar to gum, extracted from nopal cactus.

mentioned: longitudinal shear cracks that generally affect the heads of the walls (Fig. 3), flexural cracking that can affect the arches of a wall (Fig. 4), horizontal cracks, vertical cracks, diagonal cracks, inter-wall cracks, wall collapse and wall head fatigue (Achig et al., 2013).

On the other hand, among the main types of damage generally suffered by the heritage buildings of the Historic Center of the city of Quito, several types of degradation of the masonry can be established, which have been produced by different agents that trigger them, such as: atmospheric agents, deterioration of the adobe due to material fatigue (Fig.5) and by the seismic movements suffered, which contributed to the processes of structural failures that produce cracks in the masonry (Fig.6) of the heritage monuments.

Figure 3
Image of longitudinal crack in the top of the Franciscan Third Order Chape

Figure 4
Image of fissure affecting wall arches (kidney) in the church of the Hospital Psiquiátrico Corazón de Jesús.

Figure 5
Image of the Casa de las Velas head fatigue

Figure 6
Image of vertical crack in wall Casa de las Velas.

Consequently, these affectations indicate the type of intervention that must be carried out for a correct reinforcement of the structure, in order to guarantee its permanence in time through the restoration and recovery of the affected monumental buildings that are in a process of degradation and destruction.

Description of the Structure and Properties of the Materials

In architectural recovery and rehabilitation, one of the main activities is the structural reinforcement of heritage buildings. In this case, in the intervened buildings, the masonry is primarily made of adobe. They are masonry with an average width of 70 cm and an approximate height of 3 to 4 m high. These buildings have a system of mezzanine floors and roofs mainly made of wood.

The materials used for the masonry, mainly in heritage buildings, are made of adobe and, in certain parts of the walls, are combined with brick or stone. It is also worth mentioning that the roofs and mezzanines are made of eucalyptus wood, as can be seen (Figure 7).

Most of the walls are built on stone foundations, which is the element that is in contact with the ground. This foundation is responsible for transmitting the resulting mechanical forces directly to the ground.

Figure 7
Image of the adobe wall Franciscan Third Order Chapel

Degradation of the Walls

Among the main factors that can generate deterioration in a structure on land are:

- Direct attack by atmospheric phenomena, such as moisture absorbed by the wall by capillary action[3] into the interior of the wall and gradually degrading it.
- The erosive action caused by wind and rain that generates damage to the walls[4] of the building.
- Structural damage caused by its own weight, modification in the original ones, factors that cause cracking that can lead to the collapse of the structure itself.

That is to say, from these parameters arises the importance of using structural reinforcement systems that protect and reinforce adobe walls, so that the factories can be preserved and maintained indefinitely over time.

In this case, it is essential to use construction techniques such as baking and unbonding the wall in the affected area with traditional materials such as adobe and brick and reinforcing it with injections based on lime, sand, earth and mucilage[5]. This structural repair technique is adaptable to other buildings of the same characteristics and different geographical areas.

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[3] Action or movement that a liquid can perform in order to be absorbed through porous materials.
[4] Vertical element that in architecture forms the wall.
[5] Organic substance of viscous texture, similar to gum, extracted from nopal cactus.

Selection of Traditional Materials to Be Used in Reinforcements

To perform a good structural reinforcement and achieve a good restoration of the building it is essential to use traditional materials that are compatible with the elements that make up the building, this requires knowledge of methods and application techniques that ensure a good intervention, i.e., it requires the analysis of physical-chemical analytical tests of the material, it is also essential to conduct an investigation of the traditional components that were used for its construction.

As stated by Ontiveros (2006), the ideal is to carry out previous studies to identify the original materials to be used.

However, to carry out this research we have taken into account the traditional knowledge that ideas are transferred orally, these have been acquired both academically and orally, as well as through experiences in interventions that have been carried out. From here, the starting point for a good intervention implies that the senior master, together with the professional specialized in restoration, transmits his knowledge to the new generations; it is also necessary to consider that the master builder does not keep writings with which he can disseminate his knowledge.

Structural Reinforcements in Masonry

Peña and Lourenco (2012) indicate that in structural interventions, specialized professionals, whether architects or engineers, have managed a variety of repair or support techniques to optimize the structural solution of historic buildings. Several of the execution techniques have been specifically carried out to help and improve the bearing capacity of the old structures to resist a new inclement event of nature. These techniques used on the original structures must not affect the integrity and authenticity of the original materials and structural characteristics, which is why materials compatible with the original materials of the building must be used.

The structural intervention of historic buildings is and must be multidisciplinary, so apparently independent disciplines such as: Archaeology, Architecture, History, Engineering, Art restorers, etc. However, the lack of integration causes that, in several cases, a structural project does not adapt to the basic guidelines for the conservation of heritage buildings.

Structural Reinforcement Methods

Restoration and rehabilitation processes are the set of intervention methods and techniques applied for the rehabilitation of affected structures, these serve to recover their effectiveness, diminished due to some natural physical phenomenon (Garabito et al., 2015).

In order to achieve a good intervention, it is essential to use different reinforcement methods, according to the type of structure and the material of which the masonry is composed.

Thus, it can be indicated that the methods used in the different reinforcements are:
- Masonry uncoving and stitching.
- Wood anchorage with steel bars.
- Grout injections[6] of lime, additive and sand.

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[6] Masonry technique for mixing various solid materials with liquid to obtain a semi-liquid fluid for injection into walls.

These reinforcement techniques have made it possible to correct the damage to the structural elements; to this effect, the compatibility of the original materials of the building was considered, which will not damage the original ones and will be maintained over time, guaranteeing safety and durability.

Methodology for Structural Reinforcement in Walls

Structural reinforcement works were carried out on different masonry of the buildings involved. The masonry walls are made of different materials, such as stone, brick or adobe; the damages that occurred in these walls were mainly cracking, these were externalized vertically and affected the walls, even to the point of cutting them completely in the thickness of the facing, affecting them structurally. Also, among other cases, the cracks caused damage to the arches of the lateral naves, and the walls were affected in their composition, which caused deterioration in their interior, a factor that led to the execution of a reinforcement by injecting mortar grout that would allow the structural recovery of the walls due to fatigue of their components, such as adobe, for example. In this way, its mechanical stability is restored, preventing further damage to the load-bearing wall structure.

As part of the *structural reinforcement of the walls*, the intervention on the masonry is explained on masonry that were structurally affected, these work as load-bearing walls. For the research, the heritage building of the Monasterio del Carmen Bajo is taken as an example.

First of all, we will explain about an affected wall on the first floor that has a vertical crack that cuts through its entire 1.10 m thickness, with an approximate height of 3.00 m.

In order to carry out the structural reinforcement on the cracked masonry, a methodological procedure was followed that respects the canons established by the restoration processes:

- First, the sectors where cracks were present were located.
- Then we proceeded to make coves[7] of prospection on the existing paint (Figure 8).
- Verification of the existence or not of mural painting on the mud plaster (Figure 9).

Figure 8
Image of coves that are made on the painting, the presence of mural painting is not seen

Figure 9
Image of mud plaster removal detecting the type of crack affecting the masonry

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[7] Technique for the removal of existing paint layers on a wall

Once it was verified that there was no mural painting, coves were made on the plaster to check the type of crack in the masonry. In this way, a first diagnosis of the type of damage to the structure was obtained. With this, the type of material with which the masonry is made can be verified, which allowed the type of reinforcement to be applied to the structure to be defined (Figure 10).

After verifying the type of crack present in the masonry on the exterior side and the width of the opening, it is confirmed that this crack cuts the wall across its entire width. This determines the type of reinforcement to be performed on that crack. Then, the depth of the crack is measured. On the other hand, it is important to verify the length of the crack, for this purpose the plaster is removed[8], following the direction of the crack (Figure 11).

Figure 10
Image of coves that are made on the painting, the presence of mural painting is not seen

Figure 11
Image of mud plaster removal detecting the type of crack affecting the masonry

It should be noted that this process of verifying the presence of cracks by means of the shim method on the walls should be repeated on all the masonry to be subjected to a reinforcement process.

On the other hand, once it has been verified that the crack goes through the wall, the process is repeated on the other side of the wall. The type of material from which the masonry is constructed is then determined. In this case there is adobe and stone with mud mortar joints.

In this crack, which cuts the entire width of the wall, different intervention methods were used to consolidate and reinforce it, due to its complexity. The methods used were:

- Masonry uncoving and stitching.
- Anchoring wood or steel bars.
- Injections of lime grout, additive and sand.

For the treatment of this crack with an average opening of 2.00cm and a height of approximately 3.00m, which also covers the entire section of the wall and verified the materials that make up the masonry (stone, adobe and brick), it was established that it must be intervened, first with the method of decoking and sewing in the sector of the crack, since its elements are cut and can affect the ability of the elements to work

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[8] Coating layer placed on the walls to obtain a smooth surface

structurally, but this does not compromise the structure to stop performing it completely. The masonry must be worked on both the exterior and interior sides.

Masonry Reinforcement Procedure

Uncoring and stitching of the wall: the adobe bricks that were broken were removed and replaced with a new element, in this case with mambron brick, which is a material compatible with the adobe and the lime and sand mortar. It is essential that this process be started from the lower part of the wall, in sections of 4 or 5 courses per day, in order to prevent the masonry from settling and producing new cracks. The new bricks are placed one horizontally and the next transversally, so that the new elements are better anchored to the original wall (Figure 12).

This procedure is repeated along the entire length of the crack, one section per day, so that the new intervention is consolidated and does not cause settling and new cracks, the mortars used were prepared with traditional materials with the same characteristics as the original joint mortars (mud, lime and mucilage[9]), this process is repeated until the entire crack is intervened, this intervention procedure is performed on the internal and external side of the wall (Fig.13).

Figure 12
Image of sewn and unsewn crack exterior side

Figure 13
Image of the crack stitching process

An important fact to know is the compressive strength of the original adobe of the masonry being treated. The test was carried out at the PUCE materials laboratory[10] (Table 1), in order to establish the new strength of the masonry after the process of injecting the hydraulic mortars into the treated masonry.

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[9] Organic substance of viscous texture, similar to gum, extracted from nopal cactus.
[10] Pontifical Catholic University of Ecuador

Table 1
Table of compressive strength test results of the original adobe

Compression Test Results		
Adobe original		
Resistance (Mpa)		
Sample N 1	Sample N 2	Sample N 3
0.70	**0.70**	**0.70**
Average resistance (Mpa)		
0.70		
*Conversion factor: 1 Mpa = 10.2 kg/cm^2		

Note. Materials Laboratory PUCE, 2021

In addition, it should be noted that, during the stitching and sewing process, ½ inch plastic hoses were placed every 20 to 30 cm of separation, which were connected to internal wall cracks (known as kidney). This is to fully consolidate the structure with grout injections into the internal cracking. The hoses must be laid out over the entire area to be treated, and then lime-based mortars must be injected.

According to Lanas and Alvarez (2006), lime mortar has a lower amount of soluble salts, which prevents damage to the bearing system of buildings; in addition, lime mixtures are more compatible with traditional materials, which are part of the building and are related to the chemical, structural and mechanical aspects. In addition, these mortars, in the case of new cracks, have the capacity to repair themselves by means of a self-sealing process, due to the humidity that they retain as a result of the changes in temperature and humidity in the environment, which are absorbed by the masonry.

Figure 14
Image of the process of unpicking and stitching of the affected masonry

Peñaranda (2011) suggests that for a good rehabilitation against the appearance of cracks affecting the walls of a heritage building, "*wooden keys*" should be used. These are essential to reduce the seismic risk to which the affected masonry of the construction is subjected. The application of this system is intended to prevent the collapse of the building in the event of new natural phenomena (earthquakes or seismic movements).

This reinforcement technique is based on the installation of wooden boards or strips arranged horizontally and vertically on the exterior and interior face of the walls, secured together by means of a tensor, in order to increase the resistance of the masonry and maintain the consistency and unity of the structure.

With these considerations and the type of crack that was intervened, we proceeded to the placement of the *wooden keys.* These elements have the function of anchoring the wall to prevent the crack from becoming active again. Wooden keys were placed in both the lower and upper thirds of the crack. These elements were made of colorado wood and the measures used in this case were 7x7x120cm. At the ends of each key, displaced about 10 cm inward, pieces of 30 cm in length were placed vertically. These are placed in the middle of the wood, are glued and in the center of the crossing are drilled to secure the internal keys with the external ones by means of an adjustable tensioner to be able to give the tension required by this element to fix the system.

For the placement of the faucets, the wall was drilled to embed the wooden modules. Then, these were fixed with a threaded rod as a tensioner and adjusting nuts were placed at each of their ends to secure the keys on the exterior side with the module on the interior side of the wall, in this way the crack was embraced, improving its mechanical resistance to compression.

Figure 15
Graphical representation of structural reinforcement - placement of wood keys
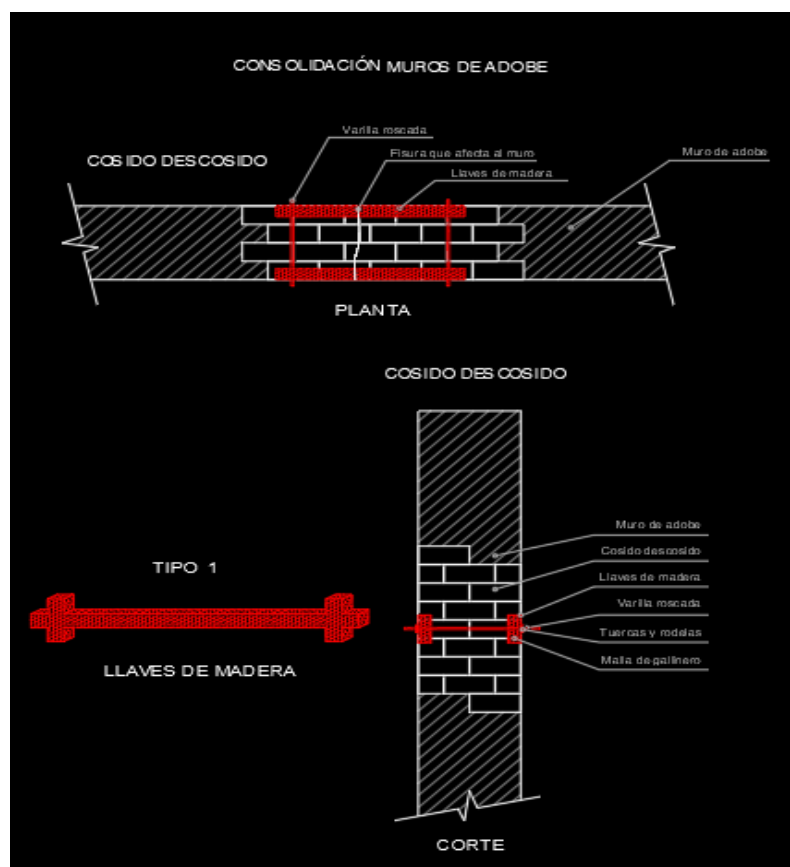
These keys were cured with *quimocide[11]*, to prevent them from being attacked by termites[12], then they were painted with asphalt paint to protect these new timbers from the humidity absorbed by the walls and eliminated by condensation.

The anchorage of these keys was made with 12mm steel rod. These steel bars are placed along the entire thickness of the wall and are anchored at each end of the battens with flat washers and lock washers secured with nuts on each side (Fig.16 and 17).

In addition, these new wooden elements, which are embedded in the wall, were also protected with mesh[13] to adhere to the **new plaster** made with traditional materials: mud / lime / mucilage[14] / straw. This mortar was placed in the entire intervened area of the structural reinforcement of the affected wall.

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[11] Chemical for wood curing against xylophages.
[12] *Termites* feed on wood and can cause significant damage to wooden structures.
[13] Steel mesh that is expanded and used in construction for cladding structures and other elements
[14] Organic substance of viscous texture, similar to gum, extracted from nopal cactus.

Figure 16
Image of wall perforation for anchoring of wooden keys

Figure 17
Wooden key image protected with asphalt paint and wrapped with mesh. Anchoring with steel rod

Once the stitching and unpicking was completed, the wooden keys were attached. Next, the plastering work was done to seal the masonry and then consolidate the wall with the mortar injection process.

Arriola (2009) states that mortar is a constructive element of the building and accounts for approximately 15% of the total volume of a masonry. It is a basic part that helps to absorb the compressive strength, since they are designed to resist this type of stress. The *mortars* in the walls help to withstand the flexural and shear forces caused by wind or seismic forces (frequent in our environment). When masonry undergoes this, the mortar plays a significant role, as the plastering mortar is responsible for working as a compact structural element, which is why great care must be taken in the preparation of the mortar. In the case of restoration it is very important to work with traditional materials compatible with the original ones that make up the building, thus avoiding future damage with the degradation of the original masonry.

For monumental buildings, in this intervention the *plastering of traditional materials* was used; its components were: slaked lime, mud, straw, mucilage[15] and water (Barbero, 2011). The thickness of the plaster varies from 1 to 3 cm. To apply this mortar, the surface must first be moistened with mucilage (it can also be moistened with calcium hydroxide) (Fig. 18), so that this process will help the new mortar to adhere better and even seal the possible micro cracks that may occur due to the drying process of the masonry (Fig. 19).

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[15] Organic substance of viscous texture, similar to gum, extracted from nopal cactus.

Figure 18

Image of masonry moistened with mucilage to receive the mortar

Figure 19

Image of masonry plaster

Vargas-Neumann et al. (2010) indicated that the injection procedure consists of inserting a fluid mortar with the same characteristics as the original materials that make up the masonry into the kidney (inside the wall) of the affected masonry. That is, with the same chemical, physical and mechanical characteristics, with the purpose of consolidating the affected walls to reestablish the original mechanical characteristics. The injections in the walls allow the consolidation of the wall and increase its compressive strength to improve its stability and improve the mechanical working capacity of the intervened masonry. Injections are used to achieve cohesion of the walls and get them to work together again

As a next step, once the plastering has been completed, the injection process continues in the masonry, to consolidate the interior of the walls by *injecting hydraulic lime mortar*. This is due to the fact that the masonry is made of adobe and brick. This mortar for the injections was prepared with the following materials and proportions: hydrated lime 3, red or brown pozzolana 1, washed river sand 2, water 3, stabilizing additive 2% of the weight of the pozzolana (Instituto Metropolitano de Patrimonio [IMP], technical specifications for execution of works, 2021).

Thus, all these materials were placed in a large vat, first the sand, then it was mixed with hydrated lime, then the pozzolan was added with the stabilizing additive and mixed dry, finally the water was added to make the total mixing of the materials and to obtain a homogeneous mixture, the mixing was done mechanically, then, once the mortar had the optimum fluidity, it is subjected to a sieving using a fine mesh in order to remove the coarse aggregates. This filtered mixture was placed in another container where the mortar to be used for injecting into the walls was deposited.

After separating the coarse aggregates, the mortar is deposited in the cylinder-type tank (injection equipment), where the hoses will be connected to inject the mortar by means of the pressure of a compressor. This system works with the air that enters the container where the mortar to be injected is located and, by means of a hose, reaches the injection gun that is placed in the hoses installed in the masonry.

The filling process starts with the lower hoses and as they are filled, the process continues to the upper hoses. Once they are filled, they are temporarily covered with paper to prevent the injection fluid from leaking out; the next day the injection process is

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repeated so that any vacuum that may have occurred due to fluid settling is filled with this new filling (Figure 20).

Figure 20
Image of the mortar injection process using an injection gun

It should be noted that these injection mortars used for structural reinforcement were subjected to PUCE laboratory mechanical tests[16], in order to measure their compressive strength. The values obtained allow the mechanical properties of the mortar tested to be assessed.

The following table shows the results of the Compressive Strength of the mortars that were injected into the wall, here it is evident that as the days go by their resistance increases and the adhesion of the new material with the old one is achieved, due to its compatibility; thus, according to the result, the resistance is obtained in Mega Pascals (MPA[17]) where 1 Mpa= 10.2 kg/cm² which is the conversion factor to have the resistance of the mortar inside the wall, for example:

- Resistance at 28 days: 1.30*10.20 kg/cm²= 13.26 kg/cm²

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[16] Pontifical Catholic University of Ecuador
[17] Mega Pascal conversion factor

Table 2
Table of test results for mortars Compressive strength

Compression Test Results of the new mortars					
Sample N 1		Sample N 2		Sample N 3	
Age (days)	Resistance Average (Mpa)	Age (days)	Resistance Average (Mpa)	Age (days)	Resistance Average (Mpa)
14	0.34	14	0.96	14	1.29
21	0.34	21	1.02	21	1.32
28	0.39	56	1.08	56	1.22
Average compressive strength (Mpa)					
Age (Days) 14		Age (Days) 21		Age (Days) 28	
0.36		**1.00**		**1.30**	

*Conversion factor: 1 Mpa = 10.2 kg/cm^2

Note. PUCE Materials Laboratory[18], 2021

To finish the reinforcement process of the intervened masonry, the excess of the hoses used for the injections was cut in order to paste the masonry, for which slaked lime was used. So that the wall is not completely smooth, the slaked lime is applied with a sponge trowel, in this way the finish is slightly irregular and its appearance is similar to the original, this has the purpose of not altering the original characteristics of the old plaster.

Once the stucco is completely dry, the masonry is prepared by sanding and sealing it with water resin. The final finish was made with traditional white paint, this was prepared with: mucilage[19]1/2u + lime 1u + salt in grain 1/10u + milk1/2u, as it was a restoration, it was decided to use a lime-based paint, salt and milk were included because they provide consistency and resistance to the final product once applied on the masonry. (Abrajan, 2008)

Results and Discussion

The application of the procedure to be followed to carry out a structural reinforcement of a cracked masonry in a heritage building, must be supported with mechanical resistance tests to compression carried out in the laboratory, in order to technically establish its improvement and the stability of the structure. By applying and following the established method, damage to other elements that may be part of the masonry is avoided, thus it is indicated that by performing coves as the first activity on the affected wall, damage to a possible existing mural painting on the plaster is avoided. Once the state of the plaster is verified, the state of the crack is checked, this indicates the

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[18] PUCE - Pontificia Universidad Católica del Ecuador.
[19] Organic substance of viscous texture, similar to gum, extracted from nopal cactus.

type of procedure to be used in the reinforcement, where the use of traditional materials and techniques is established, thus rescuing ancestral knowledge. Tests on the injection mortars showed that the mechanical characteristics of the affected walls were improved. According to the methodology proposed in the intervention, results of resistance and improvement of the walls were obtained at different ages: 14, 21 and 28 days. According to the established mortar test times, it was possible to establish that the dosage presents an ascending behavior, increasing the wall's resistance in relation to the age of the test.

In summary, the methodology used: verification of the cracks, prospecting coves, unpicking and sewing of the wall, placement of wooden keys, injection of lime mortar, plastering and painting, allowed for a correct structural reinforcement to improve the stability of the wall, which has a mixed system of adobe and stone construction. For their stitching, handmade mambron bricks, lime mortar, mud and mucilage were used[20], due to their compatibility with the original materials. On the other hand, the use of traditional techniques and materials allows the continuity and improvement of their mechanical characteristics, thus improving the physical characteristics of the structure. Thus, the dosage of the injection mortar in unit proportions was: hydrated lime 3, red or brown pozzolan 1, washed river sand 2, water 3, stabilizing additive 2% of the weight of the pozzolan, which increases the stability of the reinforced wall. (Silva & Uría, 2024)

Conclusions

Once the structural reinforcement has been completed based on an execution methodology, it can be concluded that it is feasible to determine the type of intervention necessary to avoid affecting the heritage building. Also, an adequate methodology allows for the definition of the materials to be used. In fact, this method made it possible to use materials that were similar and compatible with the original components of the wall, which resulted in a correct intervention.

On the other hand, the methodology was used to determine the quality of the cracked wall adobes. This was done with mechanical compression tests. Through these tests, which were carried out in the laboratory, it was established that the elements are no longer of good quality. Due to their age, they presented fatigue in their composition, with low results in laboratory tests.

The type of intervention, the quality of the materials and the nature of the crack, which affected the wall, indicated that this masonry should be consolidated. In this case, a hydraulic lime mortar was used to restore the compressive strength of the wall. Laboratory breakage results at 14, 21 and 28 days showed that the progressive increase in strength improves the quality of the masonry.

This intervention, based on the development of an execution methodology, aims to establish guidelines for the use of traditional techniques and materials in the structural reinforcement of the masonry. These techniques are applied in heritage restoration procedures to avoid the use of contemporary materials that alter and damage heritage buildings. On the other hand, this methodology can establish a general basis for the use of traditional materials and techniques to carry out a correct restoration and recovery of the architectural heritage.

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[20] Organic substance of viscous texture, similar to gum, extracted from nopal cactus.

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