

E
C
O
R
F
A
N

Journal - Republic of Paraguay

ISSN-On line 2414-4827



ECORFAN-Republic of Paraguay

Chief Editor

CENTENO-ROA, Ramona. MsC

Executive Director

RAMOS-ESCAMILLA, María. PhD

Editorial Director

PERALTA-CASTRO, Enrique. MsC

Web Designer

ESCAMILLA-BOUCHAN, Imelda. PhD

Web Diagrammer

LUNA-SOTO, Vladimir. PhD

Editorial Assistant

TREJO-RAMOS, Iván. BsC

Philologist

RAMOS-ARANCIBIA, Alejandra. BsC

ECORFAN Journal-Republic of Paraguay

Volume 10, Issue 18: e20241018
January – December 2024, is a Continuous publication, Journal edited by ECORFAN-Republic of Paraguay. 105 Alberdi Rivarola Captain, CP-2060. Luque City- Paraguay. WEB: www.ecorfan.org/republicofparaguay/journal@ecorfan.org. Editor in Chief: RAMOS-CENTENO-ROA, Ramona. MsC. ISSN: 2414-4827. Responsible for the latest update of this number ECORFAN Computer Unit. ESCAMILLA-BOUCHÁN, Imelda. PhD, LUNA-SOTO, Vladimir. PhD. 105 Alberdi Rivarola Captain, CP- 2060. Luque City-Paraguay, last updated December 31, 2024.

The opinions expressed by the authors do not necessarily reflect the views of the editor of the publication.

It is strictly forbidden to reproduce any part of the contents and images of the publication without permission of the Intellectual Property Register, Republic of Paraguay.

ECORFAN-Journal Paraguay

Definition of Journal

Scientific Objectives

Support the international scientific community in its written production Science, Technology and Innovation in the Field of Humanities and Behavioral Sciences, in Subdisciplines of philosophy, history and human sciences.

ECORFAN-Mexico, S.C. is a Scientific and Technological Company in contribution to the Human Resource training focused on the continuity in the critical analysis of International Research and is attached to CONAHCYT-RENIICYT number 1702902, its commitment is to disseminate research and contributions of the International Scientific Community, academic institutions, agencies and entities of the public and private sectors and contribute to the linking of researchers who carry out scientific activities, technological developments and training of specialized human resources with governments, companies and social organizations.

Encourage the interlocution of the International Scientific Community with other Study Centers in Mexico and abroad and promote a wide incorporation of academics, specialists and researchers to the publication in Science Structures of Autonomous Universities - State Public Universities - Federal IES - Polytechnic Universities - Technological Universities - Federal Technological Institutes - Normal Schools - Decentralized Technological Institutes - Intercultural Universities - S & T Councils - CONAHCYT Research Centers.

Scope, Coverage and Audience

ECORFAN-Journal Paraguay is a Journal edited by ECORFAN-Mexico, S.C. in its Holding with repository in Paraguay, is a scientific publication arbitrated and indexed with semester periods. It supports a wide range of contents that are evaluated by academic peers by the Double-Blind method, around subjects related to the theory and practice of Philosophy, history and human sciences with diverse approaches and perspectives, That contribute to the diffusion of the development of Science Technology and Innovation that allow the arguments related to the decision making and influence in the formulation of international policies in the Field of Humanities and Behavioral Sciences. The editorial horizon of ECORFAN-Mexico® extends beyond the academy and integrates other segments of research and analysis outside the scope, as long as they meet the requirements of rigorous argumentative and scientific, as well as addressing issues of general and current interest of the International Scientific Society.

Editorial Board

GUZMÁN - HURTADO, Juan Luis. PhD
Universidad de Santiago de Compostela

ANGELES - CASTRO, Gerardo. PhD
University of Kent

CAMPOS - QUIROGA, Peter. PhD
Universidad Real y Pontifica de San Francisco Xavier de Chuquisaca

CHAPARRO, Germán Raúl. PhD
Universidad Nacional de Colombia

PALACIO, Juan. PhD
University of St. Gallen

ALIAGA - LORDEMANN, Francisco Javier. PhD
Universidad de Zaragoza

NIEVA - ROJAS Jefferson. PhD
Universidad Autónoma de Occidente

BELTRÁN - MORALES, Luis Felipe. PhD
Universidad de Concepción

GARCÍA Y MOISES, Enrique. PhD
Boston University

IBARRA - ZAVALA, Darío Guadalupe. PhD
New School for Social Research

Arbitration Committee

COTA - YAÑEZ, María del Rosario. PhD
Universidad de Guadalajara

LUIS - PINEDA, Octavio. PhD
Instituto Politécnico Nacional

GULLOTTI - VAZQUEZ, María Teresa. PhD
Universidad Autónoma de Yucatán

HUERTA - QUINTANILLA, Rogelio. PhD
Universidad Nacional Autónoma de México

CEBALLOS - PEREZ, Sergio Gabriel. PhD
El Colegio del Estado de Hidalgo

MÁRQUEZ - IBARRA, Lorena. PhD
Instituto Tecnológico de Sonora

GONZÁLEZ - IBARRA, Miguel Rodrigo. PhD
Universidad Nacional Autónoma de México

COTA - YAÑEZ, María del Rosario. PhD
Universidad de Guadalajara

MOLINA-MARTÍNEZ, Rubén. PhD
Universidad Michoacana de San Nicolas de Hidalgo

MONROY-MAGALDI, Deborah. PhD
National Center for Continuous Improvement of Education

QUINTERO, Juan Manuel. PhD
Consejo Nacional de Ciencia y Tecnología

Assignment of Rights

The sending of an Article to ECORFAN-Journal Paraguay emanates the commitment of the author not to submit it simultaneously to the consideration of other series publications for it must complement the Originality Format for its Article.

The authors sign the Authorization Format for their Article to be disseminated by means that ECORFAN-Mexico, S.C. In its Holding Paraguay considers pertinent for disclosure and diffusion of its Article its Rights of Work.

Declaration of Authorship

Indicate the Name of Author and Coauthors at most in the participation of the Article and indicate in extensive the Institutional Affiliation indicating the Department.

Identify the Name of Author and Coauthors at most with the CVU Scholarship Number-PNPC or SNI-CONAHCYT-Indicating the Researcher Level and their Google Scholar Profile to verify their Citation Level and H index.

Identify the Name of Author and Coauthors at most in the Science and Technology Profiles widely accepted by the International Scientific Community ORC ID - Researcher ID Thomson - arXiv Author ID - PubMed Author ID - Open ID respectively.

Indicate the contact for correspondence to the Author (Mail and Telephone) and indicate the Researcher who contributes as the first Author of the Article.

Plagiarism Detection

All Articles will be tested by plagiarism software PLAGSCAN if a plagiarism level is detected Positive will not be sent to arbitration and will be rescinded of the reception of the Article notifying the Authors responsible, claiming that academic plagiarism is criminalized in the Penal Code.

Arbitration Process

All Articles will be evaluated by academic peers by the Double-Blind method, the Arbitration Approval is a requirement for the Editorial Board to make a final decision that will be final in all cases. MARVID® is a derivative brand of ECORFAN® specialized in providing the expert evaluators all of them with Doctorate degree and distinction of International Researchers in the respective Councils of Science and Technology the counterpart of CONAHCYT for the chapters of America-Europe-Asia- Africa and Oceania. The identification of the authorship should only appear on a first removable page, in order to ensure that the Arbitration process is anonymous and covers the following stages: Identification of the Journal with its author occupation rate - Identification of Authors and Coauthors - Detection of plagiarism PLAGSCAN - Review of Formats of Authorization and Originality-Allocation to the Editorial Board-Allocation of the pair of Expert Arbitrators-Notification of Arbitration -Declaration of observations to the Author-Verification of Article Modified for Editing-Publication.

Instructions for Scientific, Technological and Innovation Publication

Knowledge Area

The works must be unpublished and refer to topics of political, science-economics-public, policy-economic, development-technology, innovation and other topics related to Social Sciences.

Presentation of the Content

In the first article we present, *Potential geographic accessibility to municipal medical services (Cruz Verde) in the municipality of Guadalajara, Jalisco, Mexico*, by Ortiz-Curiel, Yaireth Deyanira, Niño-Gutiérrez, Naú Silverio, Andrade-García, María Dolores and Macías-Huerta, María del Carmen, with adscription in the Universidad de Guadalajara and Universidad Autónoma de Guerrero, as the next article we present, *Improvement of urban spaces, towards a sustainable habitat. BUAP Residential Case, Puebla, Puebla*, by Alonso-Pérez, Carlos, with adscription in the Benemérita Universidad Autónoma de Puebla, as the next article we present, *Augmented reality as a support for tourism promotion*, by Sánchez-Juárez, Ivan Rafael & Paredes-Xochihua, Maria Petra, with adscription in the Universidad Da Vinci and Tecnológico Nacional de México/ ITS de San Martín Texmelucan, *Marketing strategies of MIPyMES in the Cd. Mexico and metropolitan area during and after the pandemic*, by Álvarez-García, Mónica, Gutiérrez-Zepeda, Martha del Pilar, Guerrero-Ibarra, Carlos and Waldo Caamaño, José David, with adscription in the Universidad Tecnológica de Nezahualcóyotl, as the next article we present, *Identification of microplastics in bottled water, a potential risk to human health*, by Alva-Rojas, Elvia, Rivera-Ramírez Fabiola, Jiménez-Rosales, Angélica and Velázquez-Garduño, Gisela, with adscription in the Universidad Tecnológica del Valle de Toluca; as the last article we present, *Key guidelines to address technical and regulatory challenges in the adoption of cognitive radio in Mexico*, by Ortega-Laurel, Carlos, with adscription in the Universidad Autónoma Metropolitana.

Content

Article	Page
Potential geographic accessibility to municipal medical services (Cruz Verde) in the municipality of Guadalajara, Jalisco, Mexico Ortiz-Curiel, Yaireth Deyanira, Niño-Gutiérrez, Naú Silverio, Andrade-García, María Dolores and Macías-Huerta, María del Carmen <i>Universidad de Guadalajara</i> <i>Universidad Autónoma de Guerrero</i>	1-15
Improvement of urban spaces, towards a sustainable habitat. BUAP Residential Case, Puebla, Puebla Alonso-Pérez, Carlos <i>Benemérita Universidad Autónoma de Puebla</i>	1-11
Augmented reality as a support for tourism promotion Sánchez-Juárez, Ivan Rafael & Paredes-Xochihua, Maria Petra <i>Universidad Da Vinci</i> <i>Tecnológico Nacional de México/ ITS de San Martín Texmelucan</i>	1-10
Marketing strategies of MIPyMES in the Cd. Mexico and metropolitan area during and after the pandemic Álvarez-García, Mónica, Gutiérrez-Zepeda, Martha del Pilar, Guerrero-Ibarra, Carlos and Waldo Caamaño, José David <i>Universidad Tecnológica de Nezahualcóyotl</i>	1-10
Identification of microplastics in bottled water, a potential risk to human health Alva-Rojas, Elvia, Rivera-Ramírez Fabiola, Jiménez-Rosales, Angélica and Velázquez-Garduño, Gisela <i>Universidad Tecnológica del Valle de Toluca</i>	1-10
Key guidelines to address technical and regulatory challenges in the adoption of cognitive radio in Mexico Ortega-Laurel, Carlos <i>Universidad Autónoma Metropolitana</i>	1-11

Potential geographic accessibility to municipal medical services (Cruz Verde) in the municipality of Guadalajara, Jalisco, Mexico

Accesibilidad geográfica potencial a los servicios médicos municipales (Cruz Verde) del municipio de Guadalajara, Jalisco, México

Ortiz-Curiel, Yaireth Deyanira^a, Niño-Gutiérrez, Naú Silverio^{*b}, Andrade-García, María Dolores^c and Macías-Huerta, María del Carmen^d

^a Universidad de Guadalajara • [LIG-4688-2024](https://doi.org/10.35429/EJROP.2024.10.18.1.15) • 0009-0001-0353-2016

^b Universidad Autónoma de Guerrero • [AAT-3183-2020](https://doi.org/10.35429/EJROP.2024.10.18.1.15) • 0000-0001-9250-0798 • 121259

^c Universidad de Guadalajara • [LIG-5159-2024](https://doi.org/10.35429/EJROP.2024.10.18.1.15) • 0000-0002-8559-1924 • 265661

^d Universidad de Guadalajara • [KUC-4795-2024](https://doi.org/10.35429/EJROP.2024.10.18.1.15) • 0000-0002-4939-6371

CONAHCYT classification:

Area: Social Science
Field: Geography
Discipline: Regional Geography
Subdiscipline: Urban Geography

<https://doi.org/10.35429/EJROP.2024.10.18.1.15>

Article History:

Received: January 25, 2024
Accepted: December 31, 2024

* [\[nsninog@uagro.mx\]](mailto:nsninog@uagro.mx)

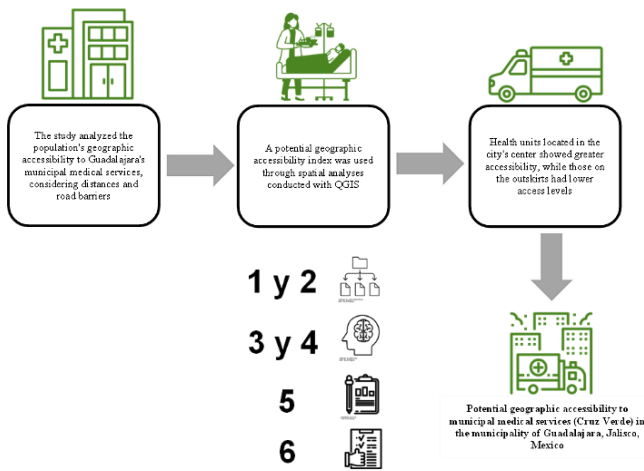


Abstract

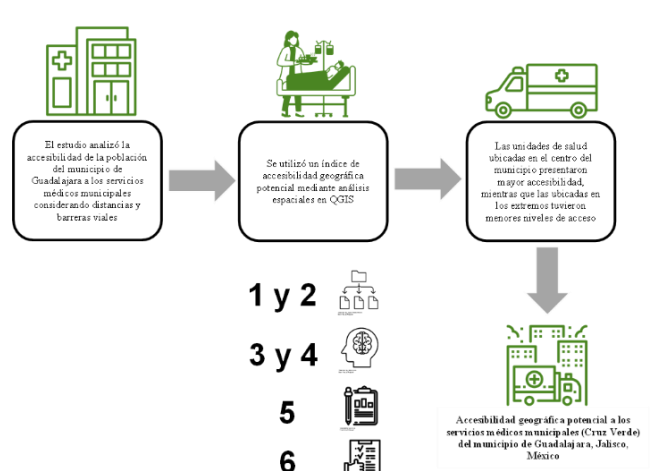
This research evaluated the potential geographic accessibility of the population in the municipality of Guadalajara to the municipal medical services units, considering distances and road barriers. The central objective was to analyze how the location of health units and road infrastructure influenced the population's access to these services. A quantitative approach was adopted, using a potential geographic accessibility index based on spatial analyses conducted with QGIS. The results showed that units located in the center of the municipality, such as Dr. J. Jesús Delgadillo Araujo, had greater accessibility, while those located on the outskirts, such as Dr. Leonardo Oliva Alzaga and Dr. Mario Rivas Souza, showed lower levels of access. It was concluded that the planning of health services must consider both geographic distribution and road infrastructure to improve equity in health access.

Resumen

Esta investigación evaluó la accesibilidad geográfica potencial de la población del municipio de Guadalajara a las unidades de servicios médicos municipales, considerando distancias y barreras viales. El objetivo central fue analizar cómo la ubicación de las unidades de salud y la infraestructura vial influyeron en el acceso de la población a dichos servicios. Se adoptó un enfoque cuantitativo, utilizando un índice de accesibilidad geográfica potencial basado en análisis espaciales realizados con QGIS. Los resultados mostraron que las unidades ubicadas en el centro del municipio, como la Dr. J. Jesús Delgadillo Araujo, presentaron una mayor accesibilidad, mientras que las situadas en los extremos, como la Dr. Leonardo Oliva Alzaga y la Dr. Mario Rivas Souza, mostraron menores niveles de acceso. Se concluyó que la planificación de los servicios de salud debe considerar tanto la distribución geográfica como la infraestructura vial para mejorar la equidad en el acceso a la salud.



Health services, Municipal medical services, Spatial analysis



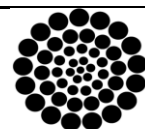
Análisis espacial, Servicios médicos municipales, Servicios de salud

Citation: Ortiz-Curiel, Yaireth Deyanira, Niño-Gutiérrez, Naú Silverio, Andrade-García, María Dolores and Macías-Huerta, María del Carmen. [2024]. Potential geographic accessibility to municipal medical services (Cruz Verde) in the municipality of Guadalajara, Jalisco, Mexico. ECORFAN Journal-Republic of Paraguay. 10[18]-1-15: e11018115.



ISSN 2414-4827/© 2009 The Author[s]. Published by ECORFAN-Mexico, S.C. for its Holding Republic of Paraguay on behalf of ECORFAN Journal-Republic of Paraguay. This is an open access article under the CC BY-NC-ND license [\[http://creativecommons.org/licenses/by-nc-nd/4.0/\]](http://creativecommons.org/licenses/by-nc-nd/4.0/)

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



RENIECYT
Registro Nacional de Instituciones y
Empresas Científicas y Tecnológicas

1702902 CONAHCYT

Introduction

The term “accessibility” can encompass various meanings, including the ease of access to technology, commerce, education, services, buildings, information, recreation, and work, among others. However, in this context, the focus is on the scientific aspect of the concept, particularly in its applications and processes aimed at public health.

[Donabedian \(1988\)](#) identified two ways to measure accessibility: socio-organizational and geographical. Socio-organizational accessibility relates to the characteristics of both the user and the service, which can either facilitate or hinder access to the service. Factors influencing this dimension include both formal and informal admission policies that may exclude individuals based on their economic capacity, diagnosis, addictions, contagious diseases, mental disorders, religious preferences, and educational levels, as well as the patient's reluctance to consult a physician or choose a health unit, and service hours, among others. On the other hand, geographical accessibility examines the physical distances between the user and the service, including linear distance, travel time and cost, as well as the total associated costs.

[Butler \(1986\)](#) emphasized that the contributions of the pioneers of Location Theory—Von Thünen, Alfred Weber, and Walter Christaller—laid the foundation for what is now known as “geographical accessibility”. Thünen focused on the agricultural context, Weber on manufacturing industry, and Christaller on the distribution and functions of urban settlements. Although each model applies to different fields, they share key variables such as distance, monetary costs, time, and the difficulties in overcoming distance.

The study of geographical accessibility from a health perspective is the subject of this research. For this purpose, it has been deemed appropriate to employ the concept defined by Brian Goodall in the Dictionary of Human Geography, which states that “accessibility is the ease with which a certain site (destination) can be reached from other points in the territory (origins)” ([Garrocho & Campos, 2006, p. 353](#)).

The primary objective is to describe the potential geographical accessibility of Municipal Medical Services (Cruz Verde) for the population of the municipality of Guadalajara ([Salinas Escobar et al., 2012](#)), as well as to identify its limitations. The relevance of applying a potential geographical accessibility index lies in its ability to perform a spatial analysis of varying intensities of accessibility within a defined geographic area. This analysis is fundamental for health service planning, contributing to the development of planning, management, and evaluation tools that reflect the international priorities established by the World Health Organization ([OMS, 2015](#)), as well as for fulfilling the objectives stipulated in the Political Constitution of the United Mexican States, the General Health Law, the State Health Law, and the Sectoral Health and Human Rights Program.

Article 4 of the Political Constitution of the United Mexican States that “Every person has the right to health protection. The law will define the bases and modalities for access to health services and will establish the concurrence of the Federation and the federal entities in matters of general health”.

Similarly, the General Health Law establishes the bases and modalities for access to health services; Article 5 expresses the commitment of the National Health System, “constituted by the federal and local public administration agencies and entities, as well as physical or moral persons from the social and private sectors that provide health services, along with the coordination mechanisms for actions, aimed at fulfilling the right to health protection” ([General Health Law, 2020, p. 5](#)).

Likewise, Article 15 of the State Health Law defines the coordination and collaboration mechanisms for health service planning, establishing that the State Health System, with the involvement of the Jalisco Health Secretariat and the State Development Planning Committee, “will define the coordination and collaboration mechanisms for health service planning in the State, to fulfil the right to health protection, in accordance with the provisions of this law and those that may be applicable” ([State Health Law, 2018, p. 5](#)).

The Sectoral Health Program 2019-2024 also emphasizes as a strategy to “improve and expand health infrastructure and equipment, creating adequate and accessible conditions to provide quality services to the entire population at all levels of care”. Meanwhile, the World Health Organization (WHO) notes that the right to health includes timely, acceptable, and affordable access to health care services of sufficient quality.

In Guadalajara, Jalisco, as in the state and other regions of the country (Niño-Gutiérrez et al., 2023), disparities are observed in the distribution of the population and the even distribution of public health services. These services are typically located near areas with higher population concentrations, leaving more remote and sparsely populated localities with fewer public services. This forces residents to travel long distances to access a health unit, increasing travel time and costs.

The potential geographical accessibility index developed by Garrocho & Campos (2006) for Mexican cities is considered applicable to both rural and urban areas. Using Geographic Information Systems (GIS), mathematical models for spatial analysis can be implemented, utilizing open-source software such as QGIS version 3.16.0. Additionally, tools like the calculation of centroids for Basic Geo-Statistical Areas (AGEB) and ORS Tools facilitate processes such as mapping and calculating the shortest distance via the road network from the centroid to the Municipal Medical Services unit, which is essential information for applying the potential geographical accessibility index.

The municipality of Guadalajara, Jalisco, has five Municipal Medical Services (Cruz Verde) units to provide emergency care to the population: “Dr. J. Jesús Delgadillo Araujo”, “Dr. Ernesto Arias González”, “Dr. Francisco Ruíz Sánchez”, “Dr. Leonardo Oliva Alzaga”, and “Dr. Mario Rivas Souza”. These units have 29 consultation rooms, 5 emergency rooms, 23 ambulances, and 5 motorcycle ambulances.

The “supply” variable is defined as the number of consultation rooms registered in the Unique Key of Health Establishments for each Municipal Medical Services unit. Meanwhile, the “demand” corresponds to the total population of the municipality of Guadalajara, which amounts to 1,385,629 inhabitants according to the 2020 Population and Housing Census, distributed across 442 Basic Geo-Statistical Areas (AGEB).

Additionally, the distance in kilometres via the road network from the centroid of each AGEB to the municipal medical services units was considered.

For the preparation of the matrix, the application of the geographical accessibility index, and the creation of the maps, it was crucial to locate the municipal medical services units, referenced in the Universal Transverse Mercator (UTM) coordinate system.

One of the main challenges in a city like Guadalajara is the high density of vehicles in circulation. According to the Jalisco Institute of Statistical and Geographic Information (IEEG), in its report of August 31, 2020, the Guadalajara Metropolitan Area concentrates 64.3% of the state's total vehicular load, with Guadalajara being the second municipality with the highest vehicle rate, at 63.8 per 100 inhabitants.

Moreover, lines 1 and 3 of the Urban Electric Train System (SITEUR) interfere with traffic, as they are not fully constructed underground, creating areas where street crossings are spaced apart or do not allow turns, forcing motorists and pedestrians to take alternative routes or detours that increase travel time.

Traffic, terrain, and communication routes are factors that limit the efficiency and fluidity of emergency unit movement in the city, affecting their ability to quickly reach the event location or return to their base unit for care.

According to the Population and Housing Census by the National Institute of Statistics and Geography (INEGI, 2020), the municipality of Guadalajara had 1,385,629 inhabitants, of which 70.06% are affiliated with some form of health service. The distribution is as follows: 58.78% with the Mexican Social Security Institute (IMSS), 5.11% with the Institute of Health for Well-being (INSABI), 2.94% with private institutions, 2.76% with the Institute of Security and Social Services for State Workers (ISSSTE), 0.19% with the State ISSSTE, 0.15% with PEMEX, SEDENA, or SEMAR, 0.18% with IMSS Bienestar, and 1.10% with other institutions. However, 29.50% of the population has no affiliation with these health institutions, forcing this segment to seek medical care through other means. It is worth noting that INSABI was founded in 2020 with the goal of providing health services to those not affiliated with IMSS.

Although most of the population is affiliated with a health service, they may also access or request Municipal Medical Services in case of emergencies.

The World Health Organization (WHO) establishes that one ambulance is required for every 25,000 inhabitants (Cruz, 2018). Considering Guadalajara's population of 1,385,629 people, the city should have at least 56 ambulances, but it only has 23 units and 5 motorcycle ambulances, indicating limited accessibility per unit.

Approximately 89.9% of the terrain in the municipality of Guadalajara is flat, with slopes of less than 5°. The remaining 10.1% has uneven terrain, which has led to modifications in road infrastructure to accommodate water bodies like the Atemajac River or the San Juan de Dios River. However, certain communication routes affect traffic due to the lack of continuous crossings, forcing detours to continue or make turns on a street, as seen with avenues such as Lázaro Cárdenas, Calzada Independencia, and Periférico, among others.

The central hypothesis of this research posits that residents in the outskirts of Guadalajara face lower levels of access to municipal medical services units, constrained by the terrestrial communication routes connecting to other municipalities in the state and other states in the country, such as Avenida Lázaro Cárdenas, which links the entry and exit of the highway to Mexico with the highway to Nogales.

The first part of the document presents the general aspects of the project, including the concept of potential geographical accessibility applied to population health and its relevance as a tool and strategy for the planning and evaluation of health services, in accordance with the health laws governing the country. It also discusses the use of Geographic Information Systems, which enable reliable and timely data processing, expediting, and generating results so that the relevant authorities have adequate information to address issues related to health access.

The second part details how the data was obtained and the process followed to apply the Potential Geographical Accessibility Index to the municipal medical services units, breaking down the formula and describing the use of the ORS Tools, which facilitate the calculation of distances in kilometres from the centroids of each AGEB to the health units.

The results describe some characteristics of the municipality of Guadalajara necessary for the application of the mentioned index. This index has two major areas of analysis: from the demand perspective, it is measured from locality centres and AGEBs to health units, revealing urban quality, understood as the advantages that the population has by residing in a specific area of the territory. From the supply perspective, the location of each health unit is evaluated in comparison to its competitors, so that by summing up the accessibility per unit and ordering the results from highest to lowest, the unit with the most advantages relative to the others can be identified.

By summing the Accessibility Index per AGEB for all health units, it is possible to determine which AGEB has the highest or lowest accessibility. Additionally, the total accessibility of the municipality is assessed, allowing for evaluation at the state, regional, or national level, and comparison with other territorial units; although in this case, the analysis is limited to the municipality of Guadalajara.

Finally, the conclusions obtained from applying the Potential Geographical Accessibility Index to the municipal medical services units—Dr. J. Jesús Delgadillo Araujo, Dr. Ernesto Arias González, Dr. Francisco Ruíz Sánchez, Dr. Leonardo Oliva Alzaga, and Dr. Mario Rivas Souza—for the resident population of the municipality of Guadalajara are presented.

Research question

What was the level of potential geographical accessibility for the population of the municipality of Guadalajara to the municipal medical services units of Cruz Verde, considering the existing distances and road barriers?

General objective

To describe and analyse the level of potential geographical accessibility for the population of the municipality of Guadalajara to the municipal medical services units, considering the existing distances and road barriers.

Specific objectives

- To identify the areas within the municipality of Guadalajara with the highest and lowest geographical accessibility to the Cruz Verde municipal medical services units.
- To determine the geographical and road barriers that influenced the population's access to the Cruz Verde municipal medical services units.
- To propose strategies for improving accessibility to health services in areas identified with lower potential geographical accessibility.

Study design

The research was structured as a descriptive, cross-sectional study aimed at analysing the potential geographical accessibility of the population of the municipality of Guadalajara to the municipal medical services units. A quantitative approach was adopted, utilizing spatial analysis tools and geographic information systems (GIS) to evaluate the relationship between the distribution of health units and the population, as well as the road barriers that might affect access.

The study was conducted in several stages. First, geospatial information related to the location of health units and population distribution was collected and processed, using data from the National Institute of Statistics and Geography (INEGI) and the Unique Key of Health Establishments (CLUES). Subsequently, the potential geographical accessibility index, adapted from the model proposed by [Garrocho & Campos \(2006\)](#), was applied to measure the population's opportunities for accessing health services. Distances between the centroids of the Basic Geo-Statistical Areas (AGEB) and the health units were calculated via road routes, using QGIS software and the ORS Tools plugin. The results were represented in thematic maps that visualized areas with varying levels of accessibility.

Finally, a comparative analysis was conducted to identify accessibility patterns based on the location of health units, population density, and characteristics of the road infrastructure. The findings were used to formulate recommendations aimed at improving the planning and distribution of health services in the municipality of Guadalajara.

Methodology

To estimate the potential geographical accessibility of emergency services, specifically the Municipal Medical Services for the population of the municipality of Guadalajara, an accessibility index based on the shortest routes via the road network was employed.

Potential geographical accessibility index

The Potential Geographical Accessibility Index, developed and applied by [Garrocho & Campos \(2006\)](#) in the Metropolitan Area of Toluca, State of Mexico, was adopted for this study. The formula used to estimate this index is as follows:

$$I = \sum_j \frac{S_j}{d_{ij}^p} \quad (1)$$

Where:

- I: Potential Geographical Accessibility Index, representing the relative measure of ease of access that the population has to health units distributed within a defined geographical space. In this case, the population of the municipality of Guadalajara and the distance in kilometres from the centroids of the Basic Geo-Statistical Areas (AGEB) to the municipal medical services units were considered.
- S_j: Magnitude of the services available at each health unit, measured by the number of consultation rooms registered in the Unique Key of Health Establishments (CLUES) in 2021.
- O_j: Total demand of the study area, represented by the total population of the municipality of Guadalajara, according to the Population and Housing Census by the National Institute of Statistics and Geography ([INEGI, 2020](#)).

- dij: Transportation cost, which in this research was considered as the distance in kilometres via the road network between the population's place of residence (AGEB) and the health unit's location.
- b: Distance friction, a parameter obtained by calibration based on user behaviour data. In this study, it was not considered due to the use of road network distances structured by streets, avenues, and thoroughfares, through which the population travels to health units by private vehicle, public transportation, or ambulance.

To conduct this analysis, the municipal boundary of Guadalajara, the AGEBs from the 2020 Geo-Statistical Framework, and the Population and Housing Census data obtained from the official INEGI website were used. Contour lines, watercourses, water bodies, urban structure, roadways, and railways in vector format were obtained from INEGI maps F13D66 and F13D65, at a scale of 1:50,000 (INEGI, 2020).

The location of health units was obtained from the CLUES file provided by the General Directorate of Health Information (DGIS) in 2021 in XLSX format. This file was filtered to extract the Cruz Verde units of Guadalajara, which were then converted to shapefile (shp) format to obtain their location on the map and the number of consultation rooms.

The information was processed using the free software QGIS version 3.16.0, available for download on its official website. The calculation of the centroids of the AGEBs was performed using the AGEB2020 and amg2020 layers, corresponding to the AGEBs located within the municipal boundary of Guadalajara and its neighbouring areas. In the toolbox, the "Centroids" option was used to create the centroid point layer. Once obtained, the points were grouped in sets of 40 to create the routes, due to the tool's point limitation, and a health unit, in this case, Rivas Souza, was added.

Distance calculation

The routing and distance calculation from each AGEB centroid to the municipal medical services units was performed by installing the ORS Tools plugin and creating an account in Open Route Service. A 24-hour valid link was obtained for the tool to use the Open Street Maps service.

The key was entered into the API Key, "Batch Jobs" was selected, followed by "Points (2 Layer)."

Records were captured as follows: the provider was Open route service, Input Start Point Layer was the health unit layer (Mario Rivas Souza), Start ID Field was a column used as an identifier (health unit name), Input End Point Layer was the AGEB centroids layer (in groups of 40), and the AGEB column was used as the identifier. The travel mode selected was "driving-car," the travel preference was "shortest" for shortest routes, the layer mode was "all-by-all," and the directions were stored in a file.

The result was a layer with 40 routes, repeating the procedure for the other 11 layers. The routes were checked using Google Maps to ensure they followed the correct street direction. The 12 layers were then merged into one using the "merge vector layers" tool with the projection EPSG: 32613 WGS84 UTM 13N.

It was verified that the file contained the 442 lines corresponding to the number of AGEBs in Guadalajara, and the process was repeated for the five health units. If any route presented errors, the corresponding distance was recalculated.

Application of the index and map creation

The Potential Geographical Accessibility Index was applied by creating a matrix in Excel 2016, organizing the information as follows:

- A sequential identifier for AGEBs in alphabetical order.
- The AGEB key
- The total population per AGEB.
- The UTM coordinates of the AGEB centroids.
- The health units.
- The design capacity measure (number of consultation rooms).
- The distance in kilometres from each health centre to the AGEB centroids.
- Application of the formula to calculate the index.

For the creation of geographical accessibility maps, based on the index results, ranges were established using the data mean magnitude method, a statistical central tendency method that reveals the position of the values around which the data clusters. Five ranges were defined: lower, below average, average, above average, and upper.

The data were ordered in ascending order, where the median divides the distribution into two subsets of equal frequency: 50% of the values are above, and the other 50% below. Quantiles, which divide the distribution into parts with a certain percentage of the total observations, were used in their decile (10%) form. The resulting five ranges were as follows:

- Lower range / Poor (155 values)
- Below average range / Inadequate (44 values)
- Average range / Acceptable (44 values)
- Above average range / Good (44 values)
- Upper range / Optimal (155 values)

Results

General aspects of the municipality

According to the State Government, the municipality of Guadalajara is located between the coordinates 20° 36' 40" and 20° 45' 00" north latitude, and 103° 16' 00" and 103° 24' 00" west longitude. This municipality is situated in the Central Region of the state of Jalisco and is bordered to the north by the municipalities of Ixtlahuacán del Río and Zapopan, to the east by Tonalá and Zapotlanejo, to the south by San Pedro Tlaquepaque, and to the west again by Zapopan.

Guadalajara covers an area of 150 km², placing it in position 114 in relation to the rest of the municipalities in Jalisco, according to the Jalisco Institute of Statistical and Geographic Information (IIEG, 2019), Figure 1.

Box 1

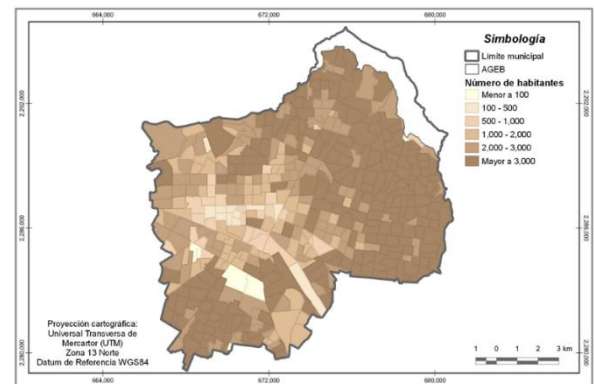


Figure 1

Population as of 2020 in the municipality of Guadalajara

Source: Own elaboration

Regarding the terrain of the municipality, 89.9% of its territory is flat, with slopes less than 5°. About 4.7% of the land consists of hills with slopes between 5° and 15°, while the remaining 5.4% is mountainous, with slopes greater than 15° (IIEG, 2019). The municipality has a Protected Natural Area: the Barranca de Huentitán, which covers a portion of the Barranca del Río Santiago belonging to Guadalajara.

In terms of hydrology, Guadalajara is traversed by the San Juan de Dios River, which is channelled underground through the city; to the northeast, the Verde River joins with the Santiago River. Additionally, the Atemajac Stream marks an inter-municipal boundary. Other water bodies include the San Andrés de los Caños and Osorio streams, the Zoquipan and Hedionda dams, and the Poniente Canal. According to the State Water Commission (CEA), Guadalajara is located in the Lerma–Santiago–Pacific Hydrological Administrative Region VIII, within the Lerma-Santiago Hydrological Region 12, in the RH12-E Santiago–Guadalajara hydrological basin.

Another relevant element for this research is the population distribution. According to the Population and Housing Census conducted by the National Institute of Statistics and Geography (INEGI, 2020), Guadalajara had 1,385,629 inhabitants, of which 48.3% are men and 52% are women. The age group with the highest concentration is 20 to 24 years, representing 4.3% of the men and 4.2% of the women.

The population is primarily concentrated in the eastern and southwestern parts of the municipality, while areas like the centre or industrial zones have lower or no population density. Similarly, areas near the centre and towards the west also show low population density (Niño-Gutiérrez et al, 2018 & Niño-Gutiérrez & Hinojosa, 2016).

The road structure of the municipality is also noteworthy. Access to Guadalajara can be made through various highways, mostly federal, such as 24, 23, 90D, and 15, which in turn connect with the Manuel Gómez Morín Periférico Ring. The city's first ring road was Avenida Circunvalación (Oblatos, División del Norte, Jorge Álvarez del Castillo, López Mateos - up to La Minerva, and Agustín Yáñez), with between 2 and 4 lanes, depending on the section. Guadalajara also has major avenues, such as Calzada Lázaro Cárdenas, which runs from west to southeast and connects the municipalities of Tonalá, Tlaquepaque, and Zapopan. Another important road is Calzada del Federalismo, which has 3 lanes in both directions and runs from north to south (Figure 2).

Box 2

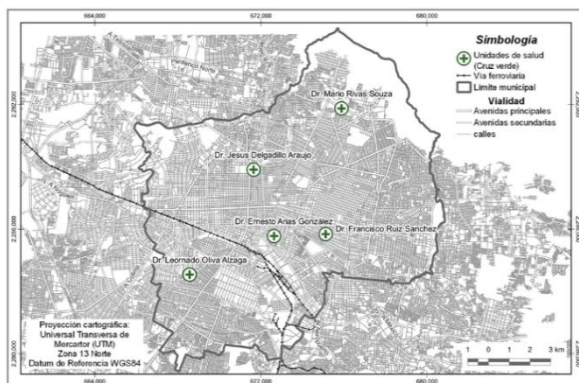


Figure 2

Road network and location of municipal medical services units

Source: Own elaboration

Calzada Independencia, one of the main roads that cross the city from north to south, was originally the San Juan de Dios River channel, crossed by bridges. In 2009, the Calzada underwent a significant change with the operation of the Macrobús, now Mi Macro Calzada, which reduced the existing lanes to two in both directions but allowed for a connection with Avenida Gobernador Luis C. Curiel via an underpass, avoiding detours around the railway tracks and the corresponding station.

Avenida Javier Mina originates in the eastern part of the city, in the Tetlán neighbourhood, and connects to Federal Highway No. 15. This avenue has three different names: it begins as Francisco Javier Mina in the Libertad sector, changes to Avenida Juárez when crossing Calzada Independencia in the Hidalgo sector, and finally becomes Avenida Ignacio L. Vallarta from Avenida Enrique Díaz de León until its transition in the municipality of Zapopan, where it becomes the exit to Federal Highway 15 to Nogales.

Avenida Alcalde was historically one of the most important roads in the city, being a major route for vehicular traffic and public transportation. However, starting in 2014, with the construction of Line 3 of the Light Rail, several adjacent roads were closed, and a section of the avenue, from Avenida Jesús García to Avenida Niños Héroe, was transformed into a pedestrian walkway and bike path, allowing only local traffic at certain points. Avenida Ávila Camacho also underwent changes due to the construction of Line 3, where the underground route becomes elevated, which required the medians to be extended, blocking some crossings.

To provide medical services to the population, the municipality of Guadalajara has five municipal medical services units: Dr. J. Jesús Delgado Araujo, Dr. Ernesto Arias González, Dr. Francisco Ruíz Sánchez, Dr. Leonardo Oliva Alzaga, and Dr. Mario Rivas Souza. According to a statement from the Guadalajara City Council, published on February 25, 2019, these units were renovated, improving their infrastructure, including the adaptation, remodelling, and re-equipment of areas such as operating rooms, central sterilization equipment, emergency rooms, among others.

Potential geographical accessibility by health unit

The application of the potential geographical accessibility index by health unit allows for the identification of the access opportunities available to the population of the municipality of Guadalajara to these health units, as well as the potential capacity of these units to serve the population. This analysis is crucial for spatially visualizing areas with lower access, corresponding to the most vulnerable populations, and thus establishing strategies and actions to mitigate or resolve issues related to access to health services.

Municipal medical services unit Dr. J. Jesús Delgadillo Araujo

The Dr. J. Jesús Delgadillo Araujo Municipal Medical Services unit is located in the Alcalde Barranquitas neighbourhood, in the Central Zone, and has 10 consultation rooms. It offers a variety of services, including emergency medical-surgical care, clinical laboratory, X-rays, tomography, ultrasound, and outpatient consultation in various specialties such as cardiology, general surgery, hypertension clinic, haematology, maxillofacial surgery, general medicine, neurology, dentistry, ophthalmology, orthopaedics, otorhinolaryngology, paediatrics, and psychology.

When applying the potential geographical accessibility index, the results ranged from values of 0.000000643 to 0.000000940, with distances of 7.68 to 11.23 km and a population of 599,611 inhabitants, distributed in 155 AGEBs, placing them in the lowest accessibility range (Poor). In the range below the average, with values from 0.000000940 to 0.000001042, the distance ranges from 6.92 to 7.67 km, covering a population of 177,481 inhabitants distributed in 44 AGEBs (Inadequate).

The accessibility index in the average range varies between 0.000001044 and 0.000001226, with distances from 5.88 to 6.90 km, and a population of 133,735 inhabitants distributed in 44 AGEBs (Acceptable). The range above the average, with values from 0.000001235 to 0.000001414, covers distances from 5.10 to 5.84 km, serving a population of 120,528 inhabitants distributed in 44 AGEBs (Good). Finally, the upper range presents values from 0.000001419 to 0.000011228, with distances from 0.64 to 5.08 km, covering a population of 354,266 inhabitants distributed in 155 AGEBs (Optimal).

AGEBs within the optimal range are located approximately 3 km from the health unit, extending southwest to Avenida Inglaterra and east to Esteban Loera Street. In the good and acceptable accessibility ranges, the unit's influence extends to about 4.5 km, surpassing Calzada Lázaro Cárdenas, westward towards the municipality of Zapopan, and reaching the Industrial Zone and crossing the railway tracks.

AGEBs in the inadequate range are approximately 6 km away in a straight line, some beyond the Periférico Ring and others at its limits. These reach eastward to Avenida Artesanos, which becomes Avenida Plutarco Elías Calles, and southward, beyond Avenida Miguel López de Legazpi. AGEBs with poor accessibility are approximately 8.5 km away in a straight line, located on the outskirts of the municipality, bordering the municipalities of Tonalá and San Pedro Tlaquepaque.

Municipal medical services unit Dr. Ernesto Arias González

The Dr. Ernesto Arias González Municipal Medical Services unit is located in the Las Conchas neighbourhood, in the Central Zone, and has 6 consultation rooms. It offers services such as psychological care (suicide prevention and care), emergency care, traumatology and orthopaedics, general consultation, clinical laboratory, X-rays, and procedures such as medical certificates. Additionally, it houses the Regional Center for Toxicological Information and Care (CRIAT), the only one in the region, covering the Central-West of Mexico. This centre provides interconsultations and medical management of poisoned patients, as well as care for animal bites or stings (Figure 3).

Box 3

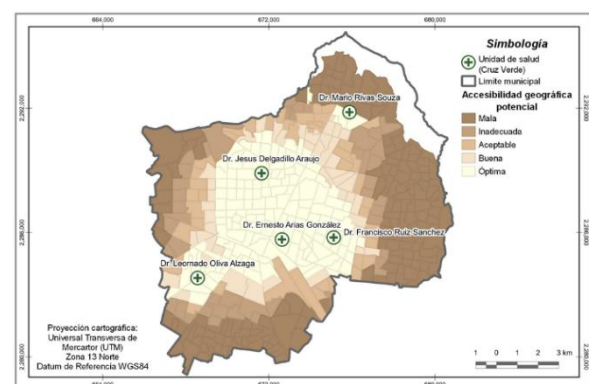


Figure 3

Total potential geographic accessibility of the population of the municipality of Guadalajara to the Municipal Medical Services

Source: Own elaboration

When applying the accessibility index, values between 0.000000417 and 0.000000632 were observed, with distances from 6.84 to 10.39 km, covering a population of 619,905 inhabitants distributed in 155 AGEBs, classifying them in the lowest accessibility range (Poor).

In the range below the average, with values from 0.000000633 to 0.000000679, the distances range from 6.37 to 6.84 km, covering 139,738 inhabitants distributed in 44 AGEBs (Inadequate).

The accessibility index in the average range varies between 0.000000681 and 0.000000754, with distances from 5.74 to 6.35 km and a population of 152,618 inhabitants distributed in 44 AGEBs (Acceptable). In the range above the average, with values from 0.000000754 to 0.000000854, the distances range from 5.07 to 5.74 km, covering 138,313 inhabitants distributed in 44 AGEBs (Good). Finally, the upper range presents values from 0.000000855 to 0.0000007590, with distances from 0.57 to 5.06 km, covering 335,047 inhabitants distributed in 155 AGEBs (Optimal).

The health unit is approximately 4 km in a straight line from AGEBs that have an optimal range, extending north to Avenida Circunvalación Doctor Atl and southeast to the border with San Pedro Tlaquepaque, crossing Calzada Lázaro Cárdenas and reaching the Industrial Zone. AGEBs with good accessibility are approximately 4.5 km away in a straight line, reaching Avenida Adolfo López Mateos; to the north, up to Avenida Circunvalación Doctor Atl, and to the south, past the Industrial Zone, near the Mercado de Abastos.

The acceptable and inadequate accessibility ranges extend southwest to the border with Zapopan, in the Chapalita neighbourhood, and northward, surpassing Avenida Circunvalación, with some AGEBs reaching Avenida Plutarco Elías Calles, covering an approximate straight-line distance of 5 km. The poor accessibility range reaches the outskirts of the municipality, passing the Periférico Ring and the avenues Adolfo López Mateos, Plutarco Elías Calles, and Patria.

Municipal medical services unit Dr. Francisco Ruíz Sánchez

The Dr. Francisco Ruíz Sánchez Municipal Medical Services unit is located in the Hernández Romo neighbourhood, in the Olympic Zone, and has 5 consultation rooms. It offers services such as emergency medical-surgical care (general surgery and traumatology), general medicine outpatient consultation, traumatology and orthopaedics, nutritional and psychological consultation, clinical laboratory services, and imaging services.

Recent renovations include the modernization of operating rooms, emergency areas, recovery and hospitalization areas, the implementation of a CT scanner for comprehensive diagnostics, improvements in infrastructure and security systems, and the construction of new areas to optimize medical care, such as triage areas and a teaching room.

The accessibility index applied to this unit showed values ranging from 0.000000301 to 0.000000485, with distances from 7.43 to 11.97 km, covering a population of 478,830 inhabitants distributed in 155 AGEBs, classifying them in the lowest accessibility range (Poor). In the below-average range, with values from 0.000000486 to 0.000000525, distances range from 6.87 to 7.41 km, covering 130,780 inhabitants distributed in 44 AGEBs (Inadequate).

The accessibility index in the average range varies between 0.000000529 and 0.000000595, with distances from 6.06 to 6.82 km and a population of 133,561 inhabitants distributed in 44 AGEBs (Acceptable). In the above-average range, with values from 0.000000596 to 0.000000665, distances range from 5.42 to 6.05 km, covering 141,869 inhabitants distributed in 44 AGEBs (Good). Finally, the upper range presents values from 0.000000669 to 0.000000690, with distances from 0.53 to 5.39 km, covering 500,581 inhabitants distributed in 155 AGEBs (Optimal).

The AGEBs with optimal range for this health unit are approximately 4 km away in a straight line, covering a broad area from the boundaries of Guadalajara with Tonalá and San Pedro Tlaquepaque to the north near Panteón Guadalajara, passing through avenues such as Belisario Domínguez, Alcalde, Reforma, Chapultepec, Inglaterra, and Dr. Roberto Michel.

AGEBs with acceptable and inadequate accessibility extend north to the Periférico Ring, reaching the Glorieta de La Normal to the west, and passing Calzada Lázaro Cárdenas and the Industrial Zone, with an approximate straight-line distance of 5.5 km. The range with poor accessibility covers the entire western side of the municipality, reaching the border with Zapopan and part of Tlaquepaque, as well as the Periférico Ring, Avenida Adolfo López Mateos, part of Calzada Lázaro Cárdenas, and Avenida Miguel López de Legazpi.

Municipal medical services unit Dr. Leonardo Oliva Alzaga

The Dr. Leonardo Oliva Alzaga Municipal Medical Services unit, located in the south of the city in the Jardines de la Cruz neighbourhood, has 5 consultation rooms. The main services offered include emergency medical-surgical care, surgery and consultation in traumatology and orthopaedics, surgery and consultation in otorhinolaryngology, anaesthesiology, general surgery, hand surgery, cardiology, paediatrics, outpatient consultation, dentistry, and nutrition.

The unit has undergone several improvements, including the rehabilitation of operating rooms, remodelling and conditioning of the sterilization area, modernization of the laboratory and X-ray area, creation of new spaces for medical care, remodelling of the emergency area with an expansion of beds, and the renovation of water tanks, compressors, emergency power plant, and electrical installations throughout the unit, according to a statement published on February 25, 2019, by the Guadalajara City Council.

When applying the accessibility index, the values obtained ranged from 0.000000236 to 0.000000346, with distances from 10.42 to 15.29 km, covering a population of 516,973 inhabitants distributed in 155 AGEBs, classified in the lowest accessibility range (Poor). The below-average range presented values from 0.000000346 to 0.000000402, with distances between 8.97 and 10.41 km, and a population of 137,798 inhabitants distributed in 44 AGEBs (Inadequate).

The accessibility index in the average range varied from 0.000000404 to 0.000000483, with distances from 7.46 to 8.93 km, covering a population of 138,784 inhabitants distributed in 44 AGEBs (Acceptable). In the above-average range, values ranged from 0.000000484 to 0.000000560, with distances from 6.44 to 7.45 km, and a population of 140,848 inhabitants distributed in 44 AGEBs (Good). Finally, the upper range presented values from 0.000000562 to 0.0000008816, with distances from 0.40 to 6.42 km, covering a population of 451,218 inhabitants distributed in 155 AGEBs (Optimal).

AGEBs within an optimal accessibility range are located at an approximate straight-line distance of 1 to 5 km, covering areas in the south and part of the west of the municipality, reaching Calzada del Ejército, Pedro Moreno Street, and passing through the Ladrón de Guevara neighbourhood (known as Barrio de Santa Tere) to Milán Street.

In the Good and Acceptable accessibility ranges, the AGEBs are approximately 7 km away, reaching Federico Medrano Street, Avenida República, Sierra Morena, Sierra Madre, Avenida Ávila Camacho, and Jardines del Country, ending at Avenida Patria, which marks the boundary with Zapopan.

AGEBs with Inadequate accessibility are approximately 8 km away, extending eastward to Avenida del Chamizal and Avenida San Jacinto, Gigantes Street, Porres Baranda (la 68), Avenida Puerto Melaque, Avenida Circunvalación, Avenida Belisario Domínguez, and neighborhoods like Jardines Alcalde up to Avenida Fidel Velázquez.

Finally, AGEBs with poor accessibility cover part of the east and north of the municipality, with an approximate straight-line distance of 8 to 12 km, passing through avenues such as Plutarco Elías Calles, Artesanos, Circunvalación, Fidel Velázquez, and the Periférico Ring.

Municipal medical services unit Dr. Mario Rivas Souza

The Dr. Mario Rivas Souza Municipal Medical Services unit is located in the Jardines de Santa Isabel neighbourhood, at Anillo Periférico Pte. Manuel Gómez Morin #350, and has 3 consultation rooms. The main services offered include emergency medical care, traumatology and orthopaedics, laboratory, and X-ray services, available 24 hours a day, 365 days a year.

In a statement published in February 2019 by the Guadalajara City Council, the renovations in the facilities and equipment were highlighted, including the comprehensive rehabilitation of the building, complete renovation of the emergency observation area, acquisition of new X-ray equipment (digital), the addition of 2 consultation rooms, rehabilitation of the waiting room, and improvements to the hydro-sanitary network and electrical installations.

When applying the accessibility index, values ranged from 0.000000135 to 0.000000226, with distances from 9.59 to 16 km, covering a population of 433,901 inhabitants distributed across 155 AGEBs, classified in the lowest accessibility range (Poor). In the below-average range, values ranged from 0.000000226 to 0.000000254, with distances from 8.52 to 9.57 km, covering a population of 116,775 inhabitants distributed across 44 AGEBs (Inadequate).

The accessibility index in the average range varied from 0.000000254 to 0.000000290, with distances from 7.47 to 8.50 km, covering a population of 126,420 inhabitants distributed across 44 AGEBs (Acceptable). In the above-average range, values ranged from 0.000000290 to 0.000000332, with distances from 6.44 to 7.45 km, covering a population of 140,848 inhabitants distributed across 44 AGEBs (Good). Finally, the upper range presented values between 0.000000332 and 0.0000003006, with distances from 0.72 to 6.51 km, covering a population of 591,591 inhabitants distributed across 155 AGEBs (Optimal).

The optimal accessibility of this unit is found within approximately 3 to 5 km, reaching areas to the north of the municipality, near the Barranca de Huentitán, extending to Avenida José María Iglesias, Pablo Valdez Street, Felipe Ángeles, Dionisio Rodríguez, Gigantes, Belén, Avenida Jesús García, Parque Alcalde, Avenida del Federalismo Norte, and reaching the northwest boundary with Zapopan.

In the Good and Acceptable ranges, the AGEBs extend further toward the city center, with 14 light rail stations from the 3 lines of the Urban Electric Train System (SITEUR) covering these areas of influence.

Finally, AGEBs with poor accessibility are mainly located towards the south of the municipality, passing Avenida González Gallo, Avenida Niños Héroe, Avenida de las Américas, and reaching the boundary with the municipality of Zapopan; the approximate straight-line distance is 11.5 km.

Total potential geographical accessibility by health unit

The municipality of Guadalajara has five municipal medical services units, which were analysed by applying the accessibility index to identify which has the highest and lowest accessibility.

The results show that the Dr. J. Jesús Delgadillo Araujo health unit, with 10 consultation rooms, has the highest total accessibility, with a value of 0.000671196. In second place is the Dr. Ernesto Arias González health unit, which has 6 consultation rooms and a total accessibility of 0.000412214.

In third place is the Dr. Francisco Ruíz Sánchez health unit, with 5 consultation rooms and an accessibility of 0.000338818. The Dr. Leonardo Oliva Alzaga health unit, also with 5 consultation rooms, ranks fourth, with an accessibility of 0.000279798. Finally, the Dr. Mario Rivas Souza health unit, with 3 consultation rooms, has the lowest accessibility, with a value of 0.000158141.

Thus, the Dr. J. Jesús Delgadillo Araujo health unit presents the best accessibility index due to its higher number of consultation rooms and its favourable geographical location, which facilitates population access. In contrast, the Dr. Mario Rivas Souza unit has the lowest accessibility, likely due to the scarcity of consultation rooms relative to demand and its location in the northern part of the municipality, along the Periférico Ring, complicating access, especially for the population in the west, which must cross several major avenues (Table 1).

Box 4

Table 1

Total potential geographical accessibility of medical services

Health unit	Number of clinics	Accessibility by health unit
Dr. J. Jesús Delgadillo Araujo	10	0.000671196
Dr. Ernesto Arias González	6	0.000412214
Dr. Francisco Ruíz Sánchez	5	0.000338818
Dr. Leonardo Oliva Alzaga	5	0.000279798
Dr. Mario Rivas Souza	3	0.000158141

Source: Own elaboration

Potential geographical accessibility by AGEB

The analysis of potential geographical accessibility by AGEB was conducted by summing the accessibility of each AGEB from the health units, allowing the identification of AGEBs with the highest and lowest accessibility.

In Guadalajara, the AGEBs with the highest accessibility are primarily located in the city centre, covering four of the five health units. These AGEBs benefit from wide roads that facilitate timely connections with the health units.

On the other hand, the AGEBs with the lowest accessibility are located on the outskirts of the municipality, especially to the east. To the north, the Periférico Ring acts as a road barrier that increases the distance required to access health services. Similar situations are observed to the south, where major avenues also act as social divides, reflecting inequality in access to health services.

Potential geographical accessibility of the municipality

By applying the potential geographical accessibility index to the health units in the municipality, a global index for Guadalajara of 0.001860167 was obtained. This value allows for the comparison of Guadalajara's accessibility level with other municipalities, providing authorities with a tool to evaluate and improve health services in the city.

Discussion

The discussion of this research focused on interpreting and contextualizing the findings obtained from applying the potential geographical accessibility index to the municipal medical services units in the municipality of Guadalajara. The results revealed significant variations in access to health services, largely determined by the geographical location of the units, population density, and existing road barriers.

In relation to previous studies, it was confirmed that the strategic location of health units, particularly in areas with high population density and good road connections, facilitated more equitable access to medical services. This finding aligns with the observations of [Garrocho & Campos \(2006\)](#), who emphasized the importance of proximity and road connectivity in the accessibility of public services. However, it was noted that despite favourable road conditions, some units, such as the Dr. Mario Rivas Souza, exhibited lower levels of accessibility, which was attributed to the scarcity of consultation rooms and their location in peripheral areas of the municipality.

Furthermore, units located in the central part of the municipality, such as the Dr. J. Jesús Delgadillo Araujo, showed significantly higher accessibility, not only due to the greater number of consultation rooms but also because they are surrounded by wide avenues and major roads.

These results underscored the decisive influence of road infrastructure on access to health services, in line with studies that have highlighted the importance of transportation networks in the effective provision of public services.

The units with lower accessibility, such as the Dr. Leonardo Oliva Alzaga and the Dr. Mario Rivas Souza, highlighted the need to consider both the geographical distribution of health units and the adequacy of resources available at each unit. This aspect was particularly relevant for the peripheral areas of the municipality, where the combination of greater distances and lower density of services contributed to the population's vulnerability in terms of access to health.

Finally, the study suggested the implementation of policies aimed at improving equity in the distribution of health services, considering not only the expansion of healthcare infrastructure but also the optimization of access routes and the increase in the number of consultation rooms in units with lower accessibility. Additionally, further studies were recommended that include variables such as travel time on public transportation and the population's perception of the quality and accessibility of health services, to provide a more comprehensive view of the problem.

In summary, the research provided significant evidence on the influence of geographical distribution and road characteristics on access to health services in Guadalajara, highlighting key areas for intervention and improvement in the planning of these services.

Conclusions

Technological advancements, along with the continuous renewal of processors, programs, and tools, have made research processes faster and more reliable, and the representation of results more visually appealing. However, it is crucial to have a solid knowledge base, use available techniques appropriately, and develop projects aimed at improving the living conditions of the population.

Regarding the results obtained by applying the potential geographical accessibility index and representing them on maps, it has been possible to clearly identify the areas of the population that face challenges in accessing health services.

This information is vital for taking measures that mitigate, reduce, or eliminate access barriers for the most vulnerable populations. Therefore, the index proves to be a valuable tool for health service planning.

In this context, it is concluded that the application of the potential geographical accessibility index to the municipal medical services units (Cruz Verde) Dr. J. Jesús Delgadillo Araujo, Dr. Ernesto Arias González, Dr. Francisco Ruíz Sánchez, Dr. Leonardo Oliva Alzaga, and Dr. Mario Rivas Souza has allowed for the spatial description and analysis of the varying intensities of access among the resident population in the municipality of Guadalajara.

Most health units, such as Dr. J. Jesús Delgadillo Araujo, Dr. Ernesto Arias González, and Dr. Francisco Ruíz Sánchez, exhibit good accessibility. However, this is not the case for other units, where barriers such as distances and roadways significantly limit access, as evidenced by the findings of this research.

The Dr. J. Jesús Delgadillo Araujo unit stands out for its greater accessibility, as it has a larger number of consultation rooms and is surrounded by wide, two-way avenues, such as Avenida Federalismo, Avenida de los Maestros, Mariano Bárcena Street, and Avenida Jesús García, which facilitate access to this unit.

On the other hand, the health units Dr. Leonardo Oliva Alzaga and Dr. Mario Rivas Souza, located at the southern and northern ends of the municipality, respectively, face the greatest accessibility challenges, both due to the longer distances users must travel and the limited number of consultation rooms available.

Based on the results of this research, it is suggested to apply an additional model that incorporates variables such as public transportation and travel times, with the aim of correlating it with the marginalization index. Additionally, it would be advisable to conduct surveys to understand the perceptions and preferences of the population regarding accessibility to health units.

Declarations

Conflict of interest

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

Author contribution

Ortiz-Curiel, Yaireth-Deyanira conducted primary research, preparation, project administration and conceptualization, methodology, QGIS software, visualization, collected data, and drafted sections related to potential geographic accessibility to municipal medical services (Cruz Verde) in the municipality of Guadalajara.

Niño-Gutiérrez, Naú Silverio validation, writing-review and editing, focused on analyzing the transformation of Guadalajara, Jalisco, México, gathering relevant literature, and synthesizing findings.

Andrade-García, María Dolores and *Macías-Huerta, María del Carmen* contributed by providing expertise in urban planning and offering insights into policy implications and recommendations for general aspects of the municipality of Guadalajara, Mexico, formal analysis, investigation, and supervision.

Availability of data and materials

Availability of data: The collected data as well as supplementary materials accompanying the publication of this research are accessible to other users. Trough request to the author.

Availability of materials: The authors specify that the materials are freely available for the users to use without any restrictions or conditioned associated with Access to them. This means that the materials, such as data sets, or other resources, can be accessed and utilized by anyone interested in the research without requiring permission or facing any limitations. This commitment to open Access promotes transparency, reproducibility, and collaboration in research, allowing others to verify findings, replicate experiments, or build upon the work without barriers.

Abbreviations

AGEB = Basic Geo-Statistical Areas

CLUES = Unique Key of Health Establishments

DGIS = General Directorate of Health Information

GIS = Geographic Information Systems

IIEG = Institute of Statistical and Geographic Information

Article

IMSS = Mexican Social Security Institute

INEGI = National Institute of Statistics and Geography

INSABI = Institute of Health for Well-being

ISSSTE = Institute of Security and Social Services for State Workers

PEMEX = Mexican state-owned company

SEDENA = Secretariat of National Defense.

SEMAR = Secretariat of the Navy

SITEUR = Urban Electric Train System

UTM = Universal Transverse Mercator

WHO = World Health Organization

References

Antecedents

Butler, J. H. (1986). *Geografía económica: aspectos espaciales y ecológicos de la actividad económica*. México: LIMUSA.

Dirección General de Información en Salud. (2020). *Catálogo CLUES*. México.

Donabedian, A. (1988). *Los espacios de la salud: aspectos fundamentales de la organización de la atención médica*. México: Fondo de Cultura Económica.

Instituto Nacional de Estadística y Geografía. (INEGI, 2020). *Censo de Población y Vivienda 2020*. México.

Basics

Congreso del Estado de Jalisco. (2018). *Ley de Salud del Estado de Jalisco*. Publicado el 5 de diciembre del 2018.

Garrocho, C. y Campos, J. (2006). *Un indicador de accesibilidad a unidades de servicios clave para ciudades mexicanas: fundamentos, diseño y aplicación*. *Economía Sociedad y Territorio*, 6 (22), 349-397.

Organización Mundial de la Salud. (OMS, 2015). *Derecho a la Salud*. Centro de Prensa de la OMS, 1-5.

Supports

Congreso del Estado de Jalisco. (2018). *Ley de Salud del Estado de Jalisco*. Publicado el 5 de diciembre del 2018.

Instituto de Información Estadística y Geográfica de Jalisco. (IEEG, 2019). *Guadalajara Diagnóstico municipal*. Guadalajara, Jalisco, México.

Differences

Cruz, E. (2018). *Requiere la ZMG 189 ambulancias*. Guadalajara, Jalisco, México. *El Diario NTR*.

Discussions

Congreso del Estado de Jalisco. (2018). *Ley de Salud del Estado de Jalisco*. Publicado el 5 de diciembre del 2018.

Niño-Gutiérrez, Naú Silverio; Macías-Huerta, M. del C.; Andrade-García, M. D. & Amaro-López, J. A. (2023). *Conflicts in the land of Tequila: a geographical approach to the socio-spatial challenges in Guadalajara*. *Journal of Social Researches*, 9(23): 1-9.

Niño-Gutiérrez, N. S.; Hinojosa, A. & Galarza, C. A. (2018). *Aporte al turismo cultural en el Centro Histórico de Guadalajara (2014-2016)*. *Topofilia*, IX, XV, 57-67.

Niño-Gutiérrez, N. S. & Hinojosa, A. (2016). *Entorno sustentable del Instituto Cultural Cabañas-Centro Histórico de Guadalajara, Jalisco, México*. En R. M. Velázquez Sánchez; A. L. Ramos Soto y M. V. Hernández Luis (Coords). *Aspectos de innovación y desarrollo en las organizaciones*. (pp. 1-17). Campeche: Universidad Autónoma "Benito Juárez" de Oaxaca.

Salinas Escobar, M. E.; Niño-Gutiérrez, N. S.; Martínez Barragán, H. & Pérez Alcántara, B. (2012). *Función social de la Geografía en México. El caso de la Universidad de Guadalajara*. En B. Pérez Alcántara; Iliana Araya Ramírez y Fernando Carreto Bernal (Coords). *La función social de la Geografía en América Latina*. (pp. 215-232). USA: Editorial Académica Española.

Improvement of urban spaces, towards a sustainable habitat. BUAP Residential Case, Puebla, Puebla

Renovación de los espacios urbanos, hacia un hábitat sustentable. Caso Residencial BUAP, Puebla, Puebla

Alonso-Pérez, Carlos*^a

^a Benemérita Universidad Autónoma de Puebla • LMN-4826-2024 • 0009-0003-3969-5436

CONAHCYT classification:

Area: Humanities
Field: Architecture and town planning
Discipline: Architecture, design and town planning
Subdiscipline: Others

<https://doi.org/10.35429/EJROP.2024.10.18.1.11>

Article History:

Received: January 30, 2024
Accepted: December 31, 2024



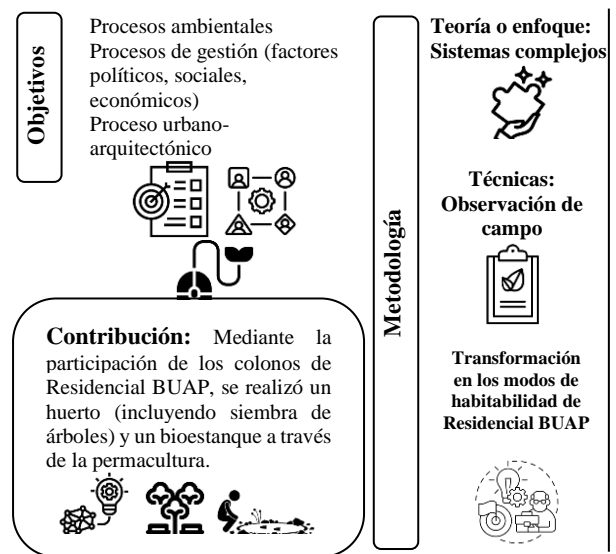
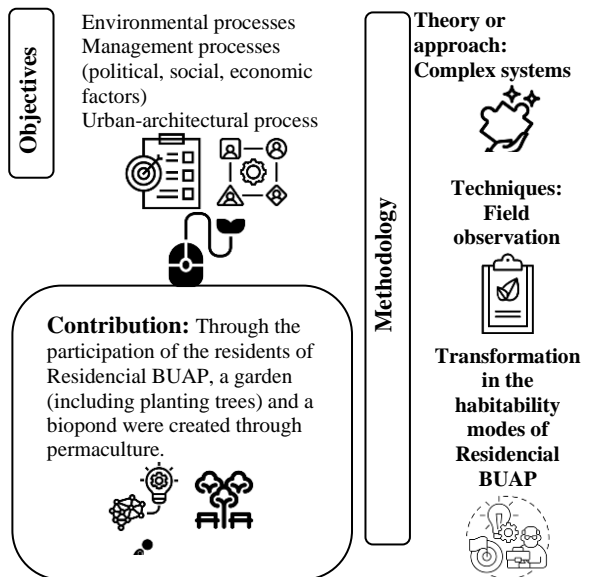
* [\[carlos.alonsop@correo.buap.mx\]](mailto:carlos.alonsop@correo.buap.mx)

Abstract

The BUAP residential subdivision, located in the southern area of Puebla, Mexico, currently has several plots of land with serious contamination problems due to lack of intervention. This, in addition to the fact that the interior spaces of the homes are very small and there is not enough green and recreational areas for residents to develop their physical and motor activities, in addition to the fact that there is no integration between neighbors to solve these problems. The research will contribute to the improvement of urban spaces that will function as an extension of the homes to generate a sustainable habitat, through the participation of the same settlers. Based on a methodology, theories or approaches from various authors that support this type of approach will be known, in addition to doing the field research work through the observation process and qualitative research so that the conclusions are finally presented.

Resumen

El fraccionamiento Residencial BUAP, ubicado en la zona sur de Puebla, México presenta actualmente varios terrenos con graves problemas de contaminación por causa de la no intervención, esto aunado a que los espacios interiores de las viviendas son muy reducidos y no se cuenta con la suficiente cantidad de áreas verdes y recreativas para que los habitantes desarrollen sus actividades físicas y motrices, además de que no hay una integración entre los vecinos para dar solución a estas problemáticas. La investigación coadyuvará al mejoramiento de los espacios urbanos que funcionarán como extensión de las viviendas para generar un hábitat sustentable, mediante la participación de los mismos colonos. Con base en una metodología se conocerán teorías o enfoques de diversos autores que fundamenten este tipo de abordaje, además de hacer la labor investigativa de campo mediante el proceso de observación y la investigación cualitativa para que finalmente se presenten las conclusiones.



Sustainability, Habitability, Urban spaces

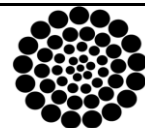
Sustentabilidad, Habitabilidad, Espacios urbanos

Citation: Alonso-Pérez, Carlos. [2024]. Improvement of urban spaces, towards a sustainable habitat. BUAP Residential Case, Puebla, Puebla. ECORFAN Journal-Republic of Paraguay. 10[18]-1-11:e21018111.



ISSN 2414-4827/© 2009 The Author[s]. Published by ECORFAN-Mexico, S.C. for its Holding Republic of Paraguay on behalf of ECORFAN Journal-Republic of Paraguay. This is an open access article under the CC BY-NC-ND license [<http://creativecommons.org/licenses/by-nc-nd/4.0/>]

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



RENIECYT
Registro Nacional de Instituciones y Empresas Científicas y Tecnológicas

1702902 CONAHCYT

Introduction

This research is fundamentally about carrying out a study –from the interdisciplinary and transdisciplinary perspective, considering that the topic must be studied, analyzed and/or evaluated with a systemic and sustainable vision, therefore it should not be treated in isolation from its historical, theoretical, social, political, economic, cultural, urban-environmental, technological, etc. context–, in order to improve the habitability and urban spaces located within the Residential Subdivision of the Benemérita Universidad Autónoma de Puebla and thus subsequently justify the need for the proposal of a network of green spaces and recreational areas in different sectors of the settlement, transforming it into a habitable place with low environmental impact so that the inhabitants have good mental and emotional health and have a better quality of life.

For the preparation of this article, different readings were reviewed and analyzed, where this type of approach to the present study is based, explaining the sciences or disciplines that contribute to it.

The main cause raised in this research topic is the interruption in the execution of the residential project and due to the change of administration at the university, the current rector has not shown interest in continuing with the progress of the works since it has other political and economic interests, in addition to the dissolution of ties with the construction company responsible for the project.

As a consequence of the situation mentioned above, the habitability and its conditions are considered, which currently present several plots with serious contamination problems due to lack of intervention. This is added to the fact that the interior spaces of the houses are very small and recently the subdivision does not have enough green and recreational areas for the inhabitants to develop their physical and motor activities, in addition to the fact that there is no integration between the neighbors to solve these problems.

It is intended that as a result of this research, a well-founded study will be generated, with clear objectives and proposals and an ethical and participatory vision on the part of the population, through the coordination of the board of directors that invites, raises awareness, integrates, organizes and informs the inhabitants that the actions carried out will be for the benefit of all the neighbors by implementing workshops, cleaning and planting days, etc., that will improve the current state of the subdivision, in addition to awakening the interest of the current rectorship so that it contributes financially and supports with various contributions with the creation of green spaces - comfortable outdoor and auxiliary areas optimal for work, rest, coexistence and hygiene that will allow transit between the settlers and will function as an important part of the extension of the houses and will be complementary to the interior space - resulting in a state of well-being in the inhabitants.

In addition to the political and economic aspects, it is necessary to resort to the social part, which is essential since the collaboration of the settlers' association and the rest of the inhabitants of different ages of the subdivision will be required in different actions for its improvement and in this way generate community life.

Problem statement

Today there is no study in certain peri-urban settlements in the southern area of the capital of Puebla that establishes guidelines or proposals for improving habitability, such is the specific case of the Residential Subdivision of BUAP, which is a forgotten territory due to the lack of interest on the part of the current officials of BUAP and the construction company Eleganza, by not giving continuity to a project designed and directed to university workers, which originally consisted of the projection of three stages that included in turn three housing prototypes, recreational areas, a shopping center and different access routes to the subdivision, leaving this incomplete and only the first section being executed. This last action is considered optimal since by having a smaller number of inhabitants in a certain place, a good organization can be originated to transform it adequately and therefore improve the living conditions, generating a habitable space.

In addition to the reasons mentioned above, it is worth mentioning that due to the change in the university administration since 2013, the ties with the real estate company in charge of building the properties were dissolved, which abandoned the project immediately and just when the construction of the first houses was finished, subsequently absolving itself of all responsibility.

The above causes the following problems to be raised in terms of the living conditions in Residencial BUAP: Presence of environmental pollution in the territory due to the fact that several vacant lots are left, resulting in physical problems during the rainy and windy season, generating the presence of pests (Figure 1), in addition to a lack of maintenance either in the access to the subdivision (deterioration in the paint, poor lighting, etc.) and the loss of style and typology (change of architectural elements or color on the facades, placement of clotheslines (Figure 2) and shops in the garage or living room area, due to the lack of culture of some inhabitants that causes the absence of functionality in the different spaces of the homes), due to the lack of adequate regulations with norms that regulate how the homes should be maintained and in general contribute to rescuing the aesthetic part and public spaces through their correct use, all this also generated by the lack of control and the lack of integration between its inhabitants of different socioeconomic conditions. (researchers, academics and administrators).

The dimensions of some of the houses are not optimal for families to live there, since the spaces needed for each activity carried out there are not defined based on what the users require. This originates from the beginning because the houses were built without being based on instructions and actions of a housing policy that provides solutions to social problems. Particularly in the present object of research, it is important to implement an adequate design of public spaces (green and recreational areas) in areas that are not being used and in this way they are favorably used as an extension of the houses that were designed in a reduced way.

Box 1



Figure 1

Improvised court in poor condition and spaces that do not fulfill any specific function

Source: Alonso (2017)

Box 2



Figure 2

Placement of clotheslines in the garage area

Source: Alonso (2017)

Just to mention, apart from what was mentioned above that affects the physical and social environment, another risk situation arises: environmental pollution. This contamination is generated by the presence of sewage and waste carried by the Atoyac River and which flow into a specific natural resource, the Valsequillo Lake, which despite attempts to clean it through three treatment plants, continues to deteriorate (Figure 3).

Box 3**Figure 3**

Pollution of Lake Valsequillo, which generates bad odors and the presence of pests

Source: *Alonso (2015)*

The problems caused by the uninhabitable conditions mentioned above psychologically affect the well-being of the inhabitants and their health. The most important to address are the lack of well-designed public spaces (green and recreational areas) in addition to the fact that the existing ones are not well maintained. All this with the objective that the users carry out outdoor activities in comfortable outdoor areas where they have contact with nature and that these function as an extension of the houses that in this case are of very small dimensions.

As mentioned above, the problem is the pollution of the environment generated by the Valsequillo lake and the absence of technologies that treat its pollution, therefore, the deterioration of the public spaces in the subdivision is an expression of the habitability not achieved in its entirety. Due to this, it is considered that the object of research is of a complex nature and must be studied from the perspective of other disciplines or sciences such as environmental psychology focused on systems in the area specifically for the improvement of habitability.

The BUAP Residential Subdivision is a peripheral settlement located in the southern region of Puebla that has the advantage of being built in a strategic location, near Lake Valsequillo (a body of water of great importance in the city of Puebla), with a magnificent view of this and other landmarks that are part of a heritage of great value and natural wealth such as the Sierra del Tentzo and the Iztaccíhuatl and Popocatepetl volcanoes.

Regarding the scientific importance of the place, it has not been studied, therefore the research, which is an analysis where the construction of the object of study is intended from the theory of complexity and other disciplines such as environmental psychology, will contribute knowledge by knowing both the conditions that have contributed to generating the deterioration of the public space of the subdivision, as well as the consequences on the living conditions of the residents, all this through documentary and field research. Particularly, to contribute through the evaluation of the aspects of social coexistence, architecture and urban environment and the way in which these have been modified by the actions of the users themselves.

Due to its social importance, the site deserves special attention, so that 'rationally environmentally-based development strategies linked to technology' are proposed that make it a habitable and at the same time sustainable place by proposing, among other vitally important aspects, green areas for recreation and the installation of urban furniture in abandoned public areas, allowing a proposal for landscape design in the subdivision and the improvement of public space, through proposing vegetation native to the place, linked to a method of water treatment in a sustainable way through the implementation of artificial wetlands that contribute to the cleaning of the Valsequillo lake, also generating in this way, with the need for a transdisciplinary approach through the communication and integration of different social sectors, better living conditions among its inhabitants.

The incorporation of other disciplines such as environmental psychology is necessary for the present research topic, since this science defends the environment.

Thus, the general objective is to show the environmental, socioeconomic, political and cultural processes in order to find out which factors have intervened or affected the development of the BUAP Residential subdivision, such as the pollution generated by harmful urban design; and that through habitable spaces and sustainability, the living conditions of this territory are improved by means of the integration of the same settlers, establishing guidelines or proposals for improving habitability that do not cause an environmental impact; and as specific objectives, it is recommended to contribute to the improvement of habitability based on an epistemic framework through possibilities for transformation in the subdivision that adequately propose alternatives and strategies for the conservation of public areas through community participation and a transdisciplinary approach where different types of inhabitants intervene and contribute to the implementation of recreational and green areas; establish social standards that come from agreements between the residents of the subdivision to avoid visual deterioration by modifying the typology and style planned from the beginning and thus not affect the aesthetic appearance of the houses; and propose alternative solutions to rationally take advantage of what nature offers us through the implementation of sustainable technologies such as rainwater collection cisterns that are later used to water green spaces, certain types of plants to mitigate the proliferation of pests (which is also part of the problem that affects habitability) and the installation of an artificial wetland that contributes to the cleaning of the Valsequillo lake, transforming that territory into a habitable place with less environmental impact that helps not to deteriorate the health of the population.

Hypothesis

The existence of conditions of environmental awareness of man (environmental psychology), will be achieved through a process of community participation among the settlers of Residencial BUAP to improve it, appropriating their territory and becoming its managers through participatory workshops (social cartography workshops and similar), which have their techniques and instruments to facilitate reflection and cause their actions in the subdivision to be conscious and not imposed by someone or by some, promoting respect for the environment and for others (the neighbors, the different) through a social pact agreed by them, to ensure the preservation of that site or transform it rationally, through possible alternatives and strategies for the maintenance of public spaces that contribute to an improvement of the appearance of the subdivision, transforming it into an aesthetic, functional, habitable and sustainable space.

Theories on urban spaces, habitability, sustainability and complex systems

Below is a general description of the main theories regarding habitability, sustainability, urban spaces and complex systems. One of the urban planning models that has influenced global urban praxis is the French school of Marxist urban sociology. The main exponent of this school is Henri Lefebvre, who, through a critical analysis of the Charter of Athens, shows that its criteria for zoning the city into functions only caricatures life, and states that homo urbanicus is something more complex than just living, working, moving around and entertaining himself, since he has other needs to cover and discover, such as desire, play, the symbolic, the imaginative, in short, infinite and innumerable desires that arise as society develops its productive forces and its daily life (Gasca, 2017).

The aspects that affect habitability and the causes are considered, carrying out an analytical and critical discourse, subsequently incorporating other concepts that help to epistemologically construct the object of study.

Alcalá conceptualizes habitability in urban space as: a housing condition where housing is physically integrated into the city, with good accessibility to services and facilities, surrounded by a quality public space, and this is lacking when the housing, even if in good condition, is located in a vulnerable, marginal and difficult-to-access area. Therefore, from the housing point of view, it is necessary to analyze urban policies that could have a direct impact on the improvement of housing conditions, which would have as areas and axes of action: inter-neighborhood spaces or areas, the road system, public space inside and outside the neighborhoods, infrastructure, services and public transportation, green spaces, functional enrichment of residential areas, programs aimed at creating new centralities (diverse activities and uses) and common reference spaces (Moreno, 2008) (Figura 4).

Box 4

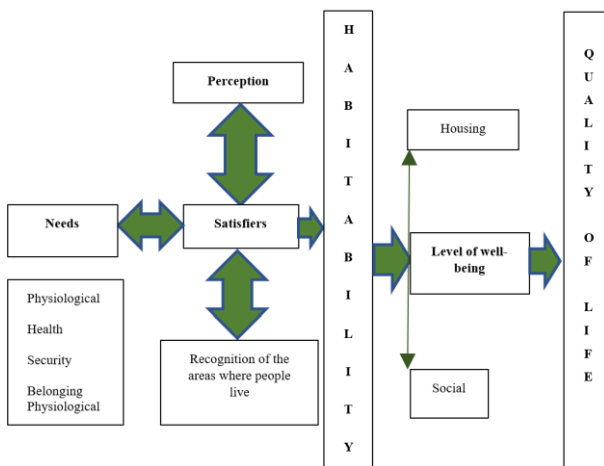


Figure 4

Needs, satisfiers, habitability, quality of life
 Source: Moreno (2008)

Rolando García's explanation regarding complex systems is important, a theory that underpins the research. Rolando García explains that: To solve environmental problems it may be necessary to resort to knowledge that comes from various disciplines (chemistry, physics, biology, specific production technologies). However, in the conception that García sets forth, this pluri (or multi) discipline does not give the study characteristics of an interdisciplinary research.

Some situations correspond to complex problems, where the physical-biological environment, production, technology, social organization, and economy are involved. Such situations are characterized by the confluence of multiple processes whose interrelations constitute the structure of a system that functions as an organized whole, which has been called a complex system (García, 2006) (Figure 5).

Box 5

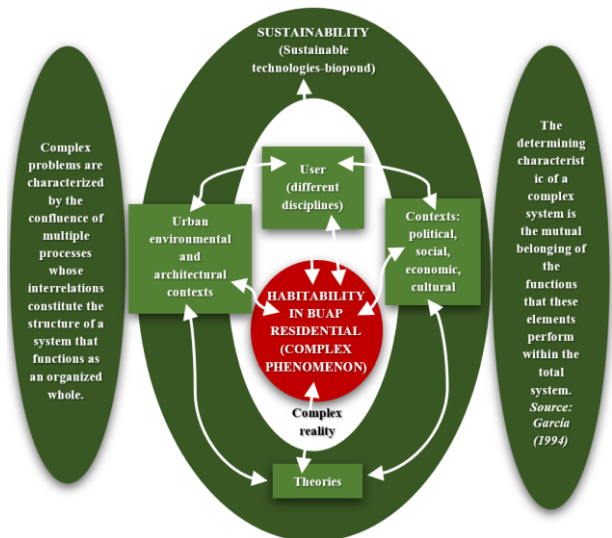


Figure 5

Habitability scheme, a complex system
 Source: Alonso (2023)

One of the reasons for this study is to consider recommendations to transform the BUAP Residential subdivision into a habitat with low environmental impact and a tendency to become sustainable. Carlos Priego González de Canales of the Institute of Advanced Social Studies IESA-CSIC in his article: 'New ways of understanding urban nature. Green areas in cities' mentions that: the international conference that took place in Singapore under the motto 'Sustainable housing: tracing new frontiers', advocated that cities be redesigned to advance towards new models of more sustainable cities both economically, socially and environmentally. In this sense, the challenge of the European Union is to incorporate sustainability into the existing city, betting on new urban developments, where urban green spaces play a primary role in increasing the quality of life of the population (Priego, 2011).

It is recommended that the regulations regarding sustainable housing really be taken into account for the design of housing in the country, since in reality the opposite is observed.

For Mexico, sustainability in its buildings is no longer a luxury or an amenity, but a requirement demanded by both users and the market, and in this sense it must have a holistic and comprehensive approach, where the environment is cared for and an optimal way of living is also guaranteed to the inhabitants of the homes.

Regarding the issue of urban spaces, it is necessary to consider that public areas in today's cities have lost their value as spaces for enriching encounters with the population's usual activity, and their reflection in the citizen's sense of belonging. In this context, urban public space, as a physical space, acquires great relevance to promote and maintain the integration of the community and the individual into it, avoiding alienation and manipulation, favoring the defense of identity, the flow of communication and collaboration on common issues. The territory of the public, in our society, is increasingly narrowing for the benefit of the private, even the existing public space is authorized for the benefit of a few. Within the aforementioned urban green spaces, those areas that, due to their size and/or function, do not allow for social uses were not considered, although it is recognized that they contribute to improving the urban environment, both visually and environmentally: medians of streets and avenues, roundabouts, gardens on sidewalks, gardens in plazas, etc. These types of areas, if they have a design appropriate to their function, play an important environmental role: as part of the urban landscape and in the improvement of microclimatic conditions: absorbing noise, capturing dust and rainwater. They also allow the use of vegetation as an architectural element to delimit, zone, prioritize and articulate public open space (Capitanachi, 2023).

The research addresses the characteristic object of study of environmental psychology, which is the interaction between people and their environments, and that this interaction is necessarily framed within a social context (or social interaction), so the 'products' of this interaction between person and environment (including the person and the environment) must be considered first and foremost as 'psycho-socio-environmental' products.

It is in these terms that the question raised allows us to reconsider environmental psychology as environmental social psychology, although social psychology is only one of the sources from which our discipline draws. However, the delimitation of what environmental psychology is has not always taken into consideration the same perspective since, as Altman and Rogoff (1987) point out, there are several positions when it comes to understanding the person-environment interaction (Valera, 1996).

As has been seen, various personal factors -whether psychological or demographic- influence the appearance and maintenance of environmental protection behaviors, also taking into account the educational system as an inducer of ecological behaviors that translate into changes towards caring for the environment. Therefore, it is pertinent to develop critical environmental thoughts, attitudes and skills that allow individuals to counteract the effects of environmental myths in order to make responsible and mature decisions, based on the ethical principles of environmental education. It is worth mentioning that the satisfaction of material needs is an element of great importance in determining the quality of life, but that it does not reduce it to this. Full well-being is possible within the framework of a life endowed with meaning that integrates the value system in the inhabitant of the subdivision (García, 2005).

Methodology

The research is a study based on the complexity approach that covers the following stages: the first one presents the theory or approach of complex systems considering habitability as the main concept to be addressed, since it is part of the construction of the object of study; the research, being of a transdisciplinary nature, takes into account the contribution of other different disciplines and concepts such as quality of life, sustainability, complex systems and habitable urban spaces, environmental psychology, etc., on which the study is based. In the second stage, field research is done through the observation process, which is carried out in the territory where the study area is located.

As a researcher, you go to the workplace for some time to identify the existing problems through different techniques such as photographic surveys, interviews, qualitative research through surveys (application of a questionnaire to the residents of the site), graphs, etc., to learn about the main needs of the users and thus be able to implement the best solution strategies to solve the problems of the subdivision. Being a resident of Residencial BUAP and having interaction with the residents, allows having references that help to know more accurately the reality of the observed object. "To collect reliable information, certain instruments such as the questionnaire are applied". The sample size was approximately a universe of 30 inhabitants, from which people with different socioeconomic levels and therefore different needs were chosen. According to this and since it is a study related to the subject of habitability and other disciplines such as environmental psychology, the questions asked to the residents of the subdivision were of a qualitative nature (Figure 6).

The following graph shows the problems indicated by the users through the interview as a percentage. The purpose of this instrument was to consider a universe of 30 residents, interviewing in an equitable manner the same number of men (fifteen) and women (fifteen) of different age ranges between 35 and 60 years.

Box 6

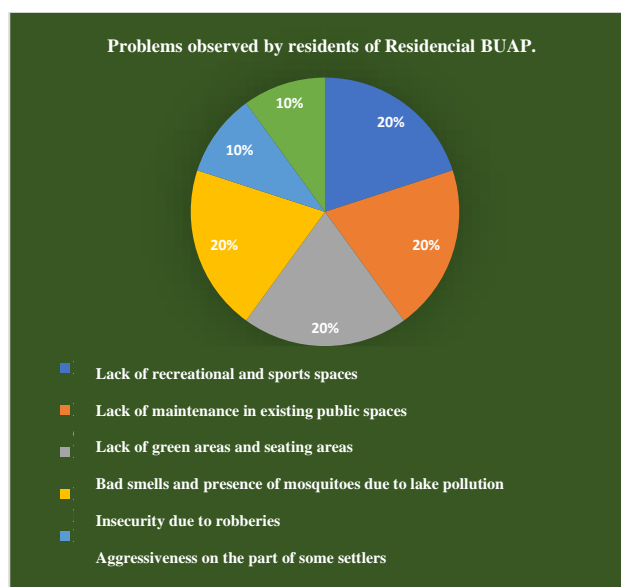


Figure 6

Chart of problems observed by residents of Residencial BUAP

Source: *Alonso (2017)*

In the third stage, results are presented and in the fourth stage, conclusions are shown and recommendations are suggested to solve the problems observed, resulting from the interviews applied to the different users. It is important to suggest from the first instance that there is an optimal community integration between the inhabitants of Residencial BUAP (it is a subdivision with few inhabitants and the objective can be achieved), and in this way agreements are reached between the Board of Directors and the residents of the subdivision to establish a regulation dictated in common agreement that responds to the knot of problems already mentioned. The regulations established based on a dialogue of knowledge, will set standards for the hiring of trained security personnel and the installation of security systems and in this way the theft rates are minimized; to achieve these objectives, the residents will contribute with the punctual payment of their monthly maintenance fee. In addition, the design of public spaces that includes the installation of lighting will help minimize insecurity. Some alternatives are pointed out related to the application of technologies for the creation of green areas and the implementation of a system called artificial wetland to contribute to the cleaning of the lake, eco-ponds, as well as some options as urban design solution strategies for recreational areas in the BUAP Residential Subdivision. The different problems that require a proposal for technological and sustainable innovation in the subdivision are addressed, transforming it into a functional, aesthetic, habitable territory that does not cause environmental impact. As previously mentioned, the BUAP Residential Subdivision is a set of urban, social and environmental scenarios. With the organization and participation of the residents of the subdivision, through forestation days and being up to date with their monthly fees, more vegetated areas will be promoted in the abandoned vacant lots of the subdivision.

Results

In January 2019-2021, through the participation of the residents of Residencial BUAP, a garden was created including afforestation (planting trees) and a biopond through permaculture: "Permaculture is the art of designing living spaces, functional territories, professions and lives rich in meaning, inspired by nature.

It also takes care of human beings, the earth and sharing equitably”, which is part of the project: Huerto Valsequillo whose motto is 'saving and rescuing the body of water of the Balsas River and the Atoyac River, its tributary' being on the riverbank of the same, in a park already proposed in Residencial BUAP next to the Valsequillo dam, with the participation of the Neighborhood Committee and the coaching of Sembrarte, who collectively propose to make a world betting on life. In 2022, there were situations that contributed to affecting the project (cutting off the water supply, etc.), which fortunately did not stop community participation but on the contrary, the group of neighbors was strengthened and currently in 2024 they are still active (Figures 7 and 8).

Box 7



Figures 7

Construction process of the biopond at BUAP Residential Complex

Source: *Alonso (2019)*

Box 8



Figures 8

Final result of the construction process of the biopond at BUAP Residential Complex

Source: *Alonso (2019)*

Since 2016, awareness has been raised among students of the Bachelor of Architecture degree at the Faculty of Architecture of the Benemérita Universidad Autónoma de Puebla (subjects: Architectural urban design criteria/Landscape architecture workshop/Architecture and environmental development/Bioclimatic design) to consider habitability as an important element and generate sustainable urban design projects.

Conclusions

The concrete contribution of this research to the dominant paradigm of recursion (apathy and disinterest on the part of the inhabitants of Residencial BUAP who believe they are in their comfort zone) will be achieved by raising awareness among the settlers, generating a new paradigm shift that will cause their interest and availability to improve the habitability of the subdivision through the transformation of urban spaces with the implementation of decent green and recreational areas that function as an extension of the homes. From the interdisciplinary field of (environmental) psychology that focuses on the interaction between people and their context, whether it be nature or the built environment (urban-architectural) and social, environmental education is recommended in the subdivision to improve its urban habitability, through the organization and participation of the neighbors, which has already begun to be implemented with previous forestation activities and the creation of the biopond where principles of the integral concept of permaculture have been implemented. The implementation of artificial wetlands that contribute to the cleaning of Lake Valsequillo is also recommended (Figure 9).

Box 9

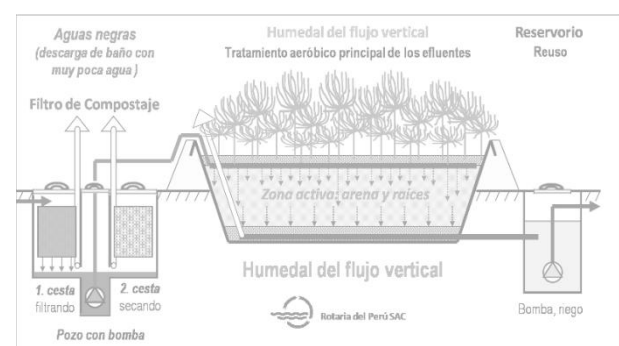


Figure 9

Artificial wetland

Source: *Rotary of Peru SAC. Sustainable sanitation solutions (2017)*

The green areas will provide comfort and health benefits to the inhabitants of the BUAP subdivision, in addition to preventing soil erosion and creating healthy environments as an extension of the homes. The untouched lands in the study area where the green areas will be implemented are located in the southern perimeter just adjacent to the Valsequillo lake and in the central area of the subdivision (Figure 10).

Box 10

Table 1

Context of benefits of urban green areas

Strategies	Process	Benefit
Shade	Reduces interior temperature	Reduces energy requirements
Organic cover	Suspended particle capture	Reduces health problems caused by pollution
Evapotranspiration	Rainwater harvesting	Reduces surface runoff
Water retention		
Successional dynamics	Reduction of areas with solar radiation	Increase in local fauna (avifauna)
Solar energy absorption		

Source: López (2012)

For the transformation of the territory, the implementation of a management instrument (internal regulations) in the subdivision is recommended, which will contribute to its few inhabitants, whether they are owners or not, in common agreement and through the dialogue of knowledge, comply with the established norms for the good use and maintenance of public and private spaces and thus generate good behavior and a friendly atmosphere among the inhabitants of the subdivision.

The regulations will establish norms to avoid modification of the typology and color of the houses, to hire trained security personnel and to install lighting and security systems and in this way to minimize theft rates; to achieve these objectives, the settlers must be up to date with the payment of their monthly maintenance fee.

Declarations

Conflict of interest

The author declares that he has no conflict of interest. He has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Author contribution

Alonso-Pérez, Carlos: Contributed to the project idea, research method and technique.

Availability of data and materials

The data obtained in this research are available.

Funding

The research did not receive any funding.

Abbreviations

BUAP	Distinguished Autonomous University of Puebla
IESA	Institute of Advanced Social Studies

References

Basics

Capitanachi, D [2023]. *Procesos urbanos*. E-RUA. Vol. 15. Núm. 03. 2-113.

García, R. [2006]. *Sistemas complejos: Conceptos, métodos y fundamentación epistemológica de la investigación interdisciplinaria*. GEDISA.

Valera, S. [1996]. *Psicología ambiental: Bases teóricas y epistemológicas*. Monografías psico-socio-ambientales. No. 9. 1-14.

Supports

García, E. [2005]. *Calidad de vida y medio ambiente. La psicología ambiental*. Universidades, núm. 30, julio-diciembre. 9-16.

Moreno, S. [2008]. *La habitabilidad urbana como condición de calidad de vida*. Palapa, vol. III, núm. 2. 47-54.

Priego, C. [2011]. *Nuevas formas de entender la naturaleza urbana. Áreas verdes en las ciudades*. *Ambienta: La revista del Ministerio de Medio Ambiente*. N°. 97. 46-65.

Discussions

Gasca, J. [2017]. [Henri Lefebvre y el derecho a la ciudad. Exégesis desde sus "Tesis sobre la ciudad"](#). Bitácora Urbano Territorial. Vol. 27, no. 2. 19-25.

Augmented reality as a support for tourism promotion

Realidad aumentada como apoyo para la difusión del turismo

Sánchez-Juárez, Ivan Rafael*^a & Paredes-Xochihua, Maria Petra^b

^a Universidad Da Vinci • ABW-3403-2022 • 0000-0001-8296-5532 • 493160

^b Tecnológico Nacional de México - ITS de San Martín Texmelucan • KVA-5814-2024 • 0000-0003-1753-2313 • 298117

CONAHCYT classification:

Area: Engineering
Field: Engineering
Discipline: Systems engineer
Subdiscipline: Computer Sciences

<https://doi.org/10.35429/EJROP.2024.10.18.1.10>

Article History:

Received: January 27, 2024
Accepted: December 31, 2024



* [ivan_r.sanchez@smartin.tecnm.mx]

Abstract

Currently, Augmented Reality (AR) facilitates interaction between virtual environments and the physical world, allowing both to blend seamlessly through technological devices such as webcams, mobile phones (iOS or Android), tablets, among others (Grapsas, 2019). Therefore, the aim is to develop an augmented reality project to promote tourism in a municipality of the state of Puebla. For this purpose, an analysis of the different types of augmented reality available will be carried out, including marker-based augmented reality, geolocation-based augmented reality, object recognition and projected augmented reality, with the aim of providing a better experience for tourists. This article presents the different characteristics of each type of AR, showing application examples, and some of the tools necessary for the development of augmented reality applications.

Resumen

Actualmente, la Realidad Aumentada (RA) asigna la interacción entre ambientes virtuales y el mundo físico, posibilitando que ambos se entremezclen a través de un dispositivo tecnológico como webcams, teléfonos móviles (IOS o Android), tabletas, entre otros. (Grapsas, 2019). Por tal motivo, se pretende desarrollar un proyecto de realidad aumentada que permita difundir el turismo en algún municipio del estado de Puebla, para ello se deberá realizar un análisis de los diferentes tipos de realidad aumentada que hay, entre los cuales se encuentra realidad aumentada basada en marcadores, en geolocalización, reconocimiento de objetos y proyectada; esto con el fin de brindar una mejor experiencia al turista. En este artículo se presentan las diferentes características que tienen cada uno de los tipos de AR, mostrando ejemplos de aplicación y algunas de las herramientas necesarias para el desarrollo de aplicaciones de realidad aumentada.

Goals	Methodology	Contribution
Generate Augmented Reality Spreading tourism. Geolocation 	AR Concept Review Identify the types of RA Find AR Software 	Tourism development. Promote local culture

Objetivos	Metodología	Contribución
Generar Realidad Aumentada Difundir turismo. Geolocalización 	Revisión de concepto AR Identificar los tipos de AR Buscar software para AR 	Desarrollo turístico Promueve la cultura local

Augmented reality, Geolocation, Tourism

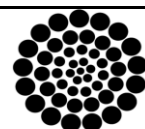
Realidad Aumentada, Geolocalización, Turismo

Citation: Sánchez-Juárez, Ivan Rafael & Paredes-Xochihua, Maria Petra. [2024]. Augmented reality as a support for tourism promotion. ECORFAN Journal-Republic of Paraguay. 10[18]-1-10:e31018110.



ISSN 2414-4827/© 2009 The Author[s]. Published by ECORFAN-Mexico, S.C. for its Holding Republic of Paraguay on behalf of ECORFAN Journal-Republic of Paraguay. This is an open access article under the CC BY-NC-ND license [http://creativecommons.org/licenses/by-nc-nd/4.0/]

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



RENIECYT
Registro Nacional de Instituciones y Empresas Científicas y Tecnológicas

1702902 CONAHCYT

Introduction

Since the pandemic confinement caused by the SARS-CoV2 virus, different economic sectors have experienced a large decrease in their population, and the tourism sector was no exception, as access to places was restricted, sometimes only a certain number of visitors were accepted, strict entry times were set or even places were closed and tourists were not allowed access. As the pandemic developed, the tourism sector had to innovate in the way it catered to its visitors, and creative responses and innovative solutions emerged, using technologies that facilitated virtual alternatives that allow the exploration of destinations through virtual tours, online experiences and augmented reality tools. Information provided by (Datos Abiertos. 2024) shows that, in January 2020, Puebla capital had 238,408 tourist arrivals, while in January 2023 there were 193,306, having a decrease of 18.91%, but for the months of September and December of the same years the information shown in table 1 was obtained:

Box 1

Table 1

Comparison of tourists in 2020 and 2023

	Sept. 2020	Sept. 2023	Dec. 2020	Dec. 2023
Tourist arrivals	47,984	244,563	60,930	296,035
Hotel occupancy rate	14.9	58.76	17.21	61.78

Source: *Open Data*

<https://datos.pueblacapital.gob.mx/dataset/estad%C3%A1stica-de-turismo-datatur>

From this information it is observed that, for the month of September 2023 compared to 2020, there was an increase in tourist arrivals of 409.67% and for the month of December of the same years there was an increase of 385.86%; while hotel occupancy increased by 394.36% in the month of September and 358.97% in the month of December; so a considerable increase in the tourism sector is visualised.

Technology has been taking a very important role in the increase of tourists, initially using live or pre-recorded video media content, podcasts, films or television programmes.

Later, tools such as virtual reality or augmented reality were incorporated, which offers tourists a better user experience, as it provides information in real time about historical places, monuments or art; it also allows for a better guide to tourist attractions that are close to the user, or shows information about restaurants, hotels, opening hours or tourist attractions.

This paper describes different types of augmented reality that will allow the selection of the appropriate tool to disseminate or improve immersive and personalised experiences that adapt to the individual preferences of the traveller. Among the types described in this paper are marker-based augmented reality, geolocation, object recognition and projection.

Some of the necessary software such as Unity, Vuforia, Blender, ARKit, ARCore, VPT8, Heavy M, Mad Mapper, Python and web augmented reality platforms such as Zappar and Onirix will also be described.

The presented article has the following sections: Review of the state of the art in which different studies conducted in the tourism field in Spanish-speaking countries will be analysed; Augmented reality, this section describes what the augmented reality technique consists of; the third section deals with the types of augmented reality, this section helps the reader to identify which type can be applied for various projects and finally, various programs that can be used for augmented reality are described.

State of the art

This section shows a number of works in the area of augmented reality, ranging from application development to user experience guides based on the tourism sector. The works reviewed come from countries such as Spain, Colombia, Ecuador and Cuba; having a panorama of Spanish-speaking countries.

In the work developed by (Bernad Conde. 2020), virtual reality technologies applied to cultural heritage were analysed, particularly the Fuendetodos app, which can only be activated once the visitor is in Fuendetodos, incorporating augmented reality, geolocation and gamification, the use of games as an educational tool.

The hypothesis put forward for this work was: the use of the Fuendetodos app would allow the user to generate a more complete and dynamic knowledge of the figure and presence of Goya in the town of Fuendetodos, which was positively verified. The use of the application generates learning and allows users to participate in this process.

On the other hand, (Alanis, Gaetan & Martín. 2021) proposed a preliminary set of User Experience guides for mobile Cultural Tourism applications, based on Augmented Reality. The proposal is based on: the review of existing studies on User Experience in software products for Cultural Tourism with Augmented Reality, and also on the analysis of User Experience experts.

In (Colpas *et al.*, 2024) they conducted a study whose main objective was to evaluate the impact of the implementation of Augmented Reality (AR) technology in the Main Square Alfonso Avila Quintero, with the hypothesis that AR can revitalise tourism and culture in Agustín Codazzi, Cesar. Specific RA experiences were designed for the square, integrating local historical and cultural aspects; likewise, data were collected to identify the characteristics of the developments to be carried out, so that they would have the articulation of the indigenous component of the region. The result was a significant increase in the improvement in the perception and cultural interest of visitors to Agustín Codazzi.

The research carried out by (Sánchez Jorge, Jiménez Valero & Velastegui López, 2022) aims to demonstrate the impact of the use of augmented reality and smart devices to improve key processes in tourism activity, market products and services of the different destinations, add added value and boost communication through interactive resources.

Finally, the work reviewed is that developed by (Núñez Arroba. 2024) which seeks a way to promote cultural tourism in museums, proposing a web application that uses augmented reality. Thus, surveys were carried out to find out visitors' interest in this technology.

In addition, the RAD (Rapid Application Development) methodology was used for the development of the application, which allows close contact with the client and rapid delivery of the product. Express.js and React.js were used as development tools along with the MySQL relational database manager. Also, Model Viewer was used to apply Augmented Reality and the technique of photogrammetry to model the museum's 3D panels.

Augmented reality

Augmented Reality is a computational technique that allows humans to interact between the real world and the digital world through a device such as a tablet or smartphone. Augmented Reality (AR) is a technology that allows virtual elements to be superimposed on our vision of reality (Iberdrola. 2023).

Blender can be used to design three-dimensional objects, as it allows the creation of 3D visualisations, still images, 3D animations and visual effects.

As a cross-platform application, it is possible to use Blender on Linux, macOS and Windows systems. It also has relatively low memory and storage requirements compared to comparable solutions. Its interface uses OpenGL to provide a consistent experience across the entire spectrum of supported hardware and software platforms (Blender, 2024).

Types of augmented reality

1. Marker-based Augmented Reality (RAM)

Marker-based augmented reality is created by using image recognition to identify objects already programmed into your AR device or application. By placing objects in view as landmarks, they can help your AR device determine the position and orientation of the camera. This is usually accomplished by switching your camera to grayscale and detecting a marker to compare that marker to all the others in your information bank. Once your device finds a match, it uses that data to mathematically determine the pose and place the AR image in the correct location (Microsoft, n.d.).

The markers or patterns are usually printed images, which the user defines what will be displayed when the phone detects it, the larger the marker, the further away from the camera it can be placed; Table 2 shows the size and distance recommended by the Ministry of Education (2024).

Box 2

Table 2

Recommended size and distance for markers

Size	Distance
16 * 16 cm.	1.90 mt.
11 * 11 cm.	1.30 mt.
7.5 * 7.5 cm.	1.00 mt.
3.5 * 3.5 cm.	0.40 mt.
1.3 * 1.3 cm.	0.16 mt.

Source: own elaboration

Figure 1 shows the design of a marker that can be used for object recognition.

Box 3

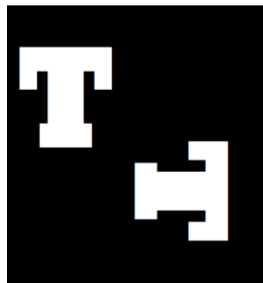


Figure 1

Marker for augmented reality

Source: own elaboration

Software that can help create this type of augmented reality includes Unity and Vuforia. 2. Geolocation-based Augmented Reality (GAR). It uses mobile phone GPS data to determine the user's position in the real world and then overlays digital information. Instead of relying solely on markers (seen in the previous point). With this type, the user can be at the geographical coordinate with latitude and longitude: 19.0437048961, -98.1981561970, which belong to the zocalo of the city of Puebla, when the user is at that exact point, he can visualise relevant tourist information, and when he goes to another point like: 19.0439763383, -98.1922419026, which belongs to the Barrio del Artista in Puebla, the phone will show him information about the different Masters, works of art and history of the neighbourhood.

To obtain geographic coordinates, you can use Google Maps, since it provides latitude and longitude of the place. Figure 2 shows the coordinates of Barrio del Artista, Puebla.

Box 4

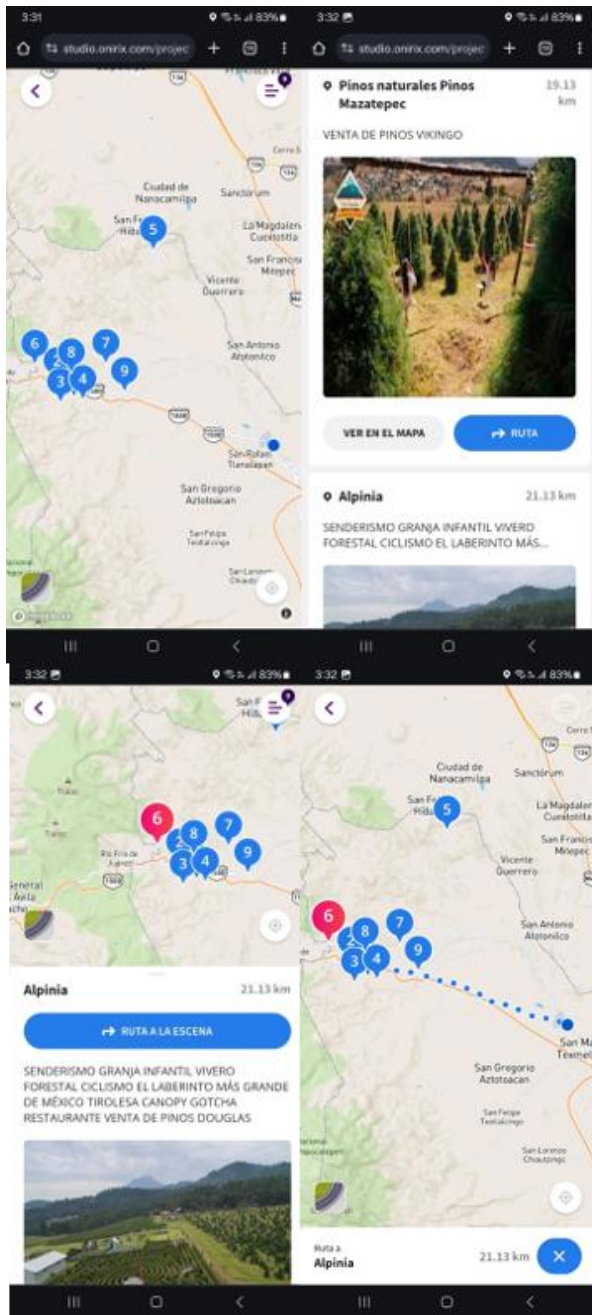


Figure 2

Obtaining latitude and longitude of Barrio del Artista, Puebla

Source: Google maps

Among the tools that allow working with RAG is Unity, ARKit or ARCore, however, it is important to mention that a geolocation API must be used that allows developers to integrate maps and location data into applications. The Google Maps Platform includes the Geolocation API. However, there are web platforms that help to generate RAG, among them are Zappar and Onirix. Within Onirix you can generate different tourist sites, show important information or some animation of the place, when you have the places ready, you can see them on a map which will show the route from the origin to the destination. Figure 3 shows an example of a tourist map with 9 places in the municipality of Santa Rita Tlahuapan, Puebla. It shows information of a specific place, the location marked with red colour and the route to follow from the current location to the destination.

Box 5**Figure 3**

Information on Onirix

Source: own elaboration

3. Augmented Reality based on Object Recognition (RARO)

An augmented reality with artificial intelligence is able to recognise objects in the real environment in such a way that it will superimpose additional content by linking it to the object (Tolsan. 2020). For example, if a tourist is in the parish of San Martín Texmelucan, Puebla, and points his phone at the monolith there, it can show him the legend of the monolith. Figure 4 shows the monolith of the parish.

Box 6**Figure 4**

Monolith of San Martín Texmelucan

Source:

<https://www.tiktok.com/@sanmartintexmelucan/video/7052441310011198725>

Software tools such as Unity, ARKit, ARCore, Vuforia, ARCore Object Detection API or ARKit Image Recognition can be used to realise RARO depending on the platform for which it is to be developed.

4. Projection-based Augmented Reality (PAR)

Finally, within the types of augmented reality is based on Projection, clarifying that there are other types of augmented reality and not only the 4 that cover this work, RAP is a technique that allows the deployment and manipulation of virtual objects in a real world such as flat surfaces or with relief, this will allow the tourist (user) to have a perception of being manipulated in a natural way a virtual object, without the need to have a smartphone.

RAP projects digital images onto physical objects in a real physical space. It may or may not be interactive and is used to create a projection of objects that are viewed in depth (Moreno, 2023).

This type of augmented reality requires special software and hardware to be able to generate the projections, within software that can be used is VPT8, Heavy M, Mad Mapper and Python, in the case of Python, the modules OpenCV - cv2 - (image and video processing) and Pynout (controls and monitors input devices) must be used.

The hardware required is short or medium distance projectors, if not available, an extended screen can be used, a Full HD 1080p, 30 FPS, 120°FOV webcam and preferably a portable tri-foot is also required.

Among the applications that could be developed for tourists in a rural environment, would be the projection of animals and that tourists could manipulate them, be it moving them, rotating them or making them bigger or smaller.

Figure 5 shows an animal of a set size, with RAP and gesture detection, it is possible to modify the size or rotate it by hand.

Box 7



Figure 5

Object in a set size

Source: own elaboration

Figure 6 shows the same object manipulated by hand to make it larger and rotated.

Box 8

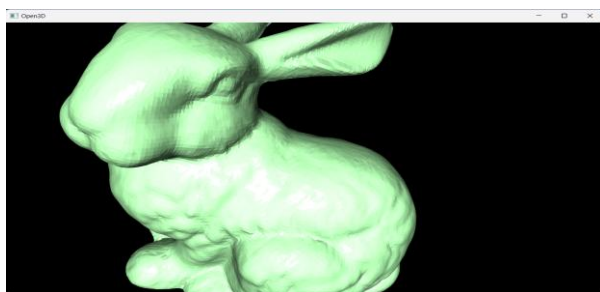


Figure 6

Manipulated object with hands

Source: own elaboration

Python and objects designed with .obj or .ply extensions are used to develop this type of augmented reality. Table 3 below shows a portion of the Python source code for object manipulation.

Box 9

Table 3

Portion of the Python source code for manipulating an object with RAP

```
with mp_hands.Hands(min_detection_confidence=0.8,
min_tracking_confidence=0.5) as hands:

while cap.isOpened():

ret, frame = cap.read()

image = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
#image = cv2.resize(image, (320,180)) #para 16:9
#image = cv2.resize(image, (640,480))

frameWidth = image.shape[1]
frameHeight = image.shape[0]

image = cv2.flip(image, 1)

image.flags.writeable = False

results = hands.process(image)

image.flags.writeable = True
image = cv2.cvtColor(image, cv2.COLOR_RGB2BGR)
pos = (0,0)
cv2.rectangle(image, pos, (frameWidth,
frameHeight),(0, 0, 0), -1)

totalHands = 0
```

Source: own elaboration

Software for augmented reality

As seen in the four types of augmented reality, software is required for its development, some of which are described below:

Unity

Masterd (2024) defines Unity as: 'is what is known as a development engine or game engine. It has a set of programming routines that enable the design, creation and operation of an interactive environment'.

Typical functionalities of a game engine include the following:

- Graphics engine to render 2D and 3D graphics.
- Physics engine to simulate the laws of physics.
- Animations.
- Sound.
- Artificial Intelligence.
- Programming or scripting.

Vuforia

Is a cross-platform Augmented Reality (AR) and Mixed Reality (MR) application development platform with robust tracking and performance on a variety of hardware (including mobile devices and head-mounted mixed reality displays (HMDs) such as Microsoft HoloLens). Vuforia's integration of Unity allows you to create vision apps and games for Android and iOS using a drag-and-drop authoring workflow. Vuforia supports many third-party devices (such as AR/MR glasses) and virtual reality devices with rear-facing cameras (such as Gear VR) (Unity Documentation. 2018).

ARKit

It is an infrastructure that allows developers to produce augmented reality experiences in their app or game. Developers can add 2D or 3D elements using the front or rear-facing cameras of an iOS or iPadOS device (Apple Inc. 2024).

ARCore

Google ARCore is a software development kit (SDK) for the Android operating system (OS). Through ARCore, developers can also create applications that allow a phone to understand real-world environments and even interact with different types of information. ARCore's functionality boils down to three key pillars that help integrate virtual and real-world content (Pocayo. 2023).

VPT8

It can be used to project mappings in complex shapes, adapt a projection to a particular space/surface, combine recorded and live images, for multi-screen HD playback, for interactive installations using arduino sensors or camera tracking ++. VPT is very flexible in terms of control, with presets and a built-in cue list, as well as control over almost all parameters via OSC, midi, serial communication, integrated LFO and ArtNet. It also supports siphon (mac) and spout (windows) for sharing video streams between applications (HC Gilje. n.d.).

Heavy M

is a video mapping software with a wide range of tools to cope with any situation: integrated visual library, musical reactivity, edge-bl, offers intuitive drawing tools to create fast and adaptive projection maps (HeavyM. 2024).

Mad Mapper

A mapping software that makes videomapping possible: it simplifies the adjustment of projections on various surfaces, whether three-dimensional or two-dimensional.

Zappar

Vegas (2017) describes Zappar as follows: it has an interesting idea to create augmented reality projects in a simple way: through a visual environment you can drag and drop the elements you want to project and finally launch the app under an intuitive and straightforward system. Zapwork has several benefits:

- Three types of creations (widgets, designer, studio).
- Transparent costs.
- Support.
- Image tracking.
- Create apps.
- Has analytics.
- Also uses virtual reality.

Onirix

Onirix is a platform that allows you to create different types of augmented reality experiences in a fast and easy way. Onirix consists of three different components: Onirix Studio, a web application to manage all your projects and content, Onirix Web AR Player which is the way to display your experiences from the browser (Web AR), and Onirix SDK, a software development kit for you to create your own augmented reality experiences for web AR (Onirix. n.d.).

Results

From the state of the art, which included the review of 5 developed projects related to augmented reality and its application to cultural tourism, it can be said that the tourism sector in Mexico needs to employ technologies that allow tourists to improve their experience, in such a way that allows them to interact with the environment they are in or to obtain historical or cultural details about a specific region or place.

The review of the concept of augmented reality allows a breakthrough in the way in which users interact with the environment, by combining digital elements and the real world, in this case, in the area of tourism; so that subsequently a classification can be given to the types of AR that exist.

By describing the different types of AR that exist, it allows those who wish to implement this type of technology to clearly understand the technological diversity that exists to implement it in tourism according to their needs, as they will be able to compare the benefits and limitations that each type of AR has.

Finally, it is very important to mention the different software available on the market, both free and paid, to facilitate the selection of appropriate tools and optimise the efficient development of augmented reality projects, adjusting to the specific needs and available budgets depending on the type of project and AR selected.

Conclusions

In the tourism sector, each of the types of augmented reality can be directly applied to provide the tourist with a better experience in person or even from a web application that works in the mobile browser. The four types of reality analysed have their advantages in the tourism sector, whether rural, nature, cultural, gastronomic, among others. The three-dimensional objects that you want to present to the user must be well realised so that the user has a great experience of the site of interest.

Declarations

Conflict of interest

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

Authors' contribution

Sánchez-Juárez, Ivan Rafael: Contributed in the search for software tools to create augmented reality and in realising different projects for AR types.

Paredes-Xochihua, Maria Petra: Contributed in the search and identification of the types of AR that exist, allowing to make the classification described, as well as searching for reality projects to feed the state of the art.

Availability of data and materials

The data obtained are available in each of the references used and if you require further information on the results, please contact the author of this article.

Funding

This work has not been funded.

Acknowledgements

We would like to express our deepest gratitude to the Da Vinci University (UDAVINCI) and to the Tecnológico Nacional de México/ ITS de San Martín Texmelucan, for their great support and motivation for the development of this research.

Abbreviations

API	Application Interfaces	Programming
AR	Augmented Reality	
FOV	Field Of View	
GPS	Global Positioning System	
HD	High Definition	

Article

HMD	Head-Mounted Display
LFO	Low Frequency Oscillator
MR	Mixed Reality
OSC	Open Sound Control
RAG	Augmented Reality based on Geolocation
RAM	Marker-based Augmented Reality
RARO	Augmented Reality based on Object Recognition
VPT	Video Projection Tool
VR	Virtual Reality
RAP	Projection-based Augmented Reality
SDK	Software Development Kit
SO	Operating System

References

Background

Alanis, L. M. V., Gaetan, G., & Martín, A. E. (2021). [Guías de experiencia de usuario para aplicaciones de turismo cultural basadas en realidad aumentada](#). Informe Científico Técnico UNPA, 13(2), 26-43.

Bernad Conde, María Sagrario (2020). [Nuevas tecnologías y difusión del turismo cultural: descubriendo a Goya con realidad aumentada](#). Rotur, Revista de Ocio y Turismo, 14(1): 81-93 <https://doi.org/10.17979/rotur.2020.14.1.5945>

Colpas, P. P. A., Melo, M. A. P., Ortega, R. C. M., Bonilla, A. F. R., & Chinchilla, L. D. C. C. (2024). [Implementación de realidad aumentada en la plaza principal Alfonso Ávila Quintero: revitalizando el turismo y la cultura en Agustín Codazzi](#), Cesar. Investigación e Innovación en Ingenierías, 12(1).

Núñez Arroba, N. A. (2024). [Aplicación web con tecnología de realidad aumentada para fomentar el turismo cultural en el museo de la Unidad Educativa Bolívar](#) (Bachelor's thesis, Universidad Técnica de Ambato. Facultad de Ingeniería en Sistemas, Electrónica e Industrial. Carrera de Software).

Sánchez Jorge, T., Jiménez Valero, B. & Velastegui López, L. E. (2022). [Realidad aumentada en el sector turístico cubano](#). Explorador Digital, 6(3.1), 173-190.

Basics

Datos Abiertos, Municipio de Puebla. (2024). [Estadística de Turismo Datatur](#).

Support

Apple Inc. (2024). [Seguridad de ARKit en iOS y iPadOS](#).

Blender. (March 28, 2024). [Blender 4.2 Manual](#).

Grapsas, T. (15 de diciembre de 2019). [Conoce la realidad aumentada y las posibilidades de interacción que la hacen sobresalir en el mundo digital](#).

HC Gilje. (s.f.). [VPT 8](#).

HeavyM. (2024). [HeavyM](#).

Iberdrola. (2023). [¿Qué es la Realidad Aumentada?](#)

Masterd (2024). [Qué es Unity y para qué sirve](#).

Microsoft. (s.f.). [¿Qué es la realidad aumentada o AR?](#)

Ministerio de Educación. (March 28, 2024). [Creación de marcadores para realidad aumentada](#).

Moreno, J. (January 20, 2023). [Qué es la realidad aumentada y 20 ejemplos de uso exitoso en empresas](#).

Onirix. (June 15, 2022). [Turismo con realidad aumentada: las nuevas experiencias de viajes](#).

Pocayo, J. (May 23, 2023). [¿Qué es Google ARCore?](#)

Article

Tolsan, V. (August 5, 2020). [Realidad Aumentada: tipos y características.](#)

Unity Documentation. (March 28, 2018). [Vuforia.](#)

Vegas. E. (March 16, 2017). [ZapWorks, la realidad aumentada para el usuario final.](#)

Marketing strategies of MIPyMES in the Cd. Mexico and metropolitan area during and after the pandemic

Estrategias mercadológicas de las MIPyMES en la Cd. México y área metropolitana durante y después de la pandemia

Álvarez-García, Mónica^a, Gutiérrez-Zepeda, Martha del Pilar^b, Guerrero-Ibarra, Carlos^c and Waldo Caamaño, José David^d

^a ROR Universidad Tecnológica de Nezahualcóyotl • B-8810-2019 • 0000-0003-3393-1277

^b ROR Universidad Tecnológica de Nezahualcóyotl • LMO-2260-2024 • 0000-0003-0256-8874

^c ROR Universidad Tecnológica de Nezahualcóyotl • B-8859-2019 • 0000-0003-0958-7912

^d ROR Universidad Tecnológica de Nezahualcóyotl • LMO-2692-2024 • 0000-0002-6138-9617

CONAHCYT classification:

Area: Social Sciences
 Field: Administration and business
 Discipline: Business and accounting
 Subdiscipline: Marketing and publicity

<https://doi.org/10.35429/EJROP.2024.10.18.4.10>

Article History:

Received: January 31, 2024

Accepted: December 31, 2024



* [carlos.alonsop@correo.buap.mx]

Abstract

In MIPyMES, it was a problem to withstand market irregularities and maintain themselves during the pandemic (SARCOV-2). Companies began using digital marketing to market, and after four years, they must carry out strategies for online and direct sales. This research aims to know the opinion of 110 companies that previously underwent a study on the marketing strategies used during the pandemic and then through a comparison. The research results show that during the pandemic, social networks were used for sales and promoted products with discounts and home deliveries, yet direct sales, deals, demonstrations, and printed advertising continued to be the most used and have greater results. Digital marketing has grown enormously, and MIPyMES must venture into it to continue competing in the market.

Resumen

En las MIPyMES fue un problema soportar las irregularidades del mercado y mantenerse durante la pandemia (SARCOV-2), las empresas emprendieron el uso del marketing digital para comercializar y después de 4 años deben realizar estrategias para las ventas en línea y directa. Esta investigación pretende conocer la opinión de 110 empresas a las que se les realizó un estudio con anterioridad sobre las estrategias mercadológicas usadas durante la pandemia y después a través de un comparativo. Los resultados en la investigación muestran durante la pandemia se usaron las redes sociales para la venta y promocionaron los productos con descuentos y entregas a domicilio y sin embargo la venta directa, los descuentos, las demostraciones y la publicidad impresa siguen siendo las más utilizadas y de mayores resultados después de la pandemia, el marketing digital ha crecido enormemente y las MIPyMES deben de incursionar en él para seguir compitiendo en el mercado.

Objectives	Methodology	Contribution
 *Opinion of the MIPyMES. *Marketing Strategies. COVID19 *Used during and after the pandemic.	 110 companies (MIPyMES) Comparative Strategies during and after the pandemic	 *Used direct sales. *Print advertising. *Growth and use digital marketing to compete in the market.
Before Sales of WhatsApp, Facebook, discounts and home deliveries.	After Direct Sale, digital marketing.	

Objetivos	Metodología	Contribución
 *Opinión de MIPYMES. *Estrategias mercadológicas. COVID19 *Utilizaron durante y después de la pandemia.	 *110 empresas (MIPYMES) *Comparativo *Estrategias antes y después de la pandemia	 *Utilizaron la venta directa. *Publicidad impresa. *Crecimiento y uso del marketing digital para competir en el mercado.
Antes Venta WhatsApp, Facebook, descuentos y entregas a domicilio.	Después Venta directa, marketing digital.	

Marketing Strategies, MIPyMES, Pandemic

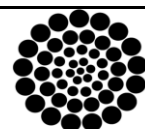
Estrategias Mercadológicas, MIPyMES, Pandemia

Citation: Álvarez-García, Mónica, Gutiérrez-Zepeda, Martha del Pilar, Guerrero-Ibarra, Carlos and Waldo Caamaño, José David. [2024]. Marketing strategies of MIPyMES in the Cd. Mexico and metropolitan area during and after the pandemic. ECORFAN Journal-Republic of Paraguay. 10[18]-1-10:e41018110.



ISSN 2414-4827/© 2009 The Author[s]. Published by ECORFAN-Mexico, S.C. for its Holding Republic of Paraguay on behalf of ECORFAN Journal-Republic of Paraguay. This is an open access article under the CC BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

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



RENIECYT
 Registro Nacional de Instituciones y Empresas Científicas y Tecnológicas

1702902 CONAHCYT

Introduction

For MSMEs as well as most companies it was a big challenge to withstand market irregularities and to stay in the market during the SARCOV-2 pandemic in the period 2020-2021, no doubt the consumer also had to change their buying and consumption habits. During this time companies undertook the use of digital marketing to market their products and services, the use of ICTs evolved to a great extent. And after 4 years of this period consumers have changed their buying habits, some of them still buy their products online, through applications or in physical shops, in this sense companies now have a dual role and make strategies for online and face-to-face sales. In this way, it is important to know what companies think about the marketing strategies they applied during and after the COVID-19 pandemic. Showing the perspectives of these periods is of utmost importance to get an idea of how marketing strategies have evolved in companies and what can give them greater results.

For this reason, the need arises to follow up on a previous study that evaluated the marketing strategies used by MSMEs during the pandemic, [Quintero, M.L., et al., \(2023\)](#). In that study the interviewees mentioned that the way to sell their products was through the shops and implemented the sale by whatsapp and facebook, the sales promotion strategies were discounts and home deliveries and in relation to advertising they used Facebook, on their website and at the point of sale and after having already spent several years it was necessary to know what strategies are applying the same companies to make a comparison of the strategies used during and after the pandemic, thus arising the following questioning:

What are the marketing strategies applied by MSMEs in Mexico City and the Metropolitan Area during and after the pandemic?

General objective

To find out the marketing strategies applied by MSMEs to reach consumers or users and manage to stay in the market in Mexico City and the Metropolitan Area during and after the pandemic.

Specific objectives

- To find out the sales methods used by MSMEs during and after the pandemic (face-to-face, digital or both) that have given them the best results.
- To identify the advertising strategies that were applied and have been most effective in MSMEs during and after the pandemic to inform their current customers about the products and services they offer and to reach new consumers or users.
- To find out which sales promotions they offered and were most effective with their customers and prospects during and after the pandemic in order to maintain or increase their sales.
- To find out whether companies have been able to adapt to changes in consumer buying habits after the pandemic ended and what other strategies they have used.

Methodology

The study universe for the research was the same 110 companies that had been the subject of a previous research study, [Quintero, M.L., et al., \(2023\)](#), in which the marketing strategies applied during the pandemic were found out. In this research, another questionnaire was applied to them to find out about the marketing strategies applied after the pandemic and to be able to make a comparison; fortunately, it was possible to count on the participation of all of them.

A quantitative, descriptive, non-experimental, but now longitudinal, research was also carried out with a quantitative approach. The results were analysed statistically through descriptive statistics and the absolute and relative frequencies were obtained for the analysis and interpretation of the information through comparative graphs of before and after that helped to show the results obtained through the description of the findings.

The information was obtained through the application of a collection instrument by means of Microsoft Teams FORMS.

The questionnaire was applied in one month, which allowed to know in a clear and precise way the current situation of the marketing strategies implemented by the MSMEs to adapt to the new behaviours and buying behaviour of the consumers.

The information obtained was processed in the EXCEL programme for subsequent analysis and graphical elaboration of the results.

Theoretical framework

This section includes different topics that help to understand how marketing strategies used by companies have evolved, especially the digital part that is here to stay.

Marketing strategies are considered by Arce L.G., (2010) as strategies related to the market and the company, which are carried out to achieve certain marketing objectives, and which present a certain degree of difficulty in their formulation and execution. Examples of marketing strategies could be developing new products, lowering prices, opening new sales outlets, etc.

Kotler and Amstron refer to the four main steps in designing a customer-oriented marketing strategy. In the first two, the company selects the customers it will serve. Market segmentation involves dividing a market into smaller segments of buyers with different needs, characteristics or behaviours that may require differentiated marketing strategies or mixes. The company identifies the multiple ways of segmenting the market and develops profiles of the resulting market segments. Target market selection (or simply market coverage) involves assessing the attractiveness of each market segment and choosing one or more segments to enter.

In the last two steps, the company decides on a value proposition: how it will succeed in creating value for the target customers. Differentiation actually involves differentiating the company's market offering to create superior value for the customer. Positioning is about organising a market offering to occupy a clear, distinctive and desirable place relative to competing products in the minds of target consumers.

Kotler P., and Amstron G., (2013) and to achieve this, differentiated sales, advertising, public relations and direct marketing strategies must be applied to reach the target market segment.

Kotler P., and Amstron G., (2012) mention that sales strategies are carried out according to the market in order to market, sell, distribute and promote their products and services.

services, hence there are different selling methods such as face-to-face selling, online selling and mixed selling. According to these authors, face-to-face selling is that which takes place in the company's branch or establishment and where consumers come to purchase them.

The disadvantages of this sales method include the fact that delivery times are uncertain, the rate of customer complaints is higher and the number of returns is also higher; and mixed selling, which is made up of characteristics of the two previous methodologies, since the products are offered via the internet, but the delivery of the products is carried out at the company's premises.

In terms of advertising, these are activities that can also be developed directly in the establishment with printed media or online through digital strategies on social networks or the web through videos or flayers among other types of content and sales promotion with coupons, 2x1, discounts, digital demonstrations, or in person with free samples, demonstrations, tastings, discounts, fairs or exhibitions, etc.

It is important to mention that marketing has evolved considerably from 1.0 to 5.0 along with the marketing processes of products and services in the history and application of the strategies used by companies to achieve success in the market. Marketing 1.0 is characterised by product-focused company strategies, companies will invest solely in the product. One of the elements to highlight in this first phase is the unidirectional communication, where the client was not listened to and it was only the companies that provided information. It was disseminated through traditional media, such as television and radio.

With a more customer-focused approach, marketing 2.0 arises, which, unlike the first, focuses on getting to know the customer with the aim of satisfying needs and being able to retain them, that is, to build customer loyalty. It seeks to get closer to the customer on an emotional level in order to differentiate itself from the competition. One of the characteristics of marketing 2.0 is the use of new information technologies, which creates a two-way communication. Marketing 2.0 is closely linked to Big Data, and according to Kotler, Kartajaya and Setianwan: Social media marketing (marketing 2.0) arises in today's information age, based on information technologies. The task of marketing is no longer so simple. Today's shoppers are well informed and can easily shop for a variety of similar product offerings. It is the consumer who defines the value of the product. Consumer preferences differ greatly from one consumer to another. The company must segment the market and develop a superior product for a specific target segment within the market. The golden rule of: the customer rules, works well for almost all companies. At the stage of marketing 3.0 it is related to care for the planet and society, i.e. social responsibility. Marketing 3.0 believes that consumers are integral human beings, and that all their needs and desires should always be met. Therefore, marketing 3.0 complements emotional marketing with a spiritual one. In marketing 3.0 companies differentiate themselves from each other by their values. Customers, apart from satisfying their needs, are looking for the satisfaction of their feelings and values. This leads companies to sell values associated with their brands seeking impact on their target audience according to [Kotler, P., Kartajaya, H., and Setiawan, I. \(2013\)](#).

Marketing 4.0 where, according to [Kotler, P., Kartajaya, H., and Setiawan, I. \(2019\)](#), New technologies, social networks and digital marketing in general are revolutionising the way we reach customers. Today's customer has different habits than a few years ago: they are hyper-informed, hyper-connected, love honest and ethical companies, do not buy without comparison shopping, trust the experiences of other consumers and are unfaithful to brands.

This is why, now more than ever, it is necessary to reorient marketing practices to win the customer's support and trust. If we manage to exceed their expectations, not only will they buy from us, but they will also recommend us. To do this, we need to offer transparent and coherent experiences, and cover every aspect of the product that they demand: more human brands, greater commitment, better and more personalised offers. It is marketing 4.0. To achieve that customer engagement and recommendation.

The new generation of 5G technologies is here to stay. The pandemic we have experienced has accelerated the adoption of technology by customers, leaving the way open for the digitisation of their relationships with their brands. The era of Marketing 5.0 is beginning, whose author of the concept, Philip Kotler ([Kotler, Kartajaya and Setiawan, 2021](#)) defines it as the union of technology and humanity.

In relation to the strategies used by companies before and after the pandemic, several studies conducted by researchers were consulted.

According to the qualitative study carried out by [Solis, F.T., \(2021\)](#) (Estrategias de mercadotecnia en microempresas ante la contingencia por COVID-19 en Ciudad Juárez), he concludes that the marketing strategies that the micro-enterprises in Ciudad Juárez established before the COVID-19 confinement are: following the rules, regulations and prevention measures established by the Ministry of Public Health, and also using new media to advertise the business. Other strategies were the production of goods adapted to the current situation, distancing barriers, reduction of the capacity of people inside the establishments, work on demand or orders, continuous disinfection of work areas and customer service, as well as the purchase of technological devices that contribute to the performance of key activities in the buying and selling process.

Due to the pandemic, the purchase and sale of products and services worldwide took a 360° turn, and sadly many businesses were forced to close permanently. And those that were able to return had to adapt to a new normality that avoided common habits such as physical contact at all costs. Therefore, they had to create new sales strategies to reach the end customer, and the wave of digital marketing grew, which already existed, but now with greater seriousness and commitment to users. [Cruz O. and Morales A.Y., \(2021\)](#)

Marketing strategies as a consequence of technological changes, user needs and consumer behaviour, have left behind the obsolete ways of planning the marketing of products and services for new forms of marketing where the priority is not only to sell or buy products but a process where communication and interaction with the customer is established. In this sense, digital marketing and the different technological tools they use, identify more easily the needs of their customers with a much more complete vision, guaranteeing new, unique and personalised experiences. These new forms of digital marketing are designed to respond to the needs of consumers, which is why they are based on four aspects: content, context, community and connections. Content, which is precise and eye-catching of the product or service, with a message according to the context to which it is presented, with maximum research of the community to which it is offered and with full knowledge of the customer's connections, to be introduced in the networks in which they actively participate. Certainly, these digital marketing strategies, which in the present technological era and in the processes of globalisation in recent years began to gain strength, were the salvation for many SMEs in times of pandemic, especially in the first confinements. The companies that had already started to make inroads into the various digital platforms and social networks continued their processes, while the number of consumers through these media increased significantly. So now digital commerce is getting stronger, the companies that opted for these strategies are staying in the crisis period, some are starting up and others are reinventing themselves to reach their customers and attract new ones, and unfortunately others are disappearing.

Evidently, the period of pandemic gave the opportunity to present and position themselves in the virtual world, some seeing it as a crisis and others as an opportunity, which definitely promoted the increase in the use of digital technologies in companies, with marketing strategies that due to customer demand have been updated and improved in order to : positioning on the web, being one of the first in search engines; prioritising the personalisation of messages through the different social networks of greater use (WhatsApp, Facebook), in order to have more lasting relationships with customers; implementing the use of social networks with content that captures the attention of customers; creating intuitive websites with immediate responses; and increasing e-commerce, with more secure and reliable platforms.

These and other instruments identified and organised in digital marketing tools will allow companies to meet customer needs and boost sales, ensure their sustainability, stay ahead in physical and virtual spaces, and position themselves in the market.

These solutions created and adapted in times of pandemic need to be strengthened in order to transcend and be sustainable in the post-pandemic period, so that these digital marketing strategies will eventually prove useful in periods of crisis. As positive aspects of the research, the novelty of the subject matter, the variety of information and the results of the different experiences, demands and transformations of the consumer are highlighted, which allow us to investigate the marketing strategies of distinguished consumers. Actions that arose during the pandemic period, but which even in the post-pandemic period continue to manifest themselves, as they have transformed society.

Likewise, companies that opted for these strategies continue in the crisis period, some start up and others reinvent themselves to reach their customers and attract new ones, and unfortunately others disappear.

Evidently, the period of pandemic gave the opportunity to present and position themselves in the virtual world, some seeing it as a crisis and others as an opportunity, which definitely promoted the increase in the use of digital technologies in companies, with marketing strategies that due to customer demand have been updated and improved in order to: positioning on the web, being one of the first in search engines; prioritising the personalisation of messages through the different social networks of greater use (WhatsApp, Facebook), in order to have more lasting relationships with customers; implementing the use of social networks with content that captures the attention of customers; creating intuitive websites with immediate responses; and increasing e-commerce, with more secure and reliable platforms. These and other instruments identified and organised in digital marketing tools will allow companies to meet customer needs and boost sales, ensure their sustainability, stay ahead in physical and virtual spaces, and position themselves in the market. These solutions created and adapted in times of pandemic must be strengthened, so that they can transcend and be sustainable in the post-pandemic period, so that these digital marketing strategies can finally prove useful in periods of crisis. [Hernandez M. E., \(2022\)](#)

One of the trends that they intended to implement in companies according to [Beltrán M. \(2019\)](#) was to note that digital companies were in their beginnings and that these applying the Buyer Person had a better impact within their beginnings in those types of businesses, instead in Mexican companies indicate us that there is no culture of applying strategies in small businesses, only some make a small discounts on some items but only spread it within the same local, hence the importance of informing them the importance of competitive advantages by implementing strategic strategies in each company as indicated by [Alaña T, Crespo M & Gonzaga S. \(2018\)](#). But nowadays according to [Camacho L. \(s/f\)](#) tells us that small companies are enthusiastic about implementing 3.0 strategies where they are looking especially that they do not invest a lot, but that gives them great opportunities, but about this in this document the real strategies that have worked for these companies are landed.

Results

Box 1

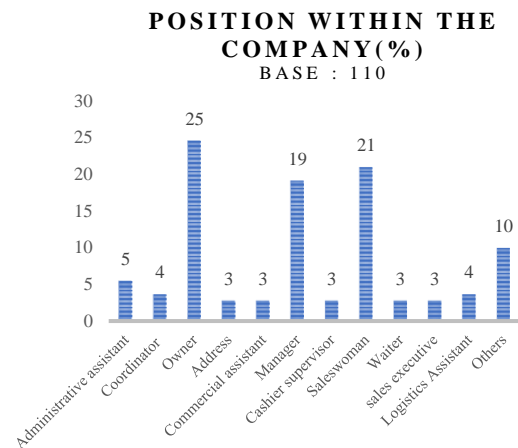


Figure 1

Source: Own elaboration

As can be seen in graphic 1, the majority of respondents in order of importance were Owners (25%), Salesperson 21% and Manager (19%), always trying to ensure that the survey was answered by decision-makers within the company or that they were interfering with the marketing strategies that are applied, the other positions are below 5%.

Box 2

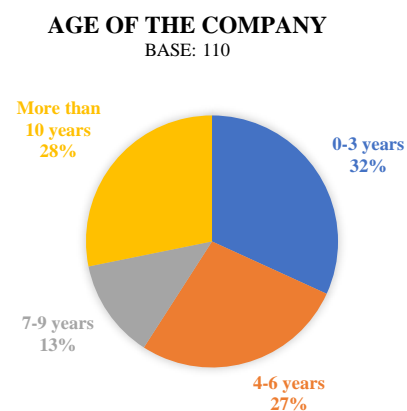


Figure 2

Source: Own elaboration

Box 3

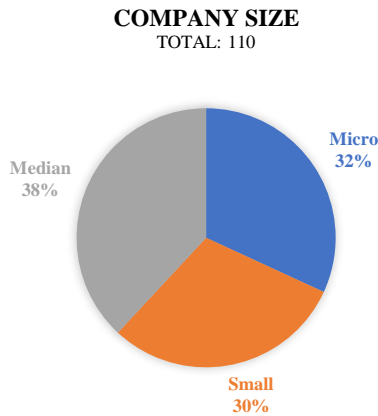


Figure 3

Source: Own elaboration

Regarding the profile of the MSMEs investigated (59%) are young companies, as they said they had been working for between 0 and 6 years and the remaining 7 years or more, and in relation to size, the percentage of participation was very even between micro, small and medium-sized companies (between 30% and 38% respectively).

Box 4

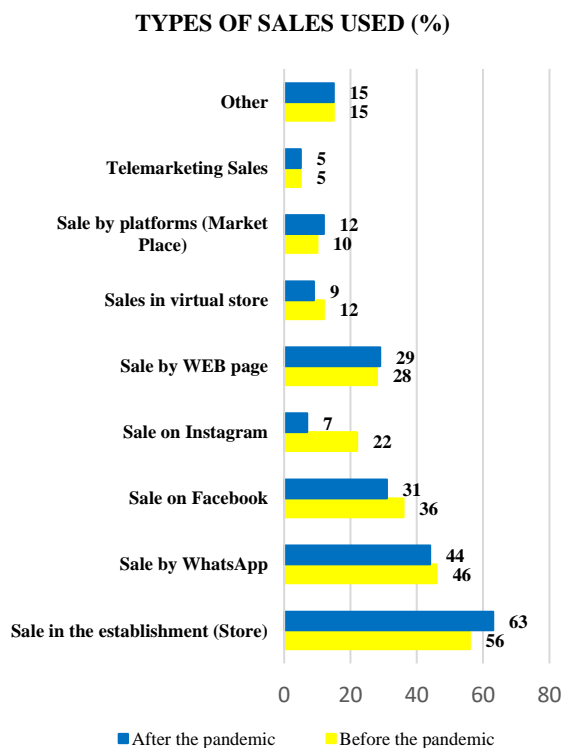


Figure 4

Source: Own elaboration

When interviewees were asked about the type of sales they used during the pandemic, Whats App and Facebook and WEB pages came out (46%, 36%, 28% respectively). Undoubtedly at that time companies were not prepared for online sales and had to improvise and start selling through social networks as the main medium because they did not use digital sales. And in the type of sales used after the pandemic, in first place is the shop (63%), once the shops are open many consumers prefer to see, try on and feel the products physically and it also allows them to make a more conscious selection. In second place, they answered that on the website (29%), and in third place virtual platforms (12%), companies continue to use this medium because some consumers want to save time and resort to the facilities of the payment method, they are also accustomed to digital shopping, where they can view the comments and recommendations of some buyers and can access many websites to make comparisons in quality and prices. It is worth mentioning that digital sales increased during the pandemic and are still increasing.

Box 5

WHAT TYPE OF SALE HAS CURRENTLY GIVEN YOU THE MOST RESULTS?
TOTAL: 110

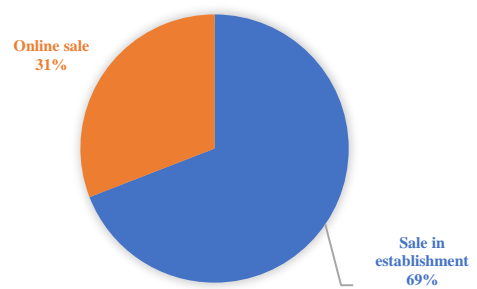


Figure 5

Source: Own elaboration

As can be seen in the graph, in-store sales are still the best performing (69%) because the buyer can have physical contact with the products or services to select them and we are still a country that continues to resist online shopping due to distrust or access to digital media to make the purchase.

Box 6

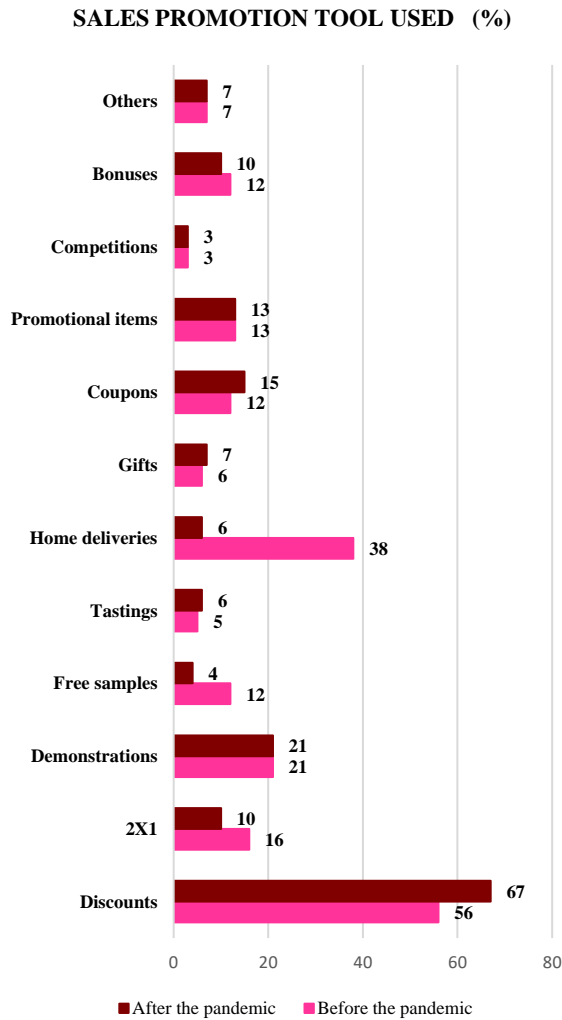


Figure 6

Source: Own elaboration

With regard to promotions, the results show that during the pandemic, the tools most used by MSMEs were home deliveries (38%), which were necessary to attract shoppers, which were useful at the time because of the fear of going out and catching COVID-19 and are still useful today. Another most commonly used tool is discounts (56%) used to attract consumers and retain sales in many businesses and companies. In terms of promotions, firstly discounts, which have the highest percentage (67%), are still a very common strategy for attracting buyers, followed by demonstrations (21%), which allow the consumer to touch, see and feel the products and select them in a more emotive way.

Box 7

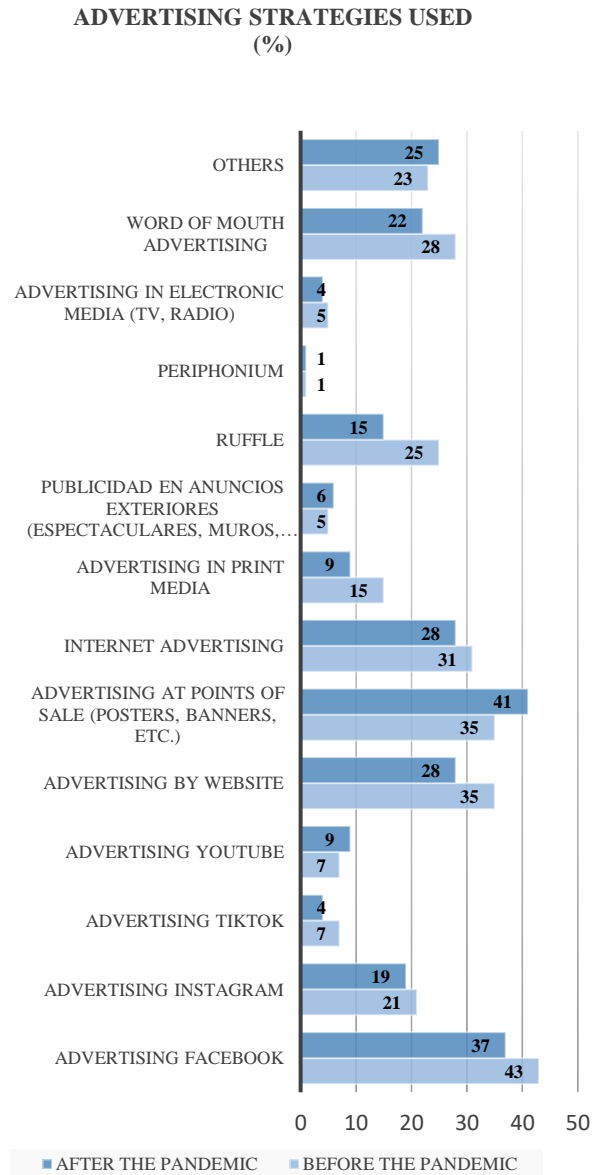


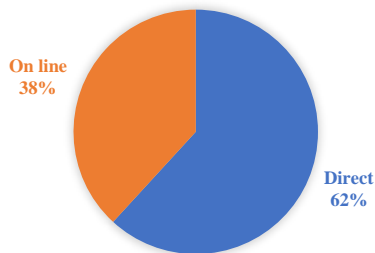
Figure 7

Source: Own elaboration

And on advertising strategies, during the pandemic as there was no personal contact and many businesses were closed or sales were limited, the most used advertising media were Facebook (43%), websites and posters (35%), internet advertising (31%) and leafleting (25%). While after the pandemic, point-of-sale advertising is still the most used (41%) and digital media are still being used, given that the increase in the use of social networks and online sales increased in large proportion, MSMEs continue to make advertising content for social networks such as Facebook (41%).

Box 8

WHAT TYPE OF SALE HAS CURRENTLY
GIVEN YOU THE MOST RESULTS?
TOTAL 110

**Figure 8**

Source: Own elaboration

In the case of advertising that has given them greater results currently in MSMEs, it is still direct advertising (62%), this reason may be due to the fact that they have a more tangible visualisation and can achieve greater exposure in the media, as well as being able to play with images, colours and texts to attract consumers. While 38% mentioned that online advertising has given them better results, undoubtedly digital media are very useful and less expensive, however, the consumer is exposed to so much information and images that they lose attention and focus on the advertisements, so these companies consider that they have not given them the expected results.

Conclusions

It was a huge challenge for the whole society and especially for companies to understand how to cope with the situation that the global pandemic brought with it and that this was forcing them to take drastic actions, as well as to understand that the habits and consumption needs of the population were changing, at that time they were totally different, people had to adapt to this new stage and get used to the idea that the digital era was advancing abysmally.

It is important to mention this, as marketing has evolved considerably hand in hand with the marketing processes of products and services in history as well as the implementation of strategies used by companies after the pandemic, to achieve success in the market, therefore, had to create new sales strategies to reach the end customer, and that the global health situation was adapted to this new way of life. Also with the growth of the digital marketing wave, left behind the old ways of planning the marketing of their products and services has been confirmed that the marketing strategies that applied MSMEs in Mexico City and Metropolitan Area during and after the pandemic, are digital in nature as WhatsApp, Facebook and Instagram and then still follow the websites, virtual platforms and through Social Media, Big Data to Digital intelligence, But the most important thing is that the majority of sales that are still made is the sale in the establishment as the first place, also most of the companies adapted quickly to changes in buying habits of consumers with home deliveries, discounts, promotions and demonstrations at points of sale in order to detect the actions that were evolving and that so far have helped them to stay in the market and have a good market share in this. Without forgetting that the best publicity was word of mouth (infallible) by those closest to the consumers and by leafleting in different areas of the city.

A milestone that provides a lot of learning, considering that the marketing strategies applied in companies in conjunction with technology have advanced approximately 10 years, and are currently based on four aspects: content, context, community and connections, and 4 years after the whole world changed, companies and especially MSMEs are excited to apply these processes to their digital marketing.

Declarations**Conflict of interest**

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

Authors' Contribution

This research was carried out as a collaborative team, contributing their knowledge and experience in accordance with the methodology employed, in order for the research to make a contribution to MSMEs.

Availability of data and materials

The data and tools used for this research are available in our Institution and the tables shown in this document can be editable for your consideration.

Funding

The researchers did not receive any funding.

Acknowledgements

We are grateful for the kindness of the companies that provided us with valuable information for this research.

Abbreviations

ANN Artificial Neural Network

MSMEs Micro, Small and Medium Enterprises

References

Alaña T., Crespo M & Gonzaga S. (2018). Revista Universidad y Sociedad, [How business strategies enable a competitive advantage in micro, small and medium enterprises in the province of El Oro](#), Volume (10, No.2).

Arce L.G. (2010). *Perspectivas, Cómo lograr definir objetivos y estrategias comerciales*. Universidad Católica Boliviana San Pablo Cochabamba.

KOTLER, P. and ARMSTRONG G. (2013). *Fundamentals of Marketing*. PEARSON EDUCATION.

Cruz O. and Morales A.Y. (2021). [Ciencia Huasteca Boletín Científico de la Escuela Superior de Huejutla, Marketing post-pandemic](#) Post-pandemic marketing.

Hernandez M. E., (2022). [Pre and Post Pandemic Digital Marketing Strategies](#). Universidad de San Buenaventura Administración de Negocios Facultad de Ciencias Administrativas y Contables Cartagena-Bolívar.

Kotler P. and Amstron G., (2012). *Marketin*. Editorial Person.

Kotler, P., Kartajaya, H. and Setiawan I. (2013). *Marketing 3.0: how to attract customers with value-based marketing*. Editorial Empresarial.

Kotler, P., Kartajaya, H., and Setiawan, I. (2019). *Marketing 4.0, Transform your strategy to attract the digital buyer*. Editorial Mexicana

Kotler, P., Kartajaya, H., and Setiawan I. (2021). *Marketing 5.0: Technology for Humanity*, Editorial Empresarial.

Quintero, M.L. et.al. (2023). *Micro, Small and Medium Enterprises and their Adaptability to Global Trends*. Chapter: MSMEs in Mexico City and Metropolitan Area after the pandemic, Editores Castellanos.

Solis F.T. (2021). *Revista de Investigaciones Universidad del Quindío*. [Marketing strategies in microenterprises in the face of the Covid-19 contingency in Ciudad Juarez, Mexico: A qualitative study](#).

Identification of microplastics in bottled water, a potential risk to human health

Identificación de microplásticos en agua embotellada, un potencial riesgo para la salud humana

Alva-Rojas, Elvia^a, Rivera-Ramírez Fabiola^{b*}, Jiménez-Rosales, Angélica^c and Velázquez-Garduño, Gisela^d

^a ROR Universidad Tecnológica del Valle de Toluca • Q-2765-2017 • 0000-0001-5183-9082 • 70033

^b ROR Universidad Tecnológica del Valle de Toluca • KMX-4601-2024 • 0000-0001-7296-1378 • 60017

^c ROR Universidad Tecnológica de Zinacantepec • AAZ-4967-2020 • 0000-0003-2822-0681 • 264842

^d ROR Universidad Tecnológica del Valle de Toluca • MCI-9106-2025 • 0000-0002-1047-6518 • 413416

CONAHCYT classification:

Area: Biology, Chemistry and Life Sciences

Field: Life Sciences

Discipline: Biotechnology

Subdiscipline: Other

doi <https://doi.org/10.35429/EJROP.2024.10.18.5.1.10>

Article History:

Received: January 27, 2024

Accepted: December 31, 2024

* ✉ [\[fabiola.rivera@utvtol.edu.mx\]](mailto:fabiola.rivera@utvtol.edu.mx)



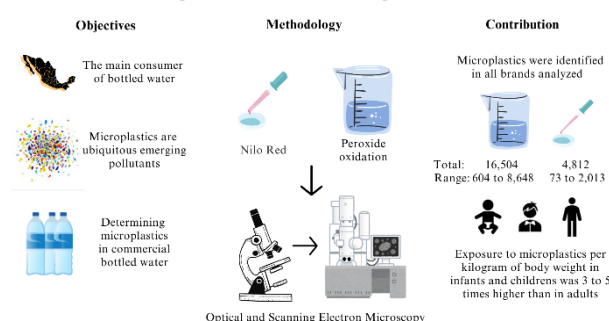
Abstract

Mexico is the leading consumer of bottled water. Microplastic pollutants are emerging that are ubiquitous in the environment, posing a risk to human and environmental health. The aim was to determine the presence of microplastics in commercial bottled water using Nile Red staining, and 30% hydrogen peroxide oxidation. Microplastics were verified by optical and scanning electron microscopy. Microplastics were identified in all brands analyzed, with higher count observed in the oxidation method (16,504 range: 604 to 8,648) compared to Nile Red staining (4,812; range: 73 to 2,013), $p = 0.04$ (Mann-Whitney U test). Granules predominated in both methods. Exposure to microplastics per kilogram of body weight in children and infants was 3 to 5 times higher than in adults. The long-term effects of this exposure remain unknown, highlighting the need to implement monitoring programs for emergency contaminants to ensure access to high-quality water.

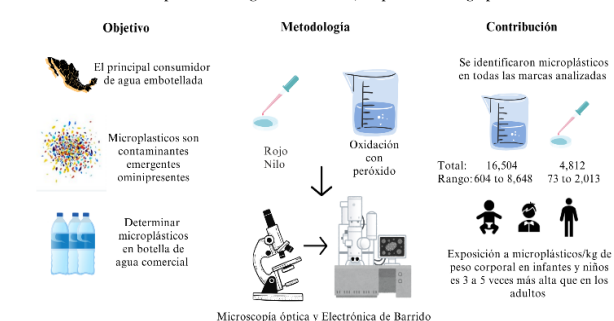
Resumen

México es el principal consumidor de agua embotellada. Los microplásticos, son contaminantes emergentes omnipresentes en el ambiente, representando un factor de riesgo para la salud humana y ambiental. El objetivo fue determinar microplásticos en agua embotellada comercial por tinción de Rojo de Nilo y Oxidación con Peróxido de Hidrógeno al 30%. Se verificaron por microscopía óptica y electrónica de barrido. En todas las marcas se identificaron microplásticos, siendo mayor por el de oxidación (16,505; rango 604 a 8,648) que el Rojo de Nilo (4,812; rango 73 a 2,013), $p = 0.04$ (U de Mann Whitney). Los gránulos predominaron en ambos métodos. La exposición a microplásticos/kg peso en niños e infantes es mayor en 3 a 5 veces que en los adultos. Se desconocen los efectos a largo plazo, por lo que es necesario implementar programas para la detección de contaminantes emergentes para garantizar el acceso al agua de buena calidad.

Identification of microplastics in bottled water, a potential risk to human health



Identificación de microplásticos en agua embotellada, un potencial riesgo para la salud humana



Microplastics, bottled water, health risks

Microplásticos, agua embotellada, riesgos para la salud

Citation: Alva-Rojas, Elvia, Rivera-Ramírez Fabiola, Jiménez-Rosales, Angélica and Velázquez-Garduño, Gisela. Identification of microplastics in bottled water, a potential risk to human health. ECORFAN Journal-Republic of Paraguay. 10[18]-1-10: e51018110.



ISSN 2414-4827/©2009 The Authors. Published by ECORFAN-Mexico, S.C. for its Holding Republic of Paraguay on behalf of ECORFAN Journal-Republic of Paraguay. This is an open access chapter under the CC BY-NC-ND license [<http://creativecommons.org/licenses/by-nc-nd/4.0/>]

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



Introduction

Bottled water (BTW) refers to water intended for human consumption, sealed in bottles or other containers with no added ingredients (U.S. Food and Drug Administration, 2023). In regions where water distribution systems are inefficient or of poor quality, EC becomes a crucial source of water. In cities with efficient and high quality distribution networks, consumption of EC is associated with the belief that it is healthier and safer, with better organoleptic properties. This perception has led to an increase in consumption worldwide, with Mexico being the country with the highest annual per capita consumption: 271.8 litres (71.8 gal) in 2017, increasing to 303.2 litres (80.1 gal) in 2022 (Aslani *et al.*, 2021; Espinosa-García *et al.*, 2015; International Bottled Water Association, 2024).

EC can be packaged in glass or plastic bottles, the latter being the most common due to its various characteristics: low cost, light weight, ease of transport, high strength and lack of taste. The most commonly used materials for bottles are polyethylene terephthalate (PET), polycarbonate and high-density polyethylene (HDPE), while caps are usually made of HDPE, low-density polyethylene and polystyrene (Brancaleone *et al.*, 2024; Kirstein *et al.*, 2021; Waghmare & Dar, 2024).

The perception that EC is a safer alternative, with fewer contaminants compared to tap water, is rooted in the belief that its production follows more rigorous standards. However, despite efforts to keep water safe and clean, the possibility of contamination during the various stages of production and consumption is undeniable. Emerging pollutants include microplastics (MP), defined as polymeric matrices with a diameter of less than 5 mm (Akhbarizadeh *et al.*, 2020; Nacaratte *et al.*, 2023).

One of the United Nations Sustainable Development Goals is universal access to safe drinking water. Recent studies have shown that aquatic bodies are becoming reservoirs of PM, resulting from the ubiquity of plastics in everyday life and the inadequate management of their waste, which end up being deposited in nature (terrestrial and aquatic) and in urban areas.

They are produced by biotic factors (biodegradation by micro-organisms) or abiotic factors (photodegradation by exposure to UV light or weathering resulting from wave or wind action). They have been found in the ocean, seas, soils and even the atmosphere as well as in various seafood, milk, salt and water (Li *et al.*, 2023; Mason *et al.*, 2018).

As a consequence, both marine and terrestrial organisms are exposed to microplastics, and thus enter food chains, representing a risk factor for various wildlife species and consequently humans. Due to their particle size they can enter tissues and organs, oxidative stress, chemical interference, cytotoxicity, inflammation, DNA damage, changes in the gut microbiome, metabolic disruption and increased immune disorders and cancer. Therefore, the World Health Organisation has called on the scientific community to study the possible short-, medium- and long-term health consequences (Brancaleone *et al.*, 2024; Kirstein *et al.*, 2021; Li *et al.*, 2023; Waghmare & Dar, 2024).

Despite the increasing number of investigations on tap and bottled water in different parts of the world, risk assessment of PM in bottled water remains a complex task, due to the lack of data on exposure limits. The toxicity of PM is known to increase in smaller fractions, as they may move through physiological systems and accumulate in organs such as the liver and kidneys, as well as generate negative impacts at the cellular level (Kirstein *et al.*, 2021; Nacaratte *et al.*, 2023).

The objective of this study was to determine the presence of microplastics in bottled water from commercial brands in the Toluca Valley by comparing two methods.

Methodology

Sample selection

Eight commercial brands of EC, purchased in convenience stores located in the municipalities of Lerma, San Mateo Atenco and Toluca, in the State of Mexico, were selected. The selection of the brands was based on a consumer survey of 120 people, determining the inclusion of those with the highest and lowest frequency of purchase. Table 1 shows the characteristics of the samples, including batch, expiry date and cost.

Box 1**Table 1**

Characteristics of the samples

M	P	Vol (ml)	Precio (MXN)	Lote	FC
A	1	1000	7	A80228L192	21-05-25
B	2	1000	7	1006717RE	23-04-25
C	3	1000	6	L0331IZT310333	29-03-25
D	9	1000	5	40523	1-11-25
E	12	500	40	LPRD109122	19-10-25
F	15	1000	6	314401215	21-05-25
G	17	900	25	Z2039	23-05-25
H	19	1000	18	LT006230350	6-05-25

M: Brand, P: Popularity, FC: Expiry Date

Source: own elaboration

Characterisation of PM

Samples of 500 mL of water were obtained after homogenisation by shaking for 30 seconds. Subsequently, the safety seal was broken, the volume was measured and resealed, repeating the same procedure for a second sample. Each mark was analysed in duplicate. MP detection was carried out using two methodologies: staining with Nile Red (NR) and oxidation with 30% H₂O₂ (OXI) (Calvo Anglada, 2020; Quinteros Espinosa, 2022), for subsequent observation of the results with optical and scanning electron microscopy.

Staining with Nile red

A solution of Nile Red (Sigma Aldrich) was prepared at 1 mg/mL dissolved in methanol (J. T. Baker), stored refrigerated at 4°C in a 125 mL amber dropper bottle, covered with aluminium foil. 500 mL of water was placed in a 1 L beaker, lined with aluminium foil. In a laminar flow hood, 5 drops of the NR solution were added and allowed to stand for 30 minutes at room temperature. Subsequently, it was filtered using a vacuum pump and a glass funnel (Shamjina), with a refined, hydrophilic, non-toxic nitrocellulose membrane of 0.45 µm pore size and 50 mm diameter.

The filter was collected with round-tipped tweezers in an aluminium-lined Petri dish and dried for 1 hour at 60°C in a drying oven, for subsequent analysis under a microscope.

Oxidation with hydrogen peroxide

In a 1000 mL beaker with 500 mL of water, previously heated to 60°C in a magnetic grill, 50 mL of 30% hydrogen peroxide (J. T. Baker) was added. The beaker was covered with aluminium foil and left to stand for 72 hours. Afterwards, it was filtered as described above.

Observation of the samples*Optical microscopy*

Filters were placed on slides using round-tipped forceps and observed at 4x and 10x magnification on an optical microscope (VELAB VE-B15), equipped with a VE-WUCAM0720PA camera (VE-WUCAM0720PA). The presence of microplastics and their morphology were identified by clockwise observations.

Scanning Electron Microscopy (SEM)

A square section of approximately 3 mm was cut from the membranes obtained from the water filtration process. Each section was placed on an aluminium disc holder and coated with a thin film of gold by sputtering (Denton Vacuum, Desk V) for observation. Subsequently, the aluminium holder was mounted on the electron microscope (JEOL model JSM-IT 100, Japan) under high vacuum. Observations were made at an accelerating voltage of 8 to 10 kV, using a secondary electron detector (SED) or backscattered electron detector (REF).

Data analysis

Descriptive statistical analysis was performed, calculating measures of central tendency and dispersion. Methods were compared using a Mann Whitney U test, considering a $p < 0.05$, using MINITAB as statistical software.

Microplastics exposure assessment

The assessment of exposure to PM was carried out by estimating its presence in the daily consumption of EC (ECD, estimated daily consumption) and the daily intake (DI) for adults, children and infants, with equations I and II (Danopoulos *et al.*, 2020; Rubio-Armendáriz *et al.*, 2022).

$$ECD = MP \left[\frac{\text{Particulas}}{500 \text{ ml}} \right] * CD_{AE} \left[\frac{L}{\text{dia}} \right] \quad (1)$$

MP = According to Cox 2019, the means of the brands analysed per method were averaged (Cox *et al.*, 2019). Because the results present outliers, the mean and standard error for the mean (SEM) were used to calculate minimum and maximum values.

CDAE= Daily consumption of bottled water.

Annual consumption data for Mexico were obtained from the Marker Report Findings from 2005 to 2022 of the IBWA ([International Bottled Water Association, 2024](#)) and a linear projection was made to determine the daily intake (DI) of MP until 2030.

$$ID = \frac{MP \times Cd}{PC} \quad (2)$$

Cd = represents the average daily water consumption (1, 2, and 0.75 L per adult, child and infant) and BW = average body weight (70, 10 and 5 kg per adult, child and infant) as suggested by WHO ([Danopoulos *et al.*, 2020](#); [Ravanbakhsh *et al.*, 2023](#)).

Quality control

All samples were processed in a laminar flow hood and glassware was used for storage. Staff wore 100% cotton gowns, and additional precautions were taken such as avoiding the use of make-up, nail polish and creams, as these products can release PM ([Schymanski *et al.*, 2018](#)).

Results

Detection of microplastics by the Nile Red method and 30% Hydrogen Peroxide oxidation in bottled water

The detection of PM in drinking water has been subject to several studies in different parts of the world as it is considered a risk to human health ([Hossain *et al.*, 2023](#)). The analysis revealed its presence in all brands of EC tested, using both detection methods (Table 2). The oxidation with hydrogen peroxide (OXI) method identified a higher amount of PM, with a total of 16,505 particles, ranging from 604 to 8,648 (C, E). On the other hand, the Nile Red (NR) staining method detected 4,812 particles, ranging from 73 to 2,013 (B, H).

The results indicate a significant difference in the amount of PM found between the applied methods ($p = 0.04$, Mann-Whitney U, Median RN = 247.5, OXI = 961).

In 75% of the samples treated with OXI, a significant increase in the amount of PM was observed, with increases ranging from 297.9% in sample D to 2140.4% in sample E. However, in samples A and H, a decrease of 58.9% and 61.3%, respectively, was recorded (Table 2).

Box 2

Table 2

Comparison of the amount of microplastics detected by both methods used in bottled water samples. (0.5 L)

M	RN				OXI			
	No. MP	M ± DE	EEM	MIN - MAX	No. MP	M ± DE	EEM	MIN - MAX
A	208	52.0 ± 24.7	8.7	31 - 86	944	236 ± 133.8	47.3	110 - 404
B	73	18.3 ± 22.7	8.0	3 - 52	1198	299.5 ± 100.0	35.4	176 - 418
C	1469	367.3 ± 230.4	81.4	144 - 568	604	151 ± 47.0	16.6	98 - 199
D	246	61.5 ± 46.8	16.5	28 - 129	978	244.5 ± 28.4	10.0	206 - 270
E	386	96.5 ± 71.3	25.2	46 - 202	8648	2162 ± 672.9	237.9	1617 - 3059
F	249	62.3 ± 52.0	18.4	29 - 139	2514	628.5 ± 160.7	56.8	482 - 824
G	168	42.0 ± 28.8	10.2	17 - 73	840	210 ± 16.4	5.8	196 - 232
H	2013	503.3 ± 425.0	150.3	132 - 914	779	194.8 ± 37.7	13.3	146 - 227
Total	4812	601.5 ± 723.5	255.8	73 - 2013	16505	2063.1 ± 2726.0	963.8	604 - 8648

RN: Nile Red staining, Oxi: Oxidation Method, MP No.: Number of microplastics, M ± SD: Mean ± standard deviation, SEM: standard error of the mean and MIN-MAX: minimum - maximum.

Source: Own Elaboration

For the detection of PM in EC, two methods were used: RN staining and oxidation with 30% Hydrogen Peroxide, due to its low cost it is used to decompose organic matter and it is reported that an increase in temperature from 70 to 100°C, can cause weight and size loss, in addition, combined with ultrasound or photocatalysis is used as treatment for degradation ([Chen *et al.*, 2022](#); [Pfeiffer & Fischer, 2020](#)), which is probably why I report a higher amount of 16,505 MP compared to 4812 with RN in 0.5L ($p = 0.04$, Mann Whitney U, table 2). RN, on the other hand, is a stain for rapid quantification and detection of MP given its selective absorption and fluorescent properties, without the need for spectroscopic analysis ([Mason *et al.*, 2018](#); [Singh, 2021](#)).

As in other reports, in both methods (table 2), a large variation in the number of PM was observed between the different brands ([Singh, 2021](#)), this is influenced by sampling and the complexity of identifying their source of origin.

The detection of PM in freshwater, groundwater or wastewater has highlighted the potential contamination of the water being extracted. The pipes and filters used during EC production are often made of Polyethylene, Polyamide, Polyvinyl and PET, which due to mechanical and chemical factors can release them (Akhbarizadeh *et al.*, 2020; Nacaratte *et al.*, 2023).

Packaging is affected by photo-oxidation, ageing and cleaning processes, especially in reusable packaging (Brancaleone *et al.*, 2024; Hossain *et al.*, 2023). And finally the use, opening and closing the bottle, generates up to 553 ± 202 MP per cycle, or mechanical stress from squeezing the bottle (Akhbarizadeh *et al.*, 2020; Singh, 2021).

Optical and scanning electron microscopy analysis

The shapes recorded for PM are fragments, films, pellets, granules, filaments and foams (Ebanks Mongalo *et al.*, 2024). Microscopic observations showed that, irrespective of the method, the PMs present are granules and fibres, with variations between samples. In the case of the RN method, the highest percentage of granules was observed in samples C and H (92%), while for the OXI method, the highest percentage was in sample E (97%). Fibres represented 46% of the particles in sample G for the RN method and 36% in sample H for the OXI method. Sponges and films were the least frequent forms (Fig. 1).

Box 3

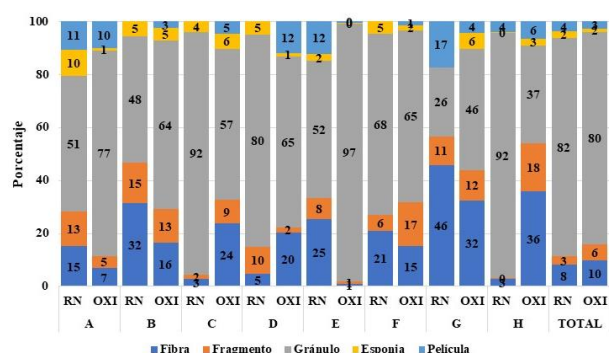


Figure 1

Distribution of microplastic forms in analysed bottled water samples

Source: Own Elaboration

Regardless of the method, the shapes and colours remain the same, the MPs observed (Fig. 2A) have different shades, the fibres (A and G) are mostly blue and grey. The granules (C and H) are transparent, while the fragments (F and B) are orange, brown or transparent, the sponges (D and C) are blue, brown to violet; the latter two forms are usually with irregular edges, finally, the films are transparent (E and F).

Also, scanning electron microscopy (SEM, Fig. 2B) observations revealed the presence of fragments of synthetic materials in almost all samples, confirming that they were microplastics. The dimensions of these fragments ranged from 3.98 to 7.70 μm in the RN-treated samples (C and H) and from 2.22 to 6.49 μm in the OXI-treated samples (E).

Box 4

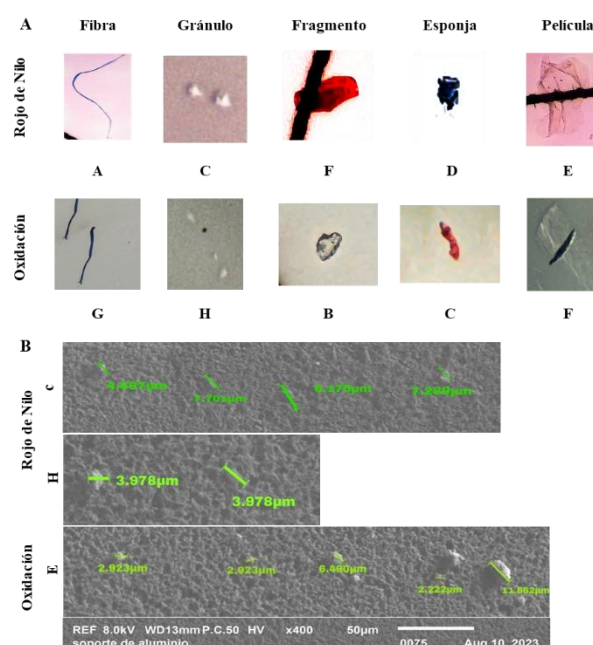


Figure 2

A) 10x optical and B) scanning electron microscopy of bottled water samples

Source: Own Elaboration

Human exposure to PM through drinking water is unavoidable, the size and form influences their absorption, adsorption and impact on organisms. The reported forms are fibres and fragments, followed by sponges and granules. What differs in this work, regardless of the method, is that granules predominate (Fig.1 and 2A), their origin is likely to be contamination of sources by industrial wastewater, and like fibres, they are difficult to remove during the treatment process (Hossain *et al.*, 2023; Kye *et al.*, 2023; Nacaratte *et al.*, 2023; Rubio-Armendáriz *et al.*, 2022).

The size found by SEM varies between 2 and 11.6 μm , which is in agreement with other studies (Brancaleone *et al.*, 2024; Rubio-Armendáriz *et al.*, 2022), a size $<5 \mu\text{m}$ with a considerable effect on human health (Taheri *et al.*, 2023).

Estimated consumption of microplastics via bottled water

According to the National Water Commission in Mexico, 78% of the population consumes bottled water (BW), placing the country in first place worldwide in this respect (Arriaga-Medina & Piedra-Miranda, 2021; International Bottled Water Association, 2024). Although the cost of EC is between 100 and 1000 times higher than tap water, the preference for EC is due to several reasons: firstly, the belief that it is healthier, safer and better tasting; secondly, distrust of drinking water systems, caused by insufficient, irregular and low quality supply in some households; thirdly, the ease and convenience of purchasing it; and finally, the lack of adequate regulatory frameworks and the power of multinational companies promoting its consumption (Nacaratte *et al.*, 2023; Sanei & Khodadad, 2024).

Annual per capita consumption of EC in Mexico increased by 67.93% between 2005 and 2022, from 180.7 L/year (0.49 L/day) to 303.2 L/year (0.83 L/day), with an average annual growth of 3.2%. Linear projections to 2030 (ASM 3.94, MAD 9.2 and MSD 111.45) suggest an increase of 14.2%, reaching 348.95 L/yr (0.96 L/day), with an increase of 1.8% from 2022 (Fig. 3A, dotted black line).

Previous studies indicate that humans may be exposed to tens of thousands to millions of PM each year or several milligrams per day. Although ingestion is considered the main source through food and water, it is difficult to determine the content of PM in different foods, and other routes such as inhalation, especially in enclosed spaces, and dermal contact are also considered (Lee *et al.*, 2023; Olea, 2024).

Daily exposure to PM was estimated at 150 ± 64 particles (86 - 214.2 PM/0.5L) for RN and 516 ± 241 particles (275 - 757 PM/0.5L) for OXI.

Therefore, in 2005 it is estimated that an individual could have ingested 149 PM (85-213 PM) daily, in 2022 that figure rose to 250 PM (186-314 PM), and by 2030 it is projected to be 287 PM (223-351 PM) for NR. For OXI, these figures were 511 MP (270-752) in 2005, 857 MP (616-1098) in 2022, and are estimated to be 836 MP (595-1077) in 2030 (Fig. 3A).

Box 5

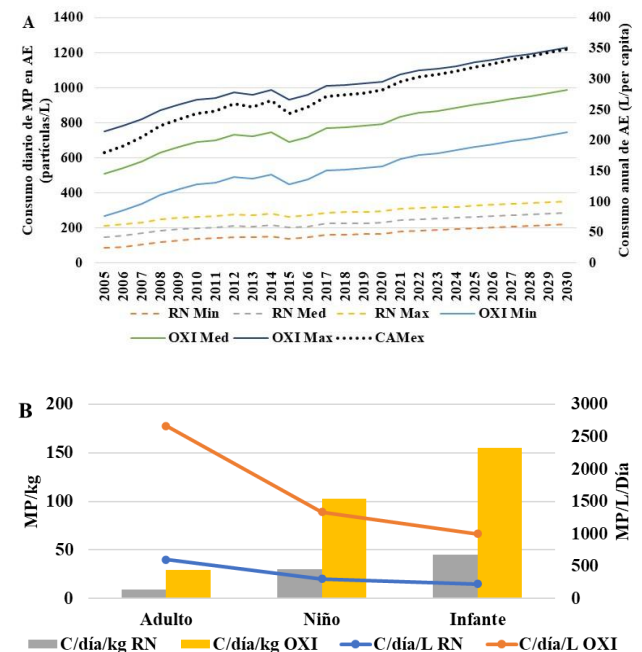


Figure 3

Projected Particulate Matter Consumption of PM/L through bottled water. A) Consumption of bottled water (right, black dotted line) and consumption per day of PM by the various methods (left, solid line oxidation method, dashed line Nile Red). B) Calculation of PM/L/day (right) and PM/kg (left) consumption in adult, child and infant.

Source: Own Elaboration

EC is a significant source of PM, such as PET, HDPE or Polypropylene (Hossain *et al.*, 2023; Nacaratte *et al.*, 2023), used in the manufacture of the bottle body or cap. Some authors claim that dietary exposure is higher than in tap water, the consumption per day for 2 L of water has been estimated at 2×10^{-5} - 33,626 particles (Danopoulos *et al.*, 2020). In this work, the per capita consumption for 2030 of EC will be 0.96 L/day, so exposure would be in the range of 223 - 351 for NR and 595-1077 for OXI, and infants and children is 5 and 3 times higher than in adults, suggesting a high risk for them (Ravanbakhsh *et al.*, 2023).

Results in animal experiments and cell cultures have shown that PM can affect several systems of the human body, including the digestive, respiratory, endocrine, reproductive and immune systems. First, one route of exposure is ingestion, through food and water contaminated by them, whereby the digestive system may become irritated and the gut microbiome altered, eventually causing inflammation and gastrointestinal symptomatology (Brancaleone *et al.*, 2024; Lee *et al.*, 2023).

Although 90% is excreted, particles smaller than 150 µm can cross the intestinal barrier by various mechanisms depending on size and type. Some may be digested by phagocytosis by M cells of Peyer's patches or dendritic cells, but MP are reported to resist gastric juices, and so, not being broken down, persist for a long time, favouring their bioaccumulation and causing chemical toxicity, if accompanied by heavy metals and polycyclic aromatic hydrocarbons. Their excretion will depend on the characteristics of the polymer matrix (Brancaleone *et al.*, 2024).

PM can be absorbed and reach the bloodstream through the intestinal mucosa, perhaps because the inflammatory process increases permeability or simply because of their size. Once in the blood they can translocate and deposit in various organs such as the gut, liver, lungs, etc., as corroborated by findings in faeces, blood, lungs and placenta, and recently the brain and testes. With the potential for immunotoxicity, alteration of oxidative stress control gene expression and activation of nuclear factor E2 expression. In addition, their hydrophobicity favours exposure to heavy metals, organic pollutants and pathogenic microorganisms (Kirstein *et al.*, 2021; Rubio-Armendáriz *et al.*, 2022). Therefore, to prevent health risks and reduce potential exposure, it is necessary to implement monitoring strategies.

EC has transformed water consumption habits, but it is necessary to reflect on its implications. Annually, EC consumption generates tons of plastic waste, of which only 7% is recycled, contributing significantly to environmental pollution. Its production and distribution require a high energy demand, in addition to the fact that three times more water is consumed than is needed to fill the bottles.

With regard to the quality of EC, it is not necessarily better than tap water and may be associated with health risks, such as exposure to phthalates and other emerging pollutants such as PM (Aslani *et al.*, 2021; Sanei & Khodadad, 2024).

Plastic pollution is a global public health and environmental problem, education on responsible use of EC is needed and proper management of plastic waste could generate economic and environmental benefits (Ebanks Mongalo *et al.*, 2024; Olea, 2024), promoting more sustainable water management. Authorities should also improve water quality in areas where water quality is not efficient and ensure access to good quality water resources (Sanei & Khodadad, 2024).

Conclusions

In this study, both methods employed detected PM in EC, verified by optical and scanning electron microscopy. The RN method was used for rapid detection of PM, while the oxidation method showed a higher abundance of PM, due to its ability to expose PM by decomposing organic matter. The results suggest that children and infants are more exposed to PM through EC consumption, which highlights the need for further studies to establish minimum limits that do not pose a health risk and to improve the characterisation of PM. This underlines the importance of implementing permanent screening programmes for emerging contaminants such as PM in order to ensure access to good quality water.

Humans are exposed to PM by various routes such as oral ingestion through food and water, inhalation mainly in enclosed spaces and dermal contact, which is reflected in increased findings in various parts of the body. Long-term effects are unknown, it is important to emphasise exposure in infants and during embryonic development. Recent reports indicate that in addition to increasing the expression of inflammatory factors, inhibiting acetylcholinesterase activity, reducing germ cell quality and affecting embryonic development, it is speculated that they may be related to the development of several chronic diseases such as cancer, diabetes, cardiovascular disease, among others.

Article

Declarations**Conflict of interest**

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

Author Contribution

Alva-Rojas, Elvia, idea, experimental design, analysis and interpretation of data, writing the article.

Rivera-Ramirez, Fabiola, idea, experimental design, analysis and interpretation of data, writing the article

Jiménez Rosales, Angélica, analysis of the samples in the scanning electron microscope, revision and approval of the final version.

Velázquez-Garduño Gisela, analysis and interpretation of data, writing and revising the article.

Funding

The Consejo Mexiquense de Ciencia y Tecnología (COMECyT) granted funding through the call 'Financiamiento para Investigación de Mujeres Científicas EDOMÉX-FICDTEM-2022-01', with the project 'Identificación y caracterización de microplásticos en agua embotellada en México', code FICDTEM-2023-49.

Acknowledgements

We would like to thank the students from the Universidad Tecnológica del Valle de Toluca in the areas of Chemistry, Biotechnology, Fatima Herandy Lomelin Aquino and José Manuel Torres Martínez, and Chemistry, Environmental Technology, Valeria Hernández Díaz and Diana Karen Pantoja Moreno for their collaboration in the realisation of this project.

Abbreviations

BTW: Bottled water

CDBTW: Daily consumption of bottled water

DI: Daily intake

HDPE: High-density polyethylene, MP: Microplastics

NR: Nile red

OXI: Oxidation with 30% H₂O₂,

PET: Polyethylene terephthalate,

SEM: Scanning Electron Microscopy

WHO: World Health Organization

References*Background*

Aslani, H., Pashmtab, P., Shaghghi, A., Mohammadpoorasl, A., Taghipour, H., & Zarei, M. (2021). [Tendencies towards bottled drinking water consumption: Challenges ahead of polyethylene terephthalate \(PET\) waste management](#). *Health Promotion Perspectives*, *11*(1), 60-68. <https://doi.org/10.34172/hpp.2021.09>

Brancaleone, E., Mattei, D., Fuscoletti, V., Lucentini, L., Favero, G., Cecchini, G., Frugis, A., Gioia, V., & Lazzazzara, M. (2024). [Microplastic in Drinking Water: A Pilot Study](#). *Microplastics*, *3*(1), 31-45. <https://doi.org/10.3390/microplastics3010003>

Espinosa-García, A. C., Díaz-Ávalos, C., González-Villarreal, F. J., Val-Segura, R., Malvaez-Orozco, V., & Mazari-Hiriart, M. (2015). [Drinking Water Quality in a Mexico City University Community: Perception and Preferences](#). *EcoHealth*, *12*(1), 88-97. <https://doi.org/10.1007/s10393-014-0978-z>

Kirstein, I. V., Gomiero, A., & Vollertsen, J. (2021). [Microplastic pollution in drinking water](#). *Current Opinion in Toxicology*, *28*, 70-75. <https://doi.org/10.1016/j.cotox.2021.09.003>

Li, H., Zhu, L., Ma, M., Wu, H., An, L., & Yang, Z. (2023). [Occurrence of microplastics in commercially sold bottled water](#). *Science of The Total Environment*, *867*, 161553. <https://doi.org/10.1016/j.scitotenv.2023.161553>

U.S. Food and Drug Administration (2023, December 22). [Code of Federal Regulations Title 21](#).

Waghmare, P. R., & Dar, M. A. (2024). Report of Microplastic [Presence in Drinking Water](#). In Mohd. Shahnawaz, C. O. Adetunji, M. A. Dar, & D. Zhu (Eds.), *Microplastic Pollution* (pp. 225-244). Springer Nature Singapore. https://doi.org/10.1007/978-981-99-8357-5_13

Article

Microplastic in Drinking Water: A Pilot Study
Microplastics, 3(1), 31-45.
<https://doi.org/10.3390/microplastics3010003>

Basic

Calvo Anglada, S. (2020). *Detection and size characterisation of micro and nanoplastics in samples of environmental interest* [Final Degree Thesis]. University of Zaragoza. <https://zaguan.unizar.es/record/97987/files/TAZ-TFG-2020-3200.pdf>

Cox, K. D., Covernton, G. A., Davies, H. L., Dower, J. F., Juanes, F., & Dudas, S. E. (2019). *Human Consumption of Microplastics. Environmental Science & Technology*, 53(12), 7068-7074.
<https://doi.org/10.1021/acs.est.9b01517>

Danopoulos, E., Twiddy, M., & Rotchell, J. M. (2020). *Microplastic contamination of drinking water: A systematic review. PLOS ONE*, 15(7), e0236838.
<https://doi.org/10.1371/journal.pone.0236838>

International Bottled Water Association (2024). *Industrial Statistic* (Market Report Finding 2005-2022). International Bottled Water Association. <https://bottledwater.org/statistics/>

Quinteros Espinosa, K. S. (2022). *Detection of plastic microparticles in the water purification system 'Mahuarca' of the city of Azogues, Ecuador*. [Bachelor Thesis]. Universidad Politécnica Salesiana.
<http://dspace.ups.edu.ec/handle/123456789/23401>

Rubio-Armendáriz, C., Alejandro-Vega, S., Paz-Montelongo, S., Gutiérrez-Fernández, Á. J., Carrascosa-Iruzubieta, C. J., & Hardisson-de La Torre, A. (2022). *Microplastics as Emerging Food Contaminants: A Challenge for Food Safety. International Journal of Environmental Research and Public Health*, 19(3), 1174.
<https://doi.org/10.3390/ijerph19031174>

Schymanski, D., Goldbeck, C., Humpf, H.-U., & Fürst, P. (2018). *Analysis of microplastics in water by micro-Raman spectroscopy: Release of plastic particles from different packaging into mineral water. Water Research*, 129, 154-162.
<https://doi.org/10.1016/j.watres.2017.11.011>

Support

Akhbarizadeh, R., Dobaradaran, S., Schmidt, T. C., Nabipour, I., & Spitz, J. (2020). *Worldwide bottled water occurrence of emerging contaminants: A review of the recent scientific literature. Journal of Hazardous Materials*, 392, 122271.
<https://doi.org/10.1016/j.jhazmat.2020.122271>

Arriaga-Medina, J. A., & Piedra-Miranda, A. G. (2021). *Water consumption practices in university campuses. The experience of the National Autonomous University of Mexico. Water Science and Technology*, 84(5), 1125-1135. <https://doi.org/10.2166/wst.2021.306>

Chen, J., Wu, J., Sherrell, P. C., Chen, J., Wang, H., Zhang, W., & Yang, J. (2022). *How to Build a Microplastics-Free Environment: Strategies for Microplastics Degradation and Plastics Recycling. Advanced Science*, 9(6), 2103764.
<https://doi.org/10.1002/advs.202103764>

Mason, S. A., Welch, V. G., & Neratko, J. (2018). *Synthetic Polymer Contamination in Bottled Water. Frontiers in Chemistry*, 6, 407.
<https://doi.org/10.3389/fchem.2018.00407>

Nacaratte, F., Cuevas, P., Becerra-Herrera, M., & Manzano, C. A. (2023). *Early screening of suspected microplastics in bottled water in the Santiago Metropolitan Region of Chile. Environmental Pollution*, 334, 122118.
<https://doi.org/10.1016/j.envpol.2023.122118>

Pfeiffer, F., & Fischer, E. K. (2020). *Various Digestion Protocols Within Microplastic Sample Processing-Evaluating the Resistance of Different Synthetic Polymers and the Efficiency of Biogenic Organic Matter Destruction. Frontiers in Environmental Science*, 8, 572424.
<https://doi.org/10.3389/fenvs.2020.572424>

Ravanbakhsh, M., Ravanbakhsh, M., Jamali, H. A., Ranjbaran, M., Shahsavari, S., & Jaafarzadeh Haghighi Fard, N. (2023). *The effects of storage time and sunlight on microplastic pollution in bottled mineral water. Water and Environment Journal*, 37(2), 206-217.
<https://doi.org/10.1111/wej.12829>

Article

Sanei, M., & Khodadad, M. (2024). [Is Bottled Water More Reliable Than Tap Water in Mexico? A Case Study of Household Mental Health Conditions in Two States.](#) *International Journal of Sustainable Development and Planning*, 19(6), 2115-2123. <https://doi.org/10.18280/ijstdp.190611>

Singh, T. (2021). [Generation of microplastics from the opening and closing of disposable plastic water bottles.](#) *Journal of Water and Health*, 19(3), 488-498. <https://doi.org/10.2166/wh.2021.025>

Differences

Hossain, M. B., Yu, J., Banik, P., Noman, Md. A., Nur, A.-A. U., Haque, Md. R., Rahman, Md. M., Albeshr, M. F., & Arai, T. (2023). [First evidence of microplastics and their characterization in bottled drinking water from a developing country.](#) *Frontiers in Environmental Science*, 11, 1232931. <https://doi.org/10.3389/fenvs.2023.1232931>

Kye, H., Kim, J., Ju, S., Lee, J., Lim, C., & Yoon, Y. (2023). [Microplastics in water systems: A review of their impacts on the environment and their potential hazards.](#) *Heliyon*, 9(3), e14359. <https://doi.org/10.1016/j.heliyon.2023.e14359>

Discussion

Ebanks Mongalo, B. F., Rivas Suazo, E. G., Siu Estrada, E. A., & Flores-Pacheco, J. A. (2024). [Microplastics in a lagoon ecosystem of the Nicaraguan humid tropics and their impact on populations of *Crassostrea rhizophorae*.](#) *Revista Científica Estelí*, 50, 198-214. <https://doi.org/10.5377/esteli.v13i50.18483>

Lee, Y., Cho, J., Sohn, J., & Kim, C. (2023). [Health Effects of Microplastic Exposures: Current Issues and Perspectives in South Korea.](#) *Yonsei Medical Journal*, 64(5), 301-308. <https://doi.org/10.3349/ymj.2023.0048>





Olea, N. (2024). [Impact of microplastics on human health.](#) 24(Eng. Congr.), 43-91.

Taheri, S., Shoshtari-Yeganeh, B., Pourzamani, H., & Ebrahimpour, K. (2023). [Investigating the pollution of bottled water by the microplastics \(MPs\): The effects of mechanical stress, sunlight exposure, and freezing on MPs release.](#) *Environmental Monitoring and Assessment*, 195(1), 62. <https://doi.org/10.1007/s10661-022-10697-2>

Key guidelines to address technical and regulatory challenges in the adoption of cognitive radio in Mexico

Pautas clave para enfrentar los desafíos técnicos y regulatorios en la adopción de la radio cognitiva en México

Ortega-Laurel, Carlos*^a

^a  Universidad Autónoma Metropolitana •  LVQ-9127-2024 •  0000-0001-6072-8480 •  104250

CONAHCYT classification:

Area: Engineering

Field: Engineering and Technology

Discipline: Electrical Engineering, Electronic Engineering

Sub-discipline: Telecommunications

 <https://doi.org/10.35429/EJROP.2024.10.18.6.1.11>

Article History:

Received: January 27, 2024

Accepted: December 31, 2024



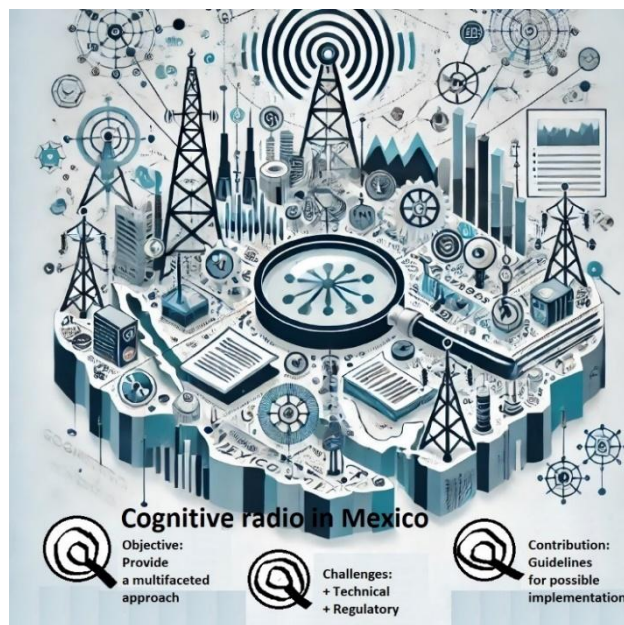
*  [\[c.ortega@correo.ler.uam.mx\]](mailto:c.ortega@correo.ler.uam.mx)

Abstract

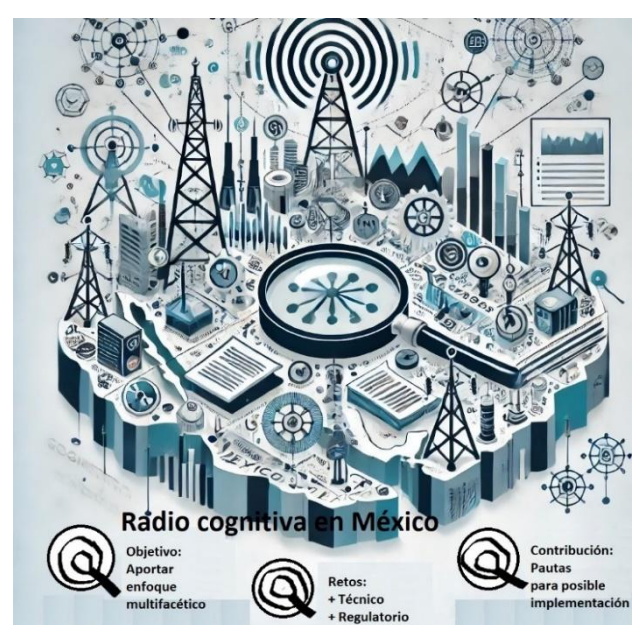
The main objective of this research is to provide a multifaceted approach to cognitive radio (CR) technology in Mexico, a technology that seeks to optimize the use of spectrum, ensuring more efficient and flexible wireless communication. CR faces significant technical and regulatory challenges in the world, with Mexico being no exception. These include the efficient management of the radio spectrum and the need for a regulatory framework adapted to emerging technology.

Resumen

El objetivo principal de esta investigación es aportar un enfoque multifacético de la tecnología de radio cognitiva (CR, por sus siglas en inglés) en México, tecnología que busca optimizar el uso del espectro, garantizando una comunicación inalámbrica más eficiente y flexible. La CR enfrenta desafíos técnicos y regulatorios significativos en el mundo, sin ser excepción México. Estos incluyen la gestión eficiente del espectro radioeléctrico y la necesidad de un marco normativo adaptado a la tecnología emergente.



Cognitive, Radio, Technology



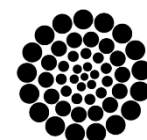
Cognitiva, Radio, Tecnología

Citation: Ortega-Laurel, Carlos. Key guidelines to address technical and regulatory challenges in the adoption of cognitive radio in Mexico. ECORFAN Journal-Republic of Paraguay. 10[18]-1-10: e61018111.



ISSN 2414-4827/©2009 The Authors. Published by ECORFAN-Mexico, S.C. for its Holding Republic of Paraguay on behalf of ECORFAN Journal-Republic of Paraguay. This is an open access chapter under the CC BY-NC-ND license [<http://creativecommons.org/licenses/by-nc-nd/4.0/>]

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



RENIECYT
Registro Nacional de Instituciones y
Empresas Científicas y Tecnológicas

1702902 **CONAHCYT**

Introduction

The concept of CR was introduced by Joseph Mitola III in 1999 (Mitola, 1999), defining it as an intelligent form of radio that can change its transmission and reception parameters based on interaction with the environment, interaction in which the availability of the radio spectrum is sensed.

General operation

1. Spectrum sensing

The CR continuously scans the spectrum to identify free bands and monitor occupied bands. It uses techniques such as energy detection, feature-based detection and cooperative methods (Yucek, 2009).

2. Analysis and decision

The collected data is analysed to assess spectrum availability, channel quality and other relevant factors. The CR controller makes decisions on spectrum usage based on these analyses (Akyildiz, 2009).

3. Assignment and access

The CR selects appropriate frequency bands and establishes communication using these bands. It employs spectrum access techniques to ensure that there is no interference with primary users (Zhao, 2007).

4. Adaptation and learning

The CR adapts its communication parameters (frequency, transmit power, modulation, etc.) in response to changes in the spectrum environment and learns from these adaptations to improve its future performance (Mitola, 1999).

The theoretical foundations of cognitive radio are therefore based on three main pillars:

1. Spectrum sensing:

Cognitive radio devices continuously monitor, quasi-permanently while active, the spectrum to identify available and used frequencies.

Spectrum monitoring: Cognitive radio devices continuously listen to the radio spectrum to identify available channels and avoid interference with other users (Haro, 2015).

2. Spectrum management:

Change from traditional fixed configurations to dynamic decisions in which it is determined which frequencies to use to firstly achieve communication, secondly to avoid interference, in order to optimise spectrum efficiency.

Dynamic spectrum: cognitive radio can detect frequencies that are not in use at a given time and adjust its transmission to those frequencies, which allows for a more efficient use of the spectrum (Márquez, 2014).

3. Adaptability and reconfiguration:

Dynamic modification - adjustment of parameters such as frequency, modulation and transmit power to achieve adaptability and reconfiguration, to improve the performance - use of the radio spectrum.

Adaptation: Cognitive radio systems can adapt their transmission parameters, such as transmit power and frequency, in response to environmental conditions (Rentería, 2011).

Other key features related to cognitive radio are:

4. Artificial intelligence and machine learning:

Advanced algorithms are used to analyse data collected from the environment and make decisions on how to operate more efficiently (Bezerra, 2024).

5. Interoperability:

Cognitive radio can communicate with different types of communication systems and networks, facilitating greater integration and cooperation between various wireless technologies (Haro, 2015).

Based on these generalities, a methodology is outlined, which is described in the following section.

This is intended to ensure a comprehensive and rigorous approach to analyse the challenges and opportunities for the adoption of CR technology in Mexico, from a technical and regulatory perspective. As such, this report was drafted in sufficient detail to present the identified challenges, integrated analysis and recommendations.

Method

The research focuses on understanding, identifying and addressing the challenges facing the adoption of a specific technology in Mexico. To this end, two main lenses are used: technical and regulatory, based on the existing literature, in order to obtain a solid understanding of the technical and regulatory challenges documented in the literature.

The objectives are

- a. Identify the technical challenges associated with technology adoption in Mexico.
- b. Analyse the current regulatory framework and how it affects technology implementation.
- c. Make recommendations to overcome the identified challenges.

Results

RC architecture

The CR architecture is an advanced wireless communication system that can dynamically adapt its operational parameters and communication strategies to optimise the use of the radio spectrum.

The main components of the CR architecture are:

1. Spectrum Sensing.

Detects available frequency bands and monitors spectrum usage to identify communication opportunities without interfering with Primary Users (PU) (Haykin, 2005).

2. Spectrum Management

Selects the best available frequency bands based on channel conditions and spectrum usage policies. This includes dynamic spectrum allocation and channel selection (Akyildiz, 2006).

3. Spectrum Sharing (Spectrum Sharing)

Coordinates spectrum usage among multiple cognitive users (Secondary Users, SU) to avoid collisions and ensure efficient communication. It implements mechanisms such as opportunistic spectrum access and coexistence with primary users (Zhao, 2007).

4. Spectrum Mobility

Allows cognitive users to switch frequencies without service interruption when the presence of a primary user is detected or when channel conditions change (Zhao, 2007).

5. Cognitive Radio Controller (CR Controller)

The core of the architecture, which integrates learning and decision-making functions (Mitola, 2002). It uses artificial intelligence and machine learning techniques to optimise real-time operation of the CR (Bezerra, 2024).

6. User Interface and Applications

Provides the means for users to configure and monitor the operation of the system. It allows the implementation of specific applications that leverage the capabilities of the CR.

The CR architecture represents the breakthrough achieved in wireless communications, which is significant in providing an intelligent and adaptive solution for the efficient use of the radio spectrum.

Benefits

1. Spectrum Efficiency

Improves spectrum utilisation by allowing opportunistic access to unused bands (Haykin, 2005).

Article

2. Interference Reduction

Minimises interference with primary users through accurate detection and dynamic frequency switching (Akyildiz, 2006).

3. Flexibility and Scalability

Adapts its operations to different environments and communication requirements, making it suitable for a wide range of applications (Mitola, 2002).

4. Improved Network Performance

Optimises quality of service and network efficiency by dynamically adjusting communication parameters (Yucek, 2009).

Challenges

1. Accurate Detection of primary users and identification of free bands are critical and can be complicated in noisy environments (Yucek, 2009).

Coexistence and Coordination

2. Efficient coordination between multiple cognitive radios and primary users is a challenge to avoid interference and maximise spectrum efficiency (Zhao, 2007).

Regulation and Policy

3. The implementation of cognitive radios must comply with the spectrum usage regulations and standards set by the competent authorities (Akyildiz, 2009).

Thus CR is a telecommunications technology that allows wireless communication devices to use the radio frequency spectrum more efficiently.

It is based on the idea that devices can ‘understand’ and ‘learn’ from the radio environment in which they operate in order to optimise their performance.

CR is a technology that allows wireless communication devices to dynamically identify and use available radio frequencies to optimise spectrum usage.

In fact, CR is an advanced technology that can allow wireless devices to automatically detect and use spectrum frequencies that are not in use at a given time, thus improving spectrum usage efficiency.

Given the characteristics CR has applications in diverse areas such as military and police communication (AllahRakha, 2024), mobile networks (Demeneghi, 2024), the Internet of Things (IoT) (El Akhdar *et al.*, 2024), smart grids (Velasquez *et al.*, 2024) and Artificial Intelligence (AI) (Espina-Romero *et al.*, 2024) where efficient spectrum management is crucial for the performance and reliability of communication systems.

Given the attractiveness of the emerging technology, a number of countries where significant CR trials have been conducted or have sought to put into operation can be found in the literature:

1. The United States:
 - The Federal Communications Commission (FCC) has been a pioneer in promoting CR. The FCC has authorised the use of ‘TV White Spaces’ devices, which are unused spaces in the television spectrum, for CR operations (Baykas, 2010).
 - Several universities and technology companies in the US have conducted research and pilot tests in the area of CR. Researchers such as Mitola and Haykin have pioneered the development of CR concepts and technologies in the US (Mitola, 2002), (Haykin, 2005).
2. United Kingdom:
 - Ofcom, the UK communications regulatory authority, has conducted trials of CR in TV White Spaces.
 - Research projects such as the Cambridge TV White Spaces Consortium have explored the use of CR to provide Internet access in rural areas (Baykas, 2010).

Article

3. Japan:

- Japan's Ministry of Internal Affairs and Communications has worked on developing regulations and testing for CR.
- Several universities and research centres in Japan have been involved in pilot projects and studies on CR.

Japan has been active in RC research and development, with organisations such as the National Institute of Information and Communications Technology (NICT) participating in experimental trials and deployments. Efforts in Japan have been crucial for the adoption of VC technologies in commercial applications (Akyildiz, 2009).

4. South Korea:

- South Korea has been a leader in the adoption of advanced wireless technologies and has conducted research and testing of CR.
- Academic institutions and technology companies have collaborated in the development of this technology (Baykas, 2010).

5. Finland:

- Finland has been a research hub for CR, with institutions such as the University of Oulu and the Technical Research Centre of Finland (VTT) leading projects in this field (Baykas, 2010).

6. China:

- China has shown a growing interest in CR, with research and testing conducted by universities and telecommunications companies.
- The Chinese government has supported research and development in this field as part of its technological innovation strategy (Fette, 2006).

7. Germany

Germany has conducted significant research in the field of RC through projects led by the Fraunhofer Institute and other research centres. These efforts have included field trials and prototype development to demonstrate the feasibility of RC in various environments (Fette, 2006).

These countries have been pioneers in the research and development of RC, conducting tests and establishing regulations that allow its use. The implementation of this technology has the potential to significantly improve the efficiency of spectrum use and provide better wireless communication services.

In Mexico, the Federal Telecommunications Institute (IFT) is the body in charge of regulating the radio spectrum. So far, the focus has been on spectrum release for mobile services and spectrum management for other telecommunications services (IFT, 2023). CR in Mexico has been only partially considered, little explored, and not at all implemented, but there is significant potential for its adoption, especially in rural areas and to improve the efficiency of spectrum use in urban areas (IFT, 2023).

Thus, radio spectrum regulation in Mexico, particularly in relation to CR, is a topic of ongoing discussion and criticism. In this sense, some criticisms and considerations on the current regulations in Mexico will be presented below.

Criticisms and Challenges

Lack of specific regulations: In Mexico, specific regulation on RC is still under development. The lack of clear and specific regulations may inhibit the implementation and development of this technology.

Therefore, the absence of a well-defined regulatory framework may generate uncertainty among operators and manufacturers of CR equipment at any given time.

Rigidity of the regulatory framework: Current regulations can be seen as rigid and not sufficiently adapted to the needs of emerging technologies such as CR.

Traditional spectrum regulations, which assign fixed frequencies to specific services, do not align well with the dynamic and flexible approach of CR, and this is just what is in place in Mexico (IFT, 2023).

Interference and compatibility: The introduction of CR devices may cause interference concerns with existing radio services. Regulations must ensure that CR devices do not interfere with licensed transmissions.

From the above that compatibility between devices from different manufacturers and technologies is another challenge that needs to be addressed in regulation.

Licensing process: The spectrum licensing process in Mexico is complex and slow, and over-regulated, which can delay the adoption of CR technologies.

In fact, the need to obtain specific permissions for the use of certain spectrum bands in Mexico limits the flexibility and efficiency that CR promises.

Incentives for innovation: In Mexico there is a lack of clear incentives for innovation in spectrum use, which may discourage companies from investing in CR technologies.

Current Mexican regulations may not provide sufficient incentives for companies to develop and adopt advanced technologies that optimise spectrum use.

Discussion

To address the current technical and regulatory challenges of CR, a multi-faceted approach involving researchers, engineers, regulators and industry is essential.

The following are specific guidelines that the IFT should listen to in order to address these challenges:

Technical challenges, for the regulator, the IFT needs to ensure:

1. Promoting the development of advanced algorithms

To improve spectrum sensing through sensors: ensure the development of more accurate and efficient algorithms for the detection of available spectrum, using advanced techniques such as deep learning and artificial intelligence.

- Accuracy and efficiency: seek to develop and improve algorithms that detect with high accuracy the available frequency bands using machine learning and signal processing techniques.
- Collaborative sensing: seek to implement systems that use collaborative sensing between multiple devices to improve the accuracy of spectrum sensing.
- Optimisation of decision making: regularly implement decision making algorithms that balance spectrum efficiency and quality of service, leveraging predictive modelling and game theory.
- Game theory and reinforced learning: regulate the application of these approaches to optimise spectrum use decisions, balancing efficiency and interference minimisation.
- Predictive modelling: address the use of predictive modelling to anticipate spectrum availability and traffic load, enabling proactive planning.

Computational efficiency: encourage the design of algorithms that can run in real time with limited computational resources, especially for mobile and IoT devices.

2. Security and reliability

Protection against malicious interference: seek to develop techniques to detect and mitigate intentional or malicious interference, such as denial of service attacks.

- Detection and mitigation: arrange for the development of techniques to identify and mitigate jamming attacks, such as the use of spectral signatures and traffic pattern analysis.

Article

- Redundancy and resilience: demand the implementation of redundancy mechanisms to ensure continuity of service in the presence of interference.
- Authentication and authorisation: call for robust mechanisms to be implemented to ensure that only authorised devices can access and use the spectrum.
- Security mechanisms: call for the establishment of robust authentication and authorisation protocols to ensure that only legitimate devices can access and use the spectrum.
- Data integrity: provide for ensuring that data exchanged and decisions made by cognitive devices are reliable and not manipulable.

3. Interoperability

Open standards: promote the development and adoption of open standards to ensure that devices from different manufacturers can operate together.

- Development and promotion: work with standardisation bodies to develop and promote open standards that facilitate interoperability between devices from different manufacturers.
- Compatibility testing: seek comprehensive interoperability testing between devices from different vendors and in a variety of operating environments.
- Common test environments: create common test environments by the IFT to validate the interoperability and performance of CR devices.

Regulatory Challenges for the regulator, the IFT has to ensure:

Flexible policy development 2.

- Dynamic regulations: establish regulatory frameworks that allow for dynamic use of spectrum, adjusting frequency allocations in real time based on demand and availability.

- Dynamic use schemes: implement regulations that allow for dynamic spectrum allocation, adjusting to real-time needs.

Temporary licensing: implement temporary or secondary licensing schemes that allow CR devices to access spectrum opportunistically without interfering with primary users.

- Secondary spectrum access: establish temporary or secondary licensing schemes that allow opportunistic spectrum access without interfering with primary users.

2. International coordination

Global harmonisation: collaborate with international bodies to harmonise spectrum regulations and facilitate the use of CR globally.

- International collaboration: promote harmonisation of regulations at the global level to facilitate cross-border use of CR.

Information exchange: create platforms for the exchange of information on spectrum use and regulatory best practices between countries.

- Communication platforms: create platforms for the exchange of information and best practices between countries and regulators.

International cooperation: actively participate in international fora to share experiences and adopt best practices in spectrum regulation. International cooperation can provide valuable insights and help harmonise regulations with global standards.

Monitoring and enforcement

Monitoring systems: develop advanced spectrum monitoring systems to detect misuse and ensure compliance with regulations.

- Monitoring technologies: develop advanced spectrum monitoring systems to detect and record misuse.

Sanctions and penalties: establish clear and effective sanctions for violations of spectrum regulations.

- Clear regulations: establish clear and effective penalties for violations of spectrum regulations to ensure compliance.

Collaboration and education the IFT is to ensure:

1. Promotion of research

Support for research projects: fund research projects in universities and institutes to advance CR technologies.

- Funding and grants: provide funding and grants for RC research projects in universities and research institutes.

Publications and conferences: to promote the dissemination of research results through academic publications and specialised conferences.

- Knowledge dissemination: encourage the publication of research and participation in specialised conferences to share advances and findings.

2. Training and awareness-raising

Training programmes: develop training programmes for engineers and technicians in new technologies and practices related to RC.

- Education and training: Develop training programmes for engineers and technicians on RC technologies and practices.

Awareness campaigns: conduct campaigns to inform the industry and the public about the benefits and challenges of RC.

- Informing the public: conduct campaigns to educate industry and the public on the benefits and challenges of RC, promoting wider and more conscious adoption.

Other considerations for improving technology regulation in general.

Developing specific regulations: It is essential to develop technology-specific regulatory frameworks that address the particularities and benefits of each technology. This includes clearly defining the conditions under which devices can operate and measures to avoid interference.

Flexibility in spectrum use: adopting a more flexible approach to spectrum allocation and use can facilitate the deployment of all types of emerging technologies. Regulations should allow, for example, for dynamic spectrum use and efficient frequency sharing.

Interference protection: implement monitoring and control mechanisms to ensure that devices of any technology do not interfere with licensed communications. This may include creating a regulatory environment that allows for the safe co-existence of multiple technologies.

Simplification of licensing: simplify and streamline the spectrum licensing process to facilitate the adoption of innovative technologies. A more accessible and less bureaucratic licensing system can accelerate the deployment of emerging technologies.

Encourage innovation: create incentives for research and development in the field of telecommunications technology in general. This can include subsidies, tax breaks, and collaborative programmes between government, academia and industry.

Implementing these guidelines will help overcome technical and regulatory challenges, facilitating the widespread and efficient adoption of RC, and technologies in general.

Implementing these guidelines will help facilitate the integration of CR into modern telecommunications. This comprehensive approach will not only improve spectrum management, but will also drive innovation in wireless telecommunications.

Conclusions

This paper highlights key guidelines for addressing the technical and regulatory challenges in the adoption of CR in Mexico, underlining the importance of a comprehensive approach that involves both technological advances and regulatory reforms.

In sum, a successful adoption of CR in Mexico will depend on a regulatory update that fosters innovation and investment in technological infrastructure to address the identified challenges.

To advance the implementation of CR in Mexico, it will be crucial to address the technical and regulatory challenges mentioned above, developing policies that support innovation and ensuring that new technologies can be safely and effectively integrated into the country's telecommunications ecosystem.

CR offers significant potential to improve the efficiency of radio spectrum use in Mexico. However, to fully exploit its benefits, regulations need to adapt and evolve. Current critiques highlight the need for a more flexible, targeted and innovation-oriented regulatory framework. Adapting regulations to address these challenges can facilitate the adoption of advanced technologies and optimise spectrum use for the benefit of all users.

Implementation of the outlined guidelines can result in a significant improvement in the efficiency of spectrum use, reducing interference and increasing the capacity of wireless networks. Advances in security algorithms and techniques will contribute to reliability and protection against attacks, while the adoption of open standards and compatibility testing will promote greater interoperability between devices. At the regulatory level, flexible policies and international coordination will facilitate more effective spectrum management, allowing more equitable and efficient access to radio frequency resources.

Together, these measures will not only optimise spectrum management in Mexico, but also drive innovation in wireless telecommunications, benefiting a wide range of applications, from mobile networks to the Internet of Things (IoT).

The CR represents a significant advance in telecommunications technology, offering an innovative solution for the efficient management of radio frequency spectrum. Through its ability to adapt and learn from the environment, it promises to improve the performance of wireless networks and meet the growing demand for bandwidth.

However, for its potential to be fully realised in Mexico, it is crucial to address existing technical and regulatory challenges.

Disclosures

Conflict of interest

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

Authors' contribution

Ortega-Laurel, Carlos: Contributed to the project idea, research method and technique.

Availability of data and materials

Please indicate the availability of the data obtained in this research.

Funding

This research was developed as part of the work initiatives devised by the author, who is part of the academic staff of the Universidad Autónoma Metropolitana, Unidad Lerma, without any specific funding.

Acknowledgements

Thanks are due to the Department of Information and Communication Systems, Universidad Autónoma Metropolitana, for their permission.

Abbreviations

Cognitive Radio (CR, for Cognitive Radio)

References

Background

Baykas, T., Wang, J., Rahman, M. A., Tran, H. N., Song, C., Filin, S., ... & Harada, H. (2010, September). [Overview of TV White Spaces: Current regulations, standards and coexistence between secondary users](#). In *2010 IEEE 21st International Symposium on Personal, Indoor and Mobile Radio Communications Workshops* (pp. 38-43). IEEE. DOI: 10.1109/PIMRCW.2010.5670401

Article

Haro, C. A., Ribas, L. C., Lorente, J. D. S., Dekorsy, A., Cortes, M. E., Gelabert, X., ... & Romo, J. A. (2015). [White Paper: Radio and Cognitive Networks](#). *arXiv preprint arXiv:1502.06810*. DOI: 10.48550/arXiv.1502.06810.

Rentería, J. H. A., & Cadavid, A. N. (2011). [Cognitive radio-State of the art](#). *Systems and Telematics*, 9(16), 31-53. DOI: 10.18046/syt.v9i16.1028

Basics

Akyildiz, I. F., Lee, W. Y., & Chowdhury, K. R. (2009). [CRAHNs: Cognitive radio ad hoc networks](#). *AD hoc networks*, 7(5), 810-836. DOI:10.1016/j.adhoc.2009.01.001.

Akyildiz, I. F., Lee, W. Y., Vuran, M. C., & Mohanty, S. (2006). [NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey](#). *Computer networks*, 50(13), 2127-2159. DOI:10.1016/j.comnet.2006.05.001

Bezerra, G. M., de Oliveira, N. R., Ferreira, T. N., & Mattos, D. M. (2024). [A comprehensive evaluation of software-defined radio performance in virtualized environments for radio access networks](#). *Annals of Telecommunications*, 79(7), 523-535. DOI: 10.1007/s12243-024-01044-2

Demeneghi, J. A., Kaur, J., Tan, K., & Abbas, H. (2024). [Sub-6 GHz beamforming with low-cost software-defined radio: Design, testing, and performance evaluation](#). *Physical Communication*, 65, 102391. DOI: 10.1016/j.phycom.2024.102391

Fette, B. A. (2006). [History and background of cognitive radio technology](#). In *Cognitive Radio Technology* (pp. 1-27). Newnes. DOI:10.1016/B978-0-12-374535-4.00001-1

Mitola, J. (1999). [Software radio architecture: a mathematical perspective](#). *IEEE Journal on selected areas in communications*, 17(4), 514-538. DOI: 10.1007/978-3-030-15416-5_4

Mitola, J., & Maguire, G. Q. (1999). [Cognitive radio: making software radios more personal](#). *IEEE personal communications*, 6(4), 13-18. DOI:10.1109/98.788210

Mitola, J. I. (2002). [Cognitive radio. An integrated agent architecture for software defined radio](#). Ph.D. Dissertation, Royal Institute of Technology (KTH), Stockholm, Sweden.

Support

AllahRakha, N. (2024). [Global perspectives on cybercrime legislation](#). *Journal of Infrastructure, Policy and Development*, 8(10), 6007. DOI: 10.24294/jipd.v8i10.6007

El Akhdar, A., Baidada, C., Kartit, A., Hanine, M., Garcia, C. O., Lara, R. G., & Ashraf, I. (2024). [Exploring the Potential of Microservices in Internet of Things: A Systematic Review of Security and Prospects](#). *Sensors*, 24(20), 6771. DOI: 10.3390/s24206771

Haykin, S. (2005). [Cognitive radio: brain-empowered wireless communications](#). *IEEE journal on selected areas in communications*, 23(2), 201-220. DOI: 10.1109/JSAC.2004.839380

Differences

IFT (2023). [Análisis en materia de acceso dinámico y uso compartido del espectro radioeléctrico y las alternativas regulatorias para su habilitación](#). IFT, 1 -94.

Márquez Ramos, H. R. (2014). [Cognitive radio architectures: a current review](#). *Tecnura*, 18(39), 181-196. DOI:10.14483/udistrital.jour.tecnura.2014.1.a13

Discussions

Espina-Romero, L., Gutiérrez Hurtado, H., Ríos Parra, D., Vilchez Pirela, R. A., Talavera-Aguirre, R., & Ochoa-Díaz, A. (2024). [Challenges and Opportunities in the Implementation of AI in Manufacturing: A Bibliometric Analysis](#). *Sci*, 6(4), 60. DOI: doi.org/10.3390/sci6040060

Velasquez, W., Moreira-Moreira, G. Z., & Alvarez-Alvarado, M. S. (2024). [Smart Grids Empowered by Software-Defined Network: A Comprehensive Review of Advancements and Challenges](#). *IEEE Access*. DOI: 10.1109/ACCESS.2024.3396402

Article

Yucek, T., & Arslan, H. (2009). [A survey of spectrum sensing algorithms for cognitive radio applications](#). *IEEE communications surveys & tutorials*, *11*(1), 116-130. DOI:10.1109/SURV.2009.090109

Zhao, Q., & Sadler, B. M. (2007). [A survey of dynamic spectrum access](#). *IEEE signal processing magazine*, *24*(3), 79-89. DOI: 10.1109/ICASSP.2007.367328

Instructions for Scientific, Technological and Innovation Publication

[Title in Times New Roman and Bold No. 14 in English and Spanish]

Surname (IN UPPERCASE), Name 1st Author†*, Surname (IN UPPERCASE), Name 1st Coauthor, Surname (IN UPPERCASE), Name 2nd Coauthor and Surname (IN UPPERCASE), Name 3rd Coauthor

Institutional Affiliation of Author including Dependency (No.10 Times New Roman and Italic)

International Identification of Science - Technology and Innovation

ID 1st author: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 1st author: (Scholar-PNPC or SNI-CONACYT) (No.10 Times New Roman)

ID 1st coauthor: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 1st coauthor: (Scholar or SNI) (No.10 Times New Roman)

ID 2nd coauthor: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 2nd coauthor: (Scholar or SNI) (No.10 Times New Roman)

ID 3rd coauthor: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 3rd coauthor: (Scholar or SNI) (No.10 Times New Roman)

(Report Submission Date: Month, Day, and Year); Accepted (Insert date of Acceptance: Use Only ECORFAN)

Abstract (In English, 150-200 words)

Objectives
Methodology
Contribution

Keywords (In English)

Indicate 3 keywords in Times New Roman and Bold No. 10

Abstract (In Spanish, 150-200 words)

Objectives
Methodology
Contribution

Keywords (In Spanish)

Indicate 3 keywords in Times New Roman and Bold No. 10

Citation: Surname (IN UPPERCASE), Name 1st Author, Surname (IN UPPERCASE), Name 1st Coauthor, Surname (IN UPPERCASE), Name 2nd Coauthor and Surname (IN UPPERCASE), Name 3rd Coauthor. Paper Title. ECORFAN Journal-Republic of Paraguay. Year 1-1: 1-11 [Times New Roman No.10]

* Correspondence to Author (example@example.org)

† Researcher contributing as first author.

Introduction

Text in Times New Roman No.12, single space.

General explanation of the subject and explain why it is important.

What is your added value with respect to other techniques?

Clearly focus each of its features

Clearly explain the problem to be solved and the central hypothesis.

Explanation of sections Article.

Development of headings and subheadings of the article with subsequent numbers

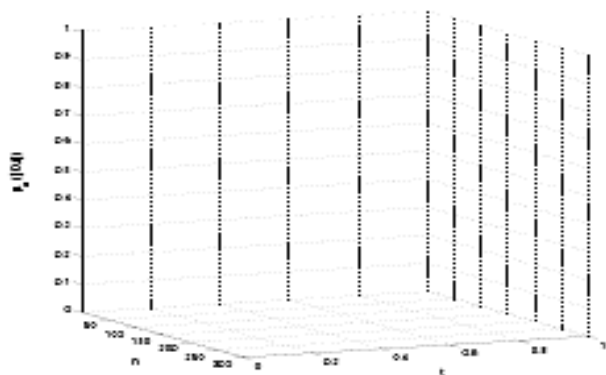
[Title No.12 in Times New Roman, single spaced and bold]

Products in development No.12 Times New Roman, single spaced.

Including graphs, figures and tables-Editable

In the article content any graphic, table and figure should be editable formats that can change size, type and number of letter, for the purposes of edition, these must be high quality, not pixelated and should be noticeable even reducing image scale.

[Indicating the title at the bottom with No.10 and Times New Roman Bold]



Graphic 1 Title and *Source (in italics)*

Should not be images-everything must be editable.

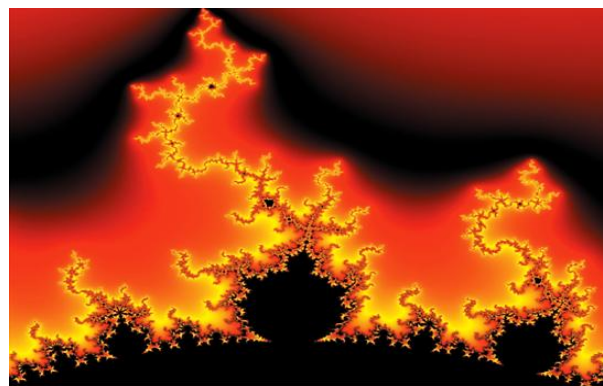


Figure 1 Title and *Source (in italics)*

Should not be images-everything must be editable.

Table 1 Title and *Source (in italics)*

Should not be images-everything must be editable.

Each article shall present separately in **3 folders**:
a) Figures, b) Charts and c) Tables in .JPG format, indicating the number and sequential Bold Title.

For the use of equations, noted as follows:

$$Y_{ij} = \alpha + \sum_{h=1}^r \beta_h X_{hij} + u_j + e_{ij} \quad (1)$$

Must be editable and number aligned on the right side.

Methodology

Develop give the meaning of the variables in linear writing and important is the comparison of the used criteria.

Results

The results shall be by section of the article.

Annexes

Tables and adequate sources

Thanks

Indicate if they were financed by any institution, University or company.

Conclusions

Explain clearly the results and possibilities of improvement.

Instructions for Scientific, Technological and Innovation Publication

References

Use APA system. Should not be numbered, nor with bullets, however if necessary numbering will be because reference or mention is made somewhere in the Article.

Use Roman Alphabet, all references you have used must be in the Roman Alphabet, even if you have quoted an Article, book in any of the official languages of the United Nations (English, French, German, Chinese, Russian, Portuguese, Italian, Spanish, Arabic), you must write the reference in Roman script and not in any of the official languages.

Technical Specifications

Each article must submit your dates into a Word document (.docx):

Journal Name

Article title

Abstract

Keywords

Article sections, for example:

1. Introduction

2. Description of the method

3. Analysis from the regression demand curve

4. Results

5. Thanks

6. Conclusions

7. References

Author Name (s)

Email Correspondence to Author

References

Intellectual Property Requirements for editing:

- Authentic Signature in Color of Originality Format Author and Coauthors.
- Authentic Signature in Color of the Acceptance Format of Author and Coauthors.
- Authentic Signature in blue colour of the Conflict of Interest Format of Author and Coauthors.

Reservation to Editorial Policy

ECORFAN-Journal Paraguay reserves the right to make editorial changes required to adapt the Articles to the Editorial Policy of the Journal. Once the Article is accepted in its final version, the Journal will send the author the proofs for review. ECORFAN® will only accept the correction of errata and errors or omissions arising from the editing process of the Journal, reserving in full the copyrights and content dissemination. No deletions, substitutions or additions that alter the formation of the Article will be accepted.

Code of Ethics - Good Practices and Declaration of Solution to Editorial Conflicts

Declaration of Originality and unpublished character of the Article, of Authors, on the obtaining of data and interpretation of results, Acknowledgments, Conflict of interests, Assignment of rights and Distribution

The ECORFAN-Mexico, S.C Management claims to Authors of Articles that its content must be original, unpublished and of Scientific, Technological and Innovation content to be submitted for evaluation.

The Authors signing the Article must be the same that have contributed to its conception, realization and development, as well as obtaining the data, interpreting the results, drafting and reviewing it. The Corresponding Author of the proposed Article will request the form that follows.

Article title:

- The sending of an Article to ECORFAN-Journal Paraguay emanates the commitment of the author not to submit it simultaneously to the consideration of other series publications for it must complement the Format of Originality for its Article, unless it is rejected by the Arbitration Committee, it may be withdrawn.
- None of the data presented in this article has been plagiarized or invented. The original data are clearly distinguished from those already published. And it is known of the test in PLAGSCAN if a level of plagiarism is detected Positive will not proceed to arbitrate.
- References are cited on which the information contained in the Article is based, as well as theories and data from other previously published Articles.
- The authors sign the Format of Authorization for their Article to be disseminated by means that ECORFAN-Mexico, S.C. In its Holding Paraguay considers pertinent for disclosure and diffusion of its Article its Rights of Work.
- Consent has been obtained from those who have contributed unpublished data obtained through verbal or written communication, and such communication and Authorship are adequately identified.
- The Author and Co-Authors who sign this work have participated in its planning, design and execution, as well as in the interpretation of the results. They also critically reviewed the paper, approved its final version and agreed with its publication.
- No signature responsible for the work has been omitted and the criteria of Scientific Authorization are satisfied.
- The results of this Article have been interpreted objectively. Any results contrary to the point of view of those who sign are exposed and discussed in the Article.

Copyright and Access

The publication of this Article supposes the transfer of the copyright to ECORFAN-Mexico, SC in its Holding Paraguay for its ECORFAN-Journal Paraguay, which reserves the right to distribute on the Web the published version of the Article and the making available of the Article in This format supposes for its Authors the fulfilment of what is established in the Law of Science and Technology of the United Mexican States, regarding the obligation to allow access to the results of Scientific Research.

Article Title:

Name and Surnames of the Contact Author and the Co-authors	Signature
1.	
2.	
3.	
4.	

Principles of Ethics and Declaration of Solution to Editorial Conflicts

Editor Responsibilities

The Publisher undertakes to guarantee the confidentiality of the evaluation process, it may not disclose to the Arbitrators the identity of the Authors, nor may it reveal the identity of the Arbitrators at any time.

The Editor assumes the responsibility to properly inform the Author of the stage of the editorial process in which the text is sent, as well as the resolutions of Double-Blind Review.

The Editor should evaluate manuscripts and their intellectual content without distinction of race, gender, sexual orientation, religious beliefs, ethnicity, nationality, or the political philosophy of the Authors.

The Editor and his editing team of ECORFAN® Holdings will not disclose any information about Articles submitted to anyone other than the corresponding Author.

The Editor should make fair and impartial decisions and ensure a fair Double-Blind Review.

Responsibilities of the Editorial Board

The description of the peer review processes is made known by the Editorial Board in order that the Authors know what the evaluation criteria are and will always be willing to justify any controversy in the evaluation process. In case of Plagiarism Detection to the Article the Committee notifies the Authors for Violation to the Right of Scientific, Technological and Innovation Authorization.

Responsibilities of the Arbitration Committee

The Arbitrators undertake to notify about any unethical conduct by the Authors and to indicate all the information that may be reason to reject the publication of the Articles. In addition, they must undertake to keep confidential information related to the Articles they evaluate.

Any manuscript received for your arbitration must be treated as confidential, should not be displayed or discussed with other experts, except with the permission of the Editor.

The Arbitrators must be conducted objectively, any personal criticism of the Author is inappropriate.

The Arbitrators must express their points of view with clarity and with valid arguments that contribute to the Scientific, Technological and Innovation of the Author.

The Arbitrators should not evaluate manuscripts in which they have conflicts of interest and have been notified to the Editor before submitting the Article for Double-Blind Review.

Responsibilities of the Authors

Authors must guarantee that their articles are the product of their original work and that the data has been obtained ethically.

Authors must ensure that they have not been previously published or that they are not considered in another serial publication.

Authors must strictly follow the rules for the publication of Defined Articles by the Editorial Board.

The authors have requested that the text in all its forms be an unethical editorial behavior and is unacceptable, consequently, any manuscript that incurs in plagiarism is eliminated and not considered for publication.

Authors should cite publications that have been influential in the nature of the Article submitted to arbitration.

Information services

Indexation - Bases and Repositories

LATINDEX (Scientific Journals of Latin America, Spain and Portugal)

REBIUN (Network of Spanish University Libraries, Spain)

SUDOC (University Documentation System, France)

RESEARCH GATE (Germany)

GOOGLE SCHOLAR (Citation indices-Google)

ROAD (Directory of Open Access scholarly Resources)

MENDELEY (Bibliographic References Manager)

REDIB (Ibero-American Network of Innovation and Scientific Knowledge- CSIC)

Publishing Services

Citation and Index Identification H

Management of Originality Format and Authorization

Testing Article with PLAGSCAN

Article Evaluation

Certificate of Double-Blind Review

Article Edition

Web layout

Indexing and Repository

Article Translation

Article Publication

Certificate of Article

Service Billing

Editorial Policy and Management

105 Alberdi Rivarola Captain, CP-2060. Luque City- Paraguay. Phones: +52 1 55 6159 2296, +52 1 551260 0355, +52 1 55 6034 9181; Email: contact@ecorfan.org www.ecorfan.org

ECORFAN®

Chief Editor

CENTENO-ROA, Ramona. MsC

Executive Director

RAMOS-ESCAMILLA, María. PhD

Editorial Director

PERALTA-CASTRO, Enrique. MsC

Web Designer

ESCAMILLA-BOUCHAN, Imelda. PhD

Web Diagrammer

LUNA-SOTO, Vladimir. PhD

Editorial Assistant

TREJO-RAMOS, Iván. BsC

Philologist

RAMOS-ARANCIBIA, Alejandra. BsC

Advertising & Sponsorship

(ECORFAN® Paraguay), sponsorships@ecorfan.org

Site Licences

03-2010-032610094200-01-For printed material ,03-2010-031613323600-01-For Electronic material,03-2010-032610105200-01-For Photographic material,03-2010-032610115700-14-For the facts Compilation,04-2010-031613323600-01-For its Web page,19502-For the Iberoamerican and Caribbean Indexation,20-281 HB9-For its indexation in Latin-American in Social Sciences and Humanities,671-For its indexing in Electronic Scientific Journals Spanish and Latin-America,7045008-For its divulgation and edition in the Ministry of Education and Culture-Spain,25409-For its repository in the Biblioteca Universitaria-Madrid,16258-For its indexing in the Dialnet,20589-For its indexing in the edited Journals in the countries of Iberian-America and the Caribbean, 15048-For the international registration of Congress and Colloquiums. financingprograms@ecorfan.org

Management Offices

105 Alberdi Rivarola Captain, CP-2060. Luque City - Paraguay

ECORFAN Journal-Republic of Paraguay

“Potential geographic accessibility to municipal medical services (Cruz Verde) in the municipality of Guadalajara, Jalisco, Mexico”

Ortiz-Curiel, Yaireth Deyanira, Niño-Gutiérrez, Naú Silverio, Andrade-García, María Dolores and Macías-Huerta, María del Carmen

Universidad de Guadalajara

Universidad Autónoma de Guerrero

“Improvement of urban spaces, towards a sustainable habitat. BUAP Residential Case, Puebla, Puebla”

Alonso-Pérez, Carlos

Benemérita Universidad Autónoma de Puebla

“Augmented reality as a support for tourism promotion”

Sánchez-Juárez, Ivan Rafael & Paredes-Xochihua, Maria Petra
Universidad Da Vinci

Tecnológico Nacional de México/ ITS de San Martín Texmelucan

“Marketing strategies of MIPyMES in the Cd. Mexico and metropolitan area during and after the pandemic”

Álvarez-García, Mónica, Gutiérrez-Zepeda, Martha del Pilar, Guerrero-Ibarra, Carlos and Waldo Caamaño, José David

Universidad Tecnológica de Nezahualcóyotl

“Identification of microplastics in bottled water, a potential risk to human health”

Alva-Rojas, Elvia, Rivera-Ramírez Fabiola, Jiménez-Rosales, Angélica and Velázquez-Garduño, Gisela

Universidad Tecnológica del Valle de Toluca

“Key guidelines to address technical and regulatory challenges in the adoption of cognitive radio in Mexico”

Ortega-Laurel, Carlos

Universidad Autónoma Metropolitana

