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Redesign of Roads for the optimization of Urban Space, integrating a Sustainable Mobility

Rediseño de Vialidad para la optimización del Espacio Urbano, integrando una Movilidad Sostenible

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Abstract

This paper addresses "Redesign of the rural roads of the municipal capital of Huichapan, Hidalgo", in order to generate the optimization of the Urban Space and integrate a Sustainable Mobility, through the analysis of the case study of Huichapan, Hidalgo, Mexico, which is a rural municipality, is characterized by being dispersed, faces specific mobility challenges such as coverage and availability. Together with its structure of narrow, winding streets that sometimes lead to dead ends. This paper addresses the implementation of a cycle path as an integral solution that benefits mobility, health and local economy, as a reference for the restructuring of dispersed urban-rural settlements. The initiative seeks to adhere to the national goals of sustainable urban development, considering the image of a magical town and the rich history of Huichapan, as an initiative that adapts to the context and exalts its qualities.

Municipal, Rural, Sustainable

Resumen

En el presente artículo se aborda el rediseño de la vialidad rural de la cabecera municipal de Huichapan, Hidalgo, a fin de generar la optimización del Espacio Urbano e integrar una Movilidad Sostenible, mediante el análisis del caso de estudio de Huichapan, Hidalgo, México, el cual es un municipio rural, se caracteriza por ser disperso, enfrenta retos de movilidad específicos como es la cobertura y disponibilidad. Aunado a su estructura de calles estrechas, sinuosas que en ocasiones conducen a callejones sin salida. En el presente trabajo se aborda la implementación de una ciclovía como una solución integral que beneficia la movilidad, salud y economía local, como un referente para la reestructuración de los asentamientos urbanos-rurales dispersos. La iniciativa busca apegarse a los objetivos nacionales de desarrollo urbano sostenible, considerando la imagen de pueblo mágico y la rica historia de Huichapan, como iniciativa que se adapta al contexto y exalta sus cualidades.

Municipal, Rural, Sostenible

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Introduction

Huichapan is a rural municipality located in the state of Hidalgo. Its urban structure is dispersed and monofunctional, featuring a mixed type of layout with a reticular typology in the center and broken plate typology in the peripheries. It has a territorial extension of 660 km2. According to data from INEGI (2020, cited in the Huichapan Municipal Development Plan 2020-2024), "Huichapan has a total population of 47,425 inhabitants, of which 7.3% of the population have some form of disability, such as motor, visual, auditory, speech, and/or mental limitations."

A relevant fact to mention is that the municipal seat was classified as a Pueblo Mágico (Magic Town) in 2012 and recently as Zona de Monumentos Históricos (Zone of Historical Monuments). These two events can significantly enhance tourist influx to the municipality, making it necessary to redesign the current mobility, which is still dependent on cars and public transportation to visit surrounding communities.

As a rural area, public transportation is the primary means of transport, used by 78% of the resident population, followed by cars at 14%, and bicycles at 6.07%, as shown in Figure 1. It is important to note that, being a rural municipality, the bicycle is one of the main means of transportation within communities, which tend to be connected by dirt roads.

Figure 1 Huichapan's Movility
Authorship: Own, based on INEGI data, 2020

Theoretical Framework

An urban design that prioritizes the use of non-motorized transportation is essential for the transformation of population centers towards a resilient design.

This approach aims to encourage the use of mobility alternatives that help reduce greenhouse gas emissions and improve air quality, promoting a more sustainable urban environment. "The concept of resilient cities constitutes an emerging metaphor to describe and interpret the capacity shown by some to face adversities, the origin of serious impacts that questioned their future, managing to recover and continue their development process." Méndez, R. (2012).

The proposed resilient design is based on the premise of prioritizing the use of non-motorized transportation and is linked to a healthy lifestyle that promotes walking and cycling as forms of transportation. This approach helps combat sedentary behavior, reduce lifestyle-related diseases, and improve the overall health of the population. "The built environment, the existing mobility system, and the perception of its inhabitants have now been proven to influence the choice of the mode of movement (means, routes)." Spadaro I., Rotelli C., & Adinolfi P. (2023).

The primary goal of the project is to drive urban improvement towards a resilient city with competitive mobility that also promotes physical activity and prioritizes the reduction in hydrocarbon usage. According to Camagni *et al.*'s argument (2002, cited in Yucesan *et al*. 2024), "urban mobility is currently a crucial component in the debate on sustainable urban development, given the economic, social, and environmental impact for which it is responsible".

On the other hand, the primary theoretical contribution lies in the restructuring of urban and rural mobility patterns in diffuse traces. This includes the proposed territorial planning and urban development in the study area to contribute to the National Program for Territorial Planning and Urban Development (PNOTDU) 2021-2024, specifically targeting Objective 3: "Transition to a model of urban development oriented towards sustainable, orderly, equitable, fair, and economically viable cities, reducing socio-spatial inequalities in human settlements" (Government of Mexico, Territorial Development, 2021). This objective is accompanied by specific strategies and actions, such as:

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Priority Strategy 3.1: Strengthening the Normative Framework for Urban Development Towards Well-being with Emphasis on Social Participation and Reduction of Inequality.

3.1.4: Promote the design and implementation of norms and programs for environmental promotion and sustainable development with the participation of those responsible for urban infrastructure, equipment, services, transportation, and other aspects related to urban development.

Priority Strategy 3.5: Develop and Implement Programs and Projects that Address Urban and Environmental Issues comprehensively in terms of public space, equipment, and mobility.

3.5.1: Promote the normative framework that drives mobility policies and Design-Oriented Transportation (DOT), with criteria for universal accessibility and considering citizen participation.

Contextual Framework

As mentioned, the study area is the municipal seat of Huichapan and the surrounding communities. It is relevant to clarify some important historical data regarding the historical influence of this location.

According to information from the INAH Mediateca, "The city of Huichapan was founded in the 16th century on an ancient Otomi pre-Hispanic settlement." (2004) Huichapan is one of the richest municipalities in Hidalgo in terms of history and culture. It was designated as Pueblo Mágico in 2012, being the site where the first commemoration of Grito de Independencia (Cry of Independence) took place on September 16, 1812.

Similarly, in the Official Gazette of the Federation published on June 30, 2023, the Presidency of the United Mexican States issues the "DECREE declaring the area of 66-67-30.6 hectares in the locality of Huichapan, municipality of Huichapan, state of Hidalgo, as a Zone of Historical Monuments" for the benefit of the conservation and safeguarding of buildings constructed during the 16th to 19th centuries. This area is located at coordinates E 432193.26 and N 2253149.15, corresponding to UTM Zone 14 North, as shown in Figure 2.

Figure 2 Plan of the Historical Monuments Area in Huichapan, INAH 2023

In addition, it is important to mention that the street typology of Huichapan consists of narrow, cobblestone streets, ranging from 6 to 8 meters in width, accommodating two-way traffic, with sidewalks less than 1 meter wide. This necessitates the redesign of vehicular routes and sufficiently wide sidewalks to ensure wheelchair accessibility and universal access in general. Furthermore, it is essential to adhere to the urban image outlined in the Urban Image Regulation for the Municipality of Huichapan, Hidalgo.

Within this regulation, there is a stipulation regarding the need for all elements such as signage and lighting to maintain a design, proportion, and color congruent with the environment, physiognomy, and image of the area in which they are located. The use of materials and plants from the region is encouraged, considering that Huichapan is an area with a mining industry for construction raw materials. These materials are exported to other states and countries, The Huichapan Municipal Government (2020) summarizes that "The main international sales in 2020 were Cubes, Dice, and Similar Articles for Mosaics, of Natural Stone (US$5.67M)." Consequently, the abundance of this material allows houses, government buildings, and places of worship to feature structures and facades made of natural stone, with quarry stone being the predominant material, characteristic of its urban image.

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Hypothesis

In this scenario, it is proposed that the implementation of an urban design with non-motorized ecological transportation in the municipality of Huichapan, specifically in the communities of Huichapan, El Cajón, Pedregoso, La Sabinita, Sabina Grande, San José Atlán, El Saucillo, Vitejhé, Estación Huichapan, Santa Bárbara, Ejido de Huichapan, and San Mateo. Among these communities, Huichapan, La Sabinita, San José Atlán, and Estación Huichapan, will improve mobility, encourage bicycle usage, and promote a healthy lifestyle. The proposal for the creation of alternative routes will benefit traffic circulation, while a bike lane will boost the local economy by increasing safe road access and interconnection between communities.

Justification

A bike lane is a road element that reduces the use of motorized vehicles and allows users mobility independence, promoting physical activity. The added value in rural road design for dispersed areas involves going beyond mere functionality, incorporating aspects that can improve the lives of residents in communities. This includes inclusive design to ensure coverage of the needs of all inhabitants, including infants, adults, seniors, individuals with disabilities, cyclists, motorists, and transporters. Ensuring equitable mobility requires engaging communities in the design process to better understand their needs and ensure that the project benefits the local population, as asserted by Spadaro I., Rotelli C., & Adinolfi P. (2023). The configuration of the built environment, the existing mobility system, and the perception of its inhabitants are factors that influence the choice of mode of transportation, whether in terms of means used or routes selected.

Description of the Method

The following are the steps followed in the research:

1. Problem Identification:

The project is currently located in the state of Hidalgo, specifically in the municipality of Huichapan, as shown in Figure 3.

Figure 3 Location of the Municipality of Huichapan, Hgo. INEGI, 2021

The study area is limited to the municipal seat of Huichapan, focusing on three points or nodes with the highest population concentration: Huichapan, San José Atlán, and El Saucillo, as well as the surrounding communities mentioned earlier. This area has a population of 9,853 inhabitants and stands out as the zone with the highest volume of vehicular traffic. On the other hand, the settlement of San José Atlán is home to 3,546 inhabitants, as shown in Figure 4. El Saucillo is also considered due to its population of 625 inhabitants and a student population of 2,643. This is because it is the location of the region's public university, the Instituto Tecnológico Superior de Huichapan (ITESHU). Consequently, public transportation routes follow a fixed path from Huichapan to San José and El Saucillo due to high demand. This situation provides an opportunity to drive improvements along this route with the goal of transforming mobility in the region.

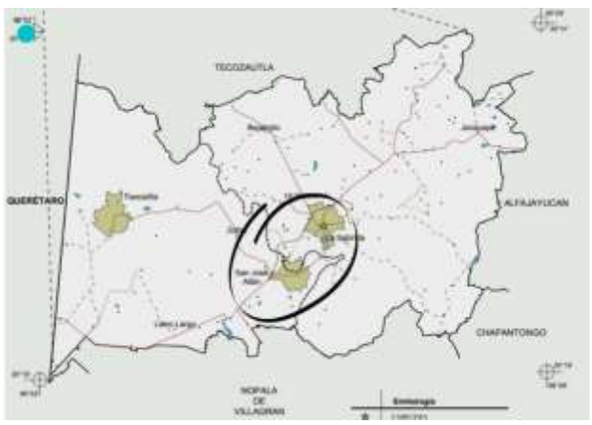

Figure 4 Main Study and Intervention Areas. Author's own work, based on INEGI map, 2010.

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2. Research and Analysis

Urban Structure of Huichapan

The municipal seat of Huichapan currently has a reticular urban structure organized with two main roadways running North-South and East-West, as observed in Figure 5. However, on the outskirts, there is a noticeable distortion of this layout, leading to an irregular typology, indicating that the population has grown in a disorderly manner.

Figure 5 Figure-Ground of the Urban Layout of the Municipal Seat of Huichapan
Source: Project archive, 2023

Urban Structure of San José Atlán

Moreover, the community of San Jose Atlán exhibits a linear and irregular urban structure, as seen in Figure 6. It is characterized by dispersed growth without a planning scheme regulating the population expansion experienced in the last 12 years. In this context, the absence of systematic planning is evident, leading to a fragmented urban configuration without clear organization.

Figure 6 Figure-Ground of the Urban Layout of San José Atlán
Source: Project archive, 2023

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Urban Image of Huichapan

Quarry plays a fundamental role in Huichapan as a key raw material in construction. Its presence is evident in the streets, where it stands out as a predominant element used in the construction of church facades, houses, cobblestones, moldings, sidewalks, columns, foundations, walls, among others, as shown in Figures 7-8. Thanks to its abundance, quarry has become a crucial resource in the construction industry in the region, contributing significantly to its development.

Figure 7 Facades of Huichapan
Source: Project archive, 2023

Figure 8 Photograph of the Streets of Huichapan
Source: Project archive, 2023

Nowadays, the architecture of the region stands out for its distinctive style, employing the construction system of adobe and stone walls, along with flat roofs supported by wooden beams, planks, and bricks. On the exteriors of the buildings, smooth finishes are noticeable, with openings framed in quarry and window protection using ironwork. This design contributes to the distinctive aesthetics of local architecture, merging functionality with decorative elements.

Regarding interior design, the presence of a central or side courtyard prevails in most constructions, accompanied by porticoed corridors, as seen in Figure 9. Additionally, it is common to find orchards in the rear, adding a green and natural component to the architectural environment. This focus on internal layout reflects the historical and cultural significance of outdoor living in the region.

Figure 9 Photograph of the Interior Garden of the Casa de la Cultura, Huichapan
Source: Project archive, 2023

Urban Image of San José Atlán

San Jose Atlán showcases civil architecture characterized by the use of brick and block in confined masonry walls as the main construction element. Architectural finishes tend to be rustic in style, with the presence of unfinished construction (obra gris) prominent in many buildings, as seen in Figures 10-11.

The use of brick and block, as predominant construction materials, imparts a solid and durable appearance to the structures. The preference for these materials may stem from their local availability, affordable cost, and versatility in construction.

Figure 10 Photograph of the Main Road in San José Atlán
Source: Project archive, 2023

Figure 11 Photograph of the Main Road in San José Atlán
Source: Project archive, 2023

3. Definition of Objectives and Design Criteria

The design aligns with the specific characteristics of the study area, where population density is low, at just 71.8 inhabitants per square kilometer. Consequently, mobility needs may differ from those in dense urban settlements. The primary goal is to ensure accessibility, connecting communities and facilitating smooth journeys, whether in motorized or non-motorized vehicles, without compromising the urban image. The use of predominant regional materials aims to minimize environmental impact while highlighting the beauty of rural areas.

4. Urban Model to Apply

The bike lane overlays the main road that directly connects the three main population centers, branching off to cultural and historically significant sites. Considering the street typology in some areas, an alternative route is chosen along the immediately parallel street to avoid vehicular obstructions.

5. Generation of Design Options

Intervention Route:

The central proposal for the intervention route focuses on the San José Atlán-Las Rosas road, connecting the localities of Huichapan, San José Atlán, and El Saucillo. This road, with a total length of 9.4 km, plays a crucial role as the main transportation route for residents and students traveling from the municipal seat to ITESHU. See Figure 12.

ISSN 2531-2162

Figure 12 Route connecting San José Atlán with Huichapan Hgo.
Source: Project archive, 2023

In the stretch from San José Atlán to Huichapan, the road has an average width of 14.62m. This dimension provides an opportune space for implementing a bike lane, aimed at promoting the use of bicycles as a means of transportation, along with the creation of two dedicated sidewalk spaces. The inclusion of these elements will significantly contribute to improving the safety and comfort of pedestrians and cyclists using this route, fostering a more friendly and accessible environment.

The second intervention stretch covers the distance between the El Saucillo-San José Atlán communities, with a total of 5 km to be addressed. This stretch is considered crucial in the intervention plan as it connects two significant localities and contributes significantly to regional connectivity. In Figure 13, we can observe the current state of the road that is planned for redesign.

Figure 13 Current road condition from San José Atlán to the expansion section to 4 lanes
Source: Project archive, 2023

Results

A route for the implementation of the bike lane was generated, considering the inclusion of nodes as rest and community meeting points. This strategy aims to use existing centers to encourage participation in new leisure activities, optimizing the use of public spaces for various activities, as seen in Figure 14.

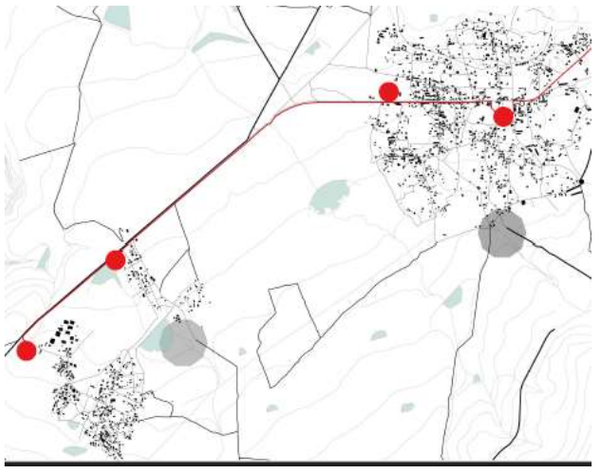

Figure 14 Location of the design proposal and nodes to design and redesign
Source: Project archive, 2023

The bike lane in the San José Atlán - Huichapan stretch aims to preserve the two existing vehicular lanes while incorporating a bike lane and two sidewalks for pedestrian use, as shown in Figure 15. This proposal seeks to provide a comprehensive solution that promotes sustainable and safe mobility for the local population.

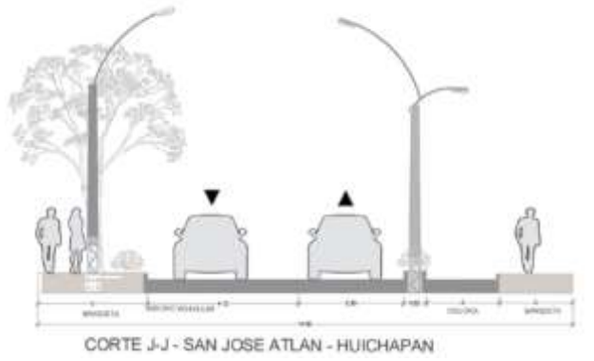

Figure 15 Road design proposal for the San Jose Atlán - Huichapan stretch
Source: Project archive, 2023

As part of the intervention plan in downtown Huichapan, the reconfiguration of J.M. Pedraza Street and Patoni Street is considered. The main purpose is to optimize traffic flow by establishing a one-way circulation while prioritizing the implementation of a bike lane, as seen in Figure 16. Both streets have a width of 12.50 meters, suggesting significant potential for improving connectivity in the area.

ISSN 2531-2162

Figure 16. Proposal for the reconfiguration of J.M. Pedraza Street
Source: Project archive, 2023

The decision to establish a one-way circulation aims to streamline vehicular traffic, reduce possible congestion, and enhance transport efficiency in the area. At the same time, the integration of a bike lane represents a focus on promoting more sustainable modes of transportation, encouraging the use of bicycles as a viable alternative for urban mobility.

It is crucial to clarify that the connection with various streets leading to the historic center and major shopping centers highlights the strategic importance of these interventions to improve accessibility and connectivity in the heart of Huichapan.

The implementation of the proposed redesign of existing roads aims to prioritize users who travel with non-motorized vehicles and/or on foot. The Figure 17 presents roadway proposals for the El Saucillo - San José Atlán stretch.

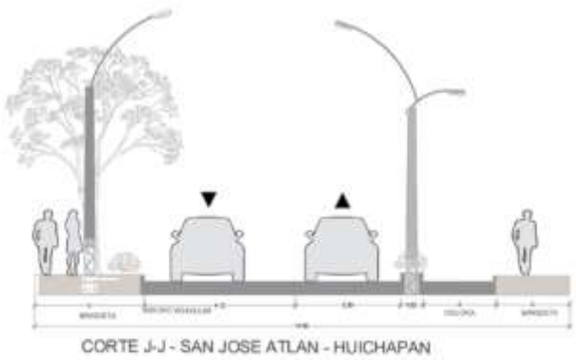

Figure 17 Proposed redesign of existing roads for the San José Atlán - Huichapan stretch
Source: Project archive, 2023

The representation in Figure 17 shows a prototype redesign of existing roads, prioritizing pedestrians and cyclists who use them. Figure 18 shows the proposed design for the El Saucillo - San José Atlán stretch.

Figure 18 Proposed redesign of the main road stretches El Saucillo - San José Atlán
Source: Project archive, 2023

In addition, as part of social integration and the enjoyment of public spaces, the implementation of secondary activities such as cultural events, reading points, sports activities, and recreational areas is suggested.

Organizing activities in public spaces, especially around bike lane areas where there are rest points, contributes to cultural enrichment. This not only improves the quality of life for residents but also strengthens their sense of community belonging. Figures 19-21 showcase renderings of the proposed urban image of the lanes and the integration with suggested rest nodes.

Figure 19 View of the bike lane San José Atlán - Huichapan
Source: Project archive, 2023

Figure 20 View of the bike lane San José Atlán - El Saucillo
Source: Project archive, 2023

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Figure 21 Integration of rest nodes
Source: Project archive, 2023

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Conclusions

It is worth reaffirming that the implementation of a route connecting neighboring rural communities through a bike lane encourages people to engage in healthy and ecological activities, allowing them to interact in society. It is important to note that one of the parameters for measuring the quality of life of human settlements is the aspect of mobility within their communities, as it is a crucial factor for generating economic benefits and thereby improving the well-being of the population.

Sustainable mobility not only has environmental benefits by reducing greenhouse gas emissions to improve air quality, but the design of urban infrastructure that favors both pedestrians and cyclists encourages people to opt for active modes of transportation. This, in turn, improves their health, promotes regular physical activity, leading to improved public health outcomes, and a reduction in cardiovascular diseases such as diabetes and hypertension, which require special care in old age.

Hence, the significance of addressing the issue from a sustainable perspective. According to the Ministry of Health of Mexico, "physical activity is one of the pillars of a healthy life: weight is kept under control, the risk of developing diabetes, hypertension, some types of cancer, and other chronic diseases is reduced... cycling improves physical fitness, respiratory health, and heart health" (2018).

It is important to highlight that the design of the bike lane was established according to the topographic patterns of the surrounding communities, focusing on the economic and social needs of the population of Huichapan Hidalgo. It presents itself as an alternative to current and, in some cases, obsolete mobility systems. It enables the promotion of urban improvement toward a resilient city with competitive mobility, providing citizens with safe, comfortable, accessible, affordable, and sustainable transportation options. Furthermore, it promotes physical activity and prioritizes the reduction in the use of hydrocarbons, contributing to the fulfillment of Goal 9 of the United Nations 2030 Agenda, "Industry, innovation, and infrastructure. The goal is to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation" (IMCO, 2020).

As Huichapan is part of the designation of "Magical Towns" registered with the Ministry of Tourism and possesses an area of Historical Monuments by the INAH, the design of this bike lane allows for the enhancement of the public image of the area, with minimal alteration to its current appearance. Having the aforementioned designations implies that its urban-rural image should not be significantly altered.

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