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Article

Analysis of Mobility in the Hospital Environment "Arturo Montiel Rojas" in the Eastern Area of Toluca, State of Mexico

Análisis de la Movilidad en el Entorno Hospitalario "Arturo Montiel Rojas" en el Oriente de Toluca, Estado de México

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Abstract

The growth of cities is closely linked to issues of mobility and urban transportation, and it was not until the end of 2019—prompted by the SARS-CoV-2 pandemic contingency—that Mexico began taking action to address this problem. For this reason, it became necessary to study the configuration and dynamics of the "Arturo Montiel Rojas" Hospital Environment, which currently functions as a tertiary-care hospital, generating over 596 movements derived from the number of consultations offered and more than 984 additional movements caused by the employees working there. This situation results in significant congestion along the main collector roads that converge in the area. Through the AHP Methodology and the operationalization of variables, it is possible to identify the zones and conflicts that restrict multimodality, a condition referred to as the "Hospital Service Level."

Hospital Environment "Arturo Montiel Rojas"

Objetives	Methodology	Contribution

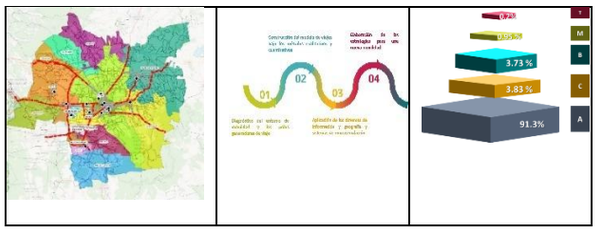
Hospital Mobility Environment, Urban Mobility, Multimodality

Resumen

El crecimiento de las ciudades está estrechamente relacionado con el tema de la movilidad y el transporte urbano y no es hasta finales de 2019 y debido a la contingencia de la Pandemia de SARCov-19, cuando en México toma acciones para atender esta problemática. Es por ello que surge la necesidad de estudiar la configuración y dinámica que presenta el Entorno Hospitalario "Arturo Montiel Rojas", el cual actualmente cumple la función de ser un hospital de tercer nivel con poco más de 596 movimientos derivados del número de consultas ofertadas y poco más de 984 adicionales causados por los empleados que ahí laboran, causando una saturación significativa sobre las principales vialidades colectoras que ahí convergen. Mediante la Metodología AHP y la operacionalización de variables, es posible identificar las zonas y los conflictos que limitan la multimodalidad, lo cual se ha denominado "Nivel de Servicio Hospitalario".

Entorno Hospitalario "Arturo Montiel Rojas"

Objetivos	Metodología	Contribución



Entorno de Movilidad Hospitalaria, Movilidad Urbana, Multimodalidad.

Area: Advocacy and attention to national problems

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Introduction

Currently, urban mobility has become significantly important and increasingly concerning worldwide, mainly due to the rapid population growth that has led to a greater number of journeys, resulting from the search for goods and services, making short trips in distance but requiring longer travel times, which disadvantages users of the transport system. This situation, which undoubtedly calls into question the efficiency with which users interact with their various modes of transport, without being able to achieve effective multimodality, has gained relevance in mobility studies, but this has not been the case for studies of Travel Generating Poles and Mobility Environments, as they have not been subject to the same level of analysis in transit and urban planning studies. Despite its significant impact on the dynamics of cities, in Latin America, the Ibero-American Network for Studies on Travel Generating Poles is the pioneer in studies of this type; however, it is only the beginning of a new line of research within our continent.

In response to this problem, this study establishes a relationship between the different actors involved in mobility environments linked to hospital infrastructure by identifying various variables and indicators that, after a field validation process, are integrated into the ITE [Institute of Transportation Engineers] models of the United States. In addition, an analysis of the continuity of urban blocks within a cluster of no more than 500 metres is incorporated, a criterion aligned with the 'Street Manual: Road Design for Mexican Cities' published in 2019 by the Mexican Ministry of Agrarian, Territorial and Urban Development. Subsequently, a diagnosis is made of the 'Arturo Montiel Rojas Hospital Environment,' located east of the Toluca Valley Metropolitan Area, analysing its peak demand hours, the modal systems most preferred by users, directional data according to the modal system, and external factors that influence the development of daily movements, among which road administration, infrastructure, and current equipment stand out.

Although private cars are the most preferred mode of transport within this hospital environment, this is because the beneficiaries who converge within this hospital unit are not only inhabitants of the state capital.

But also of the Toluca Valley Metropolitan Area, other municipalities in the state, and even other federal entities. This is due to the high level of specialisation offered by this hospital, which requires long journeys in terms of both distance and time, making the car the most suitable mode of transport for this type of mobility.

Once each of these variables had been identified and weighted, the information was processed using a Geographic Information System and with the help of ArcMap 10.8 software and the AHP add-on. hospital service levels were established, providing an accurate diagnosis of the conditions of accessibility and efficiency of mobility within this environment, which is called the 'Hospital Service Level,' in order to present an evaluation categorised by five ranges: very good, good, fair, poor, and very poor.

These findings allow us to define that the 'Arturo Montiel Rojas Hospital Environment' predominantly presents service levels between fair and good, due to a low level of factors that limit accessibility and hinder mobility. These results highlight the need to develop improvement strategies that allow for greater optimisation of mobility conditions, strengthening, among other things, the efficiency of hospital services, which is a key sector not only for the Toluca Valley Metropolitan Area, but also for the centre of the country and the state.

Methodology

The starting point is the selection of a publicly administered hospital, identifying the main modes of transport that converge in the vicinity of the hospital, the number of appointments scheduled per day, the number of employees assigned to the medical unit, the number of beds, and finally, the area it represents, thus constituting relevant factors in the travel model within the Toluca Valley Metropolitan Area. In addition, the actors involved in the hospital environment were identified, which determine mobility indirectly and directly, and thus spatially delimit the hospital mobility environments and travel generators. However, it is important to note that these actors can influence the choice of modal systems, the determination of peak demand hours, and the level of service provided by the main collector roads.

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Develop the meaning of the variables in linear writing, and it is important to compare the criteria used.

Box 1

Table 1

Key players in the hospital environment

Variable	Actors
Social	Beneficiaries
	Workers
	Residents
	Caregivers
Transport	Transport operators
	Operators
	Users
	Concessionaires
Status	State of Mexico Government Authorities
	Municipal authorities
	Decentralised bodies
Economy	Formal traders
	Informal traders
	Wholesale trade

The first of the four planned stages is the research and collection of information and documentary data, which involved reviewing bibliography, methodological approaches, key concepts, and theories focused on urban planning, mobility, and traffic engineering that allow for a unilateral understanding of the dynamics and monitoring of hospital mobility environments and travel generators in the Toluca Valley Metropolitan

Area. It is important to mention that the verification of each of the sources consulted, as well as the statistical data, is essential to guarantee their reliability and thus ensure that they are considered for the travel model. Among the most important institutions are the State of Mexico Ministry of Mobility, the State of Mexico Ministry of Health, the Mexican Government Ministry of Health, the State of Mexico and Municipalities Social Security Institute, as well as the State of Mexico Institute of Geographic, Statistical and Cadastral Information and Research [IGECEM], the National Institute of Statistics and Geography, the Secretariat of Urban Development and Works of the State of Mexico, not to mention each of the municipal departments and commissions for Urban Development, Health, Mobility, Works and Metropolitan Development of the municipal government of the City Council of Metepec and Toluca.

Fieldwork and evidence collection make up the second methodological stage, where both qualitative and quantitative information was collected. An example of this is the experiences derived from the ethnographic method, where approaching the beneficiaries provides a guideline for understanding the origin, frequency, and reason for their trips, as well as their perception of the quality of hospital service and the environment they frequent in relation to the hospital. For its part, the estimation of trips and capacity, both directional and modal, is a fundamental axis for calculating the level of service present on the main collector roads.

The information collected in this stage makes it possible to understand the behaviour of transport system users, who in turn are beneficiaries, workers, residents of the block or AGEB where the hospital is located. The result of this shows, in real terms, the peak and off-peak hours for estimating the level of service in the road network, as well as the pedestrian pavements during peak demand times.

With the above data, a comprehensive diagnosis was obtained on the mobility environment and travel generator hub derived from the Arturo Montiel Rojas Medical Centre located in the Toluca Valley Metropolitan Area, providing the necessary arguments for the application of the ITE model, 'Institute of Transportation Engineers' [USA].

The third phase consists of calculating and continuing the urban blocks, with the condition of a 450-metre distance from the medical unit, always seeking to give continuity to local traffic, economic activities, and social dynamics that occur in the vicinity of the hospital, in order to have a defined polygon and begin with the hierarchisation and operationalisation of the variables that arise there, and once weighted, to be able to geographically identify which areas have little or no mobility, areas that may be susceptible to some type of intervention, or even generate arguments for their modification with respect to the type of activity that occurs on a specific section of the road. Additionally, it was necessary to apply Geographic Information Systems [GIS], through ArcMap software and the AHP module, using a cross-matrix and previously calculated weightings to identify the 'Hospital Service Levels,'

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Which are presented in a colour palette, with red being the lowest level and green being the highest or optimal level for mobility in the 'Arturo Montiel Rojas Hospital Environment'.

Box 2

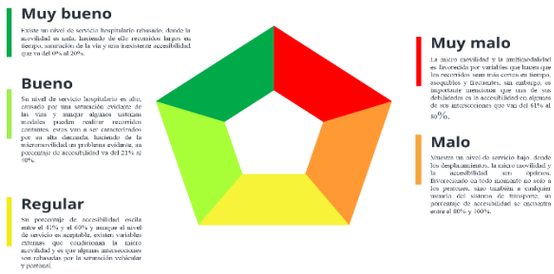

Figure 1

Hospital service level of the Arturo Montiel Rojas Environment

Source: Own elaboration.

The result of this process is a geographical representation at the block level, showing the level of hospital service available in the area, derived from the operationalisation and weighted importance given to the variables present within the Generating Pole, making it a unique environment with specific characteristics whose mobility is a dynamic phenomenon within the Toluca Valley Metropolitan Area.

Results

'Arturo Montiel Rojas' hospital environment

The 'Arturo Montiel Rojas' hospital environment is located to the east of the capital of the State of Mexico, specifically in the municipality of Metepec, bordering the municipality of Toluca, on two of the most important collector roads in the city of Toluca and the municipality of Metepec, and in general in the Toluca Valley Metropolitan Area. Paseo Tollocan Avenue and Solidaridad Las Torres Avenue connect directly with the Mexico-Toluca Highway, forming a land bridge between the Toluca Valley Metropolitan Area and the Toluca Valley Metropolitan Area. Both roads are affected by their road administration, which on the one hand falls to PRODEMEX Promotora y Desarrolladora Mexicana de Infraestructura S.A. de C.V., which administers Avenida Solidaridad Las Torres. In 2024, it signed a contract extension until 2050, making it a concessioned road for another 26 years, where the implementation of infrastructure, equipment, and development in terms of urban planning and development depend directly on the administrator.

For Avenida Paseo Tollocan, it is Empresa Mexiquense Conservadora de Vialidades S.A. de C.V. [EMCV] is responsible for managing this road, and in 2013, under the administration of the then governor of the State of Mexico, Enrique Peña Nieto, a 20-year Service Provision Project [PPS] contract was signed, and EMCV will manage this important stretch of road until September 2033.

With no opportunity to make changes to its geometric structure, a large part of metropolitan traffic circulates on these two arteries, and the recent launch of the Mexico-Toluca Interurban Train, the 'Insurgente,' conditions mobility not only for hospitals but also throughout the Toluca Valley Metropolitan Area.

Although there is only one hospital unit, its importance lies in the fact that, according to the State of Mexico and Municipalities Social Security Institute [ISSEMyM] itself, it is one of the three most important in the state, receiving not only beneficiaries from the Toluca Valley Metropolitan Area or the State of Mexico, but also patients who have some other affiliation and require specialised intervention, provided that the institutions maintain a valid agreement.

Currently, the Arturo Montiel Rojas Hospital Complex covers 252 hectares, distributed over 126 urban blocks, most of which are residential and retail. Its proximity to wholesale commercial activity is minimal, which means that a high volume of travel is by motorised transport, a situation that puts the hospital in question at a disadvantage.

Box 3

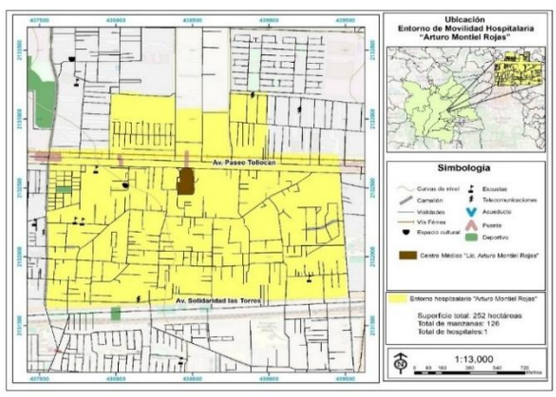

Figure 2

Location of the Arturo Montiel Rojas Hospital Environment

Source: Own elaboration.

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Its location is strategic, with a series of collector roads and major thoroughfares that shape local or neighbourhood dynamics in terms of everyday mobility. However, this does not mean that mobility is any less complex, as the semi-confined roads make travel complicated due to the lack of direct interaction with secondary activities within the environment.

Box 4

Table 2

Road system in the vicinity of the Arturo Montiel Rojas Hospital

Vialidad	Type	Administration	Length m
Paseo Tollocan	Manifold	PPS	1,908
Avenida Solidaridad las Torres	Manifold	PPS	1,982
Calle Manuel J. Clouthier	Manifold	Metepec Town Council	1,149
Prolongación Adolfo López Mateos	Manifold	Metepec Town Council	1,000
Calle Prol. Paseo Totoltepec	Primary	Toluca Town Council	434
Calle Bernardo Vara	Primary	Metepec Town Council	318
Calle Puerto de Veracruz	Primary	Metepec Town Council	735

The road system presented in the Arturo Montiel Rojas Hospital Environment has four roads considered to be collector roads and at least three primary roads, as shown in Table 1. The total accumulated length is 7,526 metres, of which 70% have some type of asphalt surfacing, mostly temperature-controlled and hydraulic concrete. In general terms, given the administrations responsible for the roads, their conditions are fair. However, in the case of the collector roads, their condition ranges from good to very good. Even though there are no significant deformations in the road surface, in most of the roads administered by PPS, the drains are below the road surface, which undoubtedly hinders traffic in the area.

The total road length covered by the Arturo Montiel Rojas Hospital Complex, according to INEGI vector data [2024], amounts to just over 60,554 linear metres distributed along 269 streets and avenues, including the road surface and pedestrian pavements, which are present in 100% of the area, meeting the necessary conditions for walkability.

With only one medical unit, covering just under two hectares, one might think that this environment is less important than the rest of the environments in the Toluca Valley Metropolitan Area. However, the Lic. Alfredo del Mazo Medical Centre alone receives a total of 596 scheduled appointments during a 14-hour working day, and although this may seem few, this number does not include scheduled tests, specialised consultations such as those in traumatology, gastroenterology, ophthalmology, cardiology or nephrology, nor does it include visits made to schedule some type of medical service or pharmacy visit to purchase controlled or speciality medication, a situation that undoubtedly increases the number of visits to the hospital, from 596 daily consultations to just over 1,589 effective daily visits, where medical and administrative staff provide personalised care to each of the requests made by the same number of beneficiaries on a daily basis.

One aspect to consider within this environment is that, as it is a tertiary care unit, most beneficiaries attend consultations with a companion, as their medical conditions require it. In addition, as shown in Table 50, the number of workers amounts to 984 people, divided into doctors, nurses, orderlies, paramedics and administrative staff.

Hospital security is not included here, as it is not administered by ISSEMYM. There are 224 beds registered, not including outpatient beds, as their use is deferred, which makes it difficult to count them.

The peak demand times are between 07:00-09:30, 14:00-16:10 and 20:30-22:00, which largely corresponds to the hours allocated for consultations, visiting hours and pharmacy hours.

However, the frequency of visits is not linked to the hospital's own dynamics. For example, people who come for haemodialysis treatments do not have fixed schedules, as they depend on recovery time.

Although they are scheduled every two hours, 24 hours a day, this schedule is not always respected, as recovery is individual, which means that their stay can be extended to more than three hours, causing a delay in subsequent consultations.

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On the other hand, a widespread problem is the lack of parking spaces. Although there are a total of 536 parking spaces in this area, they are assigned to medical staff, and even though they are not all occupied, access to the parking area is restricted to beneficiaries, resulting in traffic chaos in the vicinity of the Medical Centre, specifically on Avenida Paseo Tollocan. This situation undoubtedly reduces accessibility to the periphery of the centre, because although there is a drop-off and pick-up island for beneficiaries, the presence of the only taxi rank and the excess of vehicles parked on the far right makes it impossible to use.

The only pedestrian entrance and exit to the medical facility is located on Avenida Paseo Tollocan, right in front of the only traffic island, which during rush hour makes this area problematic not only for pedestrians but also for vehicles travelling on that stretch of road, Since they do not have the necessary infrastructure, they choose to invade the traffic lane, creating a considerable conflict zone for residents near the hospital who frequent the area.

By 2024, the Arturo Montiel Rojas hospital complex will cover a total of 126 hectares. According to the INEGI Population and Housing Census for 2020, the population is estimated at 14,451 inhabitants, a significant number that is gradually increasing as a result of the operation of the 'El Insurgente' Interurban Train.

As shown in Figure 3, the majority of the population is concentrated in the north-west and south-west, due to the presence of a series of housing units that are home to more than 35% of the total population of the hospital area. The centre of the San Jerónimo Chicahualco area has a neighbourhood-type, self-built housing morphology, with low-income housing, in contrast to the Santa María Totoltepec district, where the housing is multi-family, directly affecting mobility in the area, especially on Avenida Paseo Tollocan.

Box 5

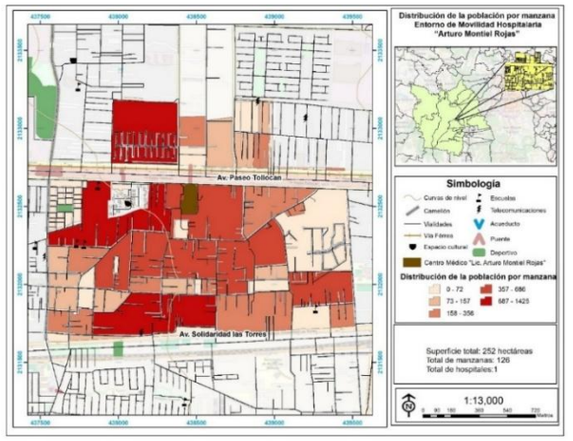

Figure 3

Population distribution by block EMH "Arturo Montiel Rojas"

Source: Own elaboration.

Arturo Montiel Rojas Hospital Mobility and Transport System

Given the conditions of the hospital's mobility environment and its proximity to two collector roads, most journeys are made by motorised transport, as the lack of cycling infrastructure and the deterioration of pedestrian infrastructure make this area difficult for multimodal development. In addition, the walking distance between public transport and the hospital is minimal, as the pick-up and drop-off point is located directly in front of the medical facility, resulting in a minimal walking distance to access the Medical Centre.

Although this hospital environment concentrates large numbers of journeys, most of them are centred on the hospital complex, as this medical unit houses a high percentage of specialities aimed at workers in the State of Mexico. Even though there are commercial and economic activities, their impact is minimal, as evidenced by the fact that one of the main activities is the hotel industry, restaurants, retail and wholesale commercial activity, based on a tianguis [street market] dynamic on Wednesdays, Saturdays and Sundays.

The 'Toluca 2000' tianguis, better known as 'El Piojo', makes this area a complicated place for mobility, as it concentrates a significant number of people who come to the site with the intention of purchasing goods or services, most of which are second-hand.

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Box 6

Table 3

Road system in the vicinity of the Arturo Montiel Rojas Hospital

Institution	Location
Ti anguis "Toluca 2000" or "El Piojo"	Santa María Totoltepec Branch 50200 Santa María Totoltepec, Mexico
Collision Express Toluca S.A. de C.V.	C. Article 27 517, Santa María Totoltepec Delegation, 50160 Santa María Totoltepec, Mexico.
Department of Foreign Affairs	1195 Paseo Tollocan Avenue, Santa María Totoltepec, 50246 Santa María Totoltepec, Mexico
Walmart	Low Speed Avenue 1201, San Jerónimo Chicahualco, 52170 San Jerónimo Chicahualco, Méx .
Nissan Drive Tollocan	Av. Paseo Tollocan KM 4.8, San Jerónimo Chicahualco, 52170 San Jerónimo Chicahualco, Méx.
Cambalache Toluca	Km. 5.2, Av. Baja Velocidad Manzana 002, San Jerónimo Chicahualco, 52170 Toluca de Lerdo, Méx.

Although the activities presented in Table 3 are few and make mobility a minor issue, it is the Lic. Arturo Montiel Rojas Medical Centre that triggers the saturation of collector roads, reaching a service level close to 'F' during peak hours, resulting in a delay of approximately 00:15: 00 on Avenida Paseo Tollocan in the direction of Toluca – Mexico City and 00:10:00 on Avenida Solidaridad las Torres, in the direction of Mexico City – Toluca, a situation that extends along the entire road, causing queues of just over 1.5 km in the morning and at least 1 km in the afternoon.

By January 2025, the cumulative TPDA in the 'Arturo Montiel Rojas' Hospital Area amounts to just over 181,000 motor vehicles, contained only on collector roads, creating a conflictive environment for mobility, accessibility and travel, within the roads that have the highest traffic volumes and conflictive service levels. Paseo Tollocan Avenue has a TPDA of 94,007 units. For its part, Solidaridad Las Torres Avenue has approximately 46,151 vehicles, with the rest distributed among primary and secondary roads, accumulating a total of 40,842 movements, where type A vehicles have the greatest presence, followed by type C vehicles and, to a lesser extent, type B vehicles. Given the conditions and morphology of the hospital environment, the latter units do not circulate within the polygon, but only on the periphery.

The hegemony of private transport use is a constant, as the conditions of the environment and its geomorphology make travel by this mode safer, more accessible, faster and also more comfortable. It should also be considered that, although there are countless public transport routes, most beneficiaries come to this medical centre from municipalities outside the Toluca Valley Metropolitan Area, which means that their journey is long in terms of distance and time, making private cars the most effective mode of transport.

It should be noted that the infrastructure for this mode of transport is minimal, as there is only one public car park with just over 40 spaces, which is open from 7:00 a.m. to 6:00 p.m. and costs around $15.00 per hour and fraction thereof. To the west of the area, there is also a shopping centre, which makes its car park available to the public at a cost ranging from $5.00 to $17.00. However, it is located just over 400 metres away from the Medical Centre. Finally, on Saturdays and Sundays, when the 'Toluca 2000' market [known as 'El Piojo'] opens its doors, neighbours choose to make private spaces available as car parks near the market, with capacities ranging from 30 to 70 vehicles.

Although this responds to the high demand for parking spaces, it also creates conflict for access to them, as the converging roads become saturated, creating traffic queues that exceed 300 metres, only on primary roads.

The proximity between the hospital environment and the industrial area of Toluca means that there is a constant flow of type C vehicles, especially in the east-west direction, towards the city of Toluca. Although the area containing the Lic. Arturo Montiel Rojas Medical Centre has little industrial activity, it is a mandatory route for transport companies that carry out logistics within the Toluca Valley Metropolitan Area.

Peak demand fluctuates between 4:00 a.m. and 7:00 a.m., as well as between 8:00 p.m. and 11:00 p.m., due to traffic restrictions imposed by the municipal authorities of both Metepec and Toluca.

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Type B transport accounts for 3.73% of traffic in the hospital area, and although this may seem like a minimal percentage, the reality is that a large part of the routes that go to the east of the Toluca Valley Metropolitan Area have to pass through the 'Arturo Montiel Rojas' hospital area, accumulating a total of 56 routes distributed among 15 transport companies, with direct variation in frequencies, because, unlike the rest of the areas, here the frequency of passage derives from the vehicle load that occurs mainly on Avenida Paseo Tollocan, going from 00:05:00 to 00:15:00, with destinations in most cases such as Lerma, San Mateo Atenco, Zinacantepec, and Almoloya de Juárez.

According to the fieldwork, it was observed that only two routes enter the polygon, six pass through Avenida Solidaridad Las Torres, four enter Santa María Totoltepec and the rest run along Avenida Paseo Tollocan, making it the route with the highest daily frequency; However, the delay time is minimal, ranging from 00:04:00 to 00:08:00, and this is in normal conditions without extraordinary external factors such as strikes, accidents or road maintenance, making this area easily accessible to the Hospital Centre by mode B.

Mode of transport classification M has a percentage that, although minimal, is representative, as 1% positions motorcycles as a mode of transport that favours local travel and effective micro-mobility.

The most common use is for delivery, where, in addition to using the motorcycle as a mode of transport, it is also a work tool for home deliveries, which are present in almost all restaurants in the Hospital Environment area. In the health sector, there are more employees of the 'Lic. Arturo Montiel Rojas' Medical Centre than beneficiaries themselves who use the motorcycle as their daily mode of transport.

Finally, there is the T-type mode of transport, whose presence is regulated by the municipal authorities of Metepec and Toluca, allowing it to circulate from 10 p.m. to 5 a.m. seven days a week.

This mode of transport is particularly important for industrial logistics in this metropolitan area, with companies such as Nestlé, Pfizer, Barcel, Marinela and even Pemex relying directly on it to transport their goods and services.

It is difficult to conceptualise the Arturo Montiel Rojas hospital environment as an area suitable for pedestrianisation. although its characteristics lend themselves to this, with wide pavements, sufficient public lighting and a high level of social interaction.

The reality is that its proximity to two semi-confined collector roads, Avenida Paseo Tollocan and Avenida Solidaridad Las Torres, makes it a suitable place for motorised mobility. In addition, the infrastructure designed for cars must be taken into account. Although there are only a couple of car parks, these tend to be moderately full at peak times. However, beneficiaries choose to park in prohibited areas such as the traffic island located just in front of the Lic. Arturo Montiel Rojas Medical Centre, creating chaos for public transport users getting on and off.

During fieldwork, it was observed that haemodialysis and dialysis patients specifically require vehicular access to the Medical Centre facilities due to their medical condition. Their stay at the facilities ranges from two to four hours, depending directly on the treatment and recovery of each patient. The schedules for this type of beneficiary are 24 hours a day, 365 days a year, in two-hour intervals, resulting in constant traffic even on holidays or days off.

For this reason, the use of bicycles exclusively for the health sector is limited and is not a response to the lack of infrastructure or poor conditions in the roadways or pedestrian pavements, but rather to the dynamic nature of the care and follow-up of patients at the Medical Centre, as most of them are accompanied by a family member or carer, adding that if their medical condition is confidential, they have specific treatments that mostly limit the use of non-motorised modes of transport. If we add the origin of their journeys, we can understand that most of them are inter-municipal, where bicycles or other non-motorised modes of transport are not an option for getting around.

Within the hospital environment, three bicycle counts were recorded, two of them on Paseo Tollocan Avenue between the intersection of Tecnológico Avenue and Manuel J. Clouthier in the east-west and west-east directions, respectively. The third count was taken at the intersection of Manuel J.

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Clouthier and Calle 16 de Septiembre. The first count is at the intersection of Manuel J. Clouthier and Calle 16 de Septiembre, where there is a TH of 37 cyclists during peak demand, which runs from 9:00 a.m. to 11:00 a.m. with a TPD of 887 daily movements. Men are the ones who make the most use of bicycles as a mode of transport, accounting for nearly 98.6% of total movements, while women account for only 1.4%. Most of these movements are inter-municipal, originating in the municipality of Metepec and ending in the municipality of Toluca.

The second survey was conducted on Avenida Paseo Tollocan between the intersections of Avenida Tecnológico and Manuel J. Clouthier in an east-west direction, on the far right, where a TH of 29 bicycle users was recorded, giving a TPD of 341 trips, 98.2% of which were made by men and only 1.8% by women. It is noteworthy that of the total number of trips, more than 97% use bicycles as a daily mode of transport, and the rest for leisure. The last count was taken at the same intersection as the previous one, but in the west-east direction. This count shows a TH of 34 cyclists at peak demand, concentrated between 5:00 p.m. and 7:00 p.m., with men making the most use of bicycles at 95.8%, and the rest, i.e. the remaining 4.2% correspond to women. Fieldwork identified that they use bicycles for care-related mobility, as they take their children to school by bicycle, a situation that creates complex mobility in the hospital environment.

Although there have been no alarming numbers of bicycle-related traffic accidents in the hospital environment, the outlook is negative, mainly due to the speeds on the road, especially on Avenida Paseo Tollocan and Avenida Solidaridad las Torres, where the maximum speeds are 60 km/h and 30 km/h in hospital areas. However, ignorance of regulations combined with a lack of both horizontal and vertical signage means that speeds in this area often exceed 60 km/h.

Conclusions

According to the AHP methodology, the Arturo Montiel Rojas Hospital Environment has a service level ranging from fair to good, i.e. there is no obvious saturation on the collector roads derived from motorised modes, but its accessibility is subject to improvement,

The level of the main collector roads ranges from ‘C’ to ‘D,’ which leads to conflictive mobility in the traffic area. It is important to note that this area does not have safety devices, except on the Manuel J. Clouthier road, which runs north-south and south-north.

For pedestrians, despite the fact that conditions exist for them to move freely, fieldwork observed that they do not have a significant presence. Mobility is centred on motorised modes, mainly represented by modes A and B. The safety perspective is important. Although there is public lighting and the pavements or sidewalks mostly meet the necessary conditions,
there is still an externality derived from traffic, namely that speed is a negative factor for pedestrians, as it is mainly private cars that do not respect speed limits, especially in the vicinity of the hospital

Signage is an aspect to be considered for all users of the transport system who converge in the area. Although Avenida Solidaridad Las Torres has appropriate horizontal and vertical signage, as it is a PPS, this is not the case for Avenida Paseo Tollocan, where there is no horizontal signage.

The absence of road markings is evident throughout the entire stretch of the road, while the vertical signage does not meet the necessary conditions set out in Mexican Official Standard NOM-034-SCT2/SEDATU-2022, Signage and road devices for streets and motorways.

Box 7

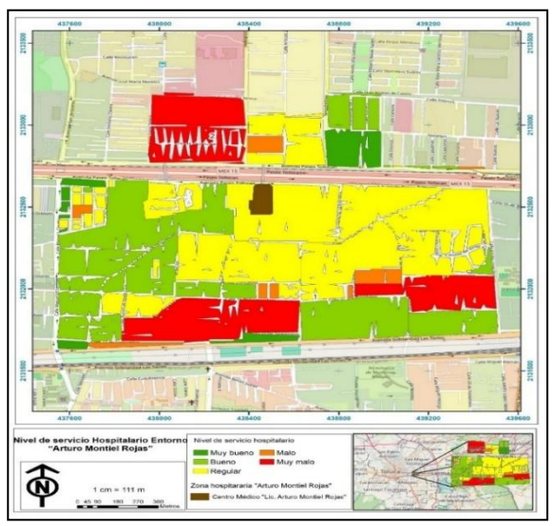

Figure 4

Level of hospital service in the "Arturo Montiel Rojas" environment

Source: Own elaboration.

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One aspect to consider in relation to the level of hospital service is that the traffic area specifically on the collector roads Avenida Solidaridad Las Torres and Avenida Paseo Tollocan is considered only on the far right, without addressing the semi-confined area or central lanes, which, despite having a direct influence on vehicular traffic, their origin and destination are different from the Lic. Arturo Montiel Rojas Medical Centre, which is why their level of service is high but acceptable, with slow but fluid traffic flow.

Specifically, the level of service on Avenida Solidaridad Las Torres is rated 'D'. According to the Mexican Government's Ministry of Communications and Transport, congestion is partial, but with moderate flow. Specifically, the hours of saturation or peak demand within the hospital environment range from 07:00 to 08:40, as well as from 17:50 to 21:00, with relatively short queues caused by safety devices such as speed bumps or bollards. On the other hand, Avenida Paseo Tollocan has a service level of 'E,' where traffic is slow, with congestion that affects the movement of transport units.

This, combined with a lack of signage and excessive appropriation of space and the road surface, makes travel difficult during peak demand hours, which normally occur between 06:40 and 10:00, as well as from 14:20 to 17:00 and from 19:00 to 22:00, mainly due to the shift changes at the Medical Centre, as well as the departure times of companies and government institutions.

Pedestrianisation is a safe option and has the necessary conditions for its development, but it is limited by direct factors such as road safety, lighting, public safety and poor social coexistence. There are indirect factors that make certain times of the year complicated, such as the months of August, September, and October, when heavy rains limit accessibility due to constant flooding, mainly on collector roads. This situation favours private cars and public transport, as they are the only modes of transport that can circulate in the area near the Arturo Montiel Rojas Medical Centre.

One social condition within the environment is the difference in housing and income, as shown in Figure 69.

On the far right of the hospital environment, there is an area marked in red, which corresponds to the urban complex 'Los Ahuehuetes,' located right next to the 'Toluca 2000' or 'El Piojo' market, creating a significant contrast, not only in terms of housing or income, but also in terms of mobility, as this complex alone is home to 1,450 people, more than 65% of whom are of working age, which translates into commuting for work. The same is true of the 'Residencial Campestre del Virrey' located to the south of the polygon between the intersections of Avenida Prolongación Adolfo López Mateos and Avenida las Torres, which alone has a population of 417 people. Together, these two urban complexes represent about 13.5% of the total population of the entire hospital environment.

The rest of the population is distributed between the town of San Jerónimo Chicahualco in the municipality of Metepec and Santa María Totoltepec in the municipality of Toluca, which, although they have acceptable micro-mobility conditions, there are tertiary roads where conditions are poor, with a width of barely 4 metres and a surface of bare rock without any type of asphalt covering, with a lack of kerbs, pavements and road markings in both towns, hindering not only mobility but also transport, as the necessary conditions for the provision of this service are not met. The route service is always questionable within the Toluca Valley Metropolitan Area. It is the mode of transport that efficiently moves users in this hospital environment, even though the number of routes is not as overwhelming as it is in environments such as the 'Cono Norte' or 'Campus Colón'. its service is efficient, at least for inter-municipal mobility, which includes the municipalities of Toluca, Almoloya de Juárez, Zinacantepec, Lerma, Ocoyoacac, and San Mateo Atenco, with frequencies ranging from 00:12:00 to 00:17:00 and an occupancy level exceeding 50% during off-peak hours and more than 100% during peak hours, reflecting the activities concentrated in the 'Arturo Montiel Rojas' hospital environment.

Therefore, it is concluded that the analysis of mobility in the 'Arturo Montiel Rojas' Hospital Environment in the east of the capital of the State of Mexico highlights the complex relationship between urban growth and the current Mobility and Transport System in the Toluca Valley Metropolitan Area derived from public health services.

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Therefore, this research is based on understanding how population growth in terms of entitlement and the lack of tertiary hospital infrastructure generate travel flows that impact the efficiency of the public and private transport system in the central area of the State of Mexico.

One factor that motivated this research from the outset is the way in which the COVID-19 pandemic transformed mobility patterns around hospitals, not only globally, but specifically within the Toluca Valley Metropolitan Area. The health contingency increased the frequency of travel for health reasons, both for patients and medical personnel, as well as for family caregivers and supply providers. This phenomenon exposed deficiencies in our city's planning and, even more so, the shortcomings of the transport system, reflected in the lack of adequate infrastructure to absorb a sudden increase in mobility demand. It is from this point that local authorities have opted to create conditions for non-motorised mobility.

Without a doubt, this analysis of mobility in the hospital environment Arturo Montiel Rojas" reveals that the problems of traffic congestion in the vicinity of the hospital are closely related to the inefficiency in the management of road and public space, the absence of adequate traffic regulations and the lack of infrastructure such as strategic car parks. Although the Medical Centre itself has a large car park, until March 2025 it is closed to beneficiaries, serving only medical staff and people with kidney problems, causing saturation of the only pick-up and drop-off bay available, creating a pedestrian conflict and thus limiting accessibility, which collapses during peak demand hours in the mobility systems, affecting both the hospital community and the inhabitants of the surrounding areas.

Another key aspect identified is the need to strengthen urban planning with a comprehensive mobility approach that considers transport intermodality and the design of pedestrian and cyclist infrastructure. However, the lack of willingness and attention on the part of state authorities limits this type of strategy. It should not be forgotten that Av. Paseo Tollocan and Avenida Solidaridad las Torres are part of the Service Provision Project [PPS], which limits intervention in these areas due to the lack of autonomy on the part of the municipalities that converge there.

For this reason, it will be the State of Mexico's Ministry of Mobility itself that will have to create this management system to optimise the space.

It is important to mention that one limitation in the Toluca Valley is the administration of public transport, which is carried out through concessions. As a result, the number of units, frequencies, routes and chassis models depend on the companies that provide the service, a situation that undoubtedly limits its organisation. If we add this to the administration of the road, the situation is even more complex, as this responsibility does not fall directly on the municipal authorities.

Since January 2025, the municipal authorities that make up the Toluca Valley Metropolitan Area have taken on the task of creating a metropolitan urban agenda, where mobility is the fundamental axis of inter-municipal agreements, and its implementation would generate strategies in line with the current situation.

For its part, non-motorised mobility, as mentioned in this paper, is not present, largely due to the lack of infrastructure dedicated to it, but it is also important to consider the origin of most journeys, which are inter-municipal, i.e. over 17 km, and considering the terrain of the Toluca Valley Metropolitan Area and its altitude of almost 2,240 metres above sea level [masl], cycling is complicated. During the fieldwork, a pattern of mobility was identified that is directed towards care mobility, where women are the most prevalent, caring for the elderly and children. Therefore, if we add these variables together, it is possible to point out that the bicycle is not the best mode of transport to promote for the ‘Arturo Montiel Rojas’ Hospital Environment.

Although it was believed that this hospital environment would present a poor level of service, the situation changed when the result of the sum of the variables ranged from fair to good. This is due in part to the type of users who frequent the Medical Centre, their mode of transport and their origin. In addition, the fact that most of the roads are part of a Service Provision Project [PPS] provides certainty regarding their optimal condition in the road network and also on the pedestrian pavements, thus generating a perspective of safety in relation to travel and thereby ensuring the minimisation of accidents.

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The issue of Travel Generating Poles and Hospital Mobility Environments is becoming increasingly important in major Mexican cities, specifically in the Toluca Valley Metropolitan Area, where mobility and transport, together with urban development, are of greater importance in decision-making related to urban growth and expansion, land regulation and the updating of regulatory instruments, aspects that require coordinated action. Clearly explain the results and possibilities for improvement.

Declaration

Conflict of Interest

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

Author contribution

Romero, Jose Manuel: Contributed to the analysis of the variables, the methodology, and the representation of the cartographic and statistical information.

Rosas-Ferrusca, Francisco Javier: Contributed to the project idea, the review of the operationalisation of variables, and the syntax correction of the project.

Pérez-Ramírez, Carlos Alberto: Contributed to the syntax review, style suggestions, and the proposal for weighting variables for the calculation of the Hospital Level present in the research.

Availability of data and materials.

100% of the data is freely accessible, downloaded from INEGI, IGECEM, and Transparencia or through SAIMEX, which were requested through official letters and applications.

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