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Urban road accessibility in Mexicali, Mexico and its impact on the quality of life of the highly marginalised population

Accesibilidad vial urbana en Mexicali, México y su impacto en la calidad de vida de la población altamente marginada

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ABSTRACT: *The objective of this research was to evaluate the impact of urban road accessibility on the quality of life of the population living in Mexicali, Baja California, Mexico. It was necessary to use the Basic Geostatistical Areas as territorial delimitation and identify critical areas, those with low quality of life or high levels of marginalisation due to the lack of basic services in their housing. The methodology analysed socioeconomic data extracted from the 2020 Population and Housing Census, seeking to develop an Urban Marginalisation Index and categorise the population status as Very High, High, Medium-High, Medium-Low, Low and Very Low. Subsequently, the accessibility conditions of the road network were analysed in two ways: relative or absolute, mainly in the most unfavourable areas, thereby identifying the relationship between quality of life and road accessibility. It is shown that 13 of the 429 Basic Geostatistical Areas in Mexicali present a High to Very High marginalisation level, these being the areas where the population lives in the most unfavourable conditions. The results revealed that most of these areas are connected to the city's road network through a tertiary road in precarious condition due to the lack of paving maintenance and upkeep. It is concluded that the population living in the most unfavourable conditions is the one with the least access to primary education, healthcare rights, and access to piped water and drainage in their housing.*

Keywords: *Road accessibility, urban marginalisation, socioeconomic indicators, basic geostatistical area.*

RESUMEN: *En esta investigación se tuvo el objetivo de evaluar el impacto de la accesibilidad vial urbana en la calidad de vida de población que habita en la ciudad Mexicali, Baja California, México. Fue necesario tomar como delimitación territorial las Áreas Geoestadísticas Básicas e identificar las zonas críticas, aquellas con baja calidad de vida o altos niveles de marginación, por no contar con servicios básicos en la vivienda. La metodología analizó datos socioeconómicos extraídos del Censo de Población y Vivienda de 2020, buscando desarrollar un Índice de Marginación Urbana y categorizar el estado de la población en una situación Muy Alta, Alta, Media Alta, Media Baja, Baja y Muy Baja. Posteriormente, se analizaron las condiciones de accesibilidad de la red vial de dos maneras, relativa o absoluta, principalmente en las áreas más desfavorables, y con ello identificar la relación entre calidad de vida y accesibilidad vial. Se muestra que 13 de 429 Áreas Geoestadísticas Básicas que hay en Mexicali presentan una marginación entre Alta y Muy Alta, siendo aquellas donde habita la población de forma más desfavorable. Los resultados permitieron identificar que la mayoría de estas áreas se conecta a la red vial de la ciudad a través de una vía terciaria y en condiciones precarias por la falta de pavimentación o conservación y mantenimiento. Se concluye que la población que habita en las condiciones más desfavorables es aquella que presenta menor acceso a educación primaria, derecho a la salud, y acceso al agua entubada y drenaje en su vivienda.*

Palabras Claves: *Accesibilidad vial, marginación urbana, indicadores socioeconómicos, área geoestadística básica.*

1. INTRODUCTION

The objective of this research was to evaluate relative and absolute accessibility in urban roads and the impact this has on the quality of life of the inhabitants of the border city of Mexicali, Baja California (BC), in order to identify areas in critical situations of marginalisation and propose strategies to improve accessibility in the territory.

Urban road accessibility and the quality of life of the population are fundamental factors to consider when defining the development of cities [1]-[3]. Road infrastructure itself is a strategic factor in the city, as it promotes various types of travel, resulting from the needs of society and the various economic activities that take place in it [4], [5]. Investing in the urban road network guarantees accessibility and promotes the development of other types of infrastructure throughout the city. This coincides with the findings in [6], [7], which highlight that road infrastructure has an impact on the social and economic development of a territory. Without a doubt, road accessibility is linked to connectivity and the possibility of connecting with other infrastructure and basic services, bringing benefits to society [8]-[10].

In Mexico, efforts have been made to measure the quality of life of the population using indices, one of which is formulated by CONAPO [11]-[13], by identifying the conditions of people living in a particular area, taking into account their housing and public services (drinking water, electricity, drainage). According to CONAPO data, in Mexicali, more than 15.00% of the population lives in conditions of medium to very high urban marginalisation, which translates into more than 132,000 inhabitants who require better quality of life conditions, most of whom are located in peripheral areas of the city [13].

The importance of this work lies in identifying the impact of the accessibility of Mexicali's road network on the quality of life of its inhabitants, in order to identify those areas that are in a critical or unfavourable situation. It is believed that the population living in areas with good urban road accessibility has low marginalisation. Several studies support the idea that road infrastructure promotes accessibility in a territory and, in turn, social and economic development, which can be direct or indirect [9], [10], [14]-[16]. It is imperative that policies be implemented to promote the conservation and modernisation of existing roads, fostering urban integration and mobility, thereby driving economic growth and social cohesion [17].

The term quality of life is often used as a synonym for the well-being of the population living in a given territory [18]. It is worth mentioning that this concept has been studied in different areas such as medicine, political science, architecture and urban planning, education and sociology [19]. However, measuring quality of life, including variables and indicators, becomes a necessary input in the planning, evaluation and management of public policies for urban development [19].

For its part, the Organisation for Economic Co-operation and Development (OECD) presented a report entitled “How's Life?”, which analyses the well-being of the population in Mexico, using 11 indicators in the evaluation, highlighting the importance of housing, health and education indicators, among those with the greatest weight in the analysis and where improvement is required, as development has been very low in recent years [20]. Besides, it was found that Mexico's welfare results are below average compared to other OECD countries.

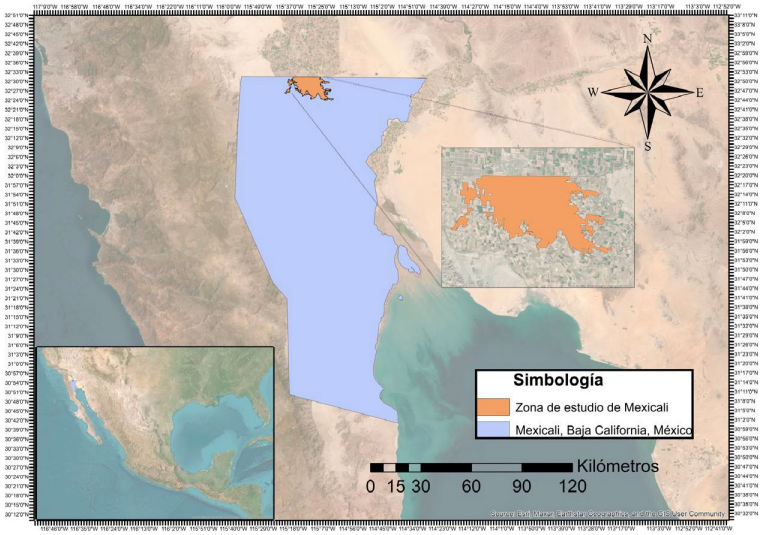
That said, governments need to be aware of the rapid population growth in some of the country's cities and the parallel urban growth that this entails, as well as recognising the quality of life of their inhabitants, so that they can then direct their investment policies towards programmes that promote urban development with a social impact, mainly in marginalised sectors or those in need of welfare.

On the other hand, accessibility is multidimensional and complex, with a geographical component attributed to the distance between the things to be accessed [21] and another component of socio-economic status that describes the population [10], [22]. It can also be defined as the ease with which a place can be reached in comparison with other places, either by one or more individuals using various modes of transport [23]. Transport routes provide spatial connectivity and are vectors of urbanisation towards new areas, contributing to urban expansion and urban decentralisation [24], [25].

1.1 Case study

The municipal capital of Mexicali is located in the northeast of BC, Mexico (see Figure 1), at an altitude of 4 metres above sea level, and is characterised by one of the most extreme climates in the world, ranging from 0 °C in winter to 50 °C in summer [26]. The total population is 854,186 inhabitants in the municipal capital alone [27].

Figure 1. Location of Mexicali City, BC, Mexico.



Source: own elaboration with cartographic data from INEGI [28].

The urban area of Mexicali is subdivided into several polygons in which different urban behaviours and cultural characteristics can be observed [29]. The northern polygon is home to most of the historical facilities and spaces of cultural appropriation, among which the Chinese community stands out. The city's first settlements were established in this area. The eastern polygon has the greatest economic boom and real estate and educational developments. The western part of the city shows the greatest economic and social backwardness. Similarly, the southern and south-eastern areas of the city are in a similar condition, which continues towards the outskirts, where abandonment and vandalism of housing is very common. Meanwhile, the south-western area is more predominantly residential and has less unfavourable housing characteristics.

2. MATERIALS AND METHODS

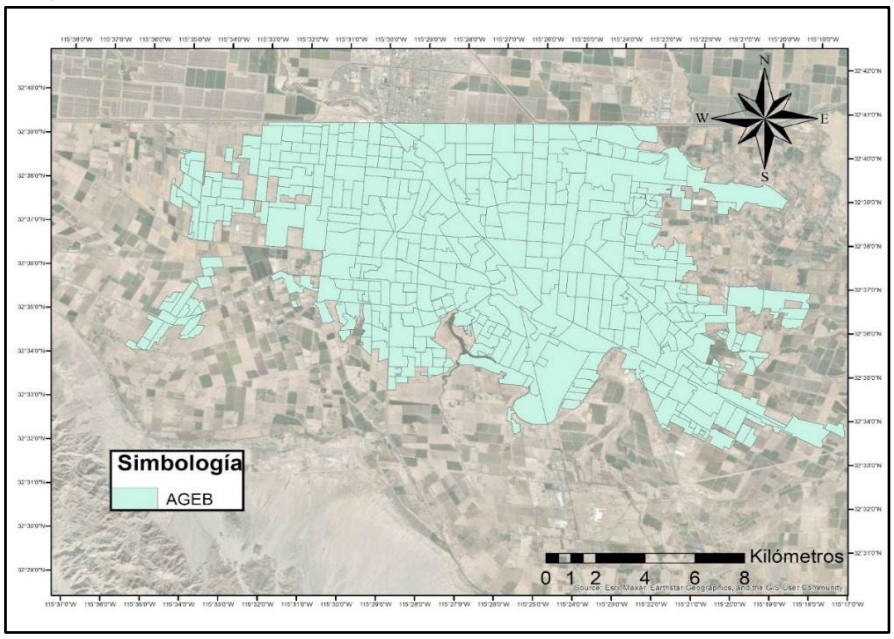
This section describes the analysis methodology, detailing the elements considered to identify road accessibility in the territory and assess the urban marginalisation of its inhabitants.

First, the study area is defined and divided into zones to determine Urban Marginalisation Indices (UMI) in the territory, as this will be necessary to identify the most disadvantaged areas. Once the quality of life of the inhabitants has been identified by evaluating the UMI, the relative accessibility of these areas is analysed with respect to their connection to the urban road network, as well as the absolute conditions of the urban road network itself, based on its operational characteristics and physical condition. Subsequently, the relationship between quality of life and road accessibility is identified.

2.1 Definition of the area and object of study

For this study, it is necessary to divide the city into urban areas for analysis, so the Basic Geostatistical Areas (AGEB) are considered as the territorial element of analysis within the case study, in accordance with the subdivisions established by the National Institute of Statistics, Geography and Informatics (INEGI) [12]. A total of 429 AGEBs in the city of Mexicali were analysed (see Figure 2), with a closer look at those with the most unfavourable results. Each AGEB collects data on population, housing, education, services and other socio-economic information. It should be noted that these are made up of one or more blocks, which are usually delimited by roads [30].

Figure 2. Distribution of AGEB in the city of Mexicali, BC, Mexico.



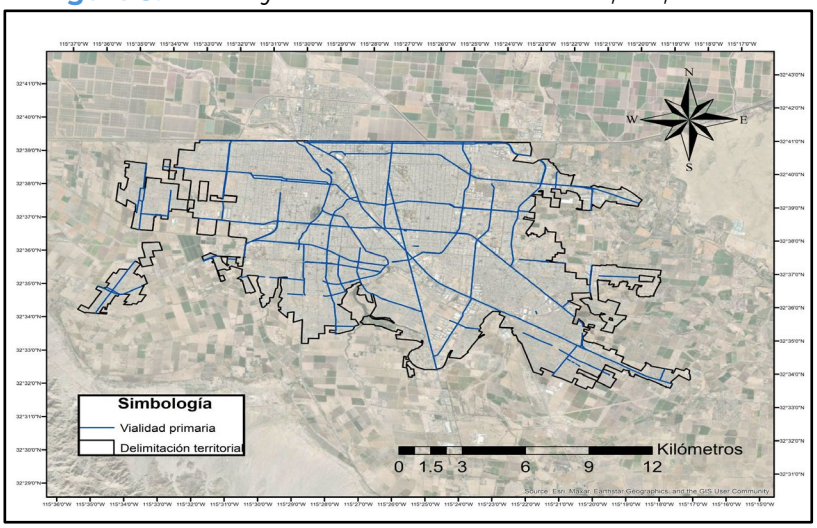
Source: own elaboration with cartographic data from INEGI [28].

Likewise, the roads in the selected urban areas will be analysed as part of the study, thereby determining their accessibility to the primary, secondary and tertiary networks. Mexicali has 4,219.01 linear kilometres of roads [29], mainly oriented in an urban grid layout, consisting of 261.68 kilometres of primary roads, 168.40 kilometres of secondary roads, and the rest of tertiary roads.

In the city of Mexicali, primary and/or secondary roads function as urban corridors, which serve as distributors of traffic flows, as they promote greater connectivity and mobility between distant areas. In general, these roads are heavily used by the population as they allow people to travel from home to work or to other destinations to meet different needs. The advantage of travelling along them is that they promote vocational activities or land use such as commercial, service, industrial, residential, vacant lots, and others, making daily traffic a recurring phenomenon.

According to the Mexicali Government, primary roads (see Figure 3) are notable for allowing speeds of up to 70 km/h and having cross sections greater than 30 m, which concentrate three lanes of traffic in each direction, one parking lane in each direction, and the presence of a central median [29].

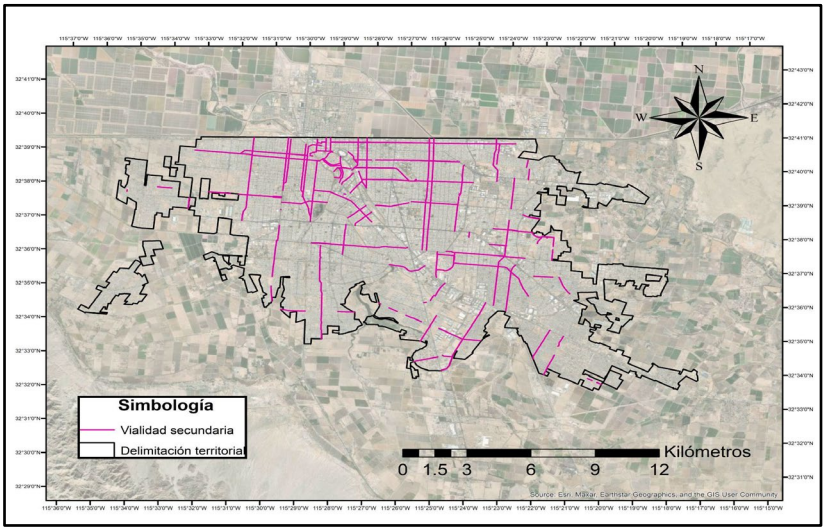
Figure 3. Primary road network in Mexicali, BC, Mexico.



Source: own elaboration with cartographic data from INEGI [28].

Secondary roads (see Figure 4) have cross sections between 23.6 m and 27.5 m, structured with two lanes in each direction, one parking lane in each direction, and some with a central median, with speed limits of up to 65 km/h.

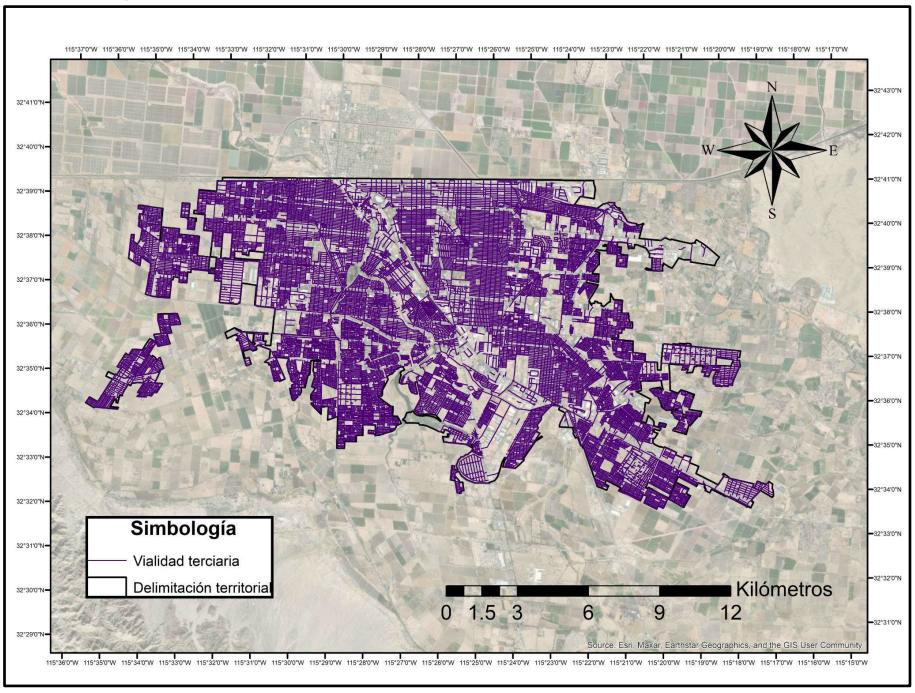
Figure 4. Secondary road network in the city of Mexicali, BC, Mexico.



Source: own elaboration with cartographic data from INEGI [28].

On the other hand, tertiary roads, also known as local streets (see Figure 5), are distinguished by providing access to residential properties and neighbourhoods, with cross-sections between 12 m and 15 m, usually consisting of one lane in each direction and allowing speeds of up to 45 km/h [29]. On these types of roads, traffic routes are short and low in volume compared to primary and secondary roads.

Figure 5. Tertiary road network of Mexicali, BC, Mexico.



Source: own elaboration with cartographic data from INEGI [28].

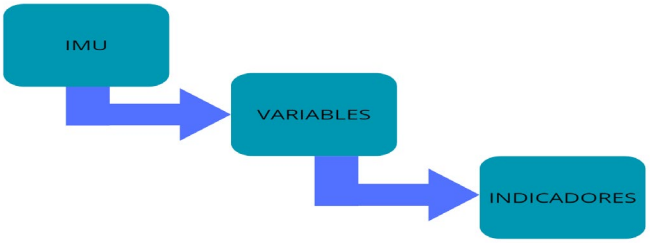
It should be noted that this study uses the ARCGIS software as a Geographic Information System (GIS), which facilitates the analysis of information from different cartographic sources from INEGI and from those provided by institutions or government agencies in the municipality of Mexicali.

2.2 Quality of life assessment

To identify the quality of life of the inhabitants of an urban area, the UMI will be calculated for the city of Mexicali by the AGEB. Therefore, it is necessary to measure the level of marginalisation in each of the areas that make up the city of Mexicali, providing a hierarchy of stratified and homogeneous territorial units, according to the statistical criterion of minimum variance [31].

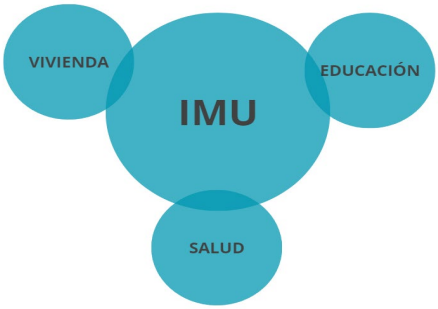
To obtain the UMI, socioeconomic variables and indicators are taken into account (see Figures 6 and 7), which allows us to determine the quality of life of the inhabitants in each of the AGEBs over time [11]. The indicators considered for the calculation of the UMI are generated with population and housing information from INEGI and are presented in Table 1. It should be noted that each indicator is assigned a weighting extracted from the principal component matrix using the SPSS statistical software.

Figure 6. Process and components for generating the UMI.



Source: own elaboration.

Figure 7. Variables for the formation of the UMI.



Source: own elaboration.

Table 1. Variables and indicators for determining the UMI.

Variables	Indicators	Weighting
Education	Percentage of population aged 15 without basic education	0.528
Health	Percentage of population without access to health services	0.384
Housing	% of occupied dwellings with dirt floors	0.88
	% of occupied dwellings without electricity	0.857
	% of occupied dwellings without drinking water	0.902
	% of occupied dwellings without drainage	0.736
	% of occupied dwellings without a refrigerator	0.602

Source: own elaboration with data from INEGI [27].

To determine the UMI in each of the AGEBs in the city of Mexicali, it is necessary to start from the sum of the selected indicators and take into account their respective weighting, according to the following formula (1).

[32] $$UMI = \sum_{j=1}^{7} a_j Z_{ij} \quad (1)$$

UMI = Urban Marginalisation Index in each AGEB
j = refers to indicators that contribute to the degree of marginalisation (j=1,..7).

a_j= weighting established by indicator j (comes from the principal component matrix generated from the SPSS Statistics software)
Z_{ij}= normalised value of indicator j, obtained by subtracting the average and dividing the difference by the standard deviation corresponding to the indicator.

For each of the AGEBs and the weighted sum of the selected indicators, it is necessary to define the ranges of urban marginalisation through a normal distribution, as well as their allocation and description at each level of marginalisation (see Figure 8). It should be noted that there are up to six different ranges of urban marginalisation, which are constructed by adding one or more standard deviations to the mean for ranges with high levels of urban marginalisation, and subtracting one or more standard deviations from the mean for ranges with low levels of urban marginalisation.

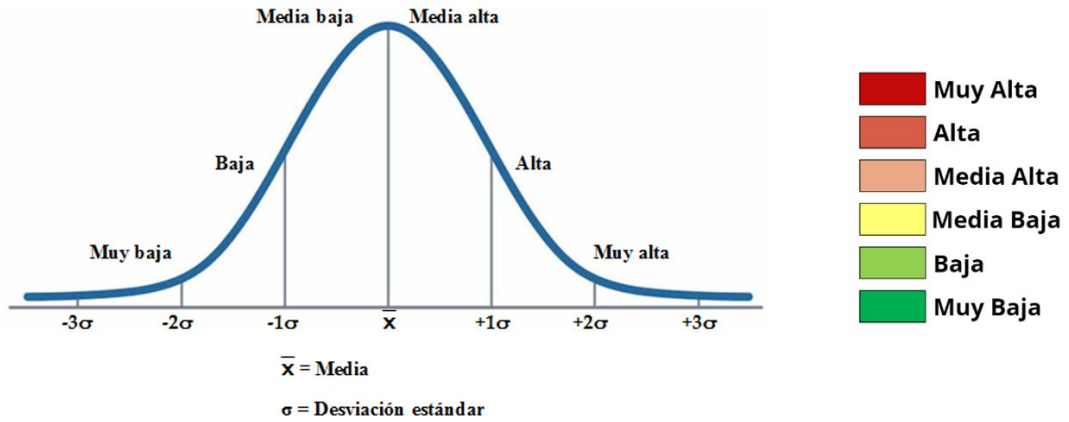


Figure 8. UMI ranges. Source: own elaboration.

2.3 Determination of relative and absolute accessibility of the territory with respect to the urban road network

It is suggested that road accessibility be analysed from a relative and absolute perspective [33]. Therefore, identifying the population's access to the urban road network requires determining relative accessibility criteria in areas considered to be the most disadvantaged in terms of marginalisation. In other words, determining by AGEB what its level of accessibility is with respect to a primary road, this being the one that allows for the greatest capacity and geometric sections. Therefore, three scenarios are defined, considering the type of road:

- **Level 1.** Directly connected by a primary road
- **Level 2.** Connected to the primary road network via secondary sections
- **Level 3.** Connected to the primary road network via tertiary sections

On the other hand, a comprehensive analysis must consider the functionality of the network, which is referred to as friction variables that generate impedances that influence the choice of a road. These variables consider a) road geometry, b) type of roads and connectivity offered, c) type of pavement and conditions, d) operating speed.

That is why conditions of absolute accessibility are closely linked to the state of urban roads. Subsequently, the aim is to relate the analysis of the quality of life in the territory to the road accessibility conditions presented by the AGEBs. This will identify critical

and strategic areas for investment, either in the road infrastructure that connects them or in the basic services they require, with a view to improving quality of life.

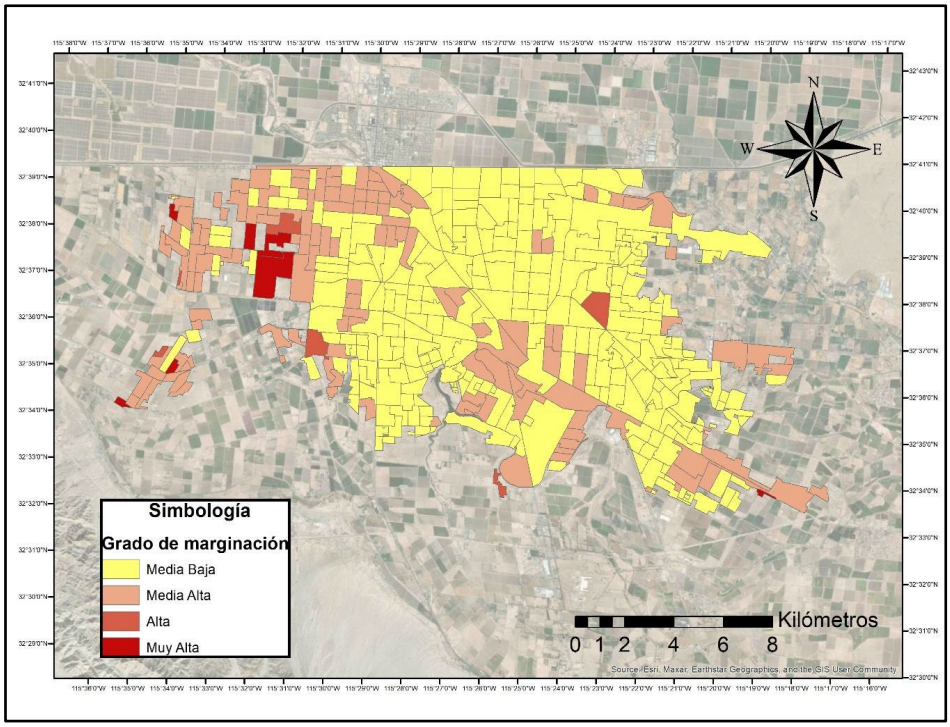
3. RESULTS

This section describes the main results of the quality of life assessment, through the development of the UMI by AGEB, as well as the analysis of road accessibility in the territory, thereby enabling discussion of the possible relationship between both approaches and identification of findings.

3.1 Quality of life analysis

Figure 9 shows how the UMI behaves in the different AGEBs of the city of Mexicali in 2020. It should be noted that only four of the six proposed urban marginalisation ranges were evident, namely: Medium-Low, Medium-High, High and Very High. It was noted that a large part of the population exhibits a situation of marginalisation between Medium-Low and Medium-High, which is distributed throughout the urban area of the city. However, areas with a High and Very High situation tend to be located towards the west and the outskirts, with a few exceptions towards the east, south and southeast.

Figure 9. UMI by AGEB in the city of Mexicali, BC, Mexico.



Source: own elaboration with data from INEGI [27] and cartography from INEGI [28].

As can be seen in Table 2, most of Mexicali shows a Medium-Low level of urban marginalisation, representing 66.90% of the population and located in 287 AGEBs. In addition, 30.07% is in a Medium-High situation in 129 AGEBs; 1.40% is in a High situation in six AGEBs; and 1.63% of the population is in a Very High situation in seven AGEBs.

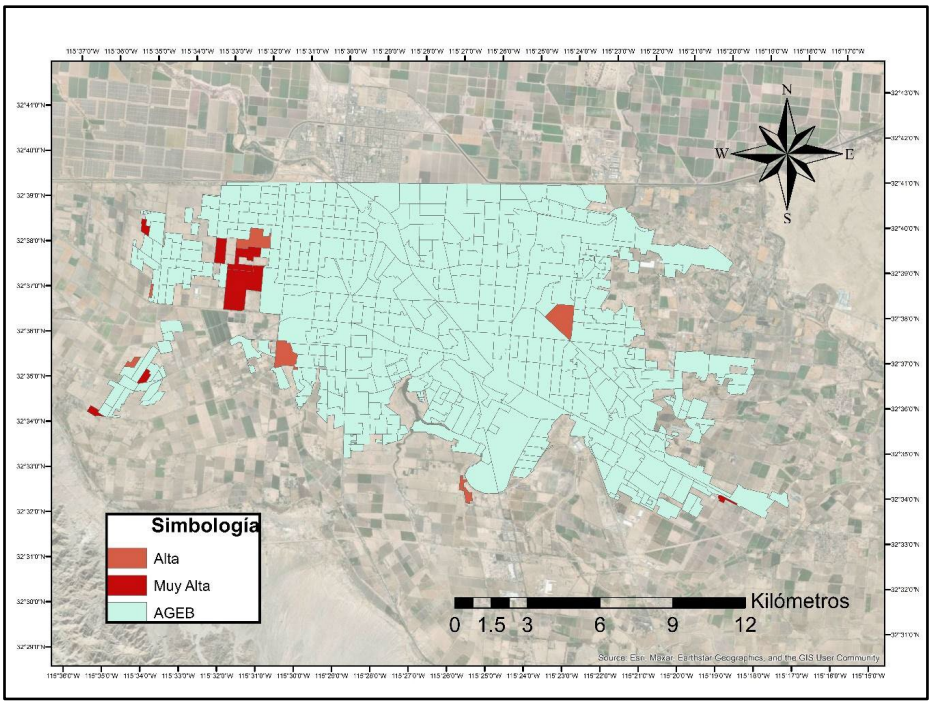
Table 2. Summary of UMI results in the city of Mexicali, BC, Mexico.

UMI ranges	Percentage	AGEB	Population
Very high	1.63%	7	1,106
High	1.40%	6	2,892
Medium-high	30.07%	129	193,761
Medium-Low	66.90%	287	656,427
Total	**100.00%**	**429**	**854,186**

Source: own elaboration with data from INEGI [27].

Therefore, 3.03% of the population is in a critical condition (High and Very High), which, according to Figure 10, is concentrated in 13 of the 429 AGEBs, most of them in the west of the city and resulting in areas of the city where the population lacks greater access to health services, education and decent housing conditions, which is largely due to their lower level of urbanisation.

Figure 10. AGEBs in critical UMI situations in the city of Mexicali, BC, Mexico.



Source: own elaboration with data from INEGI [27] and cartography from INEGI [28].

Table 3 shows that seven AGEBs have a population with Very High situation, which are distinguished by their low population density, housing that is newer than the rest of the city, and being surrounded by abandoned land, factories or maquiladoras, plots, drains and canals. It is worth mentioning that two of the seven AGEBs stand out; one of them, 7694, has the largest population with 535 inhabitants, most of whom have not completed basic education and a large proportion of whose homes lack drainage, electricity, water and refrigerators, resulting in a very poor quality of life. AGEB 0733, with a population of 380 inhabitants, is also noteworthy, as most of them do not have the necessary amenities in their homes, lacking drainage services and refrigerators, which is alarming given the high temperatures that can be reached in the city during the summer.

Table 3. Summary of UMI results in the Very High range, in the city of Mexicali, BC, Mexico.

AGEB	UMI sum	UMI range	Population
0733	10.41305292	Very high	380
7798	12.24255706	Very high	26
6287	13.30734409	Very high	46
7694	14.04574031	Very high	535
6304	18.62983917	Very high	34
6395	25.57623404	Very high	73
693A	62.56237902	Very high	12

Source: own elaboration with data from INEGI [27].

Table 4 shows the population with a high risk level in six AGEBs in the city, which has similar characteristics to the population with a very high risk level, with a low concentration of inhabitants, characterised by early construction housing surrounded by abandoned land, factories or maquiladoras, loading and unloading areas, plots of land, drains and canals. AGEB 6450 stands out, with a total of 1,836 inhabitants who have not completed basic education, several dwellings with dirt floors, no piped or drinking water service, and some without electricity and drainage. On the other hand, the case of AGEB 3916 stands out, as it has only two inhabitants, neither of whom has all the essential services required for a dwelling to be considered decent.

Table 4. Summary of UMI results in the High range, in the city of Mexicali, BC, Mexico.

AGEB	UMI sum	UMI range	Population
6450	4.994165092	High	1,836
3916	5.028877189	High	2
0729	5.150204874	High	618
558A	6.650063153	High	114
768A	9.092955194	High	246
7637	9.115655111	High	76

Source: own elaboration with data from INEGI [27].

3.2 Analysis of road network accessibility

On the other hand, to begin the analysis of relative accessibility of the urban road network, Table 5 shows that five AGEBs have a level 1 accessibility, indicating that these areas are connected to the network directly by a primary road (see Figure 11); only one AGEB has a level of 2, indicating that it is connected to the primary road network by a secondary road (see Figure 12); and seven AGEBs have a level of 3, indicating that they are connected to the primary road network by a local street or tertiary road (see Figure 13).

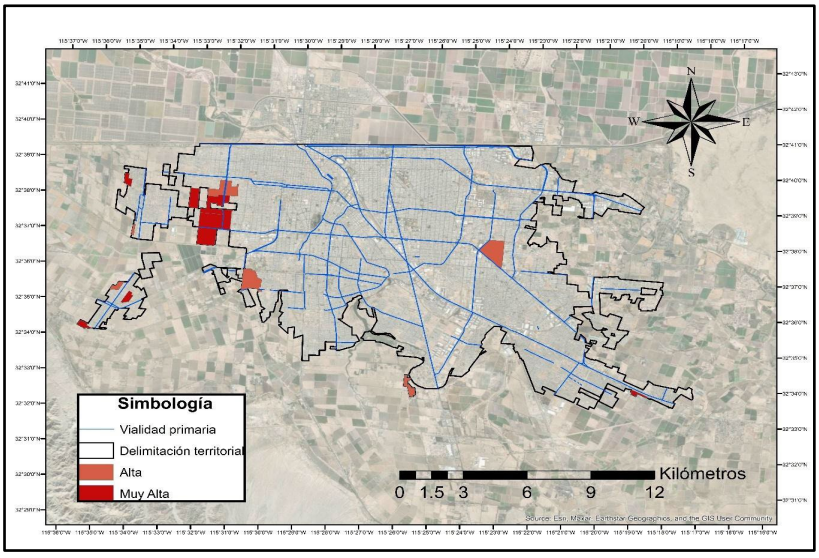
Table 5. Relative accessibility of the road network impacting critical UMI areas in the city of Mexicali, BC, Mexico.

AGEB	UMI ranges	Accessibility Level	AGEB	UMI ranges	Accessibility Level
0733	Very high	1	6450	High	1
7798	Very high	3	3916	High	1
6287	Very high	3	0729	High	2
7694	Very high	1	558A	High	3
6304	Very high	3	768A	High	1
6395	Very high	3	7637	High	3
693A	Very high	3			

Source: own elaboration.

As can be seen in Figure 11, five of the 13 AGEBs have a level 1 accessibility, including 0733, 3916, 6450, 7684 and 7694, providing network access to a total of 2,999 inhabitants, representing 75.01% of the total population in the High and Very High categories. It should be noted that, in two of the five AGEBs (0733, 3916), access is via sections with cross-sections of over 30 m, with three lanes in each direction and where the condition of the pavement is between fair and good. However, in two other AGEBs (7684 and 7694), the characteristics of the section that passes through them are different from those of a primary road, as they have two lanes in each direction, but with good pavement conditions. In turn, in another AGEB (6450), where its population alone represents 45.92% of the total population between Very High and High, the conditions are even more different, as there is only one lane in each direction and the pavement conditions are very poor, with the disappearance of the shoulder and parts of the lane in some sections.

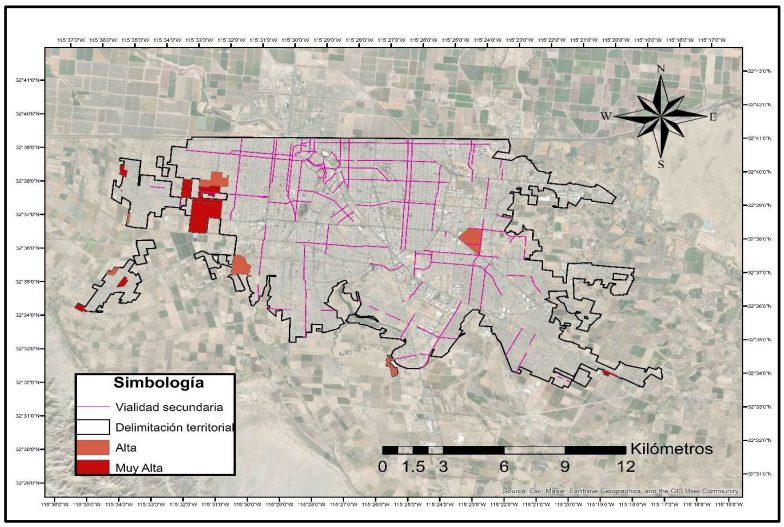
Figure 11. Primary network and its connectivity with AGEB in critical UMI situation, in the city of Mexicali, BC, Mexico.



Source: own elaboration with data from INEGI [27] and cartography from INEGI [28].

Figure 12 shows that AGEB 0729 is located in the south of the city with a level 2 accessibility, allowing a total of 618 inhabitants, representing 15.46% of the total population in a high and very high situation, to access the primary road network via a secondary road. However, the characteristics of this road are very different from those that should distinguish a secondary road, with some sections of the stretch currently in very poor condition due to lack of maintenance and with only one lane of traffic in each direction. Likewise, other sections of the stretch are unpaved, making it impossible to distinguish the number of lanes of traffic in each direction.

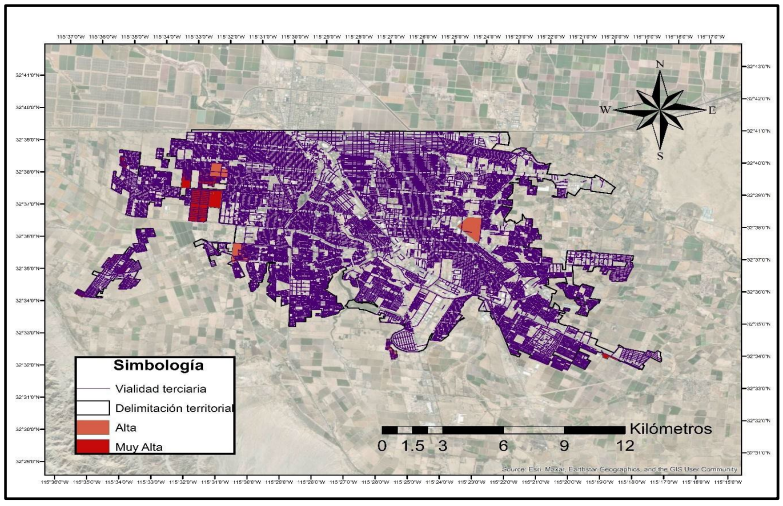
Figure 12. Secondary network and its connectivity with AGEB in critical UMI situations, in the city of Mexicali, BC, Mexico.



Source: own elaboration with data from INEGI [27] and cartography from INEGI [28].

As for the remaining seven AGEBs, six of them (558A, 6287, 6304, 6395, 693A and 7637) are located to the west of the city and only one (7798) to the east, allowing a total of 381 inhabitants, representing 9.53% of the total population in the High and Very High situations, to access the primary road network via tertiary roads (see Figure 13). It should be noted that in the seven AGEBs there are no paved tertiary roads, only dirt roads, which requires immediate investment in paving.

Figure 13. Tertiary network and its connectivity with AGEBs in critical UMI situations in the city of Mexicali, BC, Mexico.



Source: own elaboration with data from INEGI [27] and cartography from INEGI [28].

4. DISCUSSION

The contribution of this research lies in the fact that, in addition to measuring quality of life through the UMI by AGEB in the city of Mexicali, it also provides results on road accessibility conditions. This highlights how the quality of life of the population, especially the most vulnerable, is closely linked to their level of accessibility to road infrastructure. However, the main contribution is the establishment of a procedure for conducting a comprehensive diagnosis in urban areas, combining statistical data on population and infrastructure with spatial analysis to guide infrastructure investment that will reduce levels of marginalisation among the population.

In relation to the state of the art, this study confirms several of the theoretical approaches on the link between quality of life and road accessibility, among which it is worth highlighting that lower accessibility leads to a lower quality of life, as well as concrete evidence that this negative condition of road accessibility is due to the poor state of the network and, therefore, the need for interventions in the construction and maintenance of pavements [1]-[3], [9], [10]. However, unlike other studies [9], [10], this research adds greater territorial and statistical specificity by proposing an analysis in an urban context that is more limited to the local area, specifically the city of Mexicali. Another aspect that contrasts with these studies is that, in order to estimate the UMI, it was necessary to use more indicators related to access to goods. Furthermore, a unique feature of this study is that, in addition to reflecting on the literature review, it seeks to make an empirical assessment of the impact of urban road accessibility on quality of life.

Based on the results, it was found that most of the AGEBs that show a critical situation of urban marginalisation are connected to the primary network through a tertiary road or local street, i.e. they have a relative level 3 accessibility. Furthermore, an analysis of the absolute conditions of the network revealed that the tertiary roads analysed are unpaved. This causes accessibility problems and, therefore, no improvements in the quality of life of the city's inhabitants. On the one hand, it makes it difficult to access basic services such as education and health, where facilities are generally located on a primary or secondary road, and, on the other hand, it limits the availability of necessary services in the home. Furthermore, it was identified that there are AGEBs that concentrate a considerable number of the population and have a level 1 accessibility, through a primary road, but with only one lane and poor pavement conditions. Furthermore, a similar case can be found in AGEB, which has a level 2 accessibility, as it presents conditions that are different from those associated with a secondary road, since the section that provides access to the primary road network has a very poor pavement condition due to lack of maintenance. This requires decision-makers to act urgently, allocating resources to paving.

The main limitations of this research stem from the use of static data from a census published in 2020, which does not allow for the inclusion of recent changes in road infrastructure. On the other hand, the AGEBs were used as territorial boundaries, which limits the ability to understand the socio-economic characteristics of the population with precision beyond these limits. Another aspect to consider was that only quantitative indicators were used, without incorporating any surveys or interviews to obtain information on the perceptions of residents and thereby enrich the understanding of quality of life. In terms of road accessibility, only relative and absolute accessibility were addressed, but other factors such as public transport and road safety were not considered.

5. CONCLUSIONS

The UMI conditions in the case study reveal a scenario where urban development has not been accompanied by road infrastructure policies that allow connectivity between critical or more vulnerable sections of the city. This has a direct effect on the quality of life of the population in these sections and compromises current levels of well-being, as well as that of future generations in the disadvantaged territory. This is because public policies are unlikely to remedy infrastructure omissions that were not addressed in a timely manner, and when they do, it is more costly than having included them in an intervention plan. An example of this is when reconstruction work or even paving has to be done for the first time in one of the neighbourhoods in critical sections, which requires more financial resources than when investing gradually to promote development based on road infrastructure.

According to the specific results of the case study, 13 of 429 Basic Geostatistical Areas have UMI ranges from High to Very High, which are those where the population lives in the most unfavourable conditions. It is worth mentioning that most of these areas are connected to the primary road network by a tertiary section that is in poor condition and poorly maintained due to a lack of paving. It is concluded that the population living in the most unfavourable conditions of urban marginalisation is the one with the least access to basic education, health care and housing, and the worst levels of access to drinking water and drainage. Therefore, the above identifies those critical and strategic areas for investment, either in the road infrastructure that connects them or in the basic services they require, with a view to improving the quality of life of the population.

As part of subsequent studies, and after identifying those areas with the highest levels of urban marginalisation and their relationship with levels of accessibility to the network, the aim will be to analyse public transport and the coverage of its routes, whose accessibility to the population represents opportunities to reduce their level of UMI.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHOR CONTRIBUTIONS

Leonel Gabriel García Gómez: Methodology, software, validation, research, resources, data curation, writing, project management.
José Manuel Gutiérrez Moreno: Validation, research, writing.

Alejandro Sánchez Atondo: Validation, research, data curation, supervision.
Citlali Margarita Mejía Mercado: Software, formal analysis, research, data curation, visualisation.

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