URBAN MOBILITY AND ACCESSIBILITY DYNAMICS: ASSESMENT OF A CAR-ORIENTED INTERVENTION IN AGUASCALIENTES, MEXICO

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July, 2024

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ABSTRACT

As urban areas expand globally, there is a growing reliance on private cars, shaping cities into car-oriented environments. The uneven development of transport infrastructure has distinct implications for different social groups, but the most popular transport appraisal methods fail to account for these differences. Therefore, evaluating the impacts of transport projects and examining how these effects are distributed spatially and among different social groups becomes essential. This thesis investigates how the construction of extensive new car infrastructure influences urban mobility and accessibility dynamics in a developing mid-size city. Using Aguascalientes, Mexico, as a case study, it examines how accessibility to leisure destinations — parks, malls, museums, and cinemas— changed between 2019 and 2024 and whether these changes are distributed proportionally in space and among socioeconomic groups.

The study employs a mixed-method approach. It combines a descriptive analysis with an assessment of accessibility levels using contour and gravity-based indicators, focusing on both geographic and social distribution. Results indicate that, after the city became more car-oriented, inhabitants made more short trips by car instead of walking, the distance of their walking trips increased, and they are willing to travel longer distances to reach leisure destinations, regardless of the travel mode. Three benefits frequently perceived among inhabitants are the increase in car infrastructure, more access to recreational facilities, and a reduction in travel costs. The accessibility analysis revealed that car users enjoy very high levels of accessibility throughout the city, whereas pedestrians face greater difficulty reaching leisure destinations. Although the accessibility model has some limitations, the overall assessment underscores the need for more comprehensive evaluation techniques to assess the positive and negative effects of transport interventions.

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1. INTRODUCTION

1.1. Background and context of the research

In the past decades, cities around the globe, both in developed countries and developing countries, have experienced a sharp increase in urban sprawl (Chen et al., 2014). Urbanization levels vary, but globally they have already surpassed 50% (UN-Habitat, 2022). It has been observed that rapid urban growth is also accompanied by low-density patterns, especially in low-income countries, and an urban environment that privileges more private vehicles compared to other transport modes (Buehlera et al., 2016; UN-Habitat, 2013; Venter et al., 2019). This tendency reflects the belief that more vehicle infrastructure reduces traffic congestion and that increased car mobility will increase economic productivity (Downs, 2014; Litman, 2014). However, when cities experience rapid urbanization processes and urban mobility is developed upon car-oriented policies, unintended consequences like pollution, traffic accidents, inequality in the urban space, and social exclusion arise (Avilés-Polanco et al., 2022; Iglesias et al., 2019).

The uneven development of infrastructure for various transport modes has distinct implications for different societal groups. On the one hand, significant investments in road expansions, bridges, and overpasses create a convenient environment for those traveling by car. Those with access to private vehicles not only enjoy enhanced comfort and efficiency but also reach more distant and higher quality opportunities (Hernandez & Rossel, 2015; Reillo, 2018).

On the other hand, in cities that are highly car-oriented and neglect other transport modes such as walking, cycling, and public transport, users without a car become adversely affected. Studies indicate that in car-centric cities, essential services like schools and healthcare facilities are strategically located near streets that are easily accessible by motorized vehicles. In contrast, very often, people who rely on walking find themselves limited to attending schools that are not as well-performing (Hidayati et al., 2019).

Thus, when the development of transport infrastructure is not balanced, certain social groups benefit from improved mobility, while others may face restricted mobility in terms of options or affordability. In fact, if inhabitants cannot adapt to the built environment and transport policies, they risk exclusion from essential functions and services like education or work, leading to reduced socioeconomic opportunities. Therefore, evaluating the impacts of transport projects and examining how these effects are distributed spatially and among different social groups becomes essential.

While project evaluation was long based on maximizing the return on investment, nowadays, it also addresses questions related to different levels of effectiveness and the equitable distribution of resources (Meyer and Miller, 2001). As a result, commonly used methods that rely solely on monetizing all costs and benefits and aggregate the results at a macro level, such as productivity gains, are no longer suitable.

Transport project evaluation entails a complex process of measuring the costs and benefits of different project alternatives and determining their levels of desirability. During this process, decision-makers must estimate the magnitude of the impacts and identify those who are positively or negatively affected. Recently, there has been a change in how these processes define how value is measured. For this reason, more and more researchers and planners are using accessibility analysis as an appraisal method for transport projects (Marwal & Silva, 2022).

Assessing a transport project from the accessibility point of view means that the primary objective is not to facilitate cost-effective movement but to ensure that, given the spatial, temporal, and individual components, people can make use of the transport system available to them and reach a destination to meet their needs and desires. In this context, accessibility can be understood as the ease with which a person can reach opportunities within an urban environment (Geurs & van Wee, 2004; Neutens, 2015).

Analyzing transport interventions using an accessibility approach highlights the interaction between transport systems and land use. This understanding is essential for transport planning, as it clarifies that transport development does not occur in isolation. For instance, in more compact cities with mixed-uses areas, people rely less on cars; conversely, if residential areas are far from commercial centers, there will be a higher demand for transport infrastructure to connect these areas (Angel et al., 2020). Therefore, transport planning not only responds to the location of social and economic activities but can also influence decisions on where these activities should be located.

Ideally, a good accessibility measure should consider four components: transport, land use, time, and individual aspects. However, having an indicator sensitive to all these components becomes challenging in practice, and variations must be made depending on data availability and research focus.

Various measures can be applied depending on the objective. A simple indicator commonly used is the "contour-based" indicator. This measure counts the total number of opportunities that can be reached within a given time or distance threshold. It is easy to compute and interpret but has theoretical shortcomings. Another type of indicator is the "gravity-based" indicator. This approach operates on the principle that two points closer together have more attraction, and the attractiveness of a location decreases with increasing travel time or distance. While this measure has more data and methodological requirements, it successfully integrates transport, land use, time, and individual components (Geurs & Van Wee, 2004).

1.2. Statement of the problem and research question

Certainly, accessibility measures have been used before to assess the costs and benefits of transport interventions. However, these studies have been developed mainly for big cities of the global north or in contexts with extensive and available data on the accessibility components and mobility patterns (Karner, 2018; Price et al., 2023). In the case of developing countries where cities are experiencing rapid urbanization processes, research on accessibility as an evaluation method is still developing using limited intercensal data and little information about individual travel behavior (Guerra, Caudillo, Monkkonen et al., 2018). In addition, much of the literature is based on accessibility to job and education opportunities (Hu, 2015; Pereira et al., 2019). Although these two are the primary purposes for commuting, assessing access to other opportunities like leisure and recreation can bring new insights into the transport appraisal process. One of the main reasons is that job trips are considered to be part of the mandatory travel of individuals, whereas leisure is not (Jara-Díaz & Contreras, 2024). Since people have different marginal utilities for work and leisure, travel patterns can behave differently in each context (Shkera & Patankar, 2024).

In this context, it is relevant to study the recently implemented continuous car flow system in Aguascalientes, a mid-size Mexican city with a long history of car-oriented development. Although automobile infrastructure has been in place for several decades (Coordinación General de Movilidad, 2021; H. Ayuntamiento de Aguascalientes, 2019), the project to transform the Second Ring, one of the city's main arteries, into a continuous flow system is significant. Over five years, from 2017 to 2022, the project substantially modified the car infrastructure by constructing eleven vehicle bridges. The main argument for this project was based on a cost-effective analysis, which suggested that improving traffic flow through the city would reduce travel times and, consequently, lower the operating costs for various types of vehicles (Ingeniería Aplicada Mexicana, 2019; La Jornada, 2021).

The expected benefit of the continuous car flow system in Aguascalientes—namely reduced travel times and lower vehicle operating costs—is clear and straightforward. However, this view is rooted in economic rationalism and oversimplifies the situation. It overlooks other potential effects that are not typically quantified in monetary terms or time savings, such as changes in accessibility levels, travel behavior, or socio-spatial inequalities. By focusing solely on economic benefits, the broader and more complex consequences of such infrastructure projects are often ignored, leading to an incomplete assessment of their true impact. More importantly, transport projects like this one can have varying effects depending on the zone of the city, the type of transport user, and even the social group to which the users belong. Therefore, it is relevant to ask: *what is the spatial and social distribution of the costs and benefits generated by the continuous flow construction?*

1.3. Study aim and objectives

This thesis investigates how a transport intervention that develops more automobile infrastructure over other transport modes influences urban mobility and accessibility dynamics in a developing mid-size city. Using Aguascalientes, Mexico, as a case study, it examines how accessibility to leisure destinations — parks, malls, museums, and cinemas— changed following a car-oriented intervention and whether these changes are distributed proportionally in space and among socioeconomic groups. The analysis first addresses the overall changes in mobility patterns and individual behavior and then explores the geographic and social distribution of accessibility levels by measuring both contour and gravity-based accessibility.

Therefore, the two research objectives are to (1) identify changes in inhabitants' mobility patterns, costs, and benefits over the last five years and (2) assess the changes in accessibility levels across urban areas and among socioeconomic groups before and after the transport intervention.

1.4. Overview of the structure of the thesis

To cover these objectives, the thesis is organized into seven chapters. After this introduction, chapter 2 explains the theoretical framework guiding the research. This chapter begins by discussing why and how cars have shaped the urban environment and travel patterns. Then, it explores the relationship between transport systems and accessibility, how these elements are distributed in space and society, and how these two can be assessed.

Chapter 3 delves into the research design. It introduces the case study and provides an overview of the methodology. This chapter also breaks down the data sources used for the analysis and details the process for primary data collection. The final part of this chapter explains how the descriptive approach and the accessibility approach are combined to address the research objectives.

Chapter 4 is the first chapter presenting results. It provides an overview of the mobility patterns in Aguascalientes and how they have changed over time. Chapter 5 presents the results of the accessibility analysis, showing the distribution of accessibility before the intervention and contrasting these results with the post-intervention scenario. This chapter also discusses variations in these results when social characteristics are characteristics considered.

Chapter 6 discusses the results from two perspectives: first, in the context of the research objectives and then in relation to the methods used. Chapter 7 wraps up the research, offering some conclusions.

2. THEORETICAL FRAMEWORK

2.1. Car predominance within the urban form

The relationship between urban form and transportation has profoundly evolved over time. Before the industrial era, cities typically had a compact form characterized by high population densities and a reliance on walking as the primary mode of transportation. However, with the start of industrialization, urban areas began to experience significant expansion as populations grew and economic activities diversified. This expansion, often characterized by low density, changed people's mobility patterns and led to an increase in the overall transportation demand. People require both public and private transportation. Consequently, transport systems started to extend in range and capacity, and new technologies —such as electric trams, motor buses, and later cars— appeared to allow people to travel more and farther away (Pacione, 2005c).

As urban travel has increased in volume and complexity, the modal shift has also been evolving. In many cities, the reliance on cars has grown, leading to the rejection of active modes like walking and cycling, as well as public transport. For instance, in some western European and Latin American cities, public transport is only used for 10 to 20 percent of daily trips. In affluent and car-oriented cities such as Dubai, Melbourne, and Chicago, the trips made by public transport represent less than 10% of the modal share. In contrast, in several parts of eastern Europe and Asia, more than half of all the mechanized trips were made by public transport (United Nations Human Settlements Programme (UN-Habitat), 2013), and the modal share of bikes has been growing substantially in cities in Germany (Munster with 38%, The Netherlands (Leiden with 33%), and Denmark (Copenhagen with 31%) (Langeland, 2015). Although the modal share is very context-dependent, there has been a general trend of high car dependence over the years (Buehlera et al., 2016).

Literature suggests that individuals' preference for traveling by car is influenced by two main factors: the reduction of the marginal cost of commuting by private vehicle and the convenience and accessibility that owning a private car provides. The case of cost reduction needs careful consideration. On the one hand, overall incomes have indeed increased over time, making it easier for people to purchase a car. Also, technological improvements have made cars more energy-efficient, reducing fuel consumption, which is one of the most significant running costs (Downs, 2014). Nevertheless, some cities are implementing policies to manage the high demand for private vehicle usage by making car usage more expensive, such as road or parking pricing (Venter et al., 2019), and fuel prices have also increased. Additionally, people often see the costs associated with owning a private vehicle, such as purchase price and registration, as sunk costs that will not be recovered. As a result, the rational thinking of car users is to increase their vehicle usage to maximize the value of their already incurred costs (Ho et al., 2014).

On the other hand, while the cost of owning a car might be higher compared to other modes of transport, traveling by car generally provides greater convenience and access to opportunities. Research suggests that people tend to underestimate the cost of owning a car and that if they had more accurate information, they would reduce their use (Andor et al., 2020). However, recent findings indicate that, even when people are informed about the real costs, they still perceive that the benefits of having and using a car outweigh the costs of buying and maintaining it (Moody et al., 2021). The automobile is often seen as the best option for addressing complex mobility demands, such as multipurpose trips. The decision-making process regarding how to manage travel times and distances becomes less burdensome for those who own a car compared to those who do not have it (Hernandez & Rossel, 2015). Furthermore, it has been observed that people who have more mobility resources use them not to reduce travel times but to access more distant, higher quality, and diverse opportunities (Reillo, 2018). Thus, even though people may underestimate the total cost of owning a car, they still perceive that driving maximizes their benefits.

Under these circumstances, people tend to drive more, leading to an increase in the volume of vehicles on the streets. To alleviate traffic congestion and ensure a continuous flow of vehicles in the future, urban planners often respond by building more car infrastructure, such as roads, bridges, and parking facilities. This constant loop reflects the 'predict and provide' (Schiller & Kenworthy, 2018b) approach, where the anticipation of increased car use prompts the provision of more car-based infrastructure, which in turn encourages even higher levels of car use.

Because car usage and ownership have increased, the built environment and transport systems are becoming predominantly car-oriented. However, this shift is driven not only by the changing preferences of individuals but also by the assumption that car-oriented developments bring significant economic benefits. Motor vehicle travel is an input for almost every economic activity. It facilitates the transportation of goods across different locations, enabling production and consumption cycles to thrive. Likewise, it moves people around urban and rural areas to consume, produce, and participate in social dynamics. Research indicates a strong correlation between energy consumption, vehicle travel, and GDP, suggesting that increased motor vehicle travel correlates with higher economic productivity (Downs, 2014; Litman, 2014).

As a result, decision-makers and planners often prioritize developing car-oriented infrastructure, operating under the premise that expanding car-oriented mobility —faster, over greater distances, and in dispersed ways—will stimulate economic prosperity. This mindset is commonly associated with the' business as usual' approach in transport planning (Schiller & Kenworthy, 2018a).

2.2. Transport systems and accessibility: how are they distributed?

Building upon the evolution of the relationship between urban form and transportation systems, it becomes evident that the intensification of car-oriented mobility was one response to the crescent travel demands of modern urban life. While transport systems focusing on cars have indeed facilitated mobility for many, they have also exacerbated disparities within urban environments. These disparities are often observed in the social dimension, meaning that while certain social groups benefit from improved mobility, others may face restricted mobility in terms of alternatives and costs. Similarly, these disparities are linked to spatial factors, where some areas have a higher endowment of infrastructure and transport services that facilitate easier movement, while other areas are under-served in terms of infrastructure and transport services. To understand the origins of disparities in transport systems and accessibility, it is helpful to explain why these can be viewed as services and goods distributed across society and space and then examine how they are usually distributed.

Transport systems consist of various elements, such as the institutional structure, the infrastructure and service, the users, the different modes of transportation, and the intermodal connections. Focusing on the infrastructure and service component, a transport system includes a transit network, a highway network, and a nonmotorized network, all of which facilitate the movement of people and goods within an urban system (Michael D. Meyer & Eric J. Miller, 2001b). Examples of these networks are train and bus networks, as well as cycle tracks and pedestrian paths for nonmotorized transit. Transport planners construct infrastructure such as stations, terminals, roads, bridges, underpasses, and sidewalks for these elements to function effectively.

Assembling all the components of this system serves multiple purposes, one of the most important ones being to provide adequate levels of mobility and, consequently, accessibility. Mobility and accessibility are related concepts but are not the same. While mobility refers to "the ability to move between different activity sites" (Pacione, 2005c, p. 267), accessibility indicates the ability and ease with which people can reach desired locations or opportunities using available transportation systems (Geurs & van Wee, 2004; Neutens, 2015). Thus, it is worth noting that changes in mobility do not necessarily affect accessibility and vice versa (Cavallaro & Dianin, 2022). It might be the case that constructing a freeway reduces travel time, but people still need to use a car to overcome the distance barrier.

When discussing accessibility, it is also essential to distinguish, as Martens (2017b) suggests, between 'person accessibility' and 'place accessibility.' This differentiation acknowledges that even if a facility or opportunity is located within a certain distance for a group of people, individual attributes (e.g., income, gender, or education) may determine whether a person can actually reach it. Combining these perspectives introduces the notion of potentiality: if a person has a high capacity to act and the destination is well-located, they will enjoy *high levels* of accessibility. Conversely, a poor location and a low capacity to act will result in *low levels* of accessibility.

In any society, a set of 'primary social goods' allows individuals to fulfill their needs and aspirations, whatever these might be. These primary social goods are, for example, a bundle of fundamental rights and liberties, the freedom of movement, the prerogatives of offices and positions of responsibility, income and wealth, and the social base of self-respect (Rawls, 2003, as cited in Martens, 2017a). However, people would not be able to reach these social goods if they did not have good accessibility levels. Therefore, as Martens (2017a) proposes, accessibility *per se* can be considered a primary social good, even more important than wealth or income, because good accessibility is critical for achieving broader life goals and economic prosperity. As a result, it can be argued that having good levels of accessibility is a prerequisite for enjoying a good quality of life.

Many other aspects influence people's well-being apart from having access to education, jobs, or a good income. For example, access to good health care, social participation, and recreation can enhance quality of life. In this regard, research demonstrates that individuals living in areas with better accessibility to healthcare services increase the uptake of preventive treatment services (Neutens, 2015) and report higher levels of satisfaction and lower levels of deprivation (Cabrera-Barona et al., 2017). At the same time, people participate more in social and nonwork activities (Zhang, 2005) and enjoy more places with recreational activities (Price et al., 2023).

Since good accessibility positively influences people's quality of life, in a most desirable situation, the state would take the responsibility of evenly providing transport systems across space and among people. When the government provides a high level of transportation services, the misconception arises that transport systems are 'public goods.' However, as Pacione (2005a) explains, transport systems cannot be considered 'public goods' because, according to economic theory, a 'public good' has to be non-excludible and non-rivalrous.

Transport systems can fall into different categories based on their excludability and rivalry. For example, public buses can be considered 'club goods' because they exclude people who do not pay a fee, and they are non-rivalrous as long as the bus has capacity. However, they become rivalrous when they are overcrowded. Conversely, a vehicle bridge without tolls can be considered a 'common good' because it is difficult to prevent people from using it, which makes it non-excludible. Nevertheless, if there is high traffic congestion, it becomes rivalrous. Therefore, the categorization depends on the characteristics of each transport service provided, and this categorization can reach different levels of problematization. For example, in the case of bridges, it can be argued that they are also excludible, as people who do not own a car cannot use it. But, generally speaking, they are never considered 'public goods'.

Even if services like transportation and infrastructure were fully covered by the state, geography, and space would still influence this provision, making it difficult to deliver them to everyone. So, from looking at it from the spatial dimension, the reason why transport systems do not meet the non-excludability criterion is due to two complications: jurisdictional partitioning and tapering. The first complication arises from the fact that urban areas within regional or local jurisdictions often vary in terms of available resources, expenditure needs, and preferences for service provision. In other words, the services and resources individuals receive can vary significantly based on where they live. The second difficulty in providing transport services is that certain services, like a train station, are fixed in a specific location and serve a particular geographic area. To use these services, individuals must travel to the facility and cover the associated trip costs. However, as the cost of reaching the location increases, the use of the service will decline. If the impedance is too high, the service will not be utilized at all (Pacione, 2005c).

Following the explanation of why transport systems are considered “comm goods” rather than “public goods,” it becomes clearer that the delivery of transport infrastructure will never be universal. In the case of infrastructure designed for car users, building bridges and roads everywhere is simply not feasible, and cities do not have the physical space to facilitate car travel for the majority of inhabitants. Even if such infrastructure were universally available, people would still face the cost of owning a car.

There is a strong correlation between social characteristics and the location where people live, work, study, and develop. Therefore, diving into why transport systems can exacerbate social disparities and create exclusion is essential. Due to high costs, lower-income and socially disadvantaged individuals often cannot afford housing in more affluent areas. As a result, they are limited to more affordable but often deprived areas where housing is cheaper (Guerra, Caudillo, Goytia et al., 2018). Historical segregation patterns and discriminatory housing policies have confined marginalized communities to specific neighborhoods (Pacione, 2005b). These areas are often located far from the inner city and suffer from disinvestment, leading to a cycle of deprivation. While transportation systems alone cannot eliminate poverty, they play a crucial role in creating the conditions necessary for individuals to improve their economic and social circumstances.

Changes in transportation systems can have mixed impacts, potentially benefiting some groups more than others and disadvantaging marginalized groups. Transport planners often modify the infrastructure or service of the transport systems to adapt it to the travel demands. However, numerous studies have shown that transportation projects —whether they are changing bus routes, expanding roads, or constructing metro lines— can lead to unforeseen effects that negatively impact systematically disadvantaged groups.

A first example to illustrate this statement is the changes in accessibility levels experienced by different socioeconomic groups after modifications in the bus network. Research done by Pereira et al. (2019) estimated accessibility changes in Rio de Janeiro before and after the transport network changed due to the 2014 World Cup and the 2016 Olympic Games. They identified that wealthier areas had small but significantly higher gains in accessibility to jobs and schools compared to the poorer areas.

A second example is the change in property values and the sociodemographic composition at the neighborhood level after the development of rail stations. A study by Forouhar & van Lierop (2021) in the Rotterdam–The Hague metropolitan area of the Netherlands analyzing how implementing new commuter rail stations affected residential property values revealed mixed effects. On the one hand, results showed that railway stations negatively affect property values when located at a distance equal to or less than 400 meters, probably because of negative externalities, such as noise. This effect is accompanied by a significant increase in population density and the number of immigrants residing in the neighborhoods nearby. On the other hand, properties located within a radius of 400 to 800 meters increased their values, most likely because they still enjoy the transportation benefits but with fewer negative externalities. This research suggests that the benefits and costs of the rail station development were different depending on the location of the properties, which, as discussed before, is also related to the socioeconomic groups.

Moreover, it has also been observed that there is a disproportionate distribution among socioeconomic groups of the costs associated with transportation. Iglesias et al. (2019) quantify the costs and benefits associated with urban transport, such as pollution generated, energy consumed, number of traffic accidents, investment in infrastructure, and resources spent on transport by different users, and analyze the distribution of these costs in each socioeconomic quintile. Their results show that the wealthiest quintiles consume seven times more energy than the lowest quintiles and are responsible for 35.5% of the pollutant emissions. Besides, although affluent households have a high monetary cost from buying a private vehicle and paying for gasoline and parking lots, this represents a smaller proportion of their income. On top of that, the aggregated social cost generated from car usage is disproportionate compared to its actual use. Despite the fact that only 1 in 4 trips in Latin America are made by car, the negative social impacts, such as pollution, traffic accidents, or traffic congestion, are significantly higher than the monetary costs alone would suggest.

The implementation of transport projects is never isolated and constantly interacts with other elements of the urban system. Transport systems provide a service that is often considered a 'common good' or a 'club good.' Providing this good enables accessibility, which can also be seen as a primary good. Nevertheless, the distribution of these two goods can be different among societal groups and across space. Likewise, because transport systems are embedded in an entire urban system, they can derive benefits and costs for the economy, the environment, people, and land use (see diagram in Figure 2.1).

For this reason, evaluating transportation developments before and after they are implemented is essential. This approach provides decision-makers with valuable information about the outcomes of specific transport interventions. The more knowledge planners have related to the impacts of car-oriented infrastructure development, the more evidence is available to support informed decision-making processes.

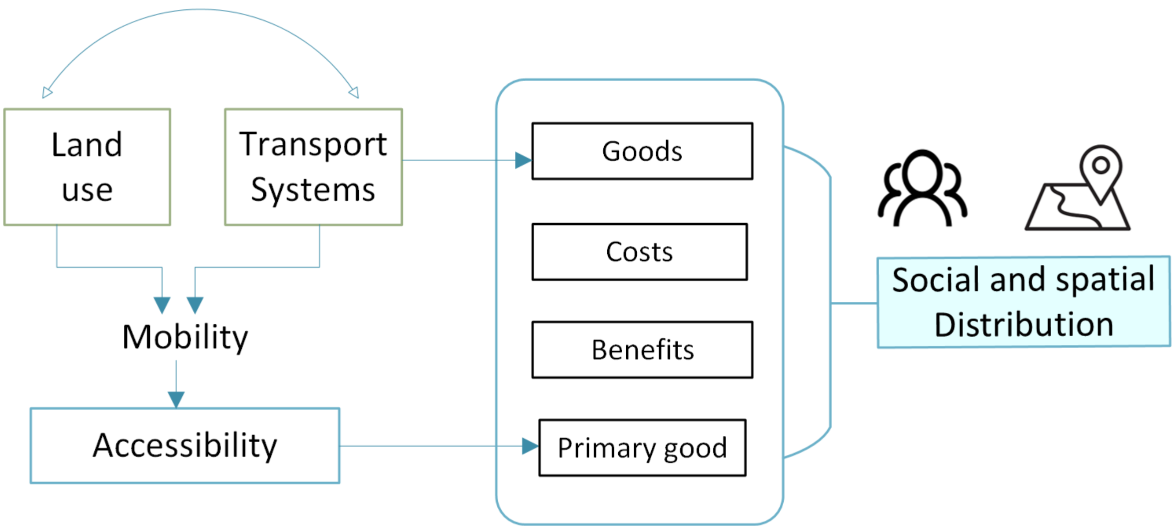


Figure 2.1. Theoretical framework

2.3. Transport project evaluation

Transport project evaluation entails a complex process of measuring the costs and benefits of different project alternatives and determining their levels of desirability. In this sense, as Michael D. Meyer & Eric J. Miller (2001a) propose:

> Evaluation thus provides information to decision-makers on the estimated impacts, trade-offs, and major areas of uncertainty associated with the analysis of alternatives. Not only does the magnitude of the impact have to be determined, but those who are positively or negatively affected should also be identified. (p. 484)

From its origins, the purpose of transport project evaluation has been to assess transportation projects' planning, implementation, and outcomes to ensure they meet their objectives effectively and efficiently. With time, there has been a change in how these processes define how value is measured. Initially, project evaluation was based on maximizing the return on investment, but in the second half of the 20th century, transportation planners started to pay attention to effects that would not be easily measured in terms of money, such as the value of time, air pollution, noise or traffic accidents.

As a result, evaluation processes started broadening the notion of effectiveness and including ways to assign monetary values to these variables. For instance, in the case of a traffic accident, if there is a victim who is unable to work, the future earnings of the victim are quantified (Michael D. Meyer & Eric J. Miller, 2001a). However, different methods have been developed to make evaluation processes more sensitive to changes in variables that cannot be easily quantified, such as social costs, or to assess distributional impacts (Petruccelli, 2015). Consequently, commonly used approaches like cost-benefit analysis (CBA), which focuses on monetizing all costs and benefits and aggregating them at a macro level, are now considered suboptimal.

The CBA has been one of the most widely used ex-ante appraisal methods in transportation planning. Despite its popularity, researchers frequently highlight significant limitations of this technique. One common drawback is the inaccuracy in calculating costs and benefits. Assigning values to variables like traffic time, pollution, or accidents is complex and often not precise. Additionally, there is uncertainty in travel demand forecasts. Even when experts manage to standardize and quantify these variables, the resulting costs are usually inaccurate or overly optimistic (Salling & Leleur, 2015).

Moreover, for road projects, the CBA approach often omits the induced demand effect. Induced demand in the context of transport planning refers to the phenomenon where increasing road capacity generates more traffic than before the expansion occurred. As Naess et al. (2012) explain, this effect should be incorporated into CBAs for road projects to ensure more accurate traffic forecasts. Otherwise, actual travel demand can exceed the forecasts, resulting in increased congestion and negating the main expected benefit of reduced travel times.

The evaluation of transport projects can be done by combining different methods. For example, traffic forecasting models, regressions, and statistical analysis can be complemented, but qualitative approaches, such as interviews or focus groups, can also provide useful information about social variables that are not easy to measure (Michael D. Meyer & Eric J. Miller, 2001a). It is worth mentioning that some methods are more suitable for the predictive phase (before the implementation), and others are more appropriate for the evaluative phase (after the implementation). If an impact evaluation is not designed since the beginning of the transport intervention, later, it becomes complicated to measure the effectiveness of the project, and the method options become limited.

More and more researchers and planners are using accessibility analysis as an appraisal method for various transport projects, such as modifications to public transit (Forouhar & van Lierop, 2021; Pereira et al., 2019) and roads (Sahitya & Prasad, 2020). Although accessibility analysis can be applied to different trip purposes, this type of analysis is frequently performed with data related to work trip opportunities (Bhat et al., 2000; Hu, 2015; Marwal & Silva, 2022). Accessibility to healthcare facilities, such as hospitals or clinics (Cabrera-Barona et al., 2017; Hernandez & Rossel, 2015), together with access to education facilities, are also frequently studied (Sanderson Edwards, 2022; Urban institute, 2017). There are also studies related to recreational facilities (Price et al., 2023), such as parks and sports facilities, but they are less frequent.

One of the main reasons why researchers are incorporating accessibility analysis in the evaluation process is that it provides a broader perspective on the effects of a transport project (Marwal & Silva, 2022). The techniques that focus solely on travel time savings, such as the CBA, assume that every user will benefit equally, overlooking the fact that the distribution of these benefits varies in scale and mode (Wang & Levinson, 2023). While mobility may indeed improve due to reductions in travel times, these gains do not always translate into improved accessibility for everyone. By focusing on accessibility rather than travel time savings and increased mobility, disparities across different populations can be identified.

There are three main groups of measures used in accessibility analysis. The first one, called infrastructure-based measures, focuses on the availability and performance of transport infrastructure, such as how good the coverage of a bus route is. The second group, called location-based measures, analyzes the accessibility of a specific location (e.g., home) to various destinations (e.g., schools or parks) based on the distance between these two points. The third group, called person-based measures, takes into account the individual characteristics of transport users (e.g., income, gender, education level) that may either facilitate or hinder their accessibility (Marwal & Silva, 2022).

A comprehensive accessibility measure should integrate four components that constantly interact with each other: transport, land use, and temporal and individual aspects. The land use component refers to the spatial distribution of activities within a city; for instance, some cities have proximity between residential and commercial areas, whereas in other cities, the distances are greater. The transport component examines changes in transportation systems and their impacts on the disutility of an individual when traveling. The temporal component addresses time constraints that affect access to opportunities, such as differences in the operating hours of shops and work schedules. Lastly, the individual component takes into account personal characteristics, such as age or gender, which can influence individual mobility needs (Geurs & van Wee, 2004).

In theory, an ideal accessibility measure would be sensitive to all four components. However, in practice, creating an indicator that successfully incorporates all these factors is challenging, and adjustments must be made based on data availability and research focus. Location-based measures can effectively help evaluate a transport project by considering the four components if detailed data is available. Otherwise, the analysis must remain simplified and consider only some of the four components.

A simple indicator from the location-based group that is commonly used is the 'contour-based measure.' This indicator counts the total number of opportunities that can be reached within a given time or distance threshold. It is easy to compute and interpret but has a few theoretical limitations. Two of these limitations are that it counts all reachable opportunities within an arbitrarily chosen threshold and assumes that all these opportunities are equally desirable. This means that if the threshold changes and individual preferences are considered, the accessibility result will likely differ (Bhat et al., 2000; Geurs & van Wee, 2004).

Another location-based indicator is the 'gravity-based measure.' This approach operates on the principle that closer points have more attraction, and the attractiveness of a location decreases with increasing travel time or distance. While this measure has more data and methodological requirements, it can successfully integrate the four components (Geurs & Van Wee, 2004). It includes the transport component by considering the travel cost between locations, often using a decay function to model the real costs. The land use component is included when considering the availability and attractiveness of the destinations (e.g., the spatial distribution of parks). The temporal component is included when the accessibility estimation is done for a specific time or day (e.g., peak hours). Finally, the individual component can be incorporated if variations in travel preferences, socioeconomic status, or mobility constraints are included in the model.

In summary, the evaluation of transportation projects has undergone significant changes over time. While these changes have helped to broaden the view of when a transportation project can be considered profitable and beneficial to society, they have also made it clear that it is now necessary to apply different methods to obtain a more comprehensive and accurate evaluation. Some qualitative methods, such as interviews or focus groups, can provide relevant information about the impacts of specific transport policies.

Other methods, such as accessibility analysis, can provide information not only about social costs that are usually difficult to measure but also about how they are distributed in space and among society. Although these studies are increasing, it is relevant to explore how accessibility indicators behave when the analysis is done for activities other than work trips, for example, leisure trips. While work trips are one of the main reasons for travel, these types of trips are mandatory trips, while leisure trips are not (Jara-Díaz & Contreras, 2024). Since people have different marginal utilities for work and leisure, travel patterns may behave differently in each context (Shkera & Patankar, 2024).

3. RESEARCH DESIGN

The research design for this study encompasses a mixed-method approach aimed at comprehensively understanding the socio-spatial effects of a car-oriented intervention in Aguascalientes. Together with the use of secondary sources that provided contextual insights, primary data was collected through fieldwork. Furthermore, this study incorporates both descriptive analysis techniques to elucidate key trends and patterns, as well as an accessibility analysis that simulates a scenario without transport intervention and one after the intervention.

3.1. Case study

Located in the center of Mexico (Map 3.1), Aguascalientes is one of the 32 states that has experienced significant economic growth in recent years. By the fourth quarter of 2023, Aguascalientes ranked second in economic growth at the national level, with a growth rate of 6.9%, surpassing the national target by 2.4 percentage points (México Cómo Vamos (MCV), 2024). In addition to its economic achievements, Aguascalientes has excelled in social progress. The state's Social Progress Index, which is a holistic measure of social progress independent of economic factors, has consistently ranked among the top five in the country over the past decade. In 2022, Aguascalientes achieved the second-highest ranking in social progress (MCV, 2023).

This economic dynamism and positive performance have brought prosperity to the city but also some challenges, especially in terms of mobility. There was a significant increase in population and a rapid and low-dense city expansion. Nowadays, the state has 1 million and 425 thousand inhabitants, from which 948 thousand reside in the capital municipality, Aguascalientes. Additionally, from 2011 to 2020, the urban sprawl grew a total of 21,248.8 hectares, of which 49% are located outside the third ring (CMOV, 2021). This growth has generated increasingly distant commuting and a higher travel demand. Consequently, traffic congestion has gradually increased.

Map 3.1. Aguascalientes' location with respect to Mexico

As a response to the changes in travel demand, the urban planners of Aguascalientes organized the city's road network primarily through three peripheral rings and two transverse corridors. The mobility strategy for several years to cope with the traffic congestion and the travel demand has been to enable a continuous flow of traffic in these main arteries and invest in car-oriented developments around the city, such as vehicular bridges and overpasses (H. Ayuntamiento de Aguascalientes, 2019). A major transportation project recently implemented in the city is the construction of a continuous flow system on Aguascalientes Avenue, commonly known as the Second Ring. This project, led by state authorities, involved constructing eleven vehicular bridges and overpasses along the Second Ring between 2017 and 2022.

The main argument for this project was that improving traffic flow through the city would reduce travel times and, consequently, lower the operating costs for various types of vehicles. The specialists in charge also claimed that this project would offer greater comfort and safety to road users, decrease the likelihood of accidents, improve service levels, and reduce environmental and noise pollution. These arguments were based on the cost-benefit analyses conducted for each bridge (Ingeniería Aplicada Mexicana, 2019). However, the available documentation indicates that these analyses were based solely on economic feasibility. The proposed alternatives are exclusively car-based solutions, and the only social cost they consider is the social discount rate. Moreover, in the risk analysis, they only considered risks associated with resource availability and project delivery delays.

As the continuous flow project progressed, authorities claimed that the entire city could be navigated in 20 minutes (Giovanni Góngora, 2022; La Jornada, 2021), which indicates an increase in travel speeds. However, critics and community members began to notice an increase in traffic accidents and speeding violations on the second ring. Some estimations suggest a 15% increase in traffic accidents in certain zones in the second ring (Mónica Cerbón, 2022). Therefore, three things remain unclear: First, apart from increased travel speeds, which of the listed objectives were achieved, and how are they being monitored? Second, what is the distribution of the intervention's benefits? Did all inhabitants of Aguascalientes benefit the same? Third, did the continuous flow project have additional positive or negative effects that were not considered during the planning stage?

With these questions in mind, the transport intervention of constructing a continuous flow in the second ring represents a good case study. It illustrates that when transportation projects are based on analyses that are not entirely accurate or are oversimplified, unforeseen effects, both positive and negative, can emerge. Research has already proved that CBA is a suboptimal technique for evaluating the appropriateness of transport projects, often leading to unforeseen costs and benefits (Naess et al., 2012). Hence, as Salling and Leleur (2015)suggest, due to the frequent inaccuracies in this type of analysis, it is advisable to also conduct either an ex-post CBA or another type of evaluation.

This thesis represents the effort to asses one of the major transport interventions developed in recent years in Aguascalientes. As the need to adapt our transportation systems to more sustainable models becomes more urgent, analyzing the effects of the continuous flow project can provide valuable evidence to support future decision-making processes.

3.2. Methodology overview

This study conducts both a descriptive analysis and an accessibility analysis to address the two research objectives. The aim is to evaluate the impacts of the continuous flow project and examine how they are distributed spatially and socially. Since the continuous flow was executed between 2017 and 2022, it would be ideal to have data regarding the mobility patterns in Aguascalientes before and after its implementation. This way, it would be easier to study the changes and identify clear explanations for the observed changes. The 2020 national census provides limited mobility data, such as vehicle ownership, aggregated travel times, and modes of transportation, and these last two are only for work and school motives. More detailed information was needed to model the conditions of the transport system before and after the continuous flow project. Therefore, this study was carried out using secondary sources and primary data. Figure 3.1 shows an overview of the steps followed.

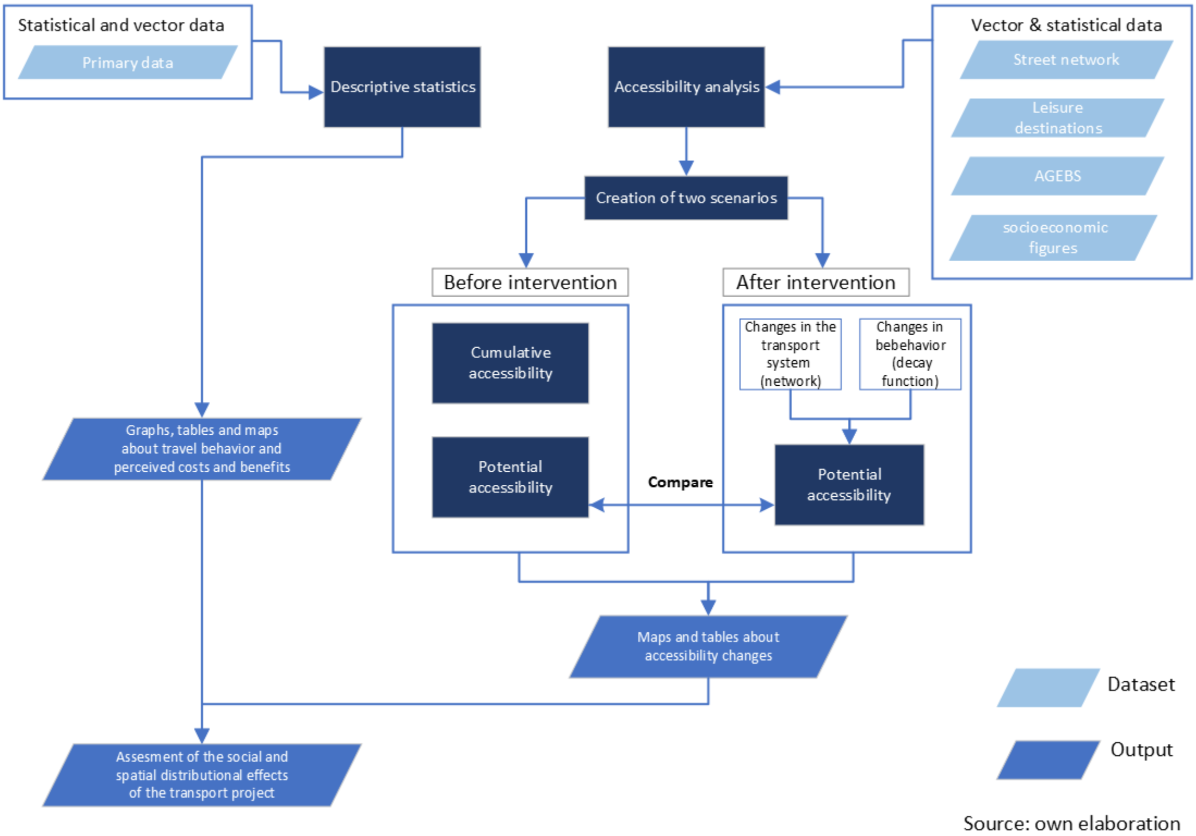


Figure 3.1. Methodology overview

3.3. Data description

3.3.1. Primary data

Fieldwork was conducted in February 2024 to acquire new and more detailed data about the mobility patterns in Aguascalientes. The main instrument designed for the data collection was a survey consisting of 54 questions. The aim was to gather information on five main topics related to transportation use: socioeconomic characteristics, trip generation, perception of urban transformation, individual travel preferences, and changes in traveled distances over time. The tool for data collection was KoBo Toolbox. Some of the questions were asked for two moments in time, five years ago (2019) and nowadays (2024), trying to capture time variations. It was considered to ask for travel patterns in 2017 (the year when the first bridge was constructed), but it was concluded that if the period became too long, it would be complicated for participants to recall their travel patterns. So, the time variations in the survey are only considered to be five years. Besides, even though the construction of the first bridge started in 2017, the effects would not appear immediately.

Another aim was to collect data from inhabitants by surveying the streets. During the survey design, the data minimization principle was considered to avoid asking for unnecessary information, especially if it was personal information. However, the survey included personal questions, such as age, gender, income, and the partial home address. Hence, it was necessary to undergo an Ethics review through the Geo Ethics committee, where they advised on aspects regarding the protection and treatment of personal data, potential impacts of the research, and the adequate data collection procedure to ensure it was safe and ethical.

Considering that one of the objectives of this thesis is to assess changes in the mobility dynamics, costs, and benefits, two crucial aspects were addressed in the design phase. Firstly, individuals frequently relocate their residence over time, and secondly, even if their residence remains unchanged, their primary trip destinations, such as for work or school, may vary. Hence, the survey was designed in such a way that it was possible to control these two aspects. On the one hand, the analysis focuses on trips to leisure destinations. People are likely to change jobs, or companies and offices might relocate. In contrast, major leisure facilities such as shopping malls, parks, and cinemas are less likely to relocate within five years. Consequently, the survey included questions related to the trips to leisure destinations. On the other hand, people were asked about changes in their home location. Later in the analysis stage, this information will facilitate filtering data to exclude people who changed their address.

A pilot process started once the survey and fieldwork collection were approved. The testing stage was performed online and in person. On January 31st, the survey was shared online with relatives and friends to get a first round of comments, and then, on February 1st, the survey was applied to participants in the street. After that, the data collection process lasted fourteen days.

Testing the instrument helped to identify and sort out three main aspects. First, some questions had to be deleted or adapted to improve readability and reduce answering time. Second, one part of the survey included questions with multiple answers about the reasons why people do not use certain travel modes. The pilot helped to adjust these reasons to cover the most significant factors that influence the decision of the user. For instance, one reason that was not included in the beginning was "I do not like it." However, during the pilot, participants constantly responded that they do not like to walk or bike, which might not seem very informative, but it gives an idea of the mobility culture. So, this answer was included afterward. Third, travel times and costs are some of the most important questions, but they are also tricky to calculate. Participants tended to round the figures (e.g., 10 or 15 minutes) or not remember them accurately, and respondents who traveled by car struggled to estimate the travel cost given that they had to consider the car's energy efficiency. So, a travel card with average costs and times based on a trip of 5km was developed and used during the survey application (see Appendix 4).

Ideally, a random sampling technique should be applied to have a representative sample. However, there are time and resource constraints when fieldwork is conducted for an MSc thesis. Because of this, applying such sampling methods is difficult, especially considering that Aguascalientes has 948,990 inhabitants. Given these constraints, the sampling method was not designed to have a representative group but to have a diverse, extensive, and balanced group as much as possible.

Thus, the approach consisted of conducting surveys in the streets. Data collection points were spread around the city and covered zones with different income levels (for more details about the data collection points, refer to Annex 2). Neutral points in terms of income, such as the city center, were also covered. Other aspects considered were diversity in the age and gender of the respondents, as well as diversity in the activities that participants were performing at the moment of being interviewed. For example, among the respondents, some people were walking, shopping, studying, waiting for the bus, looking for their car in the parking lot, working or sitting on a bench, and just waiting.

The information gathered from fieldwork made it possible to capture different individual characteristics, such as income and transportation resources, as well as changes in willingness, preferences, and frequencies of commuting by different transport modes. It also helped to identify infrastructure levels for each transport mode, highlighting that there is an unequal public investment, as well as to document changes in the built environment, costs and benefits for inhabitants, and changes in traveled distances to access recreational opportunities. Additionally, qualitative information on individual preferences was obtained not only through the survey but also through the data collection process.

3.3.2. Secondary data

Additional statistical and vector data was needed to perform an accessibility analysis. The main source of statistical information in Mexico is the INEGI, the National Bureau of Statistics and Geographic Information, which has a tremendous amount of useful and good-quality data. The National Geostatistical Framework designed by INEGI to correctly georeference geostatistical information is disaggregated into three main spatial units: state, municipal, and basic. The basic units are divided into urban basic areas and rural basic areas (see Figure 3.2). The spatial unit of analysis of this study is urban AGEB, which is defined as:

> A geographic area made up of a set of blocks that generally ranges from 1 to 50 and that is delimited by streets, avenues, walkways, or any other features that are easy to identify in the countryside and whose land use is mainly residential, industrial, services, commercial, etc. They are only assigned to the interior of urban locations (INEGI, 2019, p 5).

This analysis only takes the 332 urban AGEBs that are located within the municipality of Aguascalientes. It is relevant to highlight that an AGEB is smaller than a zip code but bigger than a block. Since AGEBs are not used for daily purposes —different from a zip code— they are not a code that inhabitants would commonly know.

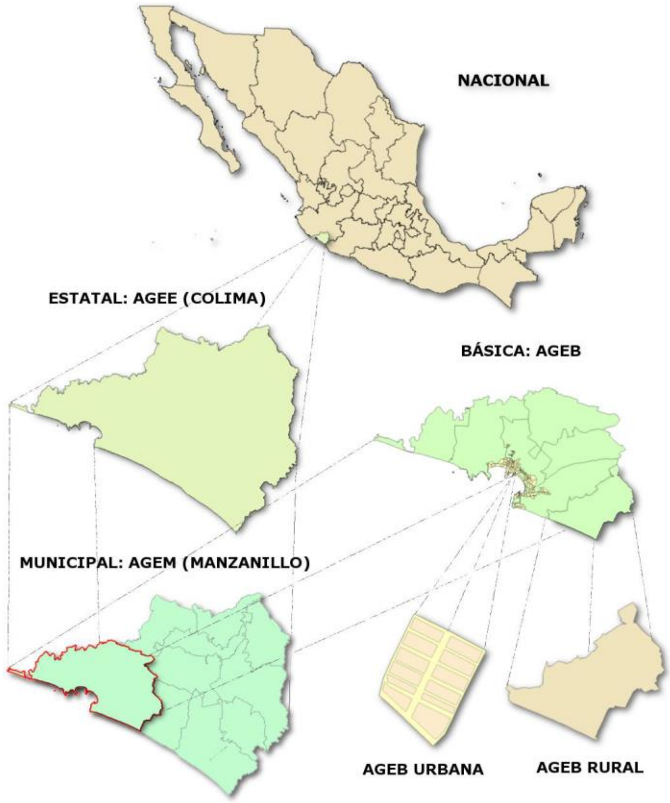
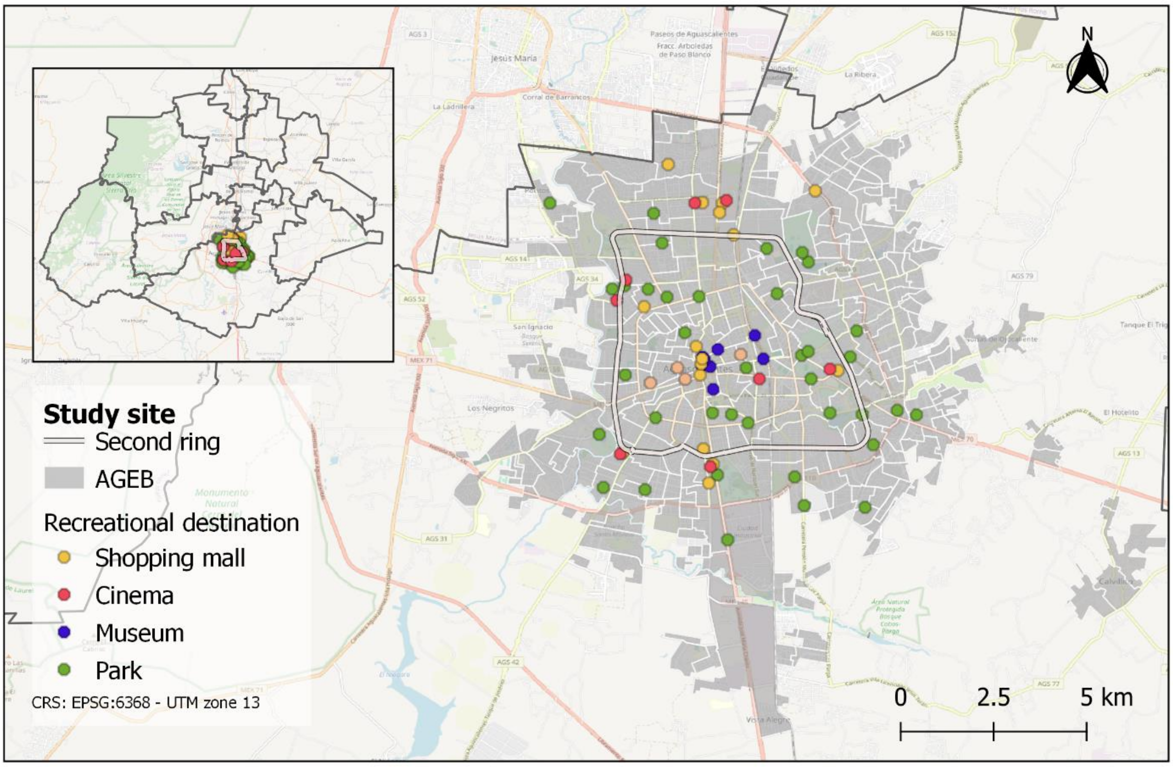


Figure 3.2. Disaggregation levels of geographic information in Mexico. Source, INEGI 2019

The 2020 national census has a significant amount of data disaggregated at the AGEB level. Hence, this dataset was used as a secondary source to extract socioeconomic variables such as education level and total population. However, the data for transport- and mobility-related information is limited. Such information is available in the results of the expanded questionnaire of the 2020 census, which corresponds to a representative sample of inhabited private homes and their occupants. Consequently, this dataset is smaller than the results from the basic questionnaire of the census. Variables available related to the transportation theme only include travel times and transport modes for trips to work and school.

INEGI also has a catalog of economic units called DENUE (National Statistical Directory of Economic Units). This catalog provides information about the identification, location, economic activity, size, and years of operation of more than 5 million economic units. In total, 73 recreational facilities were extracted from this catalog, including parks, shopping malls, museums, and cinemas that existed before 2019 and are still active. Map 3.2 displays the study site and the leisure destinations.

The street network was the last secondary dataset used. INEGI also provides this dataset; however, during the analysis, some gaps in the network were found. Because of this, the street network was extracted from Open Street Maps. Some attributes had to be corrected due to inaccuracies or missing information. For example, the maximum travel speed for cars was not complete, and the road class was changed in a few cases. The missing speeds were filled based on the methodology of the national road network (INEGI, 2017). However, other attributes, such as the direction of the streets, were not completed.



Map 3.2. Study site

3.4. The descriptive approach

Primary data was used to conduct a descriptive analysis with three goals in mind. The first one was to get an idea of the current travel demand. For this purpose, data was plotted to have an idea of the travel demand, the modal split, and the vehicle ownership. The second one was to contrast the frequencies of transport use five years ago with today's frequencies to identify behavior changes in inhabitants. Hence, data was organized in a matrix that could show some changes in travel behavior by identifying variations in transport use.

The final goal was to dig into inhabitants' perceptions in relation to two aspects. The fist aspect was about how they move in the city, especially regarding recreational trips. The second aspect was about their perceptions regarding some aspects that have changed in the city during the last five years, such as traffic congestion, ease of travel, transportation costs, and the public transport infrastructure implemented in the city. So, the variables indicating their traveled distances to leisure destinations were compared, and a change rate was calculated in relation to the total sample of individuals who did not change address and in relation to specific groups. Also, the perceived increases in infrastructure were mapped, and their mean was calculated to determine if the infrastructure for other transport modes different from cars has increased in similar proportions. With this information, it is possible to have an idea of the general travel behavior and some benefits and costs that people experience when traveling.

3.5. The accessibility approach

Literature shows that more researchers and planners are employing accessibility analysis as a method to appraise transport projects. This approach allows for the evaluation of the effects of transport changes by considering their interaction with land use. Therefore, to understand some of the implications of the transport intervention in the second ring, accessibility was measured in two scenarios: before the intervention (2019) and after the intervention (2024). For the ex-ante scenario, two accessibility indicators are calculated: contour and gravity-based. For the ex-post scenario, only the gravity-based indicator is calculated. After that, there is a comparison between the gravity-based measures of both scenarios and an estimation of the accessibility distribution accounting for socioeconomic variables.

3.5.1. Contour-based accessibility

Contour-based accessibility is a location-based measure, meaning it evaluates the accessibility from specific points within a region. This indicator counts the total number of opportunities that can be reached, given a threshold of time or distance. The formula used for contour-based accessibility to recreational facilities is described as follows (Bhat et al., 2000) :

$$A_t = \sum_t O_t$$

Where t is the threshold and O_t represents the recreational destination within the chosen threshold. For this study, the threshold value was 20 minutes. This cutoff was picked based on the average travel times reported in the 2020 census. The average travel time of people who go to work is 18 minutes by foot and 27 minutes by car.

3.5.2. Gravity-based accessibility

Changes in accessibility levels to leisure destinations before and after the transport intervention were obtained by modeling two scenarios that assume the following aspects:

1. Firs assumption: Travel speeds for cars have increased in the present with respect to the past due to the increase in car infrastructure.
2. Second assumption: There are more barriers for pedestrians in the present than in the past due to the increase in car infrastructure.
3. Third assumption: There are changes in the ease and likelihood of accessing a leisure destination with respect to the past due to a modification in the travel behavior of road users.

The first two points are modeled by changing attributes in the network dataset. For instance, maximum speeds along the second ring increased from 60km to 70km/h, without considering traffic congestion. The walking speed for pedestrians was reduced from 5km/h to 4.5km/h or 4km/h when they needed to take a pedestrian bridge. They were also prohibited from walking in some street links along the second ring.

Point number three was modeled using two different decay functions that reflect the travel behavior of people in the past and the present. A decay function is used to represent the travel costs of an individual and how the probabilities of undertaking a trip reduce as the cost increases. Thus, modeling the impedance with a decay function before and after the intervention could tell what the changes in the ease and likelihood of accessing a leisure destination are.

An impedance function is one of the basic components to estimate a gravity-based indicator, given that this approach operates on the principle that closer points have more attraction, and the attractiveness of a location decreases with increasing travel time or distance. Thus, the next step after counting all the opportunities accessible from a given origin is to multiply the number of opportunities by the actual probability of a person making that trip. The formula used for contour-based accessibility to recreational facilities is described as follows:

$$A_i = \sum_{j=1}^{n} D_j * f(C_{ij})$$

Where D_j represents all the destinations or opportunities and $f(C_{ij})$ represents the impedance function.

Travel data about the base scenario can only be found in the 2020 census for travel motives related to work and school. Therefore, it was decided that, although the study analyzes accessibility to leisure destinations, the travel motive of both decay functions would be work trips to be able to compare the results. After testing different functions, the log-logistic function had the best fit in both scenarios.

4. DESCRIPTIVE ANALYSIS

During fieldwork, 364 surveys were collected. From this dataset, two subsets were created: the first subset included all records, and the second subset was filtered to include only respondents who did not change their address during the analysis period (see Table 4.1). For the first subset, four records from individuals living outside the state were removed. However, ten records from individuals who lived outside the state in 2019 but have resided in Aguascalientes for at least three years, as well as 35 records from individuals living in another municipality, were retained. These records were preserved because they provide valuable information about the current trip generation and modal split.

Of the total responses, 240 were from individuals who did not change their home addresses between 2019 and 2024. It was important to separate these responses to match them with the spatial unit of analysis, AGEB (in the next subsection, the spatial unit will be further explained). After excluding responses from individuals who lived outside the municipality of Aguascalientes and those who did not provide an address or correct address details, the sample was reduced to 194 observations. These records can be matched to 125 different AGEBS.

Table 4.1. Original datasets

		Total surveys collected	364
Currently living in another state	4	Currently living in another state	4
		Change of address	124
		Outside of Aguascalientes	41
		Did not provide enough or correct address details	5
Subset 1	**360**	**Subset 2**	**194**

The sample is balanced in terms of gender, as 51% of the respondents were women and 49% were men. However, data is unbalanced in terms of age and income. There is a concentration of respondents who are between 18 and 25 years old; they compose 49% of the sample. In the case of income, the two lower quintiles represent 60% of the sample. Later in the conclusions, it will be important to remember these aspects.

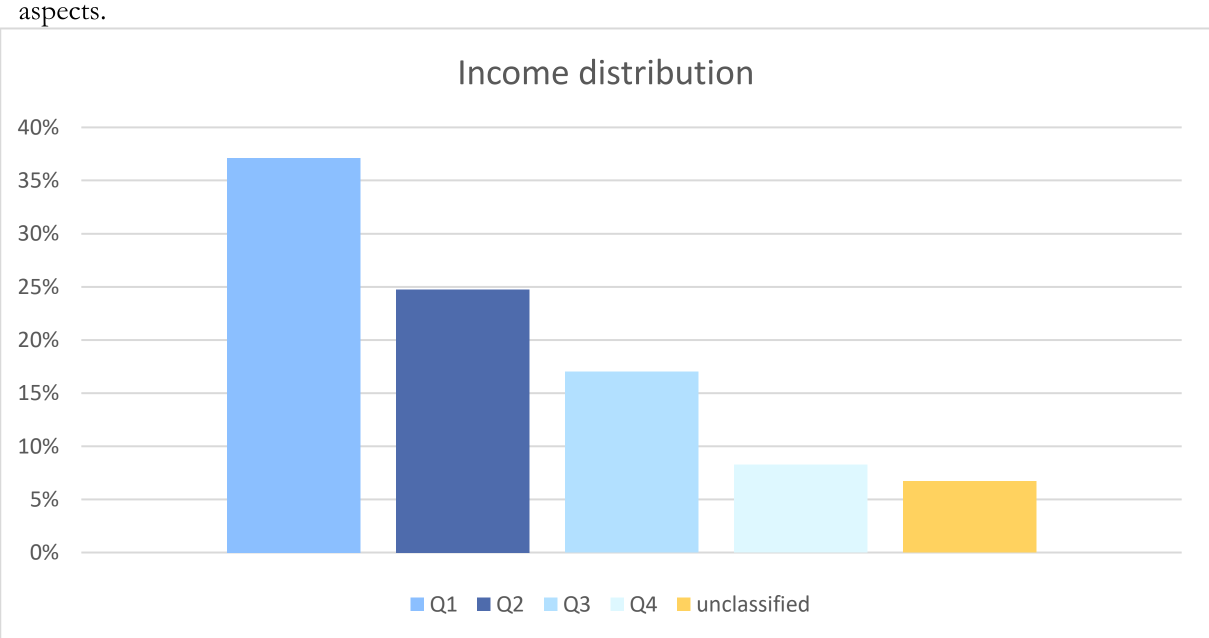


Figure 4.1. Distribution of primary data according to income group

4.1. Overview of the mobility patterns

According to primary data, people travel on average three times per day on a regular Saturday. In the first trip they make, people spend 22 minutes and 28 pesos on average. Respondents were asked about the frequency with which they use different modes of transport. Looking at the modal split in Figure 4.2**Error! Reference source not found.**, respondents revealed that they never travel by motorbike or bicycle. In contrast, when respondents were According to primary data, people travel on average three times per day on a regular Saturday. In the first trip they make, people spend 22 minutes and 28 pesos on average. Respondents were asked about the frequency with which they use different modes of transport. Looking at the modal split in Figure 4.2, respondents revealed that they never travel by motorbike or bicycle. In contrast, when respondents were asked about the modes they always use, the automobile was the most popular choice with 41% of users, followed by public transport (25%) and walking (19%).

When respondents expressed that they used automobiles the most, they were asked why they chose them. Figure 4.3 shows that respondents value the comfort and efficiency that a car can provide. The perception of cars being one of the safest modes also plays a role. It would be interesting to analyze which type of safety the car provides, according to the users. It might be the case that road safety is seen as an issue, but people still perceive cars as being safe as they provide less exposure to crime or robberies. Aspects like making many trips during the day and transporting children also make people more prone to picking the car over other modes of transport. A smaller percentage of respondents consider other transport modes to be bad options for travel and believe that the infrastructure for cars is better than that for other modes. Only a few participants mentioned that the weather is a factor that makes them travel by car.

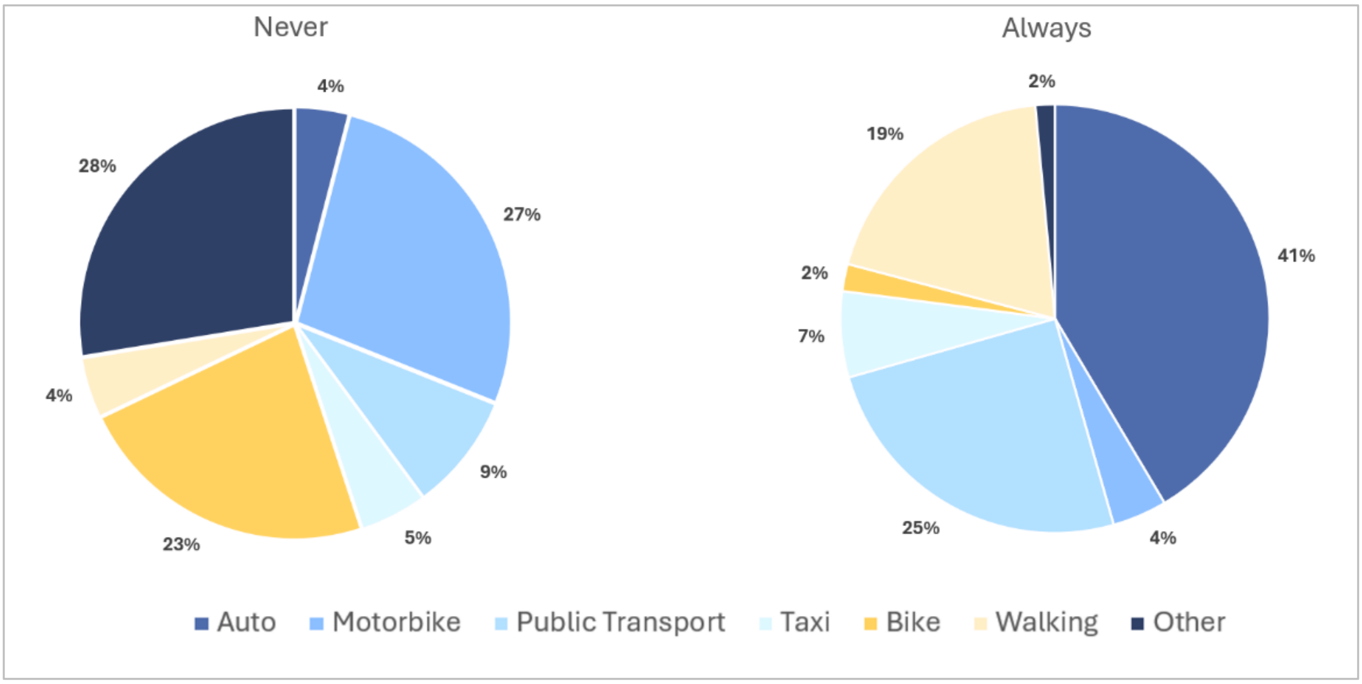


Figure 4.2. Modal split in 2024 based on primary data

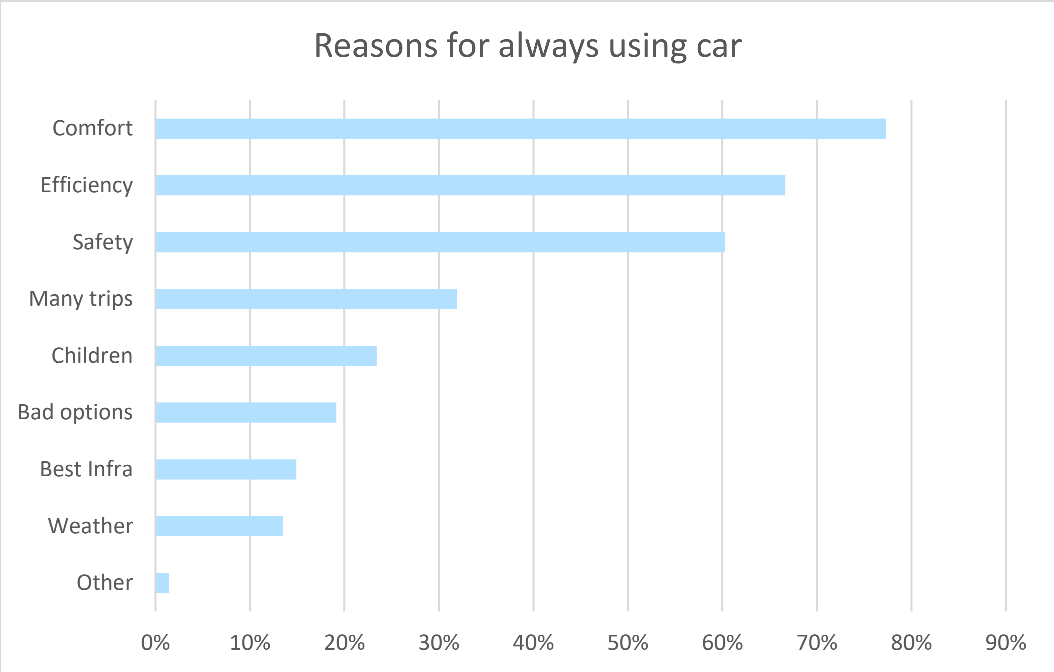


Figure 4.3. Reasons for always using the car in 2024 based on primary data

Given the preference for private cars, it is convenient to look into vehicle ownership to have an idea of the transport endowment that an average person has. Figure 3.1Figure 4.4 reveals that 74% of the sample has at least one car available at home. Few people have a motorbike, consistent with the observed modal split. Although participants responded that they move very little by bike, 45% of the sample has at least one bike at home. This indicates that people use bikes more for recreational trips than everyday functional trips.

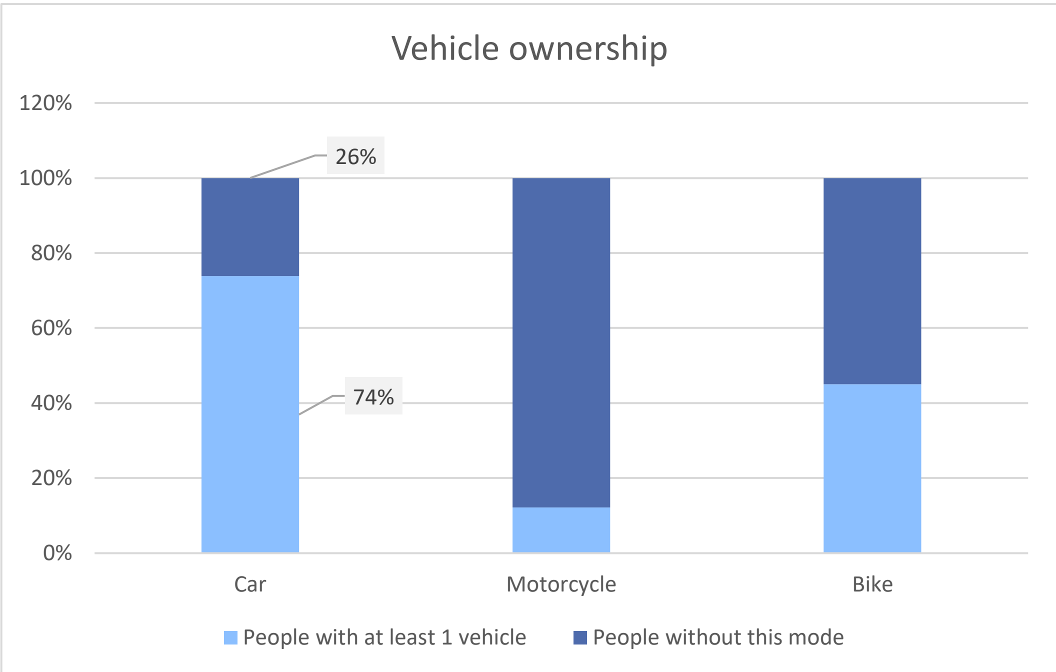


Figure 4.4. Vehicle ownership per household

Typically, there is a positive relationship between income and car usage. The relationship is intuitive as higher income provides greater financial resources to purchase a car. Therefore, it is interesting to break down the information on vehicle ownership by income segment. As Figure 4.1 reveals, the sample obtained in fieldwork is not balanced in terms of income, given that 37% of the sample belongs to the lowest quintile. Notwithstanding this concentration of low-income respondents, only 26% did not have a car (figure 3). By crossing these variables, Figure 4.5 reveals that 36% of low-income participants move by car regardless of their limited resources. People from the highest quintile usually can afford more than one vehicle.

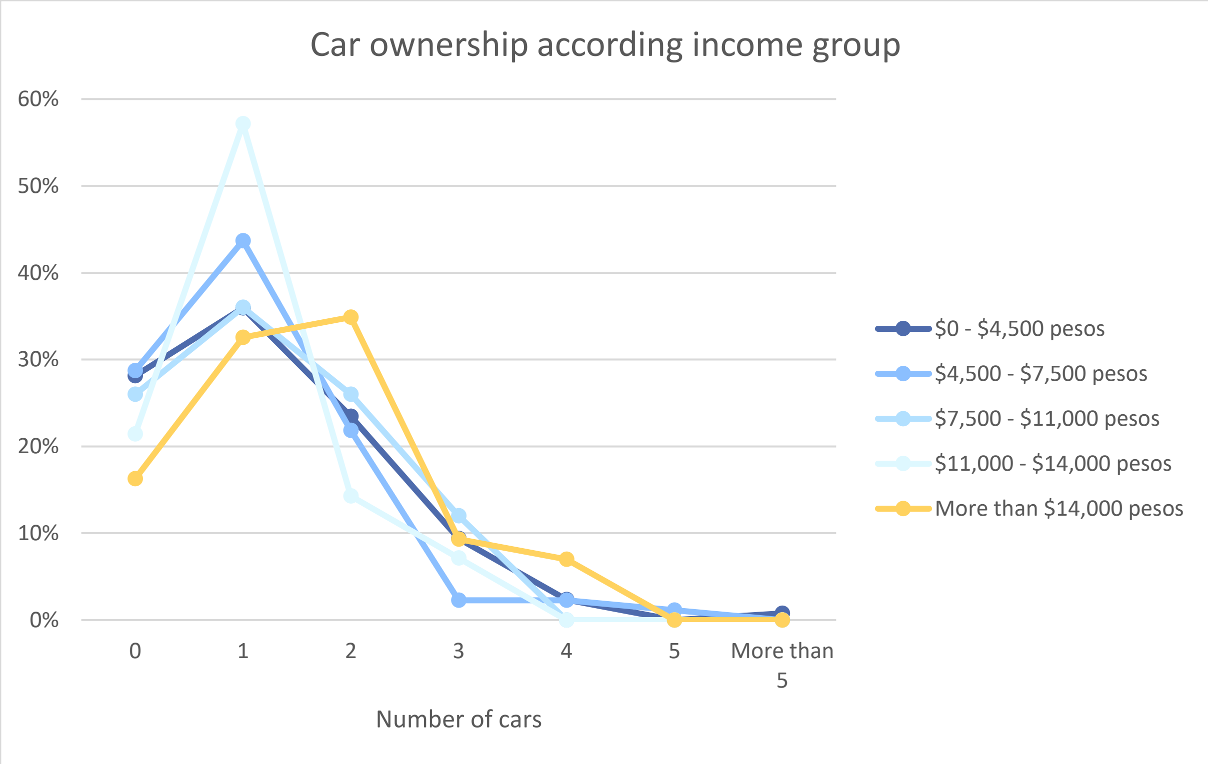


Figure 4.5. Car ownership according to income group

Table 4.2. Changes in transport use between 2019 and 2024

Overall change relative to the total sample						
	Auto	Moto	PT	Taxi	Bike	Walk
Never	-3%	2%	**7%**	-4%	**11%**	**6%**
Almost never	-2%	-1%	5%	1%	-5%	2%
Sometimes	-2%	-1%	-8%	-2%	-3%	1%
Often	0%	-1%	-6%	4%	-2%	-6%
Always	**7%**	1%	3%	1%	-1%	-3%
Change relative to the initial category value						
Never	-24%	2%	**38%**	-21%	16%	**86%**
Almost never	-11%	-8%	41%	5%	-36%	12%
Sometimes	-10%	-50%	-37%	-4%	-25%	3%
Often	0%	-50%	-25%	28%	-57%	-27%
Always	**21%**	100%	11%	22%	-25%	-11%

Primary data was filtered by people who did not change their address between 2019 and 2020. This subset of 194 observations was used to understand changes in people's behavior over time. The following table shows a change matrix (Table 4.2). By asking people how they traveled before and how they travel now, leaving their home locations constant, it was possible to calculate the percentage of respondents who reduced or increased their use of each transport mode.

Overall, there was a decrease in the use of active modes, such as bike and walking, and an increase in the use of cars. It is important to contextualize the changes; therefore, the matrix in Table 4.2 shows the differences in use with the initial value, as well as in relation to the total number of people who did not change address. In both cases, the number of trips by foot was reduced.

Respondents were asked about their perceptions of different aspects of the city to obtain explanations for the changes in transport use and to see the implications of their travel behavior. Figure 4.6 and Figure 4.7 summarize these perceptions. In the graphs of Figure 4.6, it can be seen that respondents either agreed or highly agreed in 89% of the cases with the statement that there is more traffic congestion than five years ago. Notwithstanding this response, 44% of the respondents said they experience more ease of travel compared to the past, and 56% also said they have more access to recreational places.

To explore the distribution of benefits, it was first determined which aspects could be considered as benefits and then examined their distribution among socioeconomic groups. Eight different benefits in terms of mobility were identified based on the trips people make and their perceptions of the built environment: reductions in travel time, reductions in money spent, increased ease of travel, increased access to recreation, and more improvements in the transport infrastructure for different modes. After obtaining the percentage of people who experienced these benefits in each income group, Figure 4.7 **Error! Reference source not found.** shows that middle-income people were the ones who experienced m ore benefits. Neither low-income people nor high-income people particularly benefited in any of the eight cases. Quantile 3, in particular, experienced the highest share of benefits in half of the time.

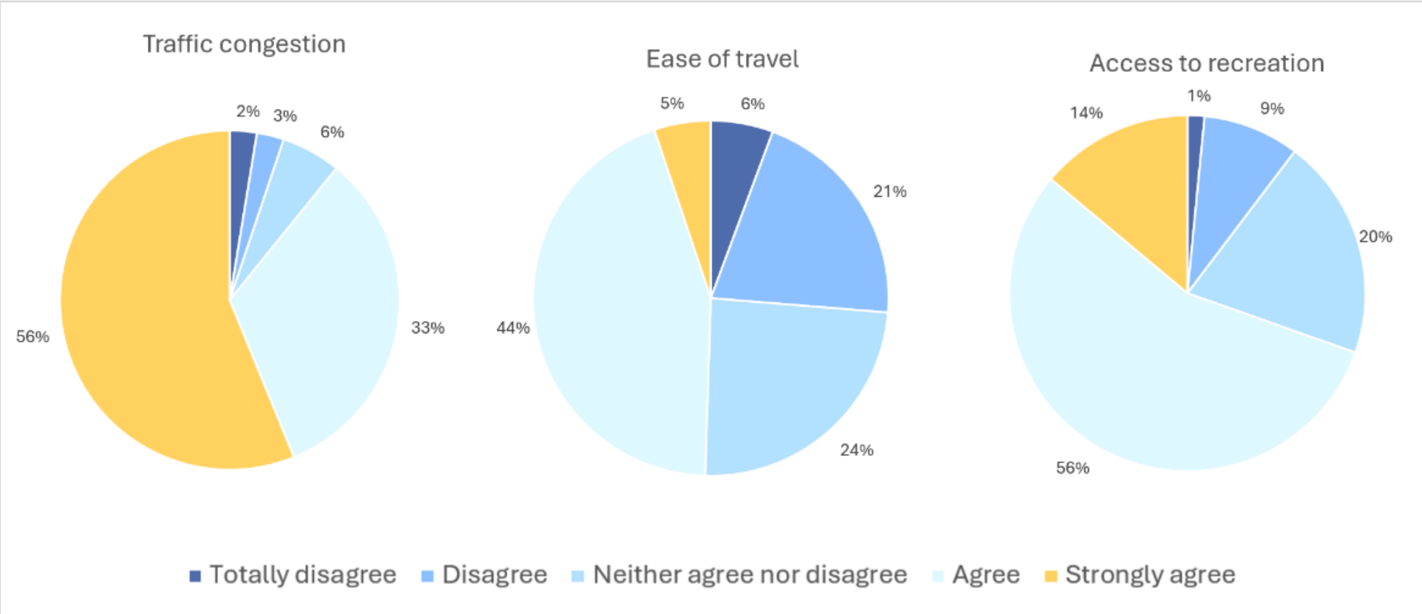


Figure 4.6. Respondents' perception of the increase in congestion, ease of travel, and accessibility between 2019 and 2024

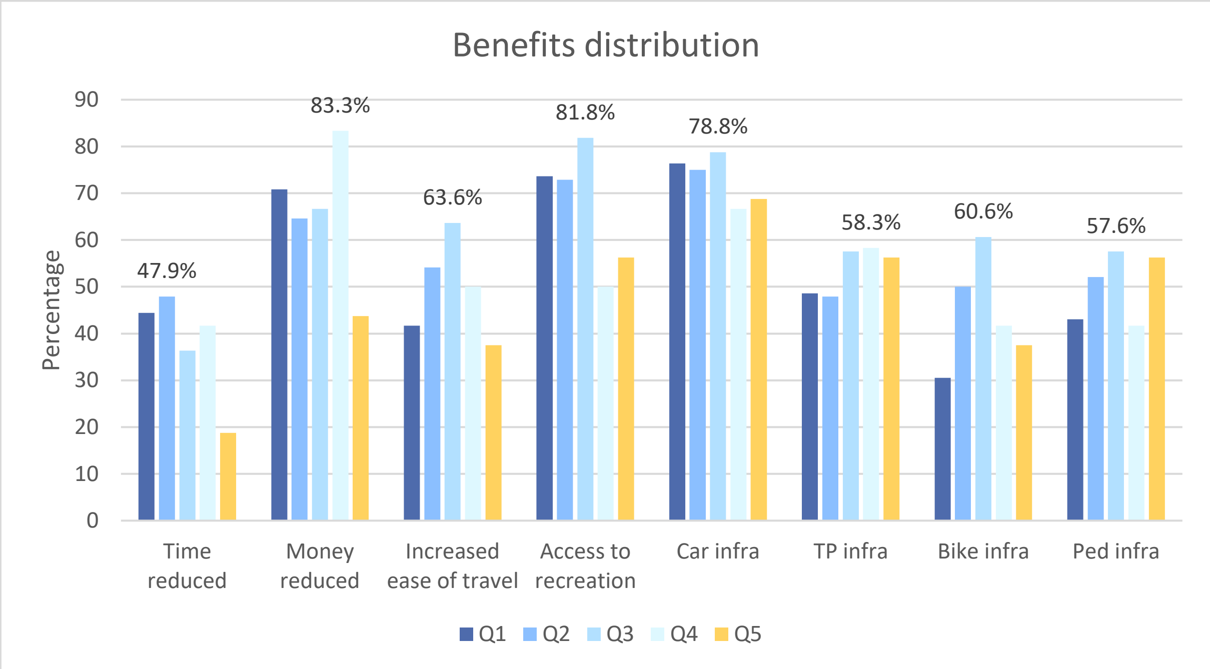


Figure 4.7. Distribution of benefits associated with changes in the transportation system between 2019 and 2024

Inhabitants' behavior also changed regarding the distance they are willing to travel to reach leisure destinations. Participants were asked about the zones where they used to do leisure activities back in 2019 and now in 2024 to have a proxy about changes in traveled distances. Initially, 51 out of 194 people traveled anywhere in the city to reach their preferred activity. Now, this number has increased to 85 people. This change is translated into an 18% increase in relation to the total sample (). However, by looking at the change in relation to the initial value, it can be said that the change had a magnitude of 67%.

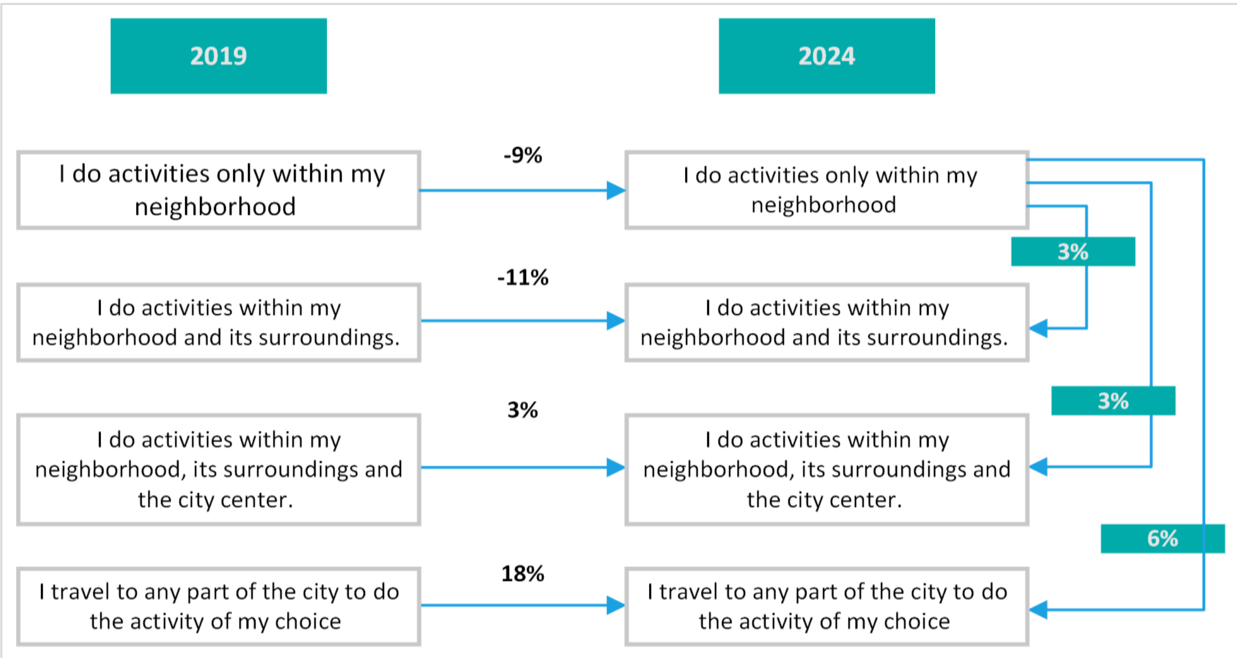
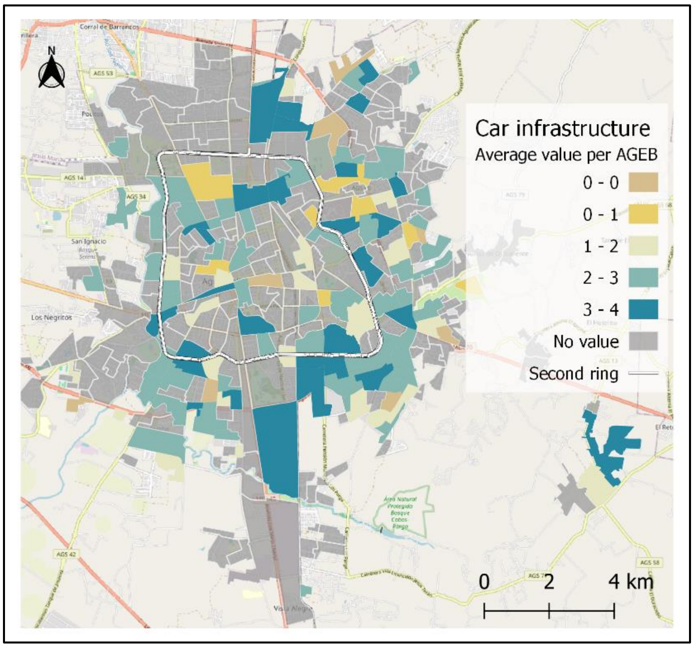


Figure 4.8. Changes in traveled distances to recreational places in relation to the total sample of people who did not change address.

It was essential to know how the built environment has changed over the past few years in Aguascalientes. So, participants were also asked about the changes they perceived in their neighborhoods regarding infrastructure. This way, it is possible to have another insight into why people modified their mobility patterns. The following figures show the distributions of different types of infrastructure according to the respondents. When asked if they had observed increases in infrastructure in their neighborhood and surrounding areas, they could give a value from 0 (totally disagree) to 4 (totally agree).

Overall, people perceive there have been more improvements in car infrastructure, with an average level of 2.74. After cars, respondents observe that public transport is the mode that has experienced more improvements, with an average of 2.25, and then bikes with an average of 2.21. Likewise, according to their perception, pedestrian infrastructure is the one that has received the slightest changes, with an average of 1.99.

The gathered data could only be matched to 125 out of 332 AGEBs. With the information provided in Map 4.1, it can be seen that the city experienced an overall increase in car infrastructure, including the east side, which is less affluent. According to Map 4.2, the perceived improvements in public transport infrastructure seem to be more present in the center of the city. The spatial distribution of bike infrastructure in Map 4.3 does not show a particular pattern, which may indicate that the city's cycling network is not yet consolidated. The pedestrian infrastructure perceived by the respondents seems to be located near the second ring, with a few exceptions on the eastern side of the city (Map 4.4).



Map 4.1. Spatial distribution of car infrastructure according to respondent's perception

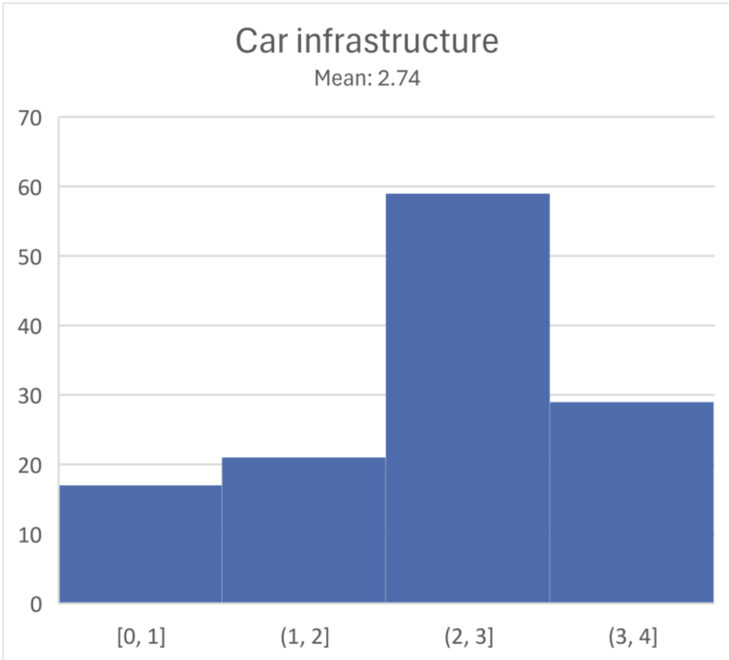
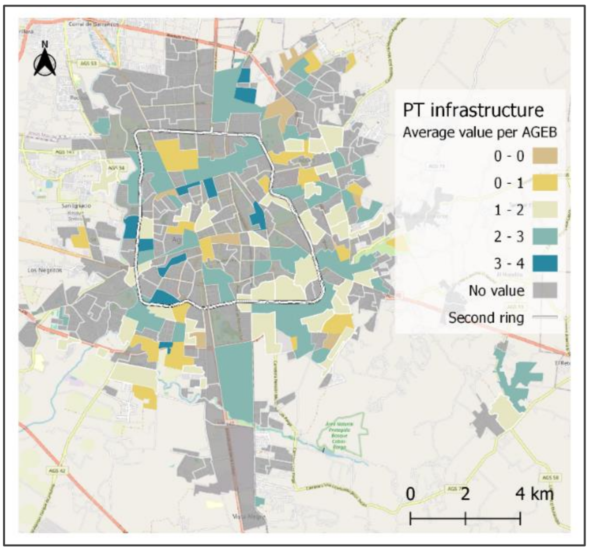


Figure 4.9. Frequency distribution of car infrastructure



Map 4.2. Spatial distribution of Public Transport infrastructure according to respondent's perception

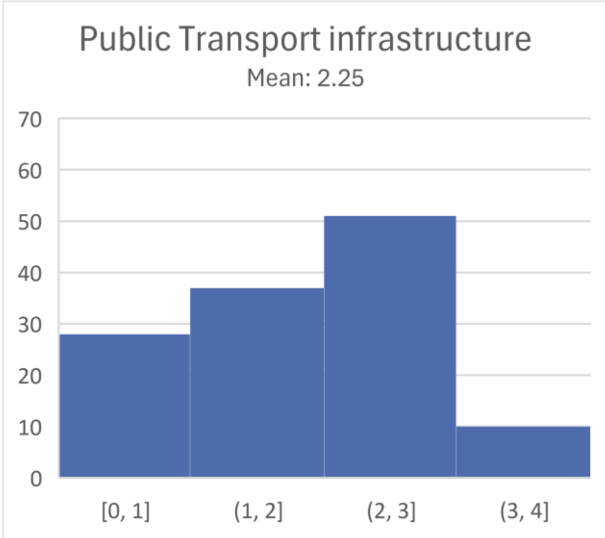
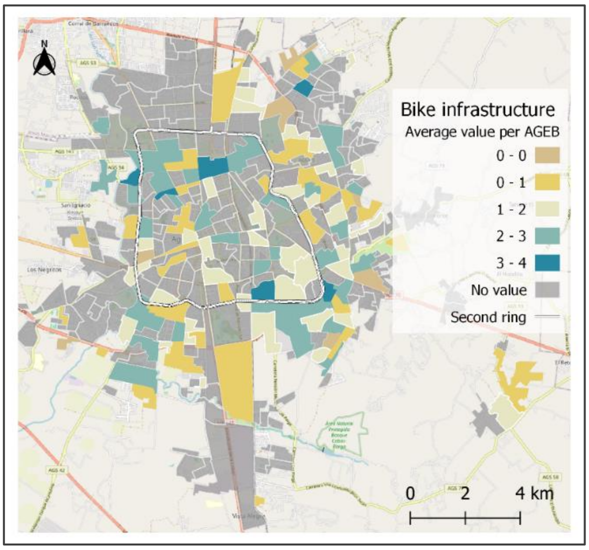


Figure 4.10. Frequency distribution of Public Transport infrastructure



Map 4.3. Spatial distribution of bike infrastructure according to respondent's perception

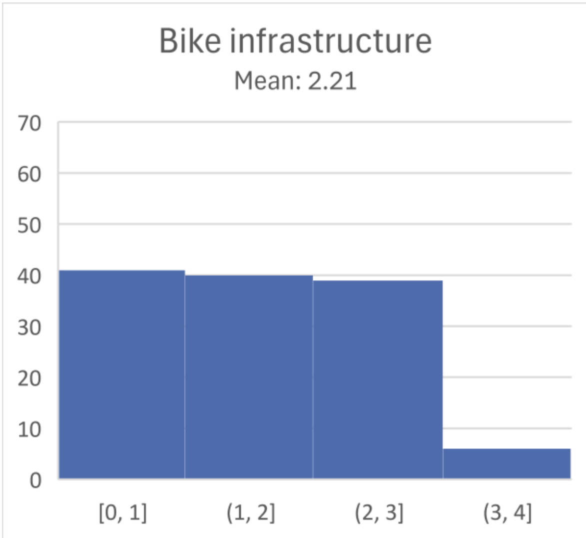
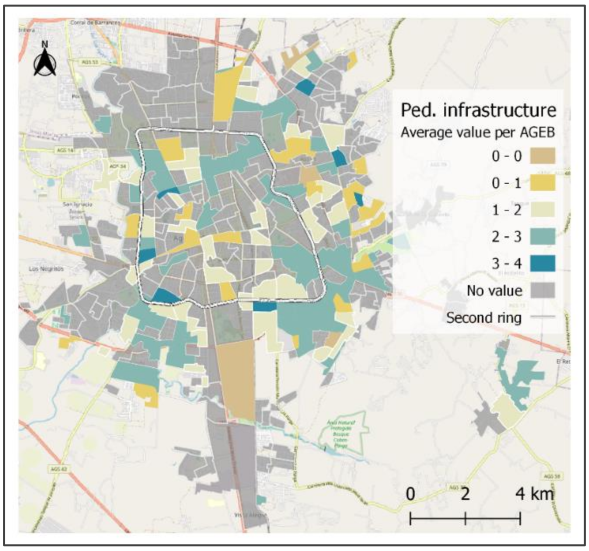


Figure 4.11. Frequency distribution of bike infrastructure



Map 4.4. Spatial distribution of pedestrian infrastructure according to respondent's perception

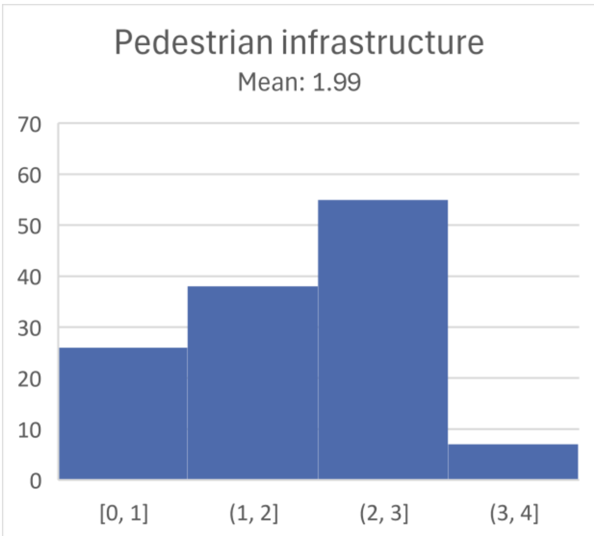


Figure 4.12. Frequency distribution of pedestrian infrastructure

4.2. Summary of primary findings

Primary data provided an overview of the mobility patterns in Aguascalientes at present and how they changed in relation to five years ago. One first highlight is that people feel that the city has become more congested and this can be associated with a 7% increase in the use of private cars and a reduction in the trips by active modes. Nevertheless, they still perceive that they can reach more recreational opportunities, which might be due to increased leisure facilities in the surroundings and increased willingness to travel longer distances. Now, fewer people do recreational activities only in their neighborhoods and travel more to the city center or even further if their preferred activity requires it.

These pattern changes represent a benefit in terms of gains in mobility and, probably, accessibility. If people cannot travel outside their neighborhood or close surroundings, the opportunities available to them become limited. Some people may have the advantage of living in affluent or well-located neighborhoods with a significant endowment of diverse opportunities, while others live in more isolated zones. Therefore, it is positive that 44% of the participants experience more ease of travel, and fewer people are confined in their neighborhoods.

The ability to travel more reduces social exclusion, but it also comes with negative externalities. As the use of cars has increased, there is now more traffic congestion that will gradually increase the travel times for road users and the greenhouse gases that contribute to climate change. The increased use of cars also represents a cost for the lowest socioeconomic quintiles. Somehow, less affluent people find the resources to access a car. Such is the case that 36% of the lowest quintile owns one private car, and 22% owns two private cars. Having a car available gives them a chance to reach more opportunities, but it also comes with the downside that now they have to spend a higher portion of their income on transportation.

The final cost observed in primary data is that, based on respondents' perception, there is a higher perceived allocation of public resources to car infrastructure compared to the infrastructure for other modes. It is positive to see that car infrastructure is spread around the city; however, for people to use it, they still need to cover other costs. On the contrary, pedestrian infrastructure has not been ameliorated in the same proportion.

5. ACCESSIBILITY ANALYSIS

This section addresses the second research objective: to assess the changes in accessibility levels in urban areas and among socioeconomic groups before and after the transport intervention. To cover this objective, a base scenario modeled accessibility levels for 2019 and then for 2024, after the construction of the continuous flow in Aguascalientes Avenue, better known as the second ring. This result provided an idea of the spatial distribution of accessibility before and after the intervention.

5.1. Base scenario: before the intervention

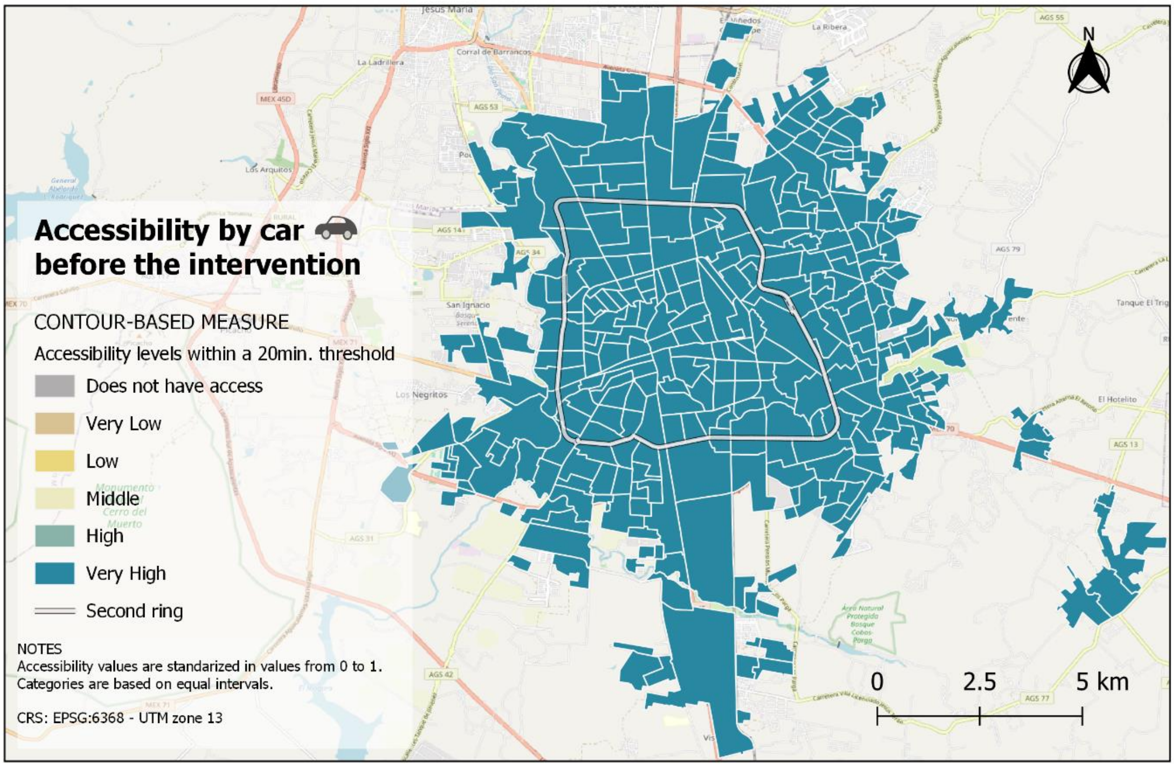
The accessibility levels estimated for Aguascalientes indicate that when people travel by car, everyone can easily reach leisure destinations regardless of their starting location. In contrast, for those traveling on foot, accessibility levels vary significantly depending on their point of origin. Two types of accessibility measures were calculated for a scenario that simulated an environment before the transport intervention took place, that is, before the continuous flow was constructed in the second ring.

For the first measure, the contour-based indicator, the level of accessibility, can be explained as the number of recreational places that can be reached from each AGEB within a given threshold of 20 minutes. Map 5.1 shows that car users can reach the maximum number of opportunities within 20 minutes. This result draws attention because it suggests that the entire city has the conditions to provide the same mobility to all people who travel by car regardless of where they live. If the dimensions of the urban area are taken into account, this seems reasonable up to a certain point. The city's length from north to south is around 17km, which means that a person traveling by car, without traffic and at a speed of 50km, could cross the city in 20 minutes, which is within the threshold time. So, it is important to stress that the model did not consider traffic congestion.

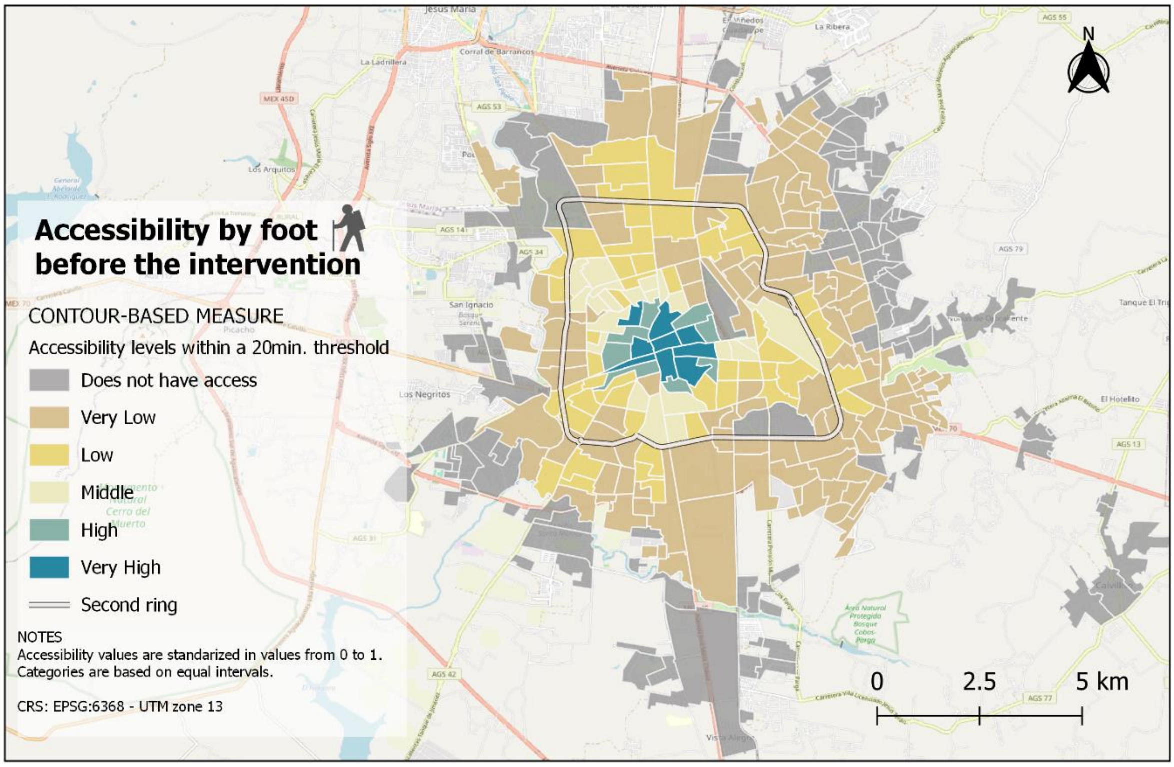
As shown in Map 5.2, accessibility levels for people walking to leisure destinations vary significantly based on their starting location. Users experience a range from very low to very high accessibility. Additionally, there are areas, mostly on the outskirts of the city, where it is not possible to reach leisure facilities within 20 minutes on foot. The map shows a concentric distribution of the accessibility levels, with the highest accessibility concentrated in the city center, gradually decreasing towards the periphery. This pattern results from the centralized urban layout of Aguascalientes and the use of a distance-based measurement. Like many cities, Aguascalientes has a centralized urban shape with a higher concentration of opportunities in the central part of the city. Consequently, as one moves outward, the number of accessible opportunities decreases. Additionally, the contour-based measure relies on travel time or distance, meaning that as travel time from the central point increases, the number of accessible opportunities decreases.

For the second measure, the gravity-based indicator, accessibility was estimated using a decay function that tries to capture the real behavior of people. As in the previous indicator, Map 5.1 reveals that no part of the city is at a disadvantage in terms of car accessibility. Although the model does not consider traffic levels, which might increase travel times and, therefore, reduce accessibility, these results also highlight the efficiency of the current road network.

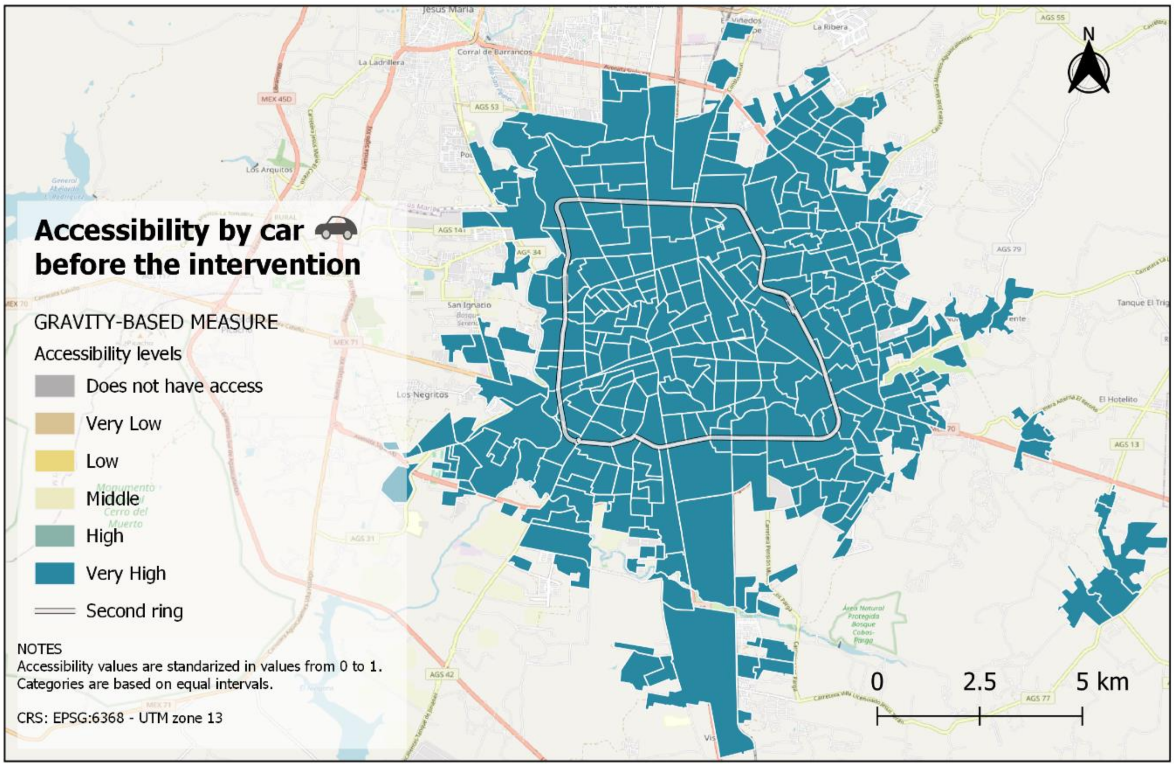
Map 5.4 shows again contrasting results in accessibility levels when people travel by foot compared to when they travel by car. Comparing this map to the one using a contour-based indicator, it is clear that the decay function decreased the accessibility levels. With the potential indicator, there are fewer polygons with high accessibility, there are more with no accessibility, and the concentric pattern seen before starts to vanish. This suggests that, even if an opportunity can be reached within a walking distance of 20 minutes, people might not be attracted enough to walk there.



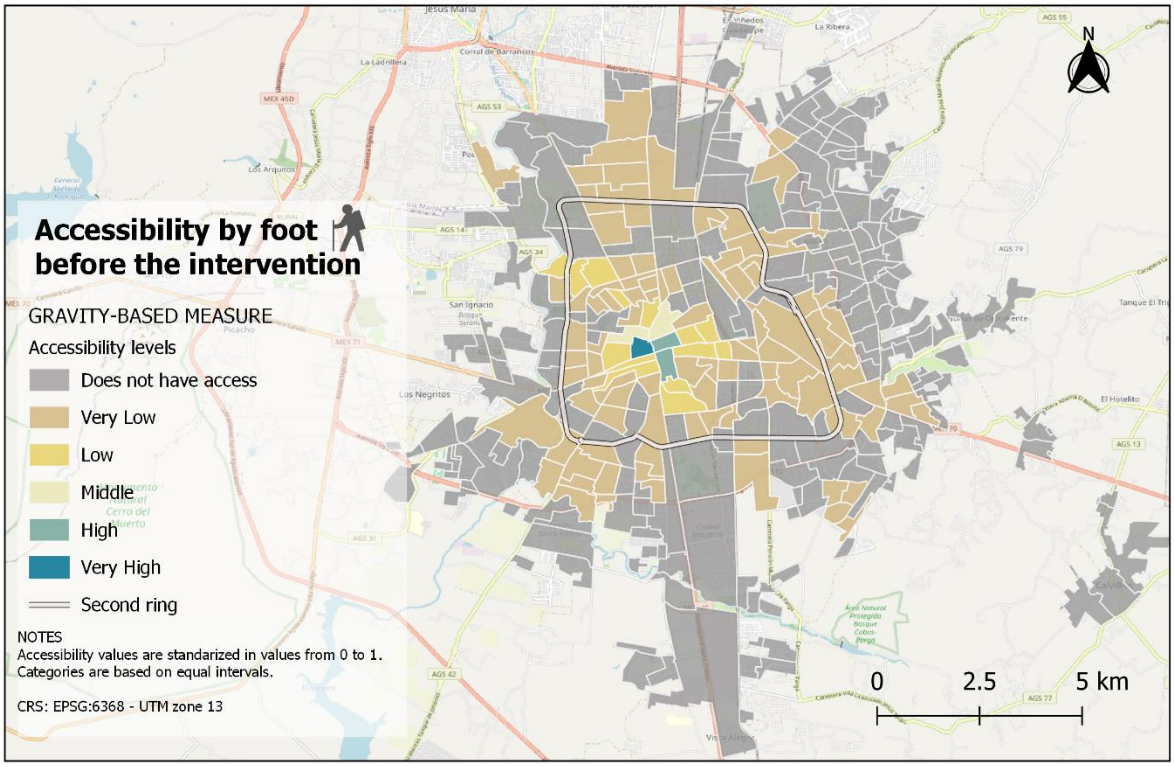
Map 5.1. Accessibility levels by car within a 20-minute threshold



Map 5.2. Accessibility levels by foot within a 20-minute threshold



Map 5.3. Accessibility levels by car before the intervention according to a potential indicator



Map 5.4. Accessibility levels by foot before the intervention according to a potential indicator

The impedance functions for the base scenario are displayed in Figure 5.1. These two functions were modeled from the census data. This source provided a large number of observations for both transport modes. However, a drawback of this data source is that the travel times were aggregated into ranges, resulting in the large jumps seen in the plotted lines. Despite this arrangement in the data, the log-logistic functions illustrate an intuitive travel behavior based on the travel costs of inhabitants. That is, for short trips with lower time costs, inhabitants are more likely to walk, whereas for longer trips with higher time costs, inhabitants are more prone to travel by car.

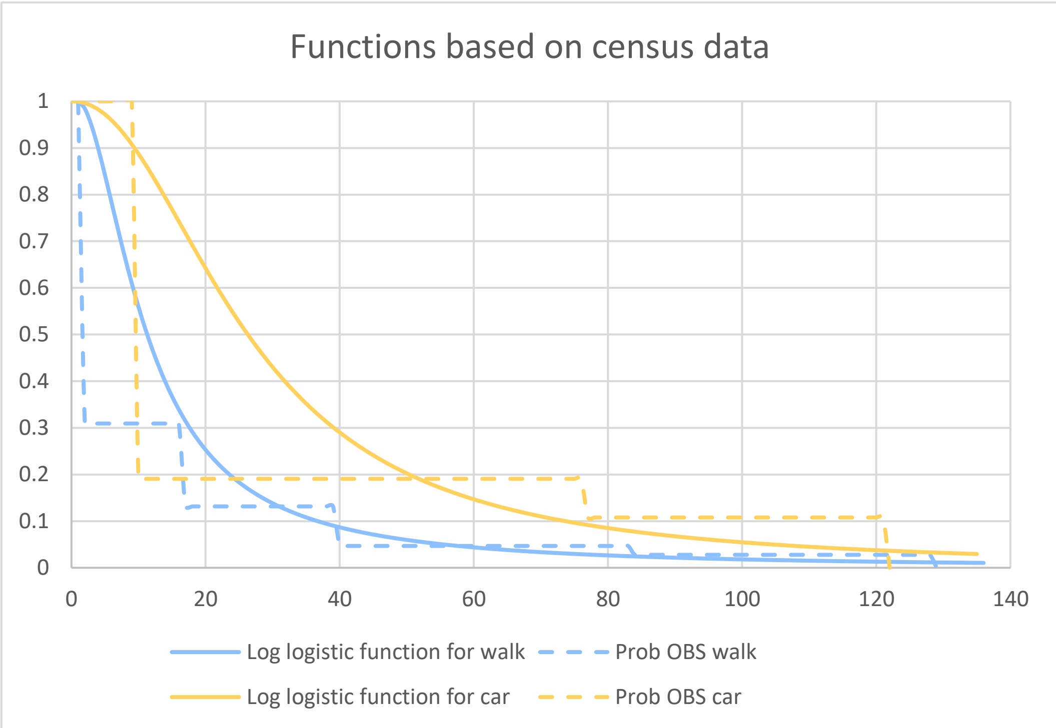


Figure 5.1. Log logistic functions modeled from observed data for walking and driving in 2020

5.2. Second scenario: after the intervention

The approach to evaluating the transport intervention was to estimate again gravity-based accessibility in a different scenario that simulated the after-intervention environment. As explained in the methodology, this scenario assumes an increase in car speed along the second ring, that inhabitants encounter new barriers to walking, and that the travel behavior of people is different due to changes in their travel costs. The decay functions of the second scenario, displayed in Figure 5.2, show a lower curve for car trips compared to those made by foot. The steeper slope of the car travel curve indicates that the probability of undertaking a trip by car decreases more quickly as travel time increases compared to walking. Consequently, the observed behavior in 2024 is that inhabitants are making shorter trips by car than by walking.

Figure 5.3 compares the decay functions for both moments in time. These functions reflect that, in 2020, the overall behavior of inhabitants pointed to a higher likelihood of making longer trips by car while shorter trips would be made by foot. In 2024, people's behavior points to a contrasting trend: now, people have a 50% probability of a 17-minute car trip and a 50% probability of a 22-minute foot trip. It might seem counterintuitive at first glance that people prefer to use the car for a short trip. However, fieldwork revealed that inhabitants perceive car trips as much more efficient and convenient.

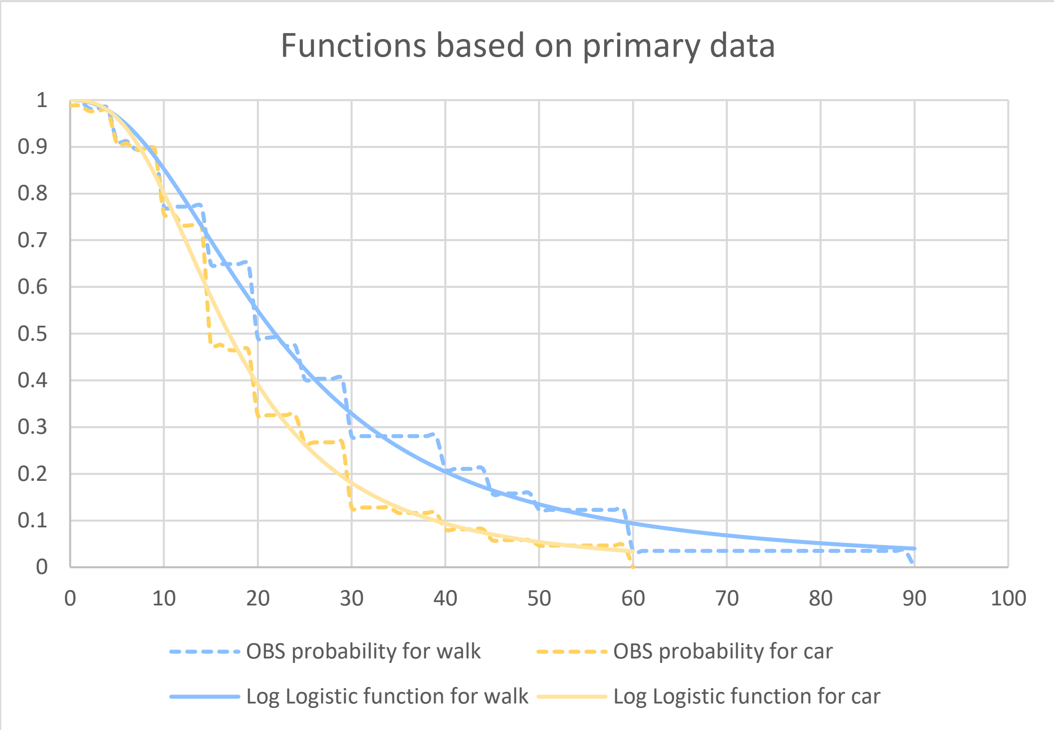


Figure 5.2. Log logistic functions modeled from observed data for walking and driving in 2024

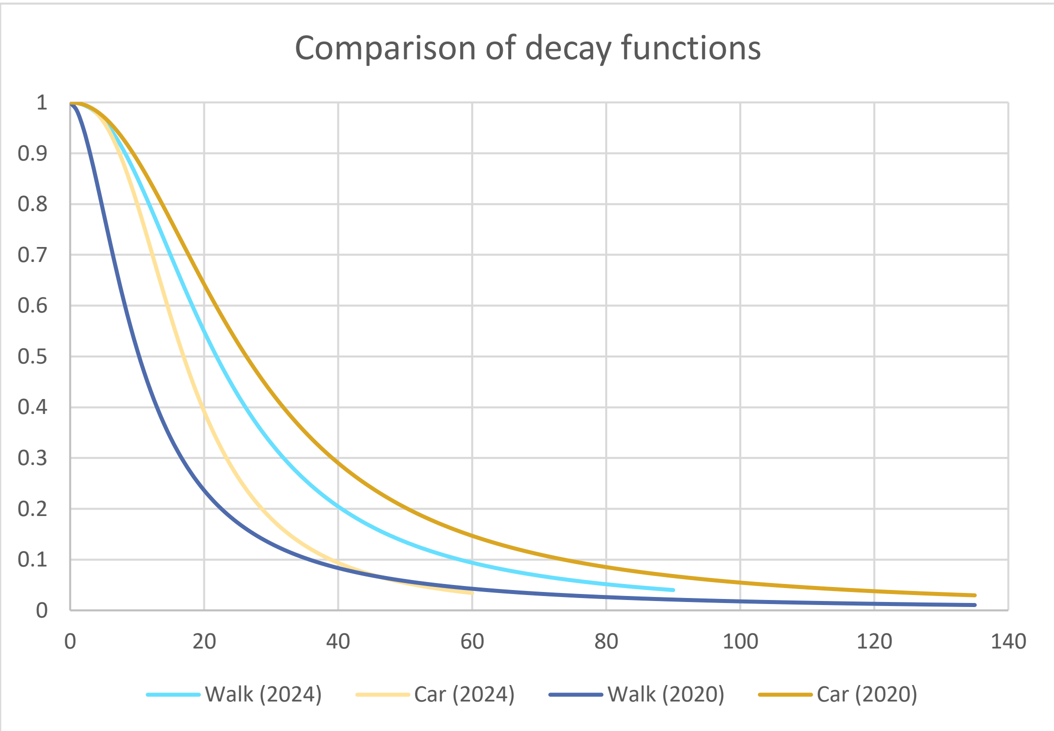
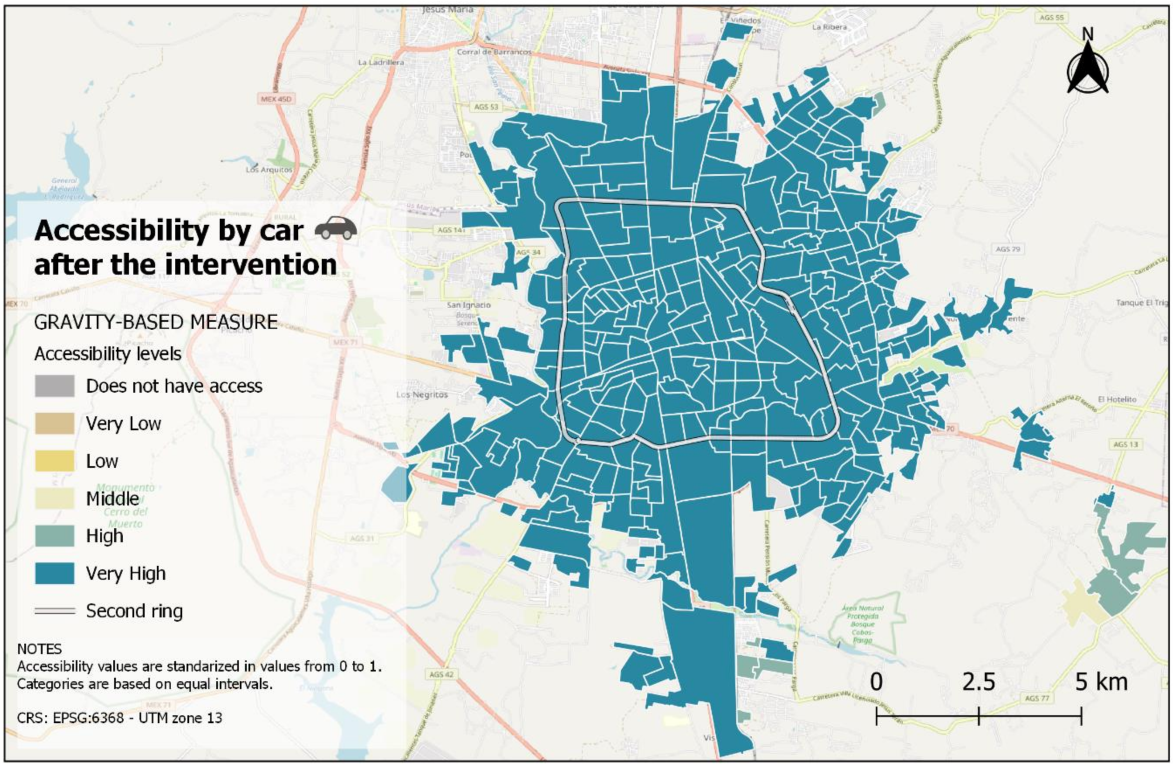
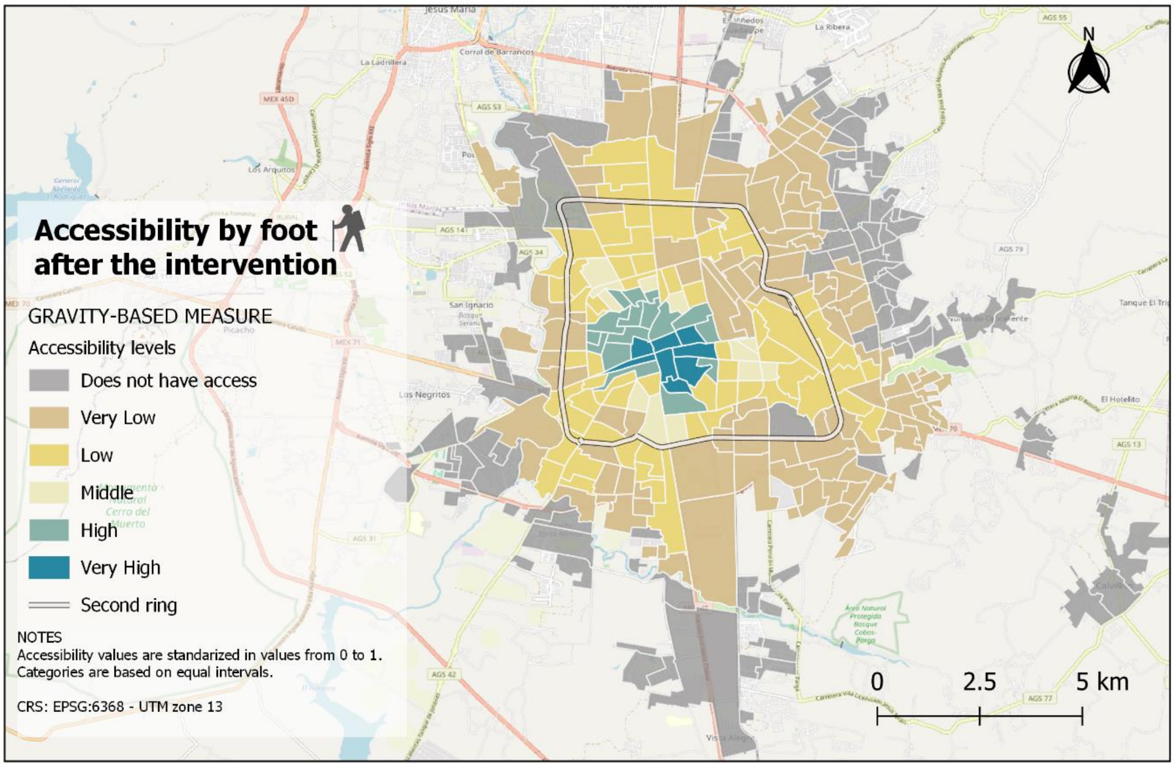


Figure 5.3. Comparisons of decay functions for driving and walking in both scenarios



Map 5.5. Accessibility levels by car after the intervention



Map 5.6. Accessibility levels by foot after the intervention

For the case of car accessibility, Map 5.5 shows that, after the transport project was implemented, almost the entire city still experienced very high accessibility. Only in a few polygons is the accessibility value reduced. This reduction might be because, although driving speeds increased for cars, the decay function of the second scenario showed that inhabitants decreased their willingness to drive very long distances. For the case of walking accessibility, the second scenario in Map 5.6 allows us to see that, even though there are more barriers for pedestrians due to the increase in car infrastructure, accessibility levels increased in comparison to the past. Now, fewer polygons appear as not having access, and there is a concentration in the city center of polygons with high or very high accessibility. Based on the decay function, it seems like people increased their willingness to walk longer trips.

Table 5.1 and Table 5.2 allow us to make a comparison between accessibility levels before and after the intervention by accounting for the inhabitants living in each polygon. When it comes to trips by car, the number of polygons with very high accessibility has reduced in the present by 10. Yet, apparently, 97% of the inhabitants experience very high levels of accessibility. If walking is used as a transport mode, more people seem to have higher accessibility in comparison to five years ago, as the percentage of inhabitants having very low accessibility reduced from 90.2% to 73.5%.

Table 5.1. Accessibility levels before the intervention and their distribution among the population

	Car				Walking			
Level	polygons	inhabitants	Percentage of inhabitants	Cumulative percentage	polygons	inhabitants	Percentage of inhabitants	Cumulative percentage
Very low	4	6627	0.7%	0.7%	289	810217	90.2%	90.2%
Low	0	0	0.0%	0.7%	34	71259	7.9%	98.1%
Middle	0	0	0.0%	0.7%	5	12163	1.4%	99.5%
High	0	0	0.0%	0.7%	1	2220	0.2%	99.7%
Very high	328	891948	99.3%	100.0%	3	2716	0.3%	100.0%
Total	332	**898575**						

Table 5.2. Accessibility levels after the intervention and how they are distributed among the population

	Car				Walking			
Level	polygons	inhabitants	Percentage of inhabitants	Cumulative percentage	polygons	inhabitants	Percentage of inhabitants	Cumulative percentage
Very low	6	9243	1.0%	1.0%	234	660199	73.5%	73.5%
Low	0	0	0.0%	1.0%	62	175533	19.5%	93.0%
Middle	1	1432	0.2%	1.2%	12	19667	2.2%	95.2%
High	7	16358	1.8%	3.0%	16	31185	3.5%	98.7%
Very high	318	871542	97.0%	100.0%	8	11991	1.3%	100.0%
Total	332	**898575**						

5.3. Social variations

Accessibility is influenced by personal characteristics and not only spatial components. Hence, it is essential to understand not only how accessibility is distributed spatially but also how it changes when the social characteristics of inhabitants are considered. Socioeconomic aspects such as income or education level give an idea of the resources a person has and, consequently, of the possibilities they will have to move. The 2020 census provides information about the average level of schooling of each AGEB and the number of people living there. The following table shows an intersection between accessibility and the inhabitant's level of schooling.

The education categories displayed in Table 5.3 are based on equal quantiles that range from 0 years of school (very low) to 15.5 years (very high). In Mexico, the average level of schooling at the national level is 9.7 years (Instituto Nacional de Estadística y Geografía (INEGI), 2020), which is equivalent to six years of primary school and 3.7 years of secondary school. According to the Mexican Institute for Competitiveness (IMCO), the average monthly income of a person with a secondary degree is 6,904 pesos, whereas someone with a completed undergraduate —equivalent to 16 years of education — earns 13,652 pesos (2022). Additionally, research done in Mexico suggests that for each additional year of education, average income increases by 9% (Villareal Peralta, 2018).

This information adverts that people inside of the "Low education" and "Middle education" categories will very likely have restricted resources to buy motor vehicles, which can cause them to acquire old cars that are cheaper but less safe. These types of vehicles can be more prone to breakdowns and require more frequent repairs, but owners may skip essential maintenance due to cost, further compromising safety.

Therefore, it is questionable that, although 97% of the population is supposed to enjoy high levels of accessibility by car, 39.22% of the inhabitants will not have the resources to own a car, will own a car that is not safe or will have to allocate a large proportion of their income to be able to move. At the same time, it is worrying that 73.5% of the inhabitants in Aguascalientes experience very low or low accessibility when they commute by foot. If people have the means to access other modes, they will overcome this low accessibility. Nevertheless, 33.7% of the people with very low accessibility by foot also have very low education levels, which translates to limited economic resources to travel by other transport modes.

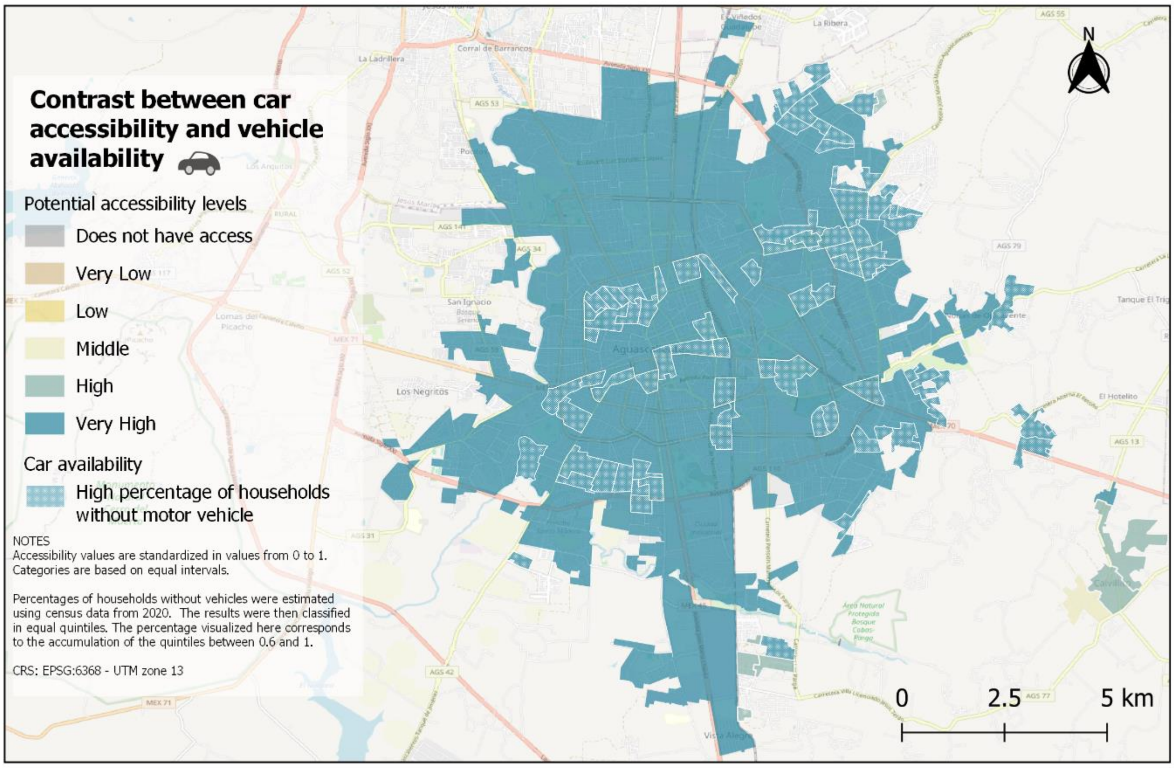
Table 5.3. Accessibility distribution accounting for the average education levels of education

Car						
Accessibility level	Very low education	**Low education**	**Middle education**	High education	Very high education	Percentage of inhabitants with **low or middle** education levels
Very low			5,421	3822		0.60%
Low						0.00%
Middle			1,432			0.16%
High			6,006	10,,352		0.67%
Very high	0	35	352,425	388,358	130,724	39.22%
Total	0	35	365,284	402,532		
Walking						
Very low	0	35	302,400	258,825	98,939	33.7%
Low			55,532	95,443	24,558	6.2%
Middle			3,057	10730	5,880	0.3%
High			4,295	26,,890		0.5%
Very high				10644	1347	0.0%
Total	0	35	365,284	402,532	130,724	

Education level is a proxy for income, which, at the same time, gives an idea of a person's travel resources. However, the 2020 census also provides information about motor vehicle availability per household. Using these data, it was possible to see that, even if accessibility results suggest high accessibility by car, 26% of the households in the city have low or very low availability of a car (see Table 5.4 and Map 5.7. Contrast between accessibility levels by car and vehicle availability per household according to the census 2020). So, even if the infrastructure is there, they will not be able to use it.

Table 5.4. Percentage of motor vehicle availability per household

Levels of car availability per household		
Very high availability (0% to 20% of the households within this AGEB do not have a motor vehicle)	68	20%
High availability (20% to 40% of the households within this AGEB do not have a motor vehicle)	72	22%
Middle availability (40% to 60% of the households within this AGEB do not have a motor vehicle)	107	32%
Low availability (60% to 40% of the households within this AGEB do not have a motor vehicle)	79	**24%**
Very low availability (80% to 100% of the households within this AGEB do not have a motor vehicle)	6	**2%**
Total	332	



Map 5.7. Contrast between accessibility levels by car and vehicle availability per household according to the census 2020

6. DISCUSSION

6.1. Discussion of the results in the context of the research objectives

6.1.1. Findings from the descriptive analysis.

The findings from the descriptive analysis can be discussed from four angles: travel patterns, benefits distribution, leisure trips, and infrastructure. The analysis showed that the travel behavior changed between 2019 and 2024. Participants during fieldwork revealed that not only did they reduce their walking frequency by 6%, but they also increased their use of private cars. In respect to five years ago, there has been a 7% increase in the number of people who always use the car for daily purposes.

The results about the distribution of benefits among income groups show that, in general, the benefits that were perceived with more frequency were related to the increase in car infrastructure and access to recreational facilities, as well as the reduction in travel costs between 2019 and 2024. However, between these three, there is less variability among income groups when it comes to car infrastructure availability, which indicates that the five income groups experienced similar changes in this respect. The distribution of the benefits revealed that the middle-income groups experienced more mobility benefits. In particular, quantile 3 experienced the highest share of benefits in half of the benefits studied.

Two things deserve discussion regarding the perceived reduction in costs. On the one hand, the main goal of the continuous flow was to increase travel speeds and, therefore, reduce operational costs for private vehicles. In 66% of the cases, respondents experienced a reduction in their travel costs. However, not all the respondents move by car; therefore, it is not clear to what extent this travel cost reduction can be attributed to new car infrastructure. Also, changes in travel patterns showed that there are more people who did not use a car before, and now they do. In theory, changing from not commuting by car to commuting by car should suppose increased travel costs. However, research suggests that car users tend to have a misconception about the real cost of a car (Andor et al., 2020) of a car should suppose. It is also interesting to see that the group who benefited the least from travel time reductions was the highest quintile. This finding aligns with research done in the Mexican context, which suggests that people with higher resources use them not to save travel time but to increase their consumption of opportunities (Reillo, 2018).

Results about the changes in leisure trips between 2019 and 2024 indicate an increased willingness to travel. This increased willingness appears to be related to the rise in car usage, as observed in Table 4.2. While it is positive that people have gained mobility and are less confined to their neighborhoods for recreational activities, this increased mobility also entails social costs. Until sustainable transportation modes are implemented, this apparent progress cannot be considered a complete success.

Finally, people perceive that in the last five years, there has been a substantial increase in car infrastructure. Since data about the presence of infrastructure is based only on the perceptions of survey participants, data is not available for all AGEBs. Thus, it is complicated to identify clear spatial patterns. Notwithstanding this limitation, it was observed that infrastructure for cycling, walking, and public transportation has been underinvested in comparison to car infrastructure.

6.1.2. Findings from the accessibility analysis

The findings from the accessibility analysis are organized into three parts: the impedance functions, the distribution of accessibility levels, and the variations in accessibility when personal variables are considered. The impedance functions represented the travel costs of individuals and how the probabilities of undertaking a trip reduce as the cost increases. A comparison between the decay functions revealed a counterintuitive travel pattern: in contrast to five years ago, nowadays, for a short trip, people are more likely to choose the car instead of walking. However, as the literature explained, owning a car is often seen as a sunk cost that needs to be maximized, and therefore, people end up substantially increasing its use (Ho et al., 2014). Likewise, previous findings indicated that people consider the automobile as the best option for traveling as it reduces the burdensome of managing travel distances and offers convenience and greater accessibility (Moody et al., 2021). These ideas were backed up during fieldwork as respondents revealed that they perceive car trips as being more comfortable, efficient, and safe compared to other modes (see Figure 4.2).

The other reason why this finding is counterintuitive is because it suggests that the willingness of inhabitants to walk longer distances increased, even though respondents reported a decrease in their frequency and desire to walk between 2019 and 2024. Previous research on the factors from the built environment that influence active mode journeys indicates that the walkability of the environment and proximity to the CBD are positively related to the frequency of active trips, such as walking. Shkera & Patankar (2024) found that areas far from commercial centers have higher frequencies of active trips, suggesting that "this could either be because peripheral areas lack amenities, necessitating longer trips, or because these areas provide a more pedestrian-friendly environment" (p.13). In the context of Aguascalientes, if people report a low desire to walk but still are willing to make long trips on foot (averaging 22 minutes), it suggests that these trips are based more on necessity than desire.

Regarding the distribution of accessibility levels, the analysis indicated that, before and after the intervention, almost the entire city enjoyed very high accessibility when traveling by car, regardless of the point of origin. Although this result could lead to the assumption that the road network in the city is very efficient, it seems very unrealistic to think that 97% of inhabitants will have very high accessibility every time that they drive. Even considering that the length of the urban area of Aguascalientes from north to south is around 17km, achieving high accessibility all the time would require very low traffic or virtually no traffic. Hence, it is important to note that there were difficulties in integrating traffic congestion and other driving impedances, such as traffic lights, into the accessibility model. While this result points to an important overestimation of accessibility for cars, it also suggests that the city already had good infrastructure conditions for cars and that the solutions to manage traffic congestion could be focused on non-car infrastructure. For example, by providing more cycling infrastructure or improving public transport, traffic congestion could be reduced.

In the case of pedestrian accessibility, inhabitants experience a full range of accessibility levels, from very low to very high. Spatial variations are evident, with the city center exhibiting the highest accessibility and the periphery the lowest. This pattern aligns with a centralized urban layout, where opportunities are concentrated in the city's core. Accessibility by foot has increased compared to five years ago, as people now make longer trips on foot. However, this increase seems to be due to a need rather than a desire. As the built environment has become more car-oriented and pedestrian infrastructure has been neglected, residents might face more barriers to walking, resulting in longer and less efficient walking routes.

An essential aspect to discuss is accessibility results in light of personal characteristics. Accessibility appeared to be very high for cars in both scenarios. Because of results like this one, decision-makers may think that it is good to invest in car-oriented infrastructure and provide this "public good" as much as possible. However, it is important to remember three things. First, accessibility is not only determined by the location of the facilities and the performance of the transport system; individual attributes also determine it. Second, transport infrastructure cannot be delivered everywhere, and cities do not have the physical space to facilitate car travel for the majority of inhabitants. Third, even if this infrastructure is extensive, people who cannot own a car will be excluded from using it. Consequently, it seems important to highlight that while 97% of inhabitants are supposed to experience high car accessibility, 33% of them do not have the resources to own a car. Hence, if they want to move by car, they will likely acquire a cheap second-hand car that is not safe and poorly maintained. This way of coping with the lack of mobility options can bring new issues, such as increased traffic accidents due to driving unsafe cars and an increase in the emission of pollutants.

6.2. Methodological discussion

Conducting an accessibility analysis to evaluate the effects of a transport intervention provides the opportunity to identify unforeseen impacts that typical appraisal techniques might overlook. While incorporating accessibility analysis into transport planning is desirable, this approach can be complex, data-intensive, and require sophisticated geographic information systems (GIS) and analytical tools. For this reason, two methodological aspects require further discussion.

Firstly, the high accessibility levels observed for trips indicate a significant overestimation. This overestimation stems from the difficulty in building a model that includes all the real-life impedances faced by car drivers, such as traffic congestion and traffic lights. This type of data was not available for this analysis. Additionally, the street network lacked complete information on important attributes, such as the maximum speeds allowed for cars and driving directions in the streets. The lack of information was rectified in the first case by using additional sources of information, but the second aspect could not be rectified. As a result, this impedance was not included in the model. In other words, the model relied on basic but very important variables for an accessibility analysis: travel cost measured in minutes, a complete street network, and the spatial distribution of origins and destinations, which, in this case, represent leisure opportunities.

Likewise, the spatial units in this analysis might not be small enough to capture variations within the units. The average size of an AGEB is 0.3 km², but the largest polygon is 5 km². Consequently, the differences within large polygons are averaged, and there can be a loss of detail when the AGEB is too big. For an urban area of approximately 260 km², such as Aguascalientes, it would be convenient to work with units that are consistent in size and that provide more detail in the analysis, for instance, hexagons of 0.5 km².

Second, using a gravity-based indicator requires information about real trips that individuals make for a specific purpose. Travel data for the present was nonexistent; this is why fieldwork was conducted. Conversely, a large sample of travel times for the pre-intervention scenario was available, but only for work and school trips. Although the analysis was focused on assessing accessibility to leisure destinations, a methodological decision was made to model the impedance functions based on trips to work for both scenarios. This decision was not ideal, but allowed for a comparison between the present and the past. However, despite this strategy, the model was not highly sensitive when to the changes in the transportation system when analyzing car accessibility.

Another limitation of the decay functions is that, although primary data was gathered to obtain travel data for the present, the sample size is small. For the trips made on foot, there were 57 observations, whereas for trips made by car, there were 87 observations. The larger the sample size, the more robust and reliable estimate of travel behaviors. So, it is important to bear in mind that the functions derived from primary data might have low precision. In the future, another option could be to run the analysis using a theoretical decay function and select the function parameters based on empirical studies.

7. CONCLUSION

As society becomes more complex, travel demands have gradually increased and led to an intensive use of private vehicles. The intensification of car-oriented mobility, both from the demand side and the offer side has facilitated mobility for many. However, it has also exacerbated disparities within urban environments. Because of this, decision-makers cannot keep planning transportation systems based solely on the maximization of economic benefits and expect that everybody benefits the same. Therefore, transportation project evaluation should not only estimate the magnitude of the impacts but also identify those who will be positively and negatively affected.

The accessibility analysis conducted in this study allowed us to see that, in the context of a mid-size Mexican city that is highly car-oriented, 97% of inhabitants presumably enjoy very high accessibility levels if they want to reach a leisure destination by car. However, approximately 40% of those people will have very few resources to buy a private vehicle. Conversely, only 5% of inhabitants will experience high or very high accessibility if they want to access recreational activities. This five percent is concentrated in the inner center of Aguascalientes, while the areas farther from the center experience very low accessibility to leisure when traveling by foot. Of the people living in the zones with low accessibility, around 34% have very few resources to spend on a more costly transportation mode. Therefore, it becomes essential that planners and decision-makers implement more affordable transportation options for this group.

The descriptive analysis showed that the travel behavior changed between 2019 and 2024, indicating that participants not only reduced their walking frequency after the car-oriented project was implemented, but they also increased their use of private cars. Some of the perceived benefits in this period were an increase in car-oriented infrastructure and accessibility to leisure destinations, as well as a reduction in travel costs. The distribution of these benefits revealed that the middle-income groups experienced these benefits in a higher proportion, especially the quantile 3. Moreover, results about changes in leisure trips also indicate that there was an increase in the willingness to travel longer distances to leisure destinations. However, while it is positive that people move more and are less confined to their close surroundings, this increase in mobility also imposes social costs on society.

Comparing accessibility changes before and after the intervention took place, it can be noted that the accessibility model for trips by car was not highly sensitive to the changes in the transportation system. A reason for this limitation is that transport systems are extensive and complex, encompassing numerous routes and infrastructure elements. A few changes in the travel speeds and impedances generally have a minor impact on the overall system. Likewise, building an accessibility model that accounts for all the real-life impedances that are present when commuting by car is data-intensive and requires sophisticated GIS and analytical tools. As a result, this analysis did not include traffic congestion, a very important factor in determining real travel times.

Despite the limitations in the accessibility model, the overall assessment underscores the need for more comprehensive evaluation techniques that focus on other aspects but just facilitate cost-effective movement. While transportation systems alone cannot eliminate the complex poverty cycle, they play a crucial role in creating the conditions necessary for individuals to improve their economic and social circumstances. Future research can focus on sophisticating the accessibility model, trying to incorporate impedances that provide more accurate travel times. Likewise, it can focus on assessing the intervention impacts in other transport modes different from walking. In the end, it is clear that transport development does not occur in isolation, and changes to it will affect a bigger system.

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APPENDIX

Appendix 1: Survey

0_ General section

This section aims to capture some of the characteristics of the transport user. Please, answer the following questions.

1	Gender a) Female b)Male c) Other
2	Age
3	How many people normally live in your home, including you?
4	How many children younger than 15 years old live at your home?
	Are you responsible of their daily transportation?
5	In your house…
	5.1 How many cars or trucks do you have to transport daily?
	5.2 How many motorcycles or scooters do you have to transport daily?
	5.3 How many bikes do you have to transport daily?
6	Up to what grade did you approve in the school? a) None b) Basic education (Preschool and/or primary) c) Secondary d) High school e) Undergraduate or postgraduate
7	During last week… a) I worked b) I had a job, but I didn't work. c) I was searching for a job. d) I didn't work. e) I am a student f) I am dedicated to household chores or take care of my children g) I am retired or pensioned. h) I am permanently disabled to work.
8	During last week… a) I sold or made some products for selling. b) I provided some service in exchange of a payment (cut hair, give classes, paint a house, etc.) c) I helped working on the land or in a family member's business or another person d) I didn't work.
9	What is your monthly income? a) $0-$4,500 pesos b) $4,500-$7,500 pesos c) $7,500-$11,000 pesos d) $11,000-$14,000 pesos e) More than $14,000 pesos f) Do not know/do not want to disclose
10	What was your monthly income 5 years ago? a) $0-$4,500 pesos b) $4,500-$7,500 pesos c) $7,500-$11,000 pesos d) $11,000-$14,000 pesos e) More than $14,000 pesos Do not know/do not want to disclose

1_ trip generation

This section has the purpose of understanding some characteristics of the trips that people who live in Aguascalientes make in their daily lives. Please, answer the following questions.

A TYPICAL TRIP DURING WEEK DAYS

1.1 How many trips do you usually make on a typical **weekday**?

*A **trip** is a journey from a place of origin to a place of destination for a specific purpose, in which we can use one or various means of transportation or walking, such as: going to work, school, coming home, etc.*

………..trips

1.2 How LONG does it take you, on average, on the first trip you make on a typical weekday?

…….. min

1.3 How much MONEY do you spend, on average, on the first trip you make on a typical weekday?

……. pesos

1.4 What was the purpose of the trip?

a) Go to work
b) Go to study
c) Go shopping (goods or services)
d) Share time with family/friends, sports or recreation.
e) Drop or pick up somebody.
f) Go to the doctor or to receive health care
g) Other

A TYPICAL TRIP DURING WEEKENDS

4.1 How many **trips** do you make on a typical **Saturday**?

*A **trip** is a journey from a place of origin to a place of destination for a specific purpose, in which we can use one or various means of transportation or walking, such as: going to work, school, coming home, etc.*

………..trips

4.2 How much time, on average, do you spend on the first trip that you make on a typical **Saturday**?

…….. min

4.3 How much money, on average, do you spend on the first trip that on a typical **Saturday**?

……. pesos

4.4 What was the purpose of the trip?

h) Go to work
i) Go to study
j) Go shopping (goods or services)
k) Share time with family/friends, sports or recreation.
l) Drop or pick up somebody.
m) Go to the doctor or to receive health care
n) Other

A TYPICAL TRIP FIVE YEARS AGO DURING WEEKDAYS

5 Compared to now, five years ago I used to spend on average

a) The same money for a trip in a typical weekday.
b) Less money for a trip in a typical weekday
c) More money for a trip in a typical weekday
d) I don't remember

5.1 How much money, on average, did you used to spend on a typical weekday.

……. pesos

6 Compared to now, five years ago it used to take me on average

e) The same time for a trip in a typical weekday.
f) Less time for a trip in a typical weekday
g) More time for a trip in a typical weekday
h) I don't remember

6.1 How much time, on average, did It use to take you to make a trip on a typical weekday.

……. pesos

2_The pattern of urban transformation

This section aims to capture the perception of inhabitants about the urban transformation of the city through time.

1. **What is your perception about the following aspects in Aguascalientes during the last 5 years:**

[From Q1.1 to Q1.10, responses will be according to the following agreement Likert scale]

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

1.1. The city has become more densely populated.
1.2. The city has expanded.
1.3. It is easier to commute within the city.
1.4. There is more traffic congestion.
1.5. I have easier access to convenience shops and supermarkets.
1.6. I have easier access to leisure and recreation options.
1.7. There is more car infrastructure in my neighborhood and the areas surrounding it (e.g. Bridges)
1.8. There is more public infrastructure in my neighborhood and the areas surrounding it. (e.g. bus stops)
1.9. There is more cycling infrastructure in my neighborhood and the areas surrounding it. (e.g. bike lanes)
1.10. There is more pedestrian infrastructure in my neighborhood and the areas surrounding it (e.g. sidewalks)

2. From your perspective, in which degree should these types of infrastructure increase in the next five years?

	Not at all	Very little	Considerably	To a great extent
Infrastructure for cars (e.g. bridges, overpasses and road expansions)				
Infrastructure for public transport (e.g. bus stops and new transport units)				
Infrastructure for bikes (e.g. bike lanes).				
Infrastructure for pedestrians (e.g. safe intersections and wider sidewalks).				

3_ Preferences

This section aims to understand tour mobility dynamics and preferences.

Please answer the following questions on your use of transport five years ago and nowadays.

1. **Five years ago**, I used the following means of transportation with this frequency.

	Never	Rarely	Sometimes	Often	Always
Private vehicle					
Public transport					
Taxi/Uber					
Walking					
Bicycle					
Motorcycle					
Other					

The following options will only display for the modes in blue.

1.1 What were the reasons for always using the private vehicle five years ago?

- ☐ Efficiency
- ☐ Safety
- ☐ Comfort
- ☐ I travelled a lot

- ☐ Weather conditions
- ☐ I transported children under 15 years of age
- ☐ The other modes of transport were not efficient
- ☐ Infrastructure for cars was better than infrastructure for other means of transport.

1.2 What were the reasons for **not using private vehicle** five years ago?

- ☐ It wasn't safe
- ☐ I didn't need it
- ☐ I didn't know how to use it.
- ☐ I could not afford it.
- ☐ To avoid traffic congestion
- ☐ To help the environment
- ☐ Other

1.3 What were the reasons for **not using a motorcycle** five years ago?

- ☐ It wasn't safe.
- ☐ I didn't need it
- ☐ I could not afford it.
- ☐ It wasn't suitable for weather conditions.
- ☐ To avoid traffic congestion.
- ☐ To help the environment.
- ☐ Other

1.4 What were the reasons for **not using public transport** five years ago?

- ☐ It wasn't safe.
- ☐ It wasn't hygienic
- ☐ I didn't need it
- ☐ I could not afford it.
- ☐ The routes of this mode lacked connectivity.
- ☐ There was not proper infrastructure.
- ☐ There wasn't public transportation near my house or near the places where I had to go.
- ☐ Public transportation was inefficient.
- ☐ Public transportation was unreliable
- ☐ Other

1.5 What were the reasons for **not using taxi or uber** five years ago?

- ☐ It wasn't safe
- ☐ I didn't need it
- ☐ I could not afford it.
- ☐ To help the environment
- ☐ To avoid traffic congestion
- ☐ Other

1.6 What were the reasons for **not using a bicycle** five years ago?

- ☐ It wasn't safe
- ☐ I didn't need it
- ☐ I didn't like it / I was lazy
- ☐ It wasn't convenient for weather conditions.
- ☐ There was no proper infrastructure for this mode (bike lanes)
- ☐ The routes of this mode lacked connectivity.
- ☐ There were physical barriers (e.g. pedestrian bridges) to reach my destination
- ☐ I didn't know how to use it.
- ☐ Other

1.7 What were the reasons for **not walking** five years ago?

- ☐ It wasn't safe
- ☐ I didn't need it

- ☐ I didn't like it / I was lazy
- ☐ It wasn't convenient for weather conditions.
- ☐ There was no proper infrastructure for this mode.
- ☐ The routes of this mode lacked connectivity.
- ☐ There were physical barriers that discouraged me (e.g. pedestrian bridges)
- ☐ Other

2 **Nowadays**, I use the following means of transportation with this frequency.

	Never	Rarely	Sometimes	Often	Always
Private vehicle					
Public transport					
Taxi/Uber					
Walking					
Bicycle					
Motorcycle					
Other					

For the modes in blue, the same questions from Q.1.1 to Q.1.7 will be displayed.

4_ Island effect and transportation barriers

This section aims to explore if people's travelled distances increase or decrease through time.

1. What are usually your favorite leisure activities in Aguascalientes?

- ☐ Go to the movies
- ☐ Go to restaurants
- ☐ Go to the park or natural areas
- ☐ Play sports in gyms and sports centers
- ☐ Shopping at malls
- ☐ Take walks in the city center
- ☐ Go to museums or cultural exhibitions

2. Five years ago, I lived in the *[zip code]:*
3. Five years ago, I lived in the [*street*]*:*
4. Five years ago, if you wanted to do a leisure activity (e.g. playing sports, going to the park or taking a walk) you were most likely to:

- ☐ I used to do activities only within my neighborhood
- ☐ I used to do activities within my neighborhood and its surroundings.
- ☐ I used to do activities within my neighborhood, its surroundings and the city center.
- ☐ I used to travel to any part of the city to do the activity of my choice

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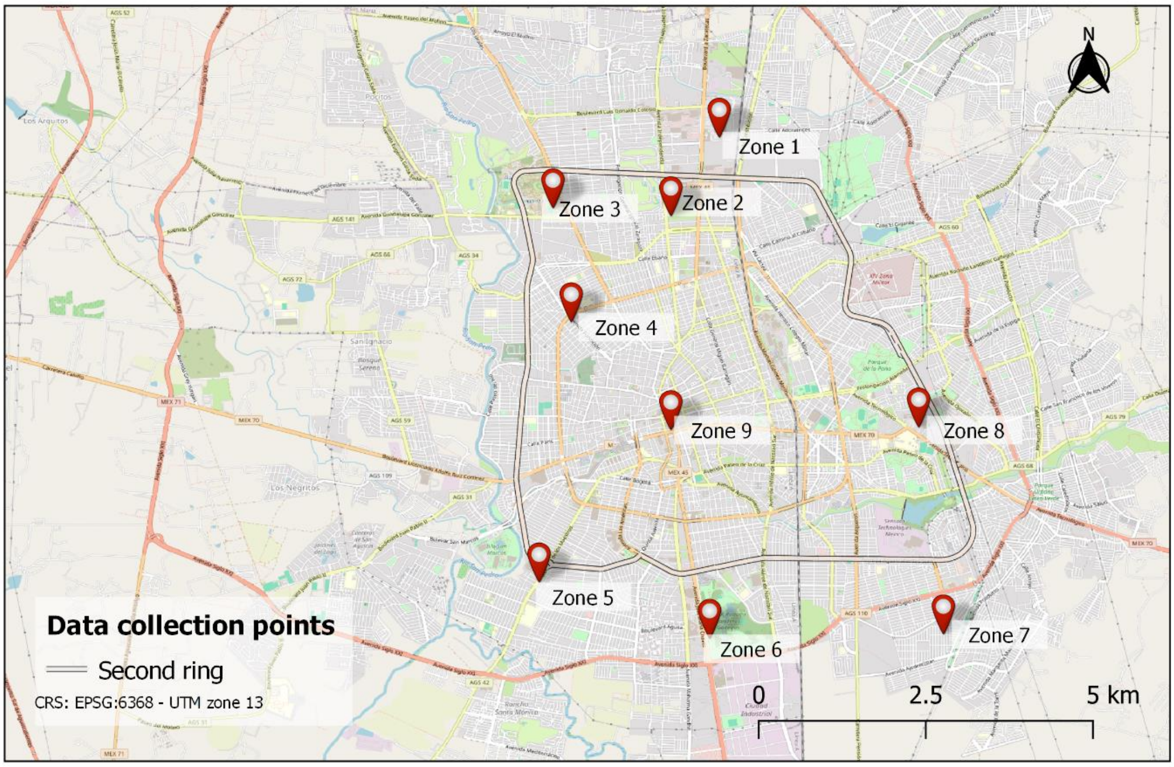
5. Nowadays, I live in the *[zip code]:*
6. Nowadays, I live in the [*street*]*:*
7. Nowadays, if you want to do a leisure activity (e.g. playing sports, going to the park or taking a walk) you are most likely to:

- ☐ Do activities only within my neighborhood
- ☐ Do activities within my neighborhood and its surroundings.
- ☐ Do activities within my neighborhood, its surroundings and the city center.
- ☐ Travel to any part of the city to do the activity of my choice

Appendix 2: Zones in which the data was collected

Data was collected in 9 different zones around the city, with the aim of having as diverse, extensive, and balanced a group as possible. Map x displays the zones where data was collected, and Table 0.1 lists the specific places and dates where data was collected.



Map 0.1. Data collection points

Table 0.1. Dates and places where data was collected

Week	Date	Zone	Location
Pilot	31- Jan	NA	Online
	1-feb	4	Shopping mall: Plaza San Marcos
	5-feb	2	Market: Agropecuario
	6-feb	3	University: UAA
1	7-feb	7	Shopping mall: Villasunción
	8-feb	6	City center: Main square
	9-feb	1	Shopping mall: Altaria
	11-feb	7	Park: Parque Héroes
	12-feb	8	Lomas de la Ajedrez
			Bus terminal: Terminal YOVOY Oriente Valle de los Cactus
2	13-feb	9	Shopping mall: Plaza Espacio
	14-feb	5	Shopping mall: Velaria Mall
	15-feb	3	University UAA
	19-feb	6	City center: El parián
3	20-feb	6	City center: El parián
	21-feb	3	University: UAA

Appendix 3: Travel card

Transporte	Viajes en el pasado	Viajes en el presente
 4 cilindros = rendimiento 12km/L	Precio de la gasolina: **$19.35** Estacionamiento: **$10/hora** Costo por un viaje de 5km = **$8.06**	Precio de la gasolina: **$22.4/L** Estacionamiento: **$16/ hora** Costo por un viaje de 5km= **$9.30**
 6 cilindros = rendimiento de 8km/L	Costo por un viaje de 5km = **$12.09**	Costo por un viaje de 5km = **$14**
	Pasaje: **$7.50**	Pasaje: **$11.00**
	Banderazo: **$13.50** costo por Km: **$3.60** Cada 60 segundos $0.90 centavos Viaje de 5km≈ **$31.50**	Banderazo: **$15.00** Costo por km: **$4.00** Cada 60 segundos: **$1.00** Viaje de 5km≈ $35.00

¿No sabes cuánto son 5km?

5km se traduce aprox. en un viaje del **Parque Héroes** a la **Exedra en el centro** de la ciudad




Appendix 4: Other evidences about data collection

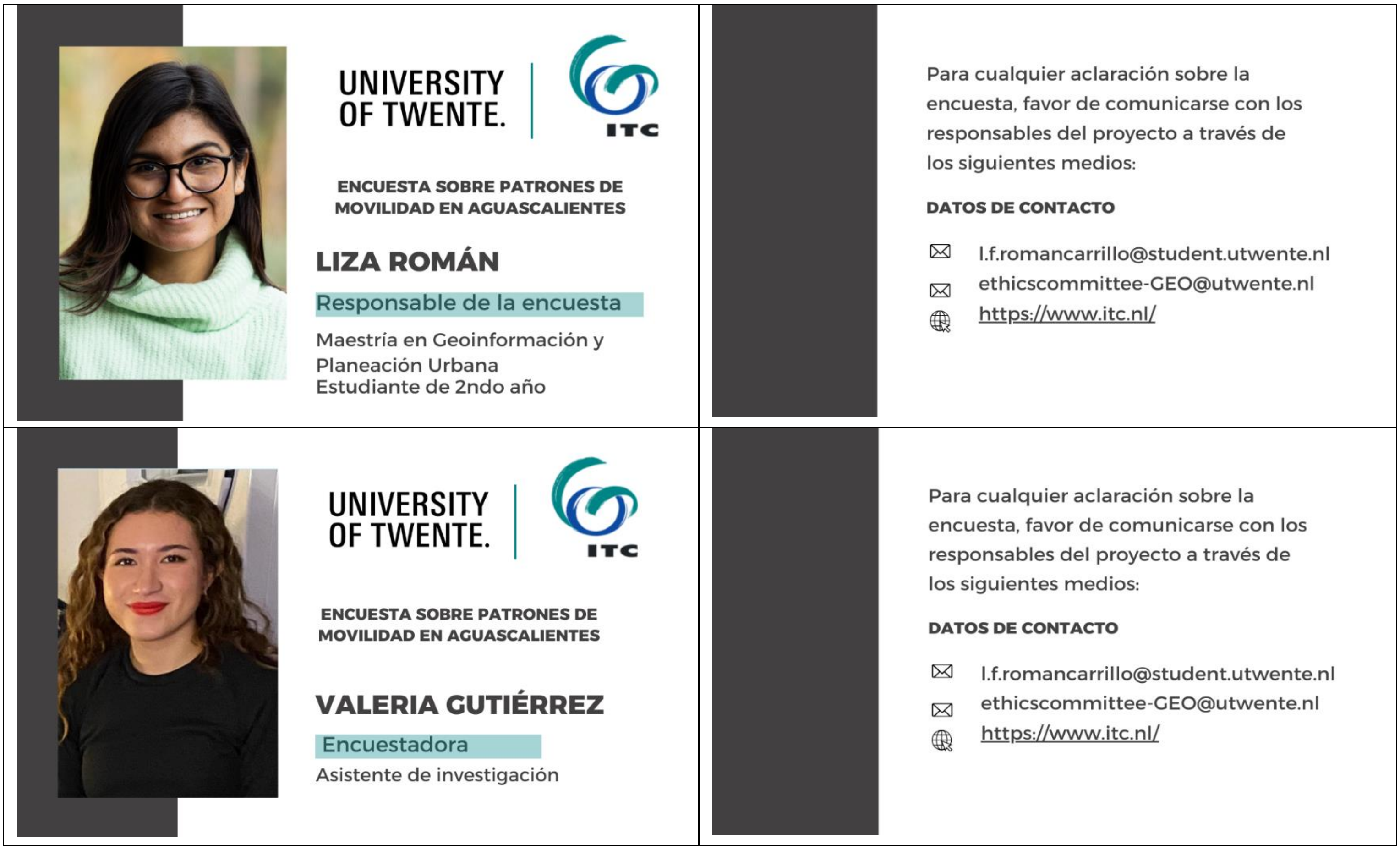


Figure 0.2. Identification badges for interviewers

Figure 0.1. Interviewers applying the survey in Plaza San Marcos and the University

Appendix 5: Some notes from fieldwork

Having the opportunity to do fieldwork for my MSc thesis was a very enriching experience. The planning and implementation process required me to be very organized, responsible, and clear about the main objectives of my research. This last point was challenging because, in the early stage of the thesis process, you are still landing a lot of your ideas. If I had to start this process again, I would have taken a little bit more time to clarify my objectives before I went to do fieldwork. However, I am satisfied with the result, and because of that, I want to share some reflections I had during my fieldwork.

General reflections for fieldwork

1. **More assistants than planned**. During the planning stage, I considered hiring two research assistants who would go with me every time I had to collect data. However, their availability changed at the last minute, and I had to hire an additional assistant. The total number of data collection hours was split between the three assistants so that fieldwork costs would not increase, but a reflection is that it is better to consider more human resources in case there is an unforeseen event.

2. **The schedule changes.** It was important to maintain a flexible schedule. Unforeseen events can delay the data collection, and the places or dates of data collection will have to change.

3. **Wear badges.** Wearing identification badges gave us more credibility when approaching people. Although almost nobody will look at all the information details, there will be one or two persons who will take note of the contact information.

4. **Incentives for participants.** In places like Mexico, it is very common for random people to approach you in the street to ask for money or try to sell you something. Because of this, people tend to immediately reject you if they think you'll do such a thing. Additionally, since we were approaching people directly in the street, often they said they did not have time. So, giving them incentives really helped to increase the participation. We offered bottles of water and candies. Candies were more successful than bottles of water.

5. **QR codes.** The survey was applied using KoboToolbox and personal cell phones. This strategy worked well in the majority of the cases. But sometimes, there were groups of friends where all of them were willing to do the survey. For those cases, it was handy to generate a WR code to apply more surveys simultaneously.

6. **Women participation vs men participation.** Despite our efforts to equally engage both genders, women were generally more accessible and more likely to participate. While we did not encounter any serious issues, men tended to be less polite during interactions.

7. **Personal cell phones are not the most convenient tools**. The budget for fieldwork was limited, so it was not possible to acquire devices specifically for data collection. Therefore, we collected data with our personal phones. However, this was not the most convenient way to work due to three reasons. First, KoboToolbox is only available for Android systems, and one of the assistants had an iPhone. So, we had to find an alternative for her and borrow an additional device. Second, since it is a personal device, sometimes, when we were interviewing people, the phone received messages or calls. Third, assistants expressed fear about their phones being robbed. In the future, it would be better to work with devices that are only for data collection.

Reflections in relation to my specific objectives

1. **Participants gave little information.** For my research, it was important to understand why people use or don't use specific travel modes. For the cases when they replied they "never" use a certain mode, a list of reasons appeared. Very often, people said "I don't ride a bike because I don't have one". But not having a bike is not a very informative answer if you don't know why they don't have it. Is it because they consider it not safe, or is it because they don't have money to have a bike? So, when people gave very limited answers, we had to make an effort to get more information.

2. **Guiding the participants through the survey.** Although the survey had explanatory notes in every section, sometimes people didn't read the texts and didn't understand certain questions or concepts well. Hence, we had to guide the participants in explaining concepts and answering some questions. For example, a tricky question was the one about calculating travel time and money spent. So, we guided them with the help of the travel card in Appendix 3.

3. **Recalling the past behavior.** Some people could immediately remember their travel patterns five years ago, but for others, it resulted in complications. When that was the case, we had to help participants remember by telling them, for instance, "So, if right now you are 27 years old, five years ago you were in university, right? Do you remember how you used to commute to university? Do you remember how much was the bus fee back then?".

4. **Remembering the postal code**. It was interesting to see that, very often, people did not remember their postal codes. This information was important to match the answers to a specific AGEB. So, during data collection, we tried to help people who did not remember the postal code by checking online. However, later in the stage of processing data, we frequently encountered mistakes in the zip codes, making it challenging to assign the responses to the spatial unit.