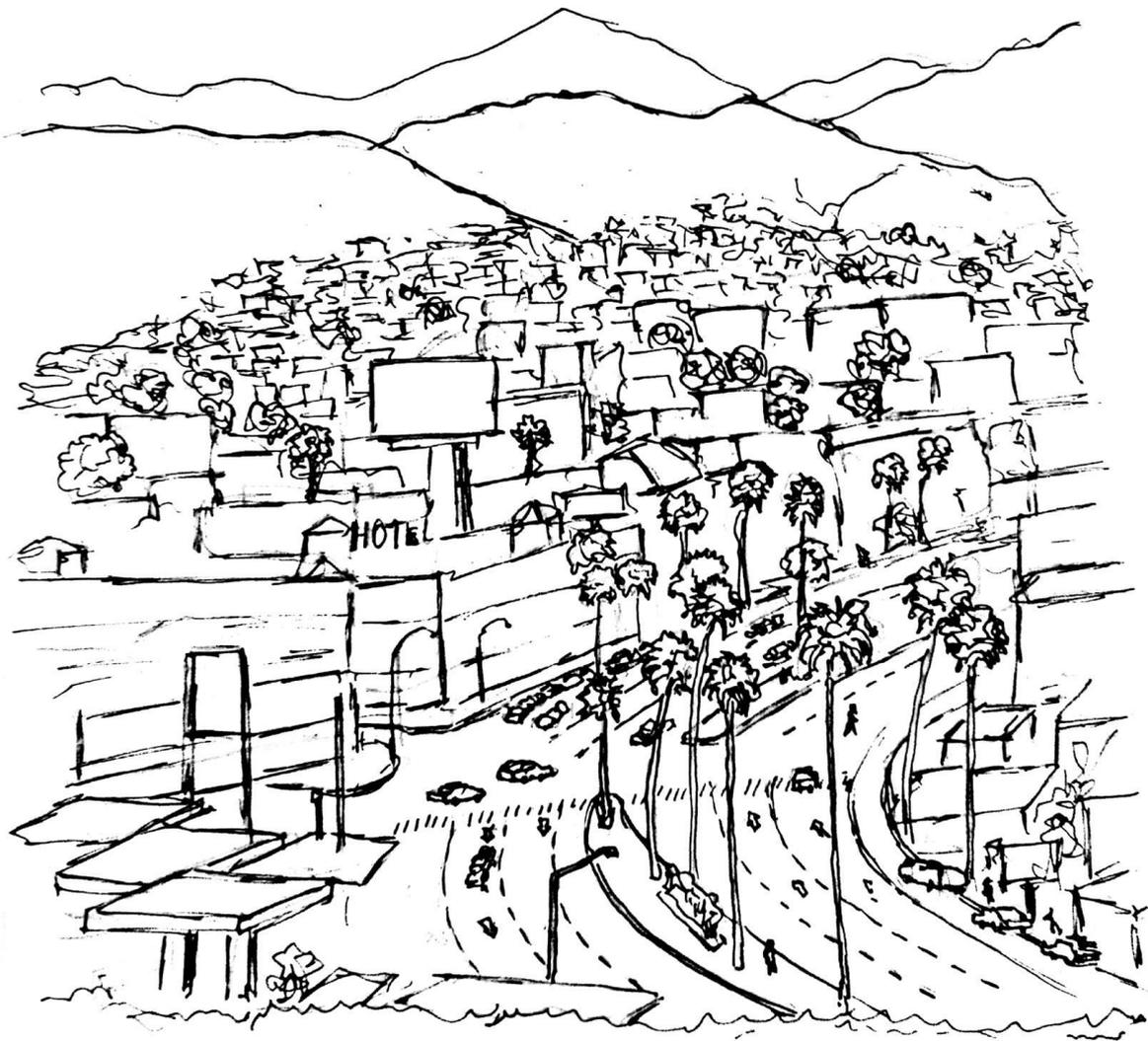


CAR DEPENDENCE FACTORS IN MID-SIZED CITIES

THE CASE STUDY OF ENSENADA, MEXICO



DANIELA ROQUE MONTES

MASTER THESIS



CAR DEPENDENCE FACTORS IN MID-SIZED CITIES

THE CASE STUDY OF ENSENADA, MEXICO

Daniela Roque

Supervisors:

Dr.-Ing. Houshmand E. Masoumi

Dr.-Ing. Wulf-Holger Arndt

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Fakultät VI Planen Bauen Umwelt

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STATEMENT OF AUTHENTICITY

This thesis contains no material which has been accepted for the award of any other degree or diploma in any institution and to the best of my knowledge and belief, the research contains no material previously published or written by another person, except where due reference has been made in the text of the thesis.

Daniela Roque

Berlin, 30th January 2015

ABSTRACT

Travel behavior has been the subject of several authors' research studies in recent decades. These studies focus on analyzing the negative consequences associated with heavily car oriented modal splits mostly on large well developed cities, however, there is a gap in research for developing countries, especially for mid-sized cities. Bigger cities can be problematic for urban planners compared with smaller cities, especially to alter the modal split. As cities grow modal splits become difficult to alter as cities become more developed. The status quo of the 62 mid-sized cities varies, but between all have a current problem: high levels of car ownership; even compared with megacities such as the capital. Conversely, mid-sized cities still have potential for implementing plans to effectively control car ownership levels. This research attempts to explain if the selected sixteen factors influence the modal split. As well it explains the relationship between these factors in the city. The city of Ensenada is selected as a case study subject, as it represents a normal mid-sized city in Mexico with the additional characteristic of being close to the USA border.

This study is an aggregated approach using linear regression analysis. Three main areas are analyzed throughout this research: urban form, transportation variables, and socio-economic factors. Linear regression analysis is used to produce more reliable results for 16 variables in the three different areas. The regression analysis clarifies whether these variables are relevant and how they have influenced car ownership ratios in Ensenada between 1980 and 2014. Relevant variables are selected and used to test initial hypotheses made from analysis of previous studies.

Results present some discrepancies with results from previous studies, but most variables proved to have an effect car ownership levels. The special characteristics of the city play a role in these findings. These results were used to develop recommendations in a short, mid and long term. The recommendations are based on the descriptive analyses and the statistics findings of this work. Further work's recommendations encompass other focuses such as disaggregated research and more in-depth aggregated investigation as the inclusion of more detailed variables.

Keywords: car dependence, mid-sized cities, linear regression, urban form, travel behavior, socio-economic, Mexico.

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LIST OF ABBREVIATIONS

| | |
|----------|--|
| CBD | Central Business District |
| CMIC | Mexican Chamber of Construction's Industry |
| COPLADE | Planning Committee for State Development |
| GOBBC | Baja California Government |
| IMIP | Municipal Institute of Research and Planning |
| INEGI | National Institute of Statistics and Geography |
| MXN | Mexican Pesos currency |
| PDUCP | Urban Development Program of the Population Center |
| PT | Public Transportation |
| SEDESOL | Ministry of Social Development |
| SISAIPBC | System for the Access of Public Information of Baja California |
| USD | United States dollar |
| VMT | Vehicles Miles Travelled |

INTRODUCTION

1.1. OVERVIEW

As a city grows with a lack of proper planning, several problems tend to arise. Studies on modal split are important to develop a sustainable city. One of the biggest problems with the current modal split in numerous cities is the overwhelming use of cars. The predominance of car use in the modal split corresponds to side effects such as environmental problems, economic losses, etc. Consequently, researchers aim to investigate the causes of car dependence using diverse approaches.

In recent years, car dependence has become a prime issue in the subject of mobility. Some approaches towards this issue favor a pull system, aiming to convince citizens to change their lifestyles by either providing them with better economic options or by increasing the cost of car use in a push approach. Other approaches seek a technological solution by producing low emission cars and a sustainable public transportation system.

In order to address any problem, its causes must be understood. Some attempts to balance modal splits by governments could fail without thorough understanding of the issue. This research aims to determine whether several specific factors have some negative effect on increasing car dependence rates.

A motorized city arises from different conditions depending on the local culture, personal preferences, and the physical structure of the city, among others. This research is focused primarily on understanding urban form with a spatial-temporal approach integrated with socioeconomic and transportation analysis.

1.2. PROBLEM STATEMENT

Since the introduction of automobiles, accessibility in many cities has shifted from a pedestrian-focused to a car-oriented structure (Newman & Kenworthy, 1999). The transition to automobiles often largely displaced the option to travel by foot, drastically skewing modal splits.

The most widely recognized consequence of increased car dependence is the resulting environmental impact. Carbon dioxide emissions and noise pollution are worldwide problems. Other effects include increasing commute times due to congestion, resulting in economic inefficiency and high energy consumption.

Rising car dependence is particularly problematic in developed countries such as the USA, Canada, and Australia (Newman & Kenworthy, 1989). USA cities present low densities and presence of sprawl, which studies have linked these characteristics with car dependence. However, this trend is also spreading into developing countries. Now other cities developing into motorized cities are displaying similar characteristics. The lack of studies on Mexican cities concerning the ratio of urban sprawl is a major concern beyond issues of mobility. Some government studies give a general view of

urban development over the last 30 years, but are insufficient for analyzing the consequences of an increasingly compacted city.

Several other factors are involved, including some which influence the citizens who must be convinced of the viability of private transportation's alternatives. It is similarly important to detect whether urban sprawl plays a role in order to take the proper responsive actions. Focusing only on one aspect of the problem could lead to incomplete solutions.

While the urban form of a city, economic conditions, and social aspects are involved in determining a modal split, personal preferences and cultural backgrounds must as well be considered. Therefore motorized cities can be derived from two scenarios: the characteristics of the city may push citizens towards a motorized modal split, or the preferences and the cultural background of the population may be the primary driving force of car dependence. A combination of studies in both scenarios is necessary to completely understand the origin of the problem. The reality may be a combination of these two cases. The difficulty with personal preferences is analyzing and influencing them for the desired outcome.

The factors that this research aims to measure are those which are more easily manipulated through government intervention. Influencing the population may partially be a matter of changing cultural mindsets which regard car ownership with economic status. The variables are: average income, average age, gender, household size, urban sprawl, density (population and employment), land use mix, main and secondary streets per capita and area, main and secondary intersections per area, bus ticket prices, and gasoline price per liter.

Urban form factors may alternatively shape a city to be more accessible to pedestrians. If cultural factors are found to be of little importance to modal split or impractical to drive towards change, then the urban form of the city will be critical towards controlling car dependence through its relation to economic growth.

Though research on urban form, socioeconomic factors, and local preferences has been conducted, many of these studies focus on developed countries or one specific area in developing countries. There is a lack of studies on the region of Latin America focusing on urban expansion in bigger cities.

Changing the urban form of a city can be difficult, particularly in large cities. Midsized cities, however, have potential for change. Currently Mexico has approximately 62 midsized cities with population growth likely to bring them up to intermediate or large cities in the near future (SEDESOL, 2012a). If these cities continue to develop according to previous trends, Mexico may expect more large cities sprawled with increasing car dependence. Documents from the Mexican government reveal that Mexican cities are experiencing increasing sprawl, and motorization rates are disproportionately high considering the size of the cities.

Considering the economic conditions in Mexico, it is problematic for car ownership to be exceedingly common. This raises the question of how necessary private transportation is for the average citizen. This can be measured with respect to different aspects as mentioned above, but this research focuses only on a disaggregated model. Some researchers argue that urban density is a major problem while others focus on the economy, but if all relevant causes are not thoroughly studied, attempts to develop a plan to reduce car dependency are likely to fail or provide only partial solutions.

1.3. RESEARCH QUESTION AND HYPOTHESES

The aim of this study is to reach a conclusion on three aspects related to car dependence: urban form, transport and socioeconomic variables. The question is how exactly these factors are related. The sixteen different variables which will be obtained are initially assumed to be relevant to the phenomenon. The question is then determining how these factors influence car dependence.

In short, the question is: Are the different variables in the three selected areas having a negative impact on car dependence levels in the mid-sized cities of Mexico?

The initial hypothesis is that the urban form of the city, socioeconomic and transportation variables are leading to increase car ownership levels. These are the expected results:

1. Low population and employment densities are negatively affecting car ownership levels.
2. Less compact cities lead to higher car ownership.
3. Better connectivity and road infrastructure is an incentive to commute by car.
4. Expensive bus tickets discourage people from using the public transportation system and therefore many favor private transportation.
5. Cheaper gasoline prices are an incentive to own cars.
6. Wealthier cities tend to have higher car ownership rates.
7. The elderly population commutes more by car.
8. Women drive less according to the average lifestyle among the female population.
9. A change in the family structure (size) leads to an impact on car ownership levels. Families of different sizes tend to have comparable numbers of vehicles. Larger families therefore own fewer cars per member on average.

1.4. RESEARCH STRUCTURE

This research is structured in several chapters, each with different purposes and collectively providing an analysis of the factors increasing the level of car ownership. The first chapter provides an overview of the purpose of this research and the different hypotheses made. According to the problem statement, the goal is clear. In order to provide useful results, it is first necessary to become familiar with different stances from other authors which are described in chapter 2. Research studies on concepts such as car dependence, travel behavior, urban forms, and other relevant topics are reviewed. From these different studies, a variety of methods and results may be studied and compared. The second chapter besides provides preliminary ideas for explaining the results of this study and developing recommendations for improvement.

Chapter 3 includes the physical work of this study, a description of the chosen case study, and describes the data obtained from government sources and institutes. An explanation of how this data was analyzed to produce relevant variables follows.

Afterwards in chapter 4 a description of what each of these variables represents is provided and is accompanied by graphs and tables. There will be no interpretation or assumptions developed in this chapter, only a description of the primary data. At the end of this chapter are the description of the analysis model and a description of the numerical results.

The discussion chapter 5 brings together the findings and the case study description with the literature review. This chapter aims to explain what may be the possible causes for the behavior of each variable relative to the dependent variable. From the resulting analysis and assumptions, recommendations can be made for improvement.

This study ends with a summary of this research and recommendations for further studies based on the limitations of this work (Chapter 6).

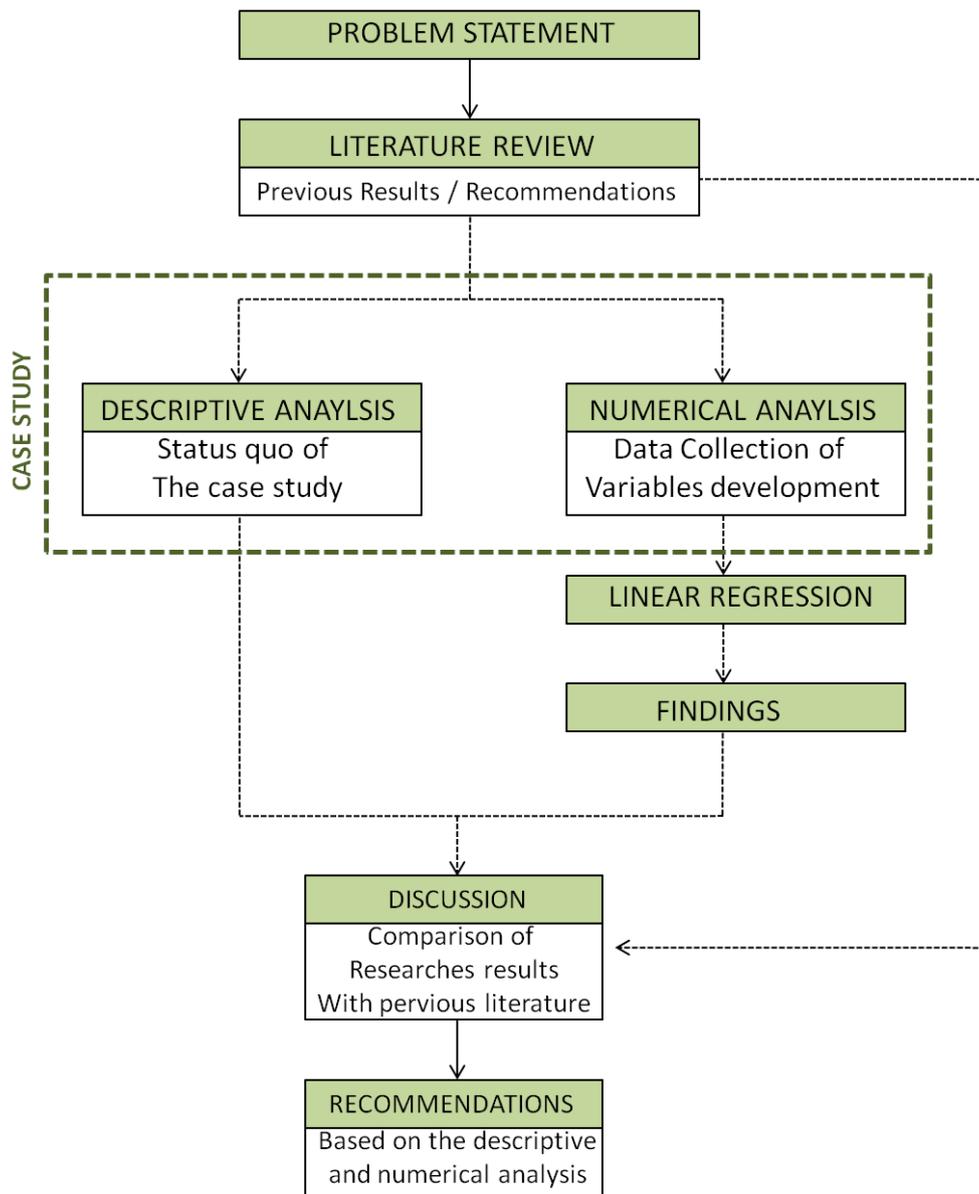


Figure 1.1 Research structure

Source: Compiled by author

LITERATURE REVIEW

2.1. FACTORS DEFINING TRAVEL BEHAVIOR

“There are so many relationships between the social, economic and environmental aspects of urban life that are determined by the city’s transport pattern and how the city is shaped”

(Newman & Kenworthy, 1989, p. 6)

Understanding travel behavior has been the focus of research for several authors using different methodologies. Studying travel behavior means identifying what variables are influencing the way people commute. But why is it important to study travel behavior? There are some modal splits which are considered unsustainable. Some cities are dependent on cars; others have virtually no biking at all, etc. How a modal split can be considered sustainable varies from different perspectives. More urban planners are against major dependence on automobile traffic, preferring a focus on metro, BRT, or bicycle traffic. There is no unique ideal modal split; an effective split is dependent on city characteristics. Therefore, to change the modal split of a specific community, there is a need to analyze and understand the causes of that community’s travel behavior.

Why does a city have a specific modal split? What factors define travel behavior? Several authors have focused their research on these topics, some of them focusing on urban form, socioeconomic factors, policies, etc., but what is clear is that the results vary from city to city. Just as economic conditions vary between countries, so do commuting preferences according to lifestyle differences (Figure 2.1). Why people commute in a specific way could be a result of several factors. Different authors have drawn different conclusions from socioeconomic factors and personal preferences, among others. While conditions differ between locations, major factors include: transportation and land use policies, socio-demographic factors, spatial development patterns, and some cultural/personal preferences (Buehler, 2011).

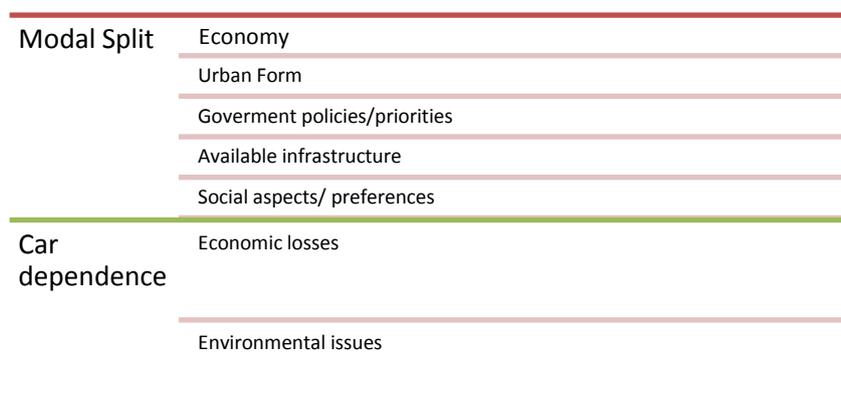


Figure 2.1 Travel behavior’s factors and consequences

Source: Compiled by the author from different sources

2.1.1. URBAN FORM

Constructed environments play a role in changing the travel behavior of a certain community. Persons adapt to their surroundings, along with cultural aspects which may influence the frequency and mode of their commute.

The urban form of a city is composed of different characteristics. The shape and topography of the type of construction, land use mix, type of neighborhoods, and the compactness of the city all interact together to shape travel behavior. Depending on the city, some factors will be more relevant than others.

2.1.1.1. NEIGHBORHOOD TYPE

Different neighborhood types have been evolving over time due to different causes such as: preferences of the citizens, economical factors, and government politics as other stakeholders have held influence. The pedestrian-friendly city that Newman and Kenworthy (1999) describe changes into an auto city with separate housing as neighborhoods evolve. However, this statement indicates that accessibility of cars affects housing, not the other way around. Some authors agree on the relationship between different types of neighborhoods and travel behavior, while others do not believe there is a strong correlation. It is not quite clear yet whether neighborhoods are shaping travel behavior or whether lifestyle and commute preferences determine where people choose to live in the first place. Crane and Crepeau (1998) argued that it is an unexplored topic, and too many questions remain unanswered in order to give an accurate statement on the matter.

In the case of Northern California, the neighborhoods' characteristics have a connection to travel behavior, especially with walking and biking; this means that the infrastructure for biking and walking are important for changing the modal split (Cao, Mokhtarian, & Handy, 2009).

It seems that urban form has greater influence compared to factors such as people's preferences. The work of Schwanen and Mokhtarian (2005) in San Francisco, California showed that in suburban neighborhoods the modal split is being directly influenced by this urban form much more strongly than the personal preferences of how people would like to commute.

Khattak and Rodriguez (2005) found a relationship in the case of North Carolina, USA. The result was that neo-traditional neighborhoods travel less and walk more than traditional neighborhoods. Traditional neighborhoods affect the modal split, but as Cervero and Kockelman (1997) explain, it is important to analyze non-work related travels, explaining that for these trips some shops inside the community could induce more walking trips.

In particular, the results suggest that when attitudinal, lifestyle, and socio-demographic variables are accounted for, neighborhood type has little influence on travel behavior (Bagley & Mokhtarian, 2001).

2.1.1.2. LAND USE MIX

One characteristic of the urban form is the distribution of the land uses. This is one of the current leading topics in creating a sustainable city. Normally when attempting to achieve a sustainable transportation system this subject is a substantial factor in developing a suitable urban form.

Several authors explore land use policies in order to mitigate negative travel behaviors, and some found a strong connection through their studies (Cao et al., 2009; Cervero, 2002; Cervero & Kockelman, 1997; Cervero & Radisch, 1995; de Abreu e Silva, Golob, & Goulias, 2006; Holden, 2006; Jabareen, 2006; Kenworthy & Laube, 1996a; Kockelman, 1991; Krizek, 2003; Lawrence & Pivo, 1994; Marshall & Banister, 2000; Nolon & Bacher, 2007). Others found little or no relationship between land use and travel behavior (Boarnet & Sarmiento, 1996; Randall Crane & Crepeau, 1998; Milakis, Vlastos, & Barbopoulos, 2008). The first group of authors agrees land use mix is important. The availability of different services close to the home can lead to decreased travel times and encourage walking (Krizek, 2003).

Newman and Kenworthy (1999) explained the “walking city” is characterized by common destinations which can be reached on foot within thirty minutes (2.5 kilometer trip). Homogeneous land use normally fails to promote walking. The rise of cars had a role in the transition from pedestrian focused cities to car dependent cities, as cars initially provided drastically reduced commutes (Newman & Kenworthy, 1999). As Jabareen (2006) explains, there are four desirable urban forms: neo-traditional development, compact cities, urban containment, and eco-cities; all of them consider land use, with the first two prioritizing proper land use. Additionally, de Abreu e Silva et al. (2006) concluded that a mixed land use by design is recommended.

In some case studies, a positive relationship was found between mixed land use and increasingly non-motorized travel behavior. This approach encourages the citizens to walk and bike as their average miles traveled decreases (Cao et al., 2009; Cervero, 2002; Cervero & Kockelman, 1997; Cervero & Radisch, 1995).

But in other cities the case was different. The research of Boarnet and Sarmiento (1996) stated that there is insufficient precedence to support land use policies to alter travel behavior. A study in San Diego by Crane and Crepeau (1998) indicated a lack of causation between land use and car usage. In the case of Athens, the mixed land use had an insignificant role in travel behavior (Milakis et al., 2008). Land use balance and mix have little significant to reduce VMT when compared with accessibility (Kockelman, 1991).

As Holden explain (2006) land use planning is only one of the several tools to reduce VMT; other variables are involved, such as the creation of city centers. A relationship between policies on land use planning and technological innovation should be explored when commute reductions are desired (Marshall & Banister, 2000). However, land use regulations do not only induce changing travel behavior; they have effects on public health, safety, and welfare (Nolon & Bacher, 2007).

2.1.1.3. URBAN SPRAWL

“In considering long-term sustainability of development, it is important to consider the efficiency of new development (i.e., hectares of new development in relation to number of people supported). Under this reasoning, sprawl is considered inefficient new urban growth.”

(Hasse & Lathrop, 2003, p. 171)

Several authors in recent decades have focused their research on urban sprawl, yet it is unclear how to define, measure, and delimit its impact. Therefore it is necessary to define urban sprawl, although disagreement among different authors towards the subject means it is difficult to arrive at an accurate and definitive description. From this discrepancy in opinion comes disagreement about its characteristics, impacts, and whether it is a positive or a negative urban form. Most authors have agreed that cities with urban sprawl suffer negative ramifications. From the standpoint of ecological, economic, and social aspects it is imperative to define and measure the characteristics of urban sprawl.

The Mexican government is aware that urban sprawl is affecting its cities, but there is a lack of in-depth studies on why or exactly how it is evolving. SEDESOL affirms that urban development in Mexican cities is excessively increasing with the presence of leapfrogs and decreasing densities. The publication “The expansion of cities from 1980-2010” (Spanish translation) explains the necessity of attacking this issue, as most Mexican cities are experiencing different growth rates between population and urban development, with the first normally growing slower. This condition is global; despite differences in assessment methods in some countries, root causes are consistent. As Masoumi (2012) explains, urban sprawl characteristics are similar between U.S. and Iranian cities; presumably this is as well the case with Mexican cities. These conditions are not exclusive to developed countries such as the U.S. or European nations (Mohammadi, Zarabi, & Mobaraki, 2012), but affect small villages (Sudhira, Ramachandra, & Jagadish, 2004).

Different authors provide contrasting definitions of urban sprawl with respect to its characteristics, impact, and measurement approaches. A definition of urban sprawl is quite complex to develop due to the lack of a common consensus between authors. However, the potential value of arriving at a more concrete definition has led some authors to focus their research with that aim, such as Johnson (2001). Johnson’s methodology was a comparison of different existing definitions, concluding with a summary of the similarities. He concluded that urban sprawl comes from a mix of urban form, transportation, and social factors. Sprawl is defined by the presence of segregated land use, automobile dependence for commutes, urban growth outside expected boundaries, higher densities (in population and employment) in the inner city, homogeneity in the population by race, ethnicity, or class, and a lack of policies to address resulting issues as they emerge (Johnson, 2001). Masoumi (2012) focused his work on five aspects to define urban sprawl: suburban development, single-use developments and zoning, street networks, accessibility, and commercial strip development.

On the other hand, from an urban growth approach urban sprawl has been defined as:

“A pattern of land-use/land cover conversion in which the growth rate of urbanized land (land rendered impervious by development) significantly exceeds the rate of population growth over a specified time period, with a dominance of low-density impervious surfaces.”

(Barnes, Morgan III, Roberge, & Lowe, 2001, p. 4)

According to Barnes et al (2001) the characteristics of urban sprawl are: strip and leapfrog development, fragmented habitats and land-use patterns, segregation and poor accessibility among land uses, lack of functional open spaces, brownfields in abandoned urban areas, automobile dependence, and ineffective public transportation systems. The four determinant elements defining urban sprawl are summarized as: urban form, land use, impacts produced, and density (Chin, 2002).

The causes of urban sprawl are not the same in every city. Causes may range from political policies to geographical factors (Barnes et al., 2001). One possible factor could be automobile subsidies and the decline of public transportation. This shift in preferred mode of transportation, by providing increased mobility and allowing for the outward movement of the population, is perhaps the single most important enabling factor to urban sprawl (Chin, 2002, p. 10). In his case study on Nigeria, Alabi (2009) agrees that rapid uncontrolled growth in population is a major cause of urban sprawl.

Brueckner & Fansler (1983) conclude that in the case of the USA, growing populations and the higher incomes of citizens have more impact on the urban form. The empirical results of some researchers argue that the urban form does not depend on economic forces of the city; rather, it depends on other variables such as population, income and rent (Brueckner & Fansler, 1983).

Urban sprawl is seen as a detrimental urban form conducive to poor service access, limited mobility of the young and elderly, long commuting times, and higher costs of infrastructure, among other consequences (Chin, 2002). Even so, some effects of urban sprawl could be perceived as beneficial. As Chin (2002) explains, urban sprawl could be related to lower housing costs and more efficient use of automobiles.

One of the attributes of urban sprawl that many authors have debated over is its relationship with travel behavior. Some argue there is a weak connection, or no such connection at all (Bagley & Mokhtarian, 2001; Boarnet & Sarmiento, 1996; Randall Crane & Crepeau, 1998); others believe that the urban form of the city is closely related with travel behavior. A more sprawling city will intuitively lead to more automobile traffic (Badland et al., 2012; Cao, Mokhtarian, & Handy, 2007a; Cervero & Radisch, 1995; de Abreu e Silva et al., 2006; Kenworthy & Laube, 1996a; Khattak & Rodriguez, 2005; Naess, 2003).

Bagley & Mokhtarian (2001) argue that the neighborhood type has relatively little importance. Boarnet & Sarmiento (1996) concluded in their research that any such relationship is negligible. On the other hand, other research suggests a strong correlation with travel behavior. Those living in certain urban forms have a modal split which is less car oriented (Cervero & Radisch, 1995). Naess (2003) recommends avoiding further urban sprawl to reduce the amount of travelling. For Crane & Chatman (2003) the relationship between sprawl and travel behavior is stronger than with other variables, such as employment.

Observing negative impacts is a typical method for measuring sprawl; still, this is not a standardized procedure. Some authors measure sprawl with a quantitative approach, while others favor qualitative methods. Analyzing some indicators such as density of new urbanization and loss of farmlands, wetlands and forests can give insight towards measuring urban sprawl (Hasse & Lathrop, 2003). Using similar methods, Frenkel and Ashkenazi (2008) specify five indicators to measure sprawl in Israel, some of them similar to those outlined by Hasse and Lathrop (2003). These indicators are growth rates (population in the periphery), density, spatial geometry (heterogeneity, leapfrogging, etc.), accessibility, and aesthetic measures. They concluded that urban sprawl is strongly related to population and land consumption growth rates.

The work of Papa (2009) is dedicated to the measurement of urban sprawl by different indexes associated with five dimensions: spatial configuration, grow rate, accessibility, travel behavior, and social impacts. She subsequently developed an integrated urban sprawl index. In two case studies she found that there are two different kinds of sprawl, resulting from filling of free spaces and new scattered lots respectively.

Others focused their work on measuring urban sprawl by concentrating on analysis of urban growth by the application of Shannon Entropy (Alabi, 2009; Deka, Tripathi, & Khan, 2011; Joshi & Bhatt, 2011; Mohammadi et al., 2012; Sun, Forsythe, & Waters, 2007; Tsai, 2005; Yeh & Li, 2001).

Tsai (2005) develops quantitative variables of the urban form in order to distinguish sprawl from compactness: metropolitan size, activity intensity in the city, and the distribution of the activities and density. Some aspects of urban form can be observed, e.g. if a city has characteristically solitary buildings. The degree of sprawl will depend on the density of the urban area. In addition, sprawl is determined by aspects such as distances between buildings and population density (Jaeger, Bertiller, Schwick, & Kienast, 2010). Measurements of these traits and additional attributes are used to develop standardized indices of sprawl development (Barnes et al., 2001, p. 16).

Throughout this paper, urban sprawl is defined as the rapid growth of urban development, especially in the periphery. This growth will not be uniform among all areas, as it could be the case that growth is limited to certain segments of the city. Urban development will be accelerated as population densities increase. The presence of leapfrogs, available empty space, and high car ownership rates are characteristic of this type of development.

2.1.1.4. POPULATION DENSITY

Population density plays an important role in determining urban form factors. In the work of Kenworthy and Newman (1989) data from several cities was analyzed, relating population density and energy consumption. According to their work, it is clear that low density is leading to more fuel consumption. Low or high densities do impact the decision of whether to walk or not, as often the most decisive aspect for people is travel distance (Greenwald & Boarnet, 2001).

It is clear that elements such as population density and employment density have strong influence, even more so than socio-demographic variables such as income or age (Leck, 2006a). In Athens, density also appears to have a substantial impact (Milakis et al., 2008). Other statements

suggest that high densities do little to promote pedestrian travel because of poor accessibility to nonresidential areas (Krizek, 2003).

2.1.2. SOCIOECONOMIC FACTORS

Van de Coevering and Schwanen (2006) explain that urban form and transportation infrastructure are not the only variables to take into account for travel behavior; socio-demographic variables are essential as well.

Lifestyle preferences come from different backgrounds. Socioeconomic factors shape the lifestyles of citizens, and therefore their preferences are altered. Socioeconomic variables such as age, income, and gender among others have an effect on travel behavior. People's preferences affecting travel behavior do not fall only on where they like to live or their lifestyle; they are also matters of time, costs and jobs. In the work of Lawrence and Pivo (1994) results show that density, jobs and housing are affecting travel behavior, with employment opportunities exerting the greatest influence. Others concluded that people do not like to commute more than half an hour on average (Newman & Kenworthy, 1999).

Some research has found a negative association between higher income and walking rates, an inclination towards less vigorous activity in women (Owen et al., 2007), and a preference for the comfort of cars among the elderly (Zegras, Eran, Hebbert, & Coughlin, 2008). Curtis and Perkins (2006) concluded that women and the elderly travel less often and for shorter periods of time, mostly due the tendency of households with children to have limiting factors on travel behavior.

2.1.3. TRANSPORT INFRASTRUCTURE

As people decide how to commute, their choice will be based on the best options available. They consider the quality of public transportation (coverage and price), the available infrastructure (road, biking lanes, etc.), and time to commute by each option. As Greenwald and Boarnet (2001) concluded, distance and costs most directly affect non-work trips. If the cost and time to commute by private modes are equal or not significantly greater than the alternatives, it is understandable that people would rather travel by car.

Some external factors will affect users as well. The suburban communities that normally travel by private transportation are directly affected by the price of fuel (Zegras et al., 2008). Gas prices are directly related to density as discussed above, but this relationship is more complex and not as linear as previously analyzed (Newman & Kenworthy, 1989). Low petrol prices could influence use of private transportation. Government concessions for car companies lead to a change on modal split (Hanson, 2002). In the case of Israel, government policies favor automobiles, deemphasizing the public transportation system and changing the modal split to a more motorized system (Hanson, 2002).

Variables such as parking costs and the availability of affordable public transportation, as in the case of Hong Kong, has led to a modal split dominated by public transportation (Cullinane, 2003).

Cervero and Radisch (1995) also agree with the importance of considering economic variables, travel times, and price.

Transport policies also play a role in determining travel behavior, even with controlled socioeconomic factors; this is a good angle for urban planners due to the difficulty of developing a plan with an approach focusing solely on socioeconomic factors (Buehler, 2011).

The different aspects affecting travel behavior are numerous and vary for each case study. What is common between each case is the importance of analyzing multiple aspects rather than focusing only on a single factor, as any conclusions drawn from a restricted analysis would be of limited value. Travel behavior analysis is an effective method for decreasing car ownership levels.

2.1.4. PERSONAL PREFERENCES

Location of residence is a personal choice for some people, while others are forced by economic factors or a lack of other options in the city. In the case where options are available, deciding between traditional or suburban neighborhoods could be a matter of personal background; why do people decide to live where they do? For example, people between the ages of 50 and 60 years describe their ideal neighborhood as merely residential, with access via highways in order to maintain low traffic, and local, due to privacy preferences (Zegras et al., 2008). Modal split is determined indirectly when people are deciding on their place of residence. Still, this is not a one way relationship: preference of where to live may affect travel behavior, but it can also be the case that preferences towards our commute will influence where we choose to reside.

In the case of Northern California, results show that residential self-selection has an impact on travel behavior. People's travel behavior and neighborhood preferences influence where people decide to live (along with other socio-demographic variables); later, this has an impact on the modal split (Cao et al., 2007a). A person's preference towards walking, for instance, will have a specific effect on the modal split. The results of research by Badland et al. (2012) indicate that 26% of the people living in suburban neighborhoods would like to live in a place which is more walkable. Tendencies to walk are often only for exercise/recreation purposes, not to commute, and are usually only internal walks within the neighborhood (Zegras et al., 2008).

A paper by Aditjandra et al. (2013) also found that personal attitudes play a significant role in travel behavior. These attitudes are primarily focused on lifestyle preferences such as the likeliness to walk or take public transportation, concerns towards contamination, and perceptions about safety (cars or public transportation). In a Hong Kong study, 39% of people surveyed affirmed that they would be happier if they owned a car (Cullinane, 2003).

Because attempting to quantify personal attitudes is unreliable, only limited interpretations can be made (Handy, Cao, & Mokhtarian, 2005). The leisure time of people, their lifestyles, and their economic status are special factors for urban planners to consider in order to decrease excessive travel demands (Williams, 2005). As mentioned above, neighborhood type can be a crucial variable, but to Bagley and Mokhtarian (2001) neighborhood type is not as significant as lifestyles or attitudes.

2.2. CAR DEPENDENCE

Car dependence is an issue which has attracted urban planners' attention in recent decades. The "auto-city" was born due to the increasing availability of cars (Newman & Kenworthy, 1999). A city with proportionally high car ownership tends to experience the phenomenon of car dependence. Brindle (2003) defines car dependence as a driver's inclination to consistently make the often suboptimal choice to travel by car, either due to a lack of better, more efficient options or because the driver is unacquainted with those alternatives. The negative externalities of car usage are essentially economic, social and environmental, and do not bring any benefit to citizens as they drive more (Litman, 1999). Reducing carbon emissions is an essential environmental consideration. In recent decades, vehicle exhaust has contributed considerably to global carbon emissions (Andrew, 2010).

As mentioned in the previous section, travel behavior will develop in response to environmental factors and public perceptions. Kenworthy and Newman (1989) attribute high car ownership rates in cities with generally low population densities. By contrast, Van Wee (2011) argues that compacting a city while keeping other variables constant will reduce travel distances, but commute times would remain unchanged as people pursue other opportunities (jobs, stores, etc.) on the city's periphery. Still, Newman and Kenworthy (2006) support their previous assertions regarding the density factor, claiming that a city would need at least 3500 persons per km² to support a public transport system; a travel time of at most ten minutes to a station is acceptable for an effective system, as determined by the relative density of the city.

Road provisions, parking availability, and non-motorized modes of transportation are all also strongly associated with the pattern of auto-dependence across cities (Kenworthy & Laube, 1996a, p. 4). However, Litman (1999) explains that automobile dependence is not simply determined by low densities in cities; it is also dependent on factors such as transportation characteristics and land use. He emphasizes the inaccuracy of focusing on a single factor of car dependence. It is possible to induce a change in the modal split towards a reduction of car use with a focus on reducing travel distances (Marshall & Banister, 2000).

The effectiveness of private transportation is partially determined by the efficiency of highway connections between residential areas and places of employment (de Abreu e Silva et al., 2006). Consequently, greater investment into highway systems rather than public transportation encourages commute by private modes (Hanson, 2002). Khattak and Rodriguez (2005) found a relationship between vehicle miles traveled and walking trips in neo-traditional neighborhoods against the conventional neighborhood model. An age distribution skewed towards a younger population is likely to have fewer drivers, regardless of household availability of cars; household income plays a similar substantial role (Stradling, Meadows, & Beatty, 2000).

The concept of an "auto city" emerged as a means to achieve low densities, affordable housing and separation of land uses (Newman & Kenworthy, 1999). As automobiles became increasingly common, roads became progressively more oriented towards vehicle traffic rather than accommodating pedestrians (Andrew, 2010). Political aspects such as conflicting policies, subsidies and concessions to car companies, as in the case of Israel, may also promote car use (Hanson, 2002). It seems that cars hold several decisive benefits, from flexibility to increasing economic affordability (Camagni, Gibelli, & Rigamonti, 2002).

The phenomenon of increasing car dependence seems to appear more in the cities of the developed world (Newman & Kenworthy, 2011, p. 39). A study found the greatest instances of car dependence in the USA and Australian cities, followed by Canadian and European cities and some wealthy Asian cities (Kenworthy & Laube, 1996a). While Germany has less density and comparable levels of car ownership to the US, trips made by car in the US are on average 40% longer (Buehler, 2011). High car dependence is common in developed countries while car usage is increasingly widespread in developing countries (Andrew, 2010, p. 72). In the case of Israel, in the last ten years car ownership has increased by 80%, parallel to a simultaneous decrease in public transportation (Hanson, 2002).

As car dependence continues to increase, the question of reducing its growth and its repercussions becomes imperative. Andrew (2010) explains that through transportation policies, carbon emissions can be reduced; controlling emissions through regulatory policies is potentially even more effective than the development of new energy technologies. Towards these goals, effective integration of parking policies and establishing efficient connections between employment areas and public transportation systems become valuable tools to urban management. (Scott, McEldowney, Tyley, & Smyth, 2005).

“Avoid shopping malls that can be mainly accessed by car. Accessibility of public transport is an important factor in competing with car transport, and is normally more important than price.”

(“Urban Planning for Reduced Car Use,” 2007)

By contrast, Boarnet and Sarmiento (1996) claim in their research that the implementation of land use policies is not significantly effective in reducing car dependence. Also, Cullinane (2003) argues that density factors alone cannot explain the low levels of car ownership in Hong Kong; higher car costs paired with lower costs of the public transportation system are a more likely cause. The availability of public transportation has a major impact on car dependence, as observed in the case of Sydney, Australia (Holden, 2006). Scott et al (2005) affirmed that some initiatives on land use, public transportation, and parking restrictions as well as the accessibility to trains in new housing developments have measurable benefits towards a reduction in car dependence.

Understanding the causes of high car ownership rates in several cities will provide insight on how to regulate them. Naess (2003) arrives at the following solution: avoid urban sprawl, increase densities and employment in the inner city, and focus high densities in new urban areas to ensure infrastructure development and reduce investment in road and parking infrastructure. Jabareen (2006) describes the urban form in seven concepts: compactness, sustainable transportation, density, mixed land use, diversity, solar energy design, and green urbanism.

As Newman and Kenworthy (1999) summarize, the city is being changed by new transportation technologies along with economic and cultural factors. These three aspects can lead to the development of an auto city or they may help avoid the issues of detrimental modal splits entirely. Newman and Kenworthy conclude with a series of goals similar in concept to those proposed by other authors (de Abreu e Silva et al., 2006; Jabareen, 2006; Khattak & Rodriguez, 2005; Litman, 1999; Naess, 2003; Owen et al., 2007; Scott et al., 2005):

-High prioritization of new roads and parking spaces, leading to decreased travel times, and less space for housing development in the inner areas deferring it to the outer areas.

-Less priority on walking modal splits de-prioritize the factor of compact housing.

-High prioritization for low density suburban neighborhoods results in low densities.

-Granting priority for economic and social development instead of suburban development will lead to a less car orientated city.

-The prioritization of suburban neighborhoods is not only an economic matter, but also one of cultural preferences.

Government research in Mexico affirms that urban sprawl is directly related with major car use (British Embassy in Mexico, 2013; ONU HABITAT & SEDESOL, 2011). The rapid growth of Mexican cities would not be problematic if there existed proper plans to introduce the widespread use of public transport systems and bicycle use, but unfortunately this has not been the case. In Mexico, the urban planning process often does not take into account the subject of mobility.

Urban planning orientated towards public transport systems (combined with other social programs) would lead to a change on the modal split away from a car-orientated focus to improved sustainability, revitalization of neighborhoods, less environmental impacts such as noise and contamination, less congestion and accidents, reduced urban growth, and lower infrastructure costs as well as bringing other social benefits such as improved leisure and health (British Embassy in Mexico, 2013).

METHODOLOGY

3.1. OVERVIEW

After reviewing relevant literature, analysis of the problem statement and initial hypotheses began. The methodology used when approaching the problem is critical to reaching relevant and useful conclusions. Different approaches for analysis and interpretation of data towards testing of hypotheses can be observed from related literature. Selection of a viable methodology for this study was partially a matter of time and available resources. In order to test the hypothesis, a mathematical approach is used to assess data collected through a case study.

There are several viable approaches towards evaluating a hypothesis. Different methods may be used such as a numerical or a descriptive approach; the disadvantage of the second option is the personal predisposition of the authors or the sample interviewed. The fact is that an integrated work considering all those areas will be more thorough; most research attempts to accomplish a full study considering all relevant perspectives to the problem.

For this study, a numerical approach is used - more specifically a linear regression analysis. This analysis enables verification of the relationships among different variables; in this case all variables will be tested against car ownership

A case study is a practical approach towards understanding the interactions between different factors and making concrete recommendations for improvement, as these interactions are dependent on a city's characteristics. Due to time constraints, it was decided to work with available existing data. Given more time, a disaggregated model could be developed to measure preferences and to quantify cultural aspects of the city. Only limited information regarding housing and public transportation is available for a given period of time. Conversely, more complete census data is available, such as socioeconomic data, maps, and infrastructure details.

The variables selected for testing based on the availability of data are: average income per year, average age of the population, gender, household size, speed of urban sprawl, population and employment density, land use mix, length of primary and secondary streets per capita, length of primary and secondary streets per area, main and secondary intersections per area, single ticket bus prices, and the price of gasoline per liter.

To test the hypotheses mentioned previously, a statistical method which has been previously used for similar studies will be used. There are different methods for testing this kind of hypothesis; among statistical approaches, for example linear, nonlinear, and multiple-linear regression analysis methods are applicable methodologies. Choosing the best option depends on the material available. A multiple linear regression can give better insight, as it provides the relative significance of relationships among all the analyzed variables. Linear and nonlinear regressions give a bi-variable relationship. Unfortunately in this case, a multiple linear regression would not give appropriate results due to the lack of sufficient samples for the quantity of tested variables. The lack of data and the need to extrapolate and interpolate fit better within a linear regression. The outcome is the relationship between only two variables, potentially overlooking the connection between the collective variables.

The linear regression model will be used to determine which variables are relevant for car ownership rates. In order to perform such an analysis, a description of the city is made with the diverse data. This data must be manipulated or converted into more meaningful variables for testing.

This method provides numerical results which, when interpreted along with the city's characteristics, can help develop useful recommendations for improvement.

3.2. LINEAR REGRESSION ANALYSIS

Linear regression analysis provides insight into how factors in three different categories influence car dependence. Testing every variable separately against the dependent variable of cars per 1000 inhabitants using linear regression analysis will give a numerical indication of whether they are statically significant or not. In the cases when they are significant, analysis will also indicate what sort of relationship exists between each variable and car dependence.

Linear regression analysis is used for measuring the association between two quantitative variables. In this model, variables may be continuous (fractions) or discrete (whole numbers).

Box 3.1 Linear regression model

The final linear regression model is represented by:

$$Y = \beta_0 + \beta_1 X + u$$

Y = dependent variable – response

X = independent variable –predictor

β_0 = constant

β_1 = slope parameter

u = error or disturbance

This method is suitable for this case study, where different variables in three areas need to be tested in order to establish how relevant they are to the problem statement (dependent variable). As Sykes (1993) explains, regression analysis is a tool that researchers can use to approve or reject theories about the effect of one variable on another, along with making predictions and causal inferences.

Linear regression analysis will not indicate which variable is dependent on the other; it shows variation, not causation. Causes will be inferred based on background from literature and information gathered during the case study.

This case study uses IBM SPSS statistics 22 software to develop the final model. If a variable presents a significance value higher than 10%, it will be dismissed. The slope (β_1) indicates the direction and magnitude of a relation. If beta is positive, the dependent and independent variables

grow in the same direction. Magnitude indicates how significant the effect on the dependent variable is.

Before taking these variables into consideration, the confidence level must be revised to check significance. The model will give the p-value, which depending on the confidence level will reject or accept the null hypothesis. The null hypothesis in this case is that the variables are related in general meaning that their slopes are similar. The alternate hypothesis is that the slopes are different and therefore the variables are not related.

P-values are defined as the probability of obtaining a result or event; the significance level will be the parameter to determine if the probability is too high. A smaller p-value indicates a strong null hypothesis.

The p-values will be compared with the significance levels chosen: between 0 and 1% are highly significant, between 1 and 5% are significant, 5 and 10% are marginally significant and the rest of the values are not statistically significant. This range of significant levels will help to accept or reject the null hypothesis stated before.

Sample size is important for the accuracy of the model. Ideally the sample size is as large as possible. Unfortunately, for this study in the best case variable values are known for five year intervals. Although some of the variables are only available for three years, they are still viable for use in the model, according to De Winter (2013). De Winter finds that using small samples ($n=3$) will provide an error rate around 5% in most of the cases. Six samples (years) are available for all other variables, except for dissimilarity index (three samples). The final model consists of sixteen independent variables and one dependent: car ownership rates.

The null hypothesis assumes that the supposedly independent variables will control the behavior of the dependent variable. For this model, all the urban form, transportation infrastructure, and socioeconomic variables are considered independent.

In the case where a variable is considered significant according to the significance value specified, the next step is to determine whether the effect on the dependent variable is negative or positive, as indicated by the B value.

This would be the process for interpretation of the model as it is, but further interpretation of the model will be discussed in context of a specific city's characteristics.

3.3. CASE STUDY: ENSENADA, MEXICO



Figure 3.1 Ensenada's harbor and oldest part of the city

Source: <http://www.mexicanbusinessweb.mx/>

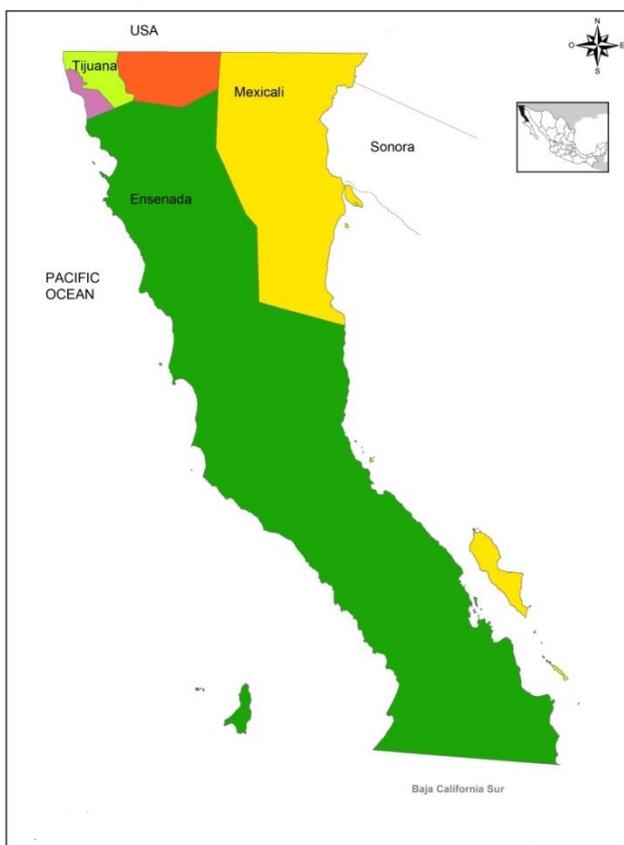


Figure 3.2 Localization of Ensenada

Source: Compiled by the author based on INEGI.

The city of Ensenada is located in the northwest of Mexico in the state of Baja California, approximately 150 kilometers from the border with the USA (Figure 3.2). SEDESOL (Ministry of Social Development) has classified Ensenada as a mid-sized city due to its population size, along with another 61 cities in Mexico. Ensenada is selected from these cities due to its classification as a middle size city and absence of extraordinary characteristics such as Los Cabos, for example, as its development has been altered due to tourism.

The city is young compared with others in the central and southern parts of the country. Despite consisting of only some small indigenous settlements, Ensenada was declared the capital of Baja California in 1882. In 1915, the capital was moved to Mexicali. From 1910 to 1930 the population was stagnant, with an average of 2800 inhabitants. The population started to grow rapidly in 1950 and currently has approximately 420,000 inhabitants in the

urban area (COPLADE, 2014). In Mexico, the growth model of cities has been dispersed, especially in middle-sized cities. In sixty years the change in the urban area of Ensenada has been substantial, from a few houses near the harbor to a highly motorized city today, partially because it developed in an age of rising car use and industrialization.

The municipality of Ensenada is the biggest in the country, with an area of 51,952.3 km², but the urban area is only around 90 km². This presents problems in the outer rural areas, as distances to the city are considerably large. These settlements are mostly in the south, and take part in the planning, budgeting, and other activities of the city. This sometimes causes

disagreement between the settlements, as some may feel underrepresented. This case study does not cover the entire municipality; it only considers the urban area referred to as the municipality head. The municipality head is currently divided into five zones. The oldest is called the Center Zone, located in front of the harbor. The other zones are Northeast, Sauzal, Chapultepec, and Maneadero (Figure 3.3).

At the national level, Mexico has a population growth rate of 1.7%. The city experienced the same growth rate in the last census period (2000-2010). By 2030, the municipality in its entirety is expected to have a population of 623,656 with more than half a million concentrated in the urban area. Therefore, Ensenada will be considered an intermediately sized city in only 15 years (COPLADE, 2014).

According to SEDESOL, the city presents a proportionally high number of automobiles, even compared with the capital; Ensenada has almost double the rate of cars per inhabitant than Mexico City. Linked with this ratio is the availability of cars per household, which in 2010 was around 72%. While the city does have high car ownership, the official number provided by SEDESOL of 460 cars per 1000 inhabitants is misleading. External factors, particularly proximity to the USA and accessibility to cheaper cars, cause rising numbers. The majority of cars bought in the city are imported with corresponding fees paid in full; there is not an exact statistic on the number of illegal cars, but this is a common issue in border cities.

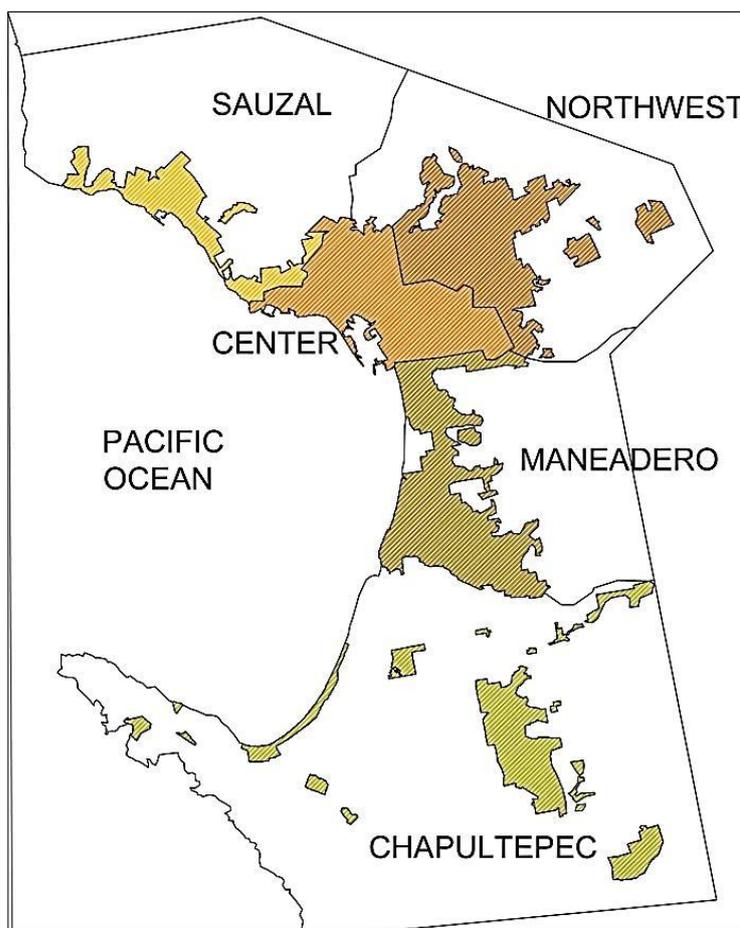


Figure 3.3 Zones of Ensenada (districts)

Source: Made by the author based on IMIP



Figure 3.4 Left: Boulevard Lazaro Cardenas Right: "Primera" Street

Source: S. Magdaleno 2014

The city was born as a harbor, and the harbor remains a center of economic activity (Figure 3.1). Economic activities revolve around fishing for export to North America and Asia. The fishing market represents a big employment sector; almost all these jobs are located in the Sauzal zone, with some others in the south. When the city started to grow, another harbor was constructed in Sauzal, and fishing activities moved from the harbor of the Center Zone. According to the Baja California Government (GOBBC), Tijuana and Mexicali have had better employment opportunities in the last decades, affecting Ensenada's growth in population and migration rate.

Other economic activities in the city are cattle and agriculture; these activities are in the periphery of the city in the south, close to the district of Maneadero. Wine production also represents a big sector of commerce in the city, but is located in "Valle de Guadalupe", approximately 45 minutes from the city center commuting by car. This settlement is not considered part the study area, but in recent years it has undergone urban developments, mostly housing projects, which in a few years would encourage more travel between this area and the head municipality.

Tourism has also become important due to proximity to the border and cruises coming from the USA. Still, the tourist area in the city is not particularly large, and tourists do not generally travel outside of the Center Zone. Violence in Tijuana affected this sector a few years ago. "Primera" Street (Figure 3.4), located in the Center Zone, mainly consists of hotels, souvenir stores, restaurants, and bars. Surrounding streets are lined with more commercial stores with low housing density. This zone presents some of the most significant congestion problems and lack of parking in Ensenada. The principal boulevard "Lazaro Cardenas" (parallel to the coast) has some of the heaviest traffic, as it is one of two routes for accessing the freeway to Sauzal or Tijuana (Figure 3.4).

The government proposed four industrial zones in Sauzal, Northeast, Maneadero and Chapultepec, but only Sauzal has developed due to the poor accessibility of the other three zones (IMIP, 2007). As explained before, Sauzal is characterized by its fishing industry and some manufacturing. The Chapultepec and Northeast zones contain some factories, but low connectivity is an obstacle to development in these centers. According to PDUCP, the south end of the city is experiencing less urbanization, lower densities, more leapfrog, and fewer public services.

Table 3.1 Middle size cities in Mexico with the highest car ownership; growth from 1980 to 2010 for population and urban sprawl.¹

| No. | City | Cars per inhabitant | Population growth (times) | Urban growth (times) |
|-----|-----------------------|---------------------|---------------------------|----------------------|
| 1 | Cabo San Lucas | 2.62 | 30.25 | 73.49 |
| 2 | Uruapan | 0.76 | 2.25 | 4.12 |
| 3 | Chetumal | 0.67 | 2.76 | 3.65 |
| 4 | Cordova y Ordoñez | 0.63 | 2.5 | 8.11 |
| 5 | La Paz | 0.63 | 2.35 | 2.07 |
| 6 | Irapuato | 0.54 | 2.31 | 7.76 |
| 7 | San Luis Rio Colorado | 0.53 | 2.06 | 3.27 |
| 8 | Ensenada | 0.46 | 2.4 | 3.74 |

Source: Compiled by the author based on SEDESOL 2012

IMIP and GOBCC state that the centers and sub-centers of Ensenada are not consolidated. Lack of connectivity corresponds to this statement, along with a lack of public services in some areas. There are two main centers, one in the center zone and the other in Chapultepec. The first presents good connectivity, while the second one lacks sufficiently effective street connections. There are three other sub-centers that have not been consolidated (IMIP, 2005).

In terms of sprawl, some studies from the government already support the idea that Ensenada, along with other Mexican cities, is experiencing substantial sprawl. According to SEDESOL, from 1980 to 2010 the city's area has grown 3.74 times while the population has increased by only 2.4 times (Table 3.1). Other Mexican cities had even less favorable growth rates, such as Ciudad del Carmen and San Cristobal de las Casas (more tourist development). The

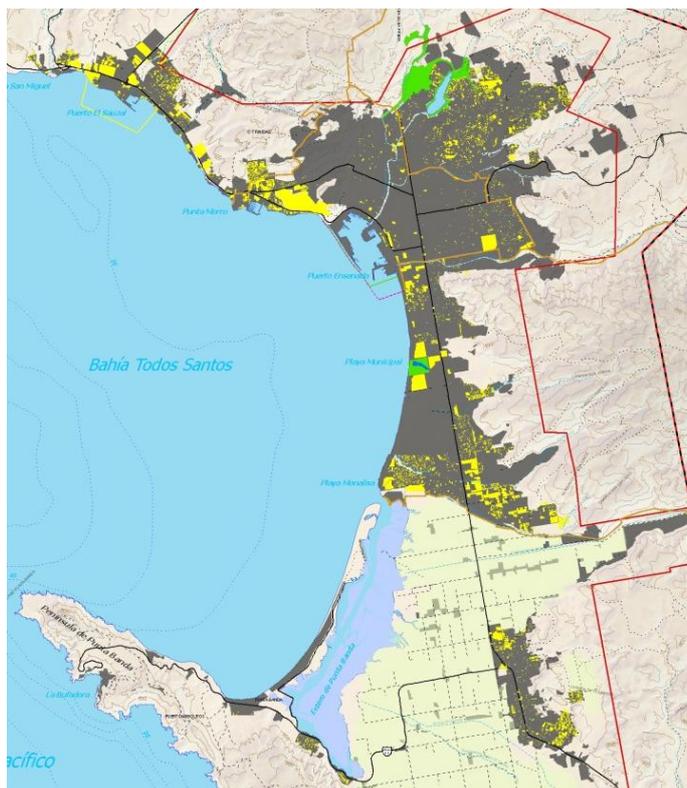


Figure 3.5 Empty lots in the inner city (yellow)

Source: IMIP: 2007

¹ The data in this table is gathered from SEDESOL and are not considered for this research. Only represents the awareness of the government that the cities are sprawling.

average growth of the country is concerning, with a population growth of two times compared to a tenfold growth in area.

Ensenada is a typical example of a middle-sized city in Mexico, in terms of population growth and urban sprawl. There are exceptional cases focused around tourist areas such as Cabos San Lucas, with a population growth of 32 times and urban sprawl growth of 74 times over the same time period (SEDESOL, 2012). The city now has a population density of 3400 inhabitants per km², low compared with the national average of 5400 inhabitants per km² (INEGI, 2014). Of the 62 middle-sized cities, Ensenada is ranked 8th in car ownership rates, as can be seen in Table 3.1. The urban growth of the city is also concerning. More detail information about the 62 middle size cities of Mexico are in Annex 1.

Ensenada is surrounded in the east by mountains and in the west by the coast, causing growth to be focused towards the north and south of the city. Sauzal is undergoing significant growth due to its industrial strength. It could be the case that topography is now delimiting Ensenada’s urban growth. The growth tendencies of the city are towards the south (Maneadero and Chapultepec) and northeast (IMIP, 2007).

Empty lots comprise approximately 9 km² of the urban area, representing almost 10% of the urban sprawl (IMIP 2007). The lack of sufficient control of land use has affected Maneadero and Chapultepec as well, where residential zones are being developed on land the government designated for agricultural use (IMIP 2007). City growth tends to occur at the periphery for several reasons, such as unregulated construction of informal settlements and the development of social houses, leading to dense residential zones in the periphery with a need to commute to the CBD.

Social houses are likely being built in these areas to take advantage of abundant free space.



Figure 3.6 Social houses

Source: Google Maps and RadaNoticias

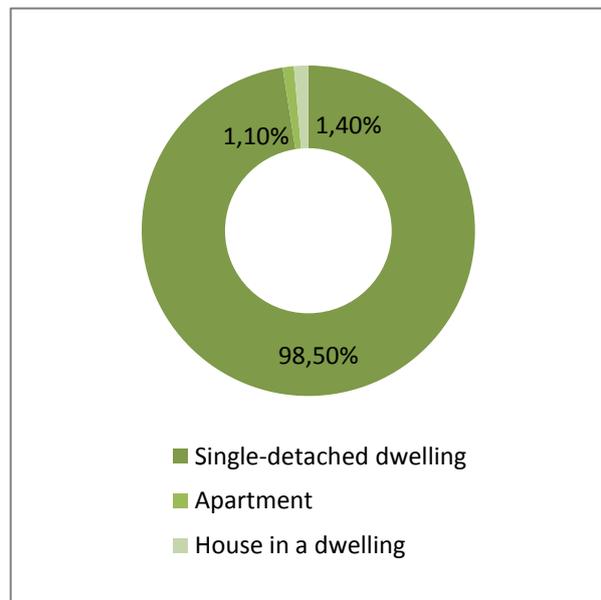


Figure 3.7 Preferences for a house

Source: GOBBC 2008

Some of these areas do not incorporate the expected public services; most commonly, these areas may lack proper streets.

Ensenada construction is mostly horizontal. Most residential houses are one floor, and in the older residential areas a typical plot of land is around 250 m² for a single family. The construction of social houses has increased in frequency for the last couple of decades in Ensenada. With the implementation of social housing, it is now less common for citizens to construct their own houses. Social housing has been more popular due to the ease of obtaining a house in less time than constructing a house by one's own resources. These kinds of houses are similar in design to the single family detached homes often found in suburban neighborhoods. According to a government survey, 98,5% of the population in Baja California prefers to live in a house rather than an apartment (GOBBC 2008), which is reflected in the abundance of suburban style neighborhoods like in the USA (Figure 3.8 and Figure 3.7).

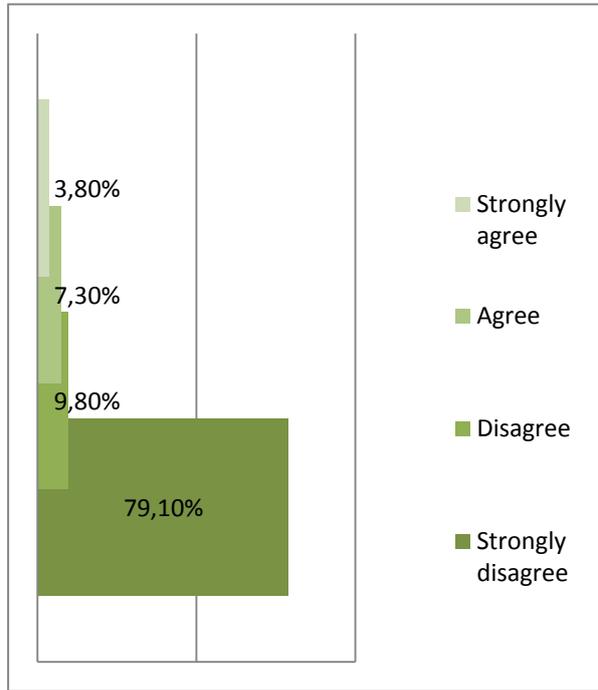


Figure 3.8 Agreement on vertical construction (more m²) against single detached dwelling (less m²)

Source: GOBBC 2008

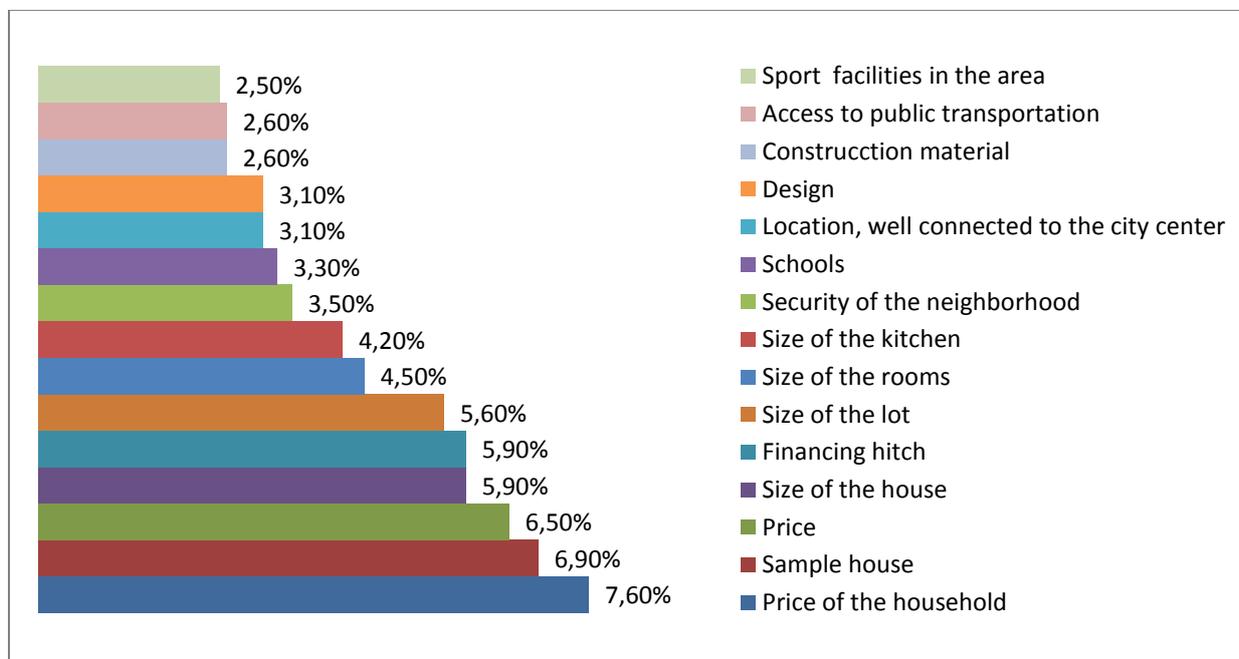


Figure 3.9 Factors taken into consideration when seeking a house

Source: GOBBC 2008



Figure 3.10 Style of parking in the Center zone and current status of some streets

Source: S. Magdaleno and M. Aragon (2014)

The same survey indicated that citizens choose their homes based on factors such as price and size of the house rather than location and accessibility to the public transportation system (Figure 3.9). The neighborhoods comprised of these social houses are designed to rely on local transit, and do not usually support many stores and markets. Consequently, informal stores sometimes arise in these neighborhoods to provide basic necessities (normally with little variety of food).

Ensenada has a building code based on the code of Baja California. However, according to the CMIC, planning and land use management has not been a priority for the last federal public administration. Additionally, at the municipality level, due to reduced town council term lengths, these issues are not prioritized in the agendas of council members.

The design of these houses is different from the oldest part of the city (Center zone and Northeast). The houses are designed for a family of at most 4 members and with an area of approximately 30 to 45 m², leading to greater population density in these areas. Botello Valle (2011) attributes the housing problem with a lack of coordination between different government entities.

This causes a lack of accessibility of public services, high costs to both citizens and the government, and abandonment of houses after construction (6%).

Ensenada's street network has presented problems in more recent years. Lack of efficient connectivity between streets causes roads to carry disproportionately high concentrations of traffic. For example, the boulevard "Lazaro Cardenas" near the coast is meant to serve as a connection between the North Highway and the south end of the city, but remains incomplete at Chapultepec due to a housing settlement, causing a bottleneck. Other streets operate under similar conditions, but none worse than Lazaro Cardenas. In recent years, poor street quality (Figure 3.10) has also become a problem of urbanization, with potholes becoming increasingly common (Newspaper El Vigia, 2012).

Street designs vary for each sector of the city. In the oldest sectors, the streets are wider, while in the center zone the streets have enough space to allow perpendicular parking (parking at an angle to the curb as can be seen in Figure 3.10). Sidewalks in housing areas are normally two meters wide, though this may vary depending on the streets. Street's construction projects are developed and financed by a government institution, but the citizens of the target area must approve the project and pay the loan in the subsequent years. The sidewalks are only delimited by the concrete curb. Citizens eventually pave their own sidewalks when and how they want; because these sidewalks are extended to reach homes and garages, sidewalks are often uneven (Figure 3.11).

In the last 5 years the number of cyclists has increased substantially for recreational, fitness, and transportation purposes, but accidents have simultaneously increased by 38% in the state (Newspaper El Vigia, 2014). The nonexistence of bike lanes and the lack of safety awareness towards biking are likely contributing factors (Figure 3.12).



Figure 3.11 Sidewalks in different parts of the city.

Source: S. Magdaleno (2014)



Figure 3.12 Cyclist in a sidewalk

Source: J. Cortes (2014)

The other option for commute is the city’s public transportation system, built solely around buses (Figure 3.14). The bus network is managed by six different companies and has nearly 100% effective coverage, according to a government report made by the city council in 2007. However, the government makes final decisions on routes, equipment, and ticket prices. In 2007 92 bus routes were granted, but only 65 are in operation. The other 27 routes do not operate due to a lack of demand, according to transportation companies.

Four companies operate 12 routes in the periphery of the city (City center to Sauzal and Maneadero) and operate from 5 a.m. to 10 p.m. with intervals of 5 to 30 minutes depending on the route. There are no designated bus stops; pedestrians walk to a route and signal for the bus to stop, as there is also no fixed schedule.

The city center is controlled by the two other bigger transportation companies, with 53 routes operating from 5 a.m. to 11 p.m. at intervals of 8 to 30 minutes. The average waiting time is between 6 to 10 minutes, but 25% of users wait more than 10 minutes (Figure 3.13). On average, 114,500 passengers commute daily, or equivalently, 1.25 passengers per kilometer. The typical age range of frequent bus passengers is from 18 to 25 years. Approximately 72 % of users need to commute with the buses twice or more per day. The greatest demand is from the periphery to the “Center Zone” district. Pedestrians mostly use the public transport system to commute to work and to study (Figure 3.16). According to this research, there is an excess of buses relative to demand, but only 48% of users think that the frequency of buses is satisfactory.

The public transportation network covers about 195 kilometers, and approximately 30% of buses are in poor condition. The majority of the buses are 1990 models, which according to an agreement with the government have already surpassed their intended life span; still, the units remain in circulation. According to IMIP, there exist three routes which overlap from 50 to 70% and 20 routes with 30 to 50% overlap.



Figure 3.14 Buses from two different companies

Source: S. Magdaleno (2014)

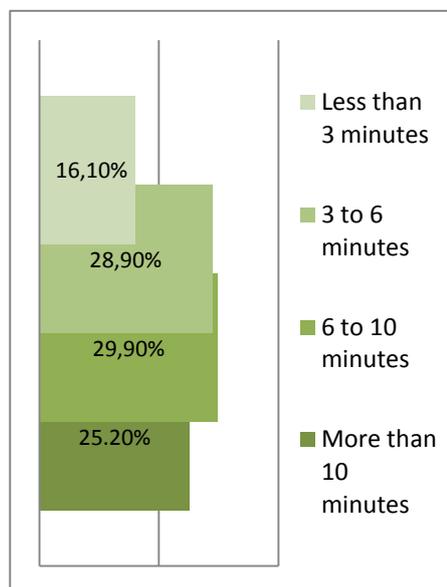


Figure 3.13 Average waiting for PT

Source: IMIP 2007

In 2007 54% of users considered ticket prices expensive (8 MXN) and complained that drivers did not respect fees and discounts (Figure 3.15). Considering that 73% of the users commute twice every day (Figure 3.17) and taking into account the lowest income of users in that year (57% of the users earns between 1,800 and 4,200 MXN according to IMIP), between 10% and 25% of income was spent on public transportation. Since the beginning of 2014, transportation companies have applied for a 35% raise in bus fares (13.5 MXN); the request is still being considered by the government. This has prompted complaints from users about the conditions of the buses, and often towards the drivers for not respecting discount rates for students and children, along with their driving skills.

The report made by IMIP in 2007 revealed some inconsistencies and critical points in the area of PT in Ensenada that is in need of improvement:

1. In a legal matter, the investigation reveals that some companies have more buses than the municipality government permitted.
2. Lack of concessions permits.
3. A lack of training for drivers (64% did not receive any training).
4. Lack of fixed schedules and designated bus stations.

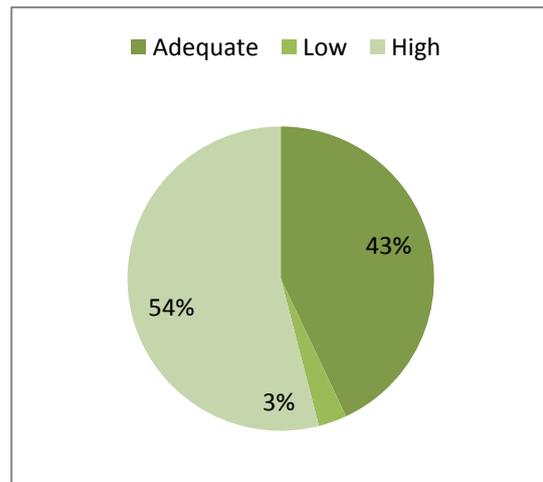


Figure 3.15 Perceptions of the public towards the bus ticket price

Source: IMIP 2007

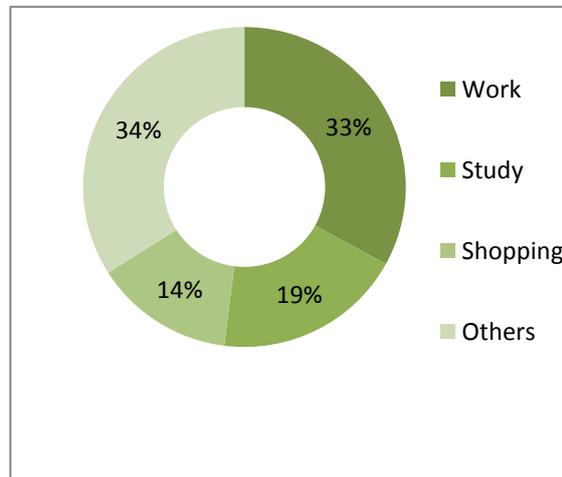


Figure 3.16 Reasons to commute in PT (excluding travelling home)

Source: IMIP 2007

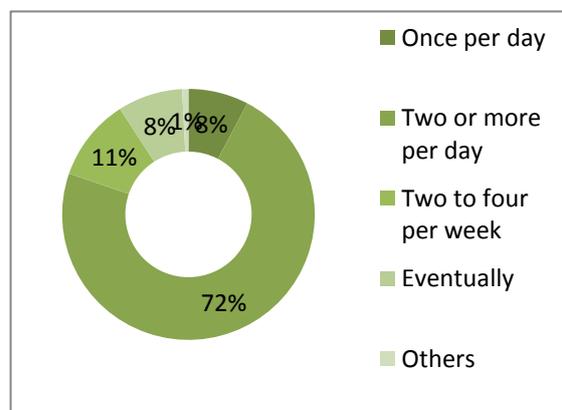


Figure 3.17 Trips per passenger in PT

Source: IMIP 2007

3.4. DATA

The collected data aims to provide insight into increasing car ownership in the municipal head of Ensenada resulting from three different categories: socioeconomic factors, transport infrastructure, and urban form. In order to quantify variables, a variety of types of data was required, especially maps. Data was primarily gathered from government sources for accuracy and legitimacy, and from alternative sources consulted in the absence of more official documents.

To create the most accurate model possible, the analyzed time period begins in 1990. The data obtained is for the following years: 1990, 1995, 2000, 2005, 2010 and 2014.

The gathered data is intended for creating as many possible variables relevant for travel behavior, as discussed in the literature review.

Car ownership data is available for each year since 1980 to 2013 from the INEGI database and for year 2014 from the state government (Annex 2).

This data is for registered cars in the municipality of the city. It seems there are some inconsistencies in the number of cars given by INEGI; the decrease in autos year to year seems inaccurate. The tendency of car usage will be from 1995, and is extrapolated for 1990.

Table 3.2 Number of registered cars

| 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|--------|--------|--------|---------|---------|---------|
| 71,999 | 78,545 | 96,890 | 108,779 | 131,972 | 153,156 |

Source: INEGI and GOBBC

As mentioned in the previous sub-chapter 3.3, the city contains illegal unregistered automobiles due to close proximity to the US border. Due to the lack of reliable information regarding exactly how many such vehicles exist in the city, this factor is ignored.

The main issue with acquiring accurate data for this purpose is that most available information is for the entire municipality of Ensenada; specific data for the head municipality alone is not completely available.

Several settlements are not directly connected to the city, but are associated closely enough by mobility to be worth considering in this study. Settlements considered in this study were selected based on their proximity to the CBD and common public transportation network coverage.

INEGI databases were the source of the majority of referenced socioeconomic data. Almost all such data was obtained from the institute's census records, updated every five years. Other data was obtained from state government web pages.

Income data was obtained from both INEGI and from state data. Mexico's shift to its current unit of currency in 1993 may cause a discrepancy in monetary figures, but conversions appear to give acceptable figures for comparison. The minimum salary per day imposed by the government was considered for use in analysis but was discarded, as it does not reflect reality in the majority of cases.

The men-to-women ratio data provided by INEGI is for the whole municipality. For the head municipality, the relationship is taken based on the urban population. The ratio is fairly balanced, only slightly in favor of the quantity of men as Table 3.3 shows. INEGI has no available data for the year 2014, but COPLADE predicts that in ten years the number of women will surpass men. More meaningful information would be the number of cars registered by men and women. This fluctuation of car owners depending on the gender would bring insight into the effect of gender on the levels of car ownership. This research focuses on an aggregated model; because of this, aspects such as preferences of gender to commute, or age based preferences and any other such information of this kind is not included, due additionally to a lack of data for analysis.

Table 3.3 Quantity of men, women and how many men per 100 women in the municipality of Ensenada

| Year | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|-----------------------------|---------|---------|---------|---------|---------|---------|
| Men | 130,462 | 158,779 | 185,494 | 206,978 | 235,13 | 261,106 |
| Women | 129,517 | 156,51 | 185,236 | 206,503 | 231,684 | 258,707 |
| Men/women proportion | 100.73 | 101.45 | 100.14 | 100.23 | 101.49 | 101.70 |

Source: Compiled by the author based on INEGI

For household size, data is available for all years prior to 2014. The household for INEGI is defined a private property occupied normally by a family. Data therefore excludes hotels, guest houses, or other similar establishments. Data on household size for 2014 will be extrapolated in the next section, 3.5.1.

A limitation on the accuracy lies in defining a household. A single dwelling may support more than one family, which may increase the number of potential drivers per household in a manner which may produce misleading data. Information regarding this distinction is not available, so this research will work with the household average size as summarized in Table 3.4.

Table 3.4 Average members per household in Ensenada

| Year | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|---------|------|------|------|------|------|------|
| Members | 4.3 | 4.1 | 3.9 | 3.7 | 3.6 | 3.5 |

Source: INEGI

To analyze urban growth, several maps from IMIP, INEGI and Google Earth were consulted. Comparing different sources, some discrepancies were discovered, such as differing city boundaries between maps (See Annex 3). These incongruities arise from differing concepts of city boundaries between the entities. One map may follow city limits while others only consider developed areas. In order for the results of this study to be logical, borders from previous years were always respected. The land use maps were obtained through IMIP digitally, and were available online for the year 2014 (See Annex 4 for land use maps).

The population of the entire municipality is available for each five year interval. For some years, data specifically concerning the urban population is not available. Estimated data for the missing years was calculated using the approximate percentages of people living in rural areas from INEGI publications. Table 3.5 shows the data found by INEGI and GOBCC.

Table 3.5 Population in the municipality, in the urban area and percentage in rural areas

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|---------|---------|---------|--------|---------|---------|---------|
| Total | 259,979 | 315,289 | 370,73 | 413,481 | 466,814 | 519,813 |
| Urban | 169426 | 192,55 | 206,7 | 260,075 | 392,124 | 441,841 |
| Rural % | 17.7% | 17.65% | 17.6% | 17% | 16% | 15% |

Source: Compiled by the author based on INEGI and GOBCC

Labor force participation rates are available from state sources or INEGI, depending on the year. Due to a gap in information about the employment rate, 1995 data was approximated using the state rate (56%). The informal activities in Ensenada are not determinate and only some percentages are available from sources such as newspapers. Due to the lack of official and precise data, this factor is ignored.

On socioeconomic aspects, other information could give further insight, such as quantity of jobs and population by neighborhood. The lack of information in the city at the neighborhood level is a recurrent problem; even so, some data was difficult to obtain for the municipality head. Infrastructure in the city such as parking spaces, construction density and other variables were considered, but sufficient relevant information could not be successfully obtained. Additionally, the kilometers of bus routes were not available except for one year (2007) in which IMIP did a study of public transportation; most of the data of this study is described in the subchapter 3.3. Case Study: Ensenada, Mexico. Similar difficulty was experienced in obtaining data on the street networks from the state, as the government does not appear to record and manage this information.

Public transportation data was not available directly from the different companies that manage the buses in Ensenada; instead, this data was requested from SISAIPBC. The street network is divided between primary and secondary avenues. Official data only specifies total length in kilometers for a given year. In order to complete this data, information will be derived from the maps provided by IMIP. Annex 5 provides the map for street networks created by IMIP for the year 2005.

Bus ticket prices were obtained from local newspapers and inquiries to senior citizens. For the year 2014 there is some uncertainty regarding whether it would be appropriate to use the actual current price or the likely projected price of a bus ticket by the end of the year. In middle of September 2014, bus companies attempted to raise the price around 30% without final authorization of the town council. The same week, the price reverted to its previous level. Throughout this paper, the price of 10 MXN² set at the beginning of the year will be used. Gasoline prices were obtained from the same source as bus ticket prices. The gasoline price is for standard grade; diesel and premium grades are not considered, as nearly all commuters use standard grade fuel except for

² 10 MXN is approximately equivalent to 0.60 Euros

trailers and other exceptional cases. In 1993 Mexico changed its official currency from Mexican pesos to “New Mexican pesos;” the data for the year 1990 are converted to the present currency.

3.5. FORMULATION OF THE VARIABLES

This chapter explains how every variable was obtained from the primary data. The primary data alone does not represent variables that can be compared with the ratio of cars in the city; therefore the raw data is converted into more useful terms.

The dependent variable is the ratio of cars per 1000 inhabitants, as this is the most common form in representing this variable. This variable was obtained from the number of cars given by INEGI and the State Government, along with figures for the urban population. Due to the lack of reliable data on the year of 1990 for the number of cars, this data was ignored. In order to still include the year 1990 in this model, an extrapolation was made with the help of IBM SPSS statistics software.

Box 3.2 Lineal equation form to interpolate and extrapolate

$Y = mx + b$

From SPSS the following function is obtained:

$F(x) = -4926.412 + 2.591x$

Where x follows for year and the function f(x) is the ratio of cars per 1000 inhabitants.

$F(1990) = -4926.412 + 2.591(1990) = 229.68$

Therefore for the year of 1990 the ratio is: 230 cars/1000 inhabit.

The years and the car ratios were inputted into the software to obtain the linear equation representing this set of data.

Box 3.2 shows the process of extrapolation for year 1990. Table 3.6 summarizes the results of the dependent variable.

Table 3.6 Number of cars per 1000 inhabitants (1990-2014)

| Year | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|---------------------------|------|------|------|------|------|------|
| Cars per 1000 inhabitants | 230 | 249 | 250 | 263 | 283 | 295 |

Source: Compiled by the author based on INEGI and GOBCC

3.5.1. SOCIOECONOMIC VARIABLES

This particular model takes into account the socioeconomic variables of income, age, gender and household size. Socioeconomic variables became increasingly relevant to car dependence research after urban form factors alone could not explain all aspects of travel behavior (Aditjandra, Mulley, & Nelson, 2013; Bagley & Mokhtarian, 2001; Buehler, 2011; Cao, Mokhtarian, & Handy, 2007a; Handy, Cao, & Mokhtarian, 2005; Holden, 2006; van de Coevering & Schwanen, 2006).

The income data listed is based on the average annual income for a working citizen with salary and compensations included, and are expressed in MXN. Income for the year 1990 was converted as mentioned previously. The average age of the population was calculated based on data from the INEGI database containing the number of inhabitants in each age range (0 to 100 years).

Box 3.3 Extrapolation of average age and household size for year 2014.

$Y = mx + b$

From SPSS the following function is obtained for average age:
 $F(x) = 0.24x - 453.6$ $F(2014) = 0.24(2014) - 453.6 = 29.76$

Therefore for the year of 2014 the average age is 30.

From SPSS the following function is obtained for household size:
 $F(x) = -0.036x + 75.92$ $F(2014) = -0.036(2014) + 75.92 = 3.416$

Therefore for the year of 2014 the household size is 3.4

The gender ratio is expressed as the percentage of men in the population. Household size was directly available from the INEGI database, and did not require any conversion or manipulation. Table 3.7 summarizes the data for the obtained socioeconomic variables.

Table 3.7 Socioeconomic variables

| Year | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|----------------------------------|--------|--------|--------|--------|--------|--------|
| Average income (MXN/year) | 43,972 | 45,699 | 48,648 | 66,530 | 86,505 | 98,404 |
| Average age | 24 | 25 | 26 | 29 | 28 | 30 |
| Gender Ratio (Men) | 50.20% | 50.40% | 50.00% | 50.10% | 50.37% | 50.42% |
| Household size | 4.3 | 4.1 | 3.9 | 3.7 | 3.6 | 3.4 |

Source: INEGI and GOBCC

3.5.2. URBAN FORM VARIABLES

3.5.2.1. SPRAWL SPEED

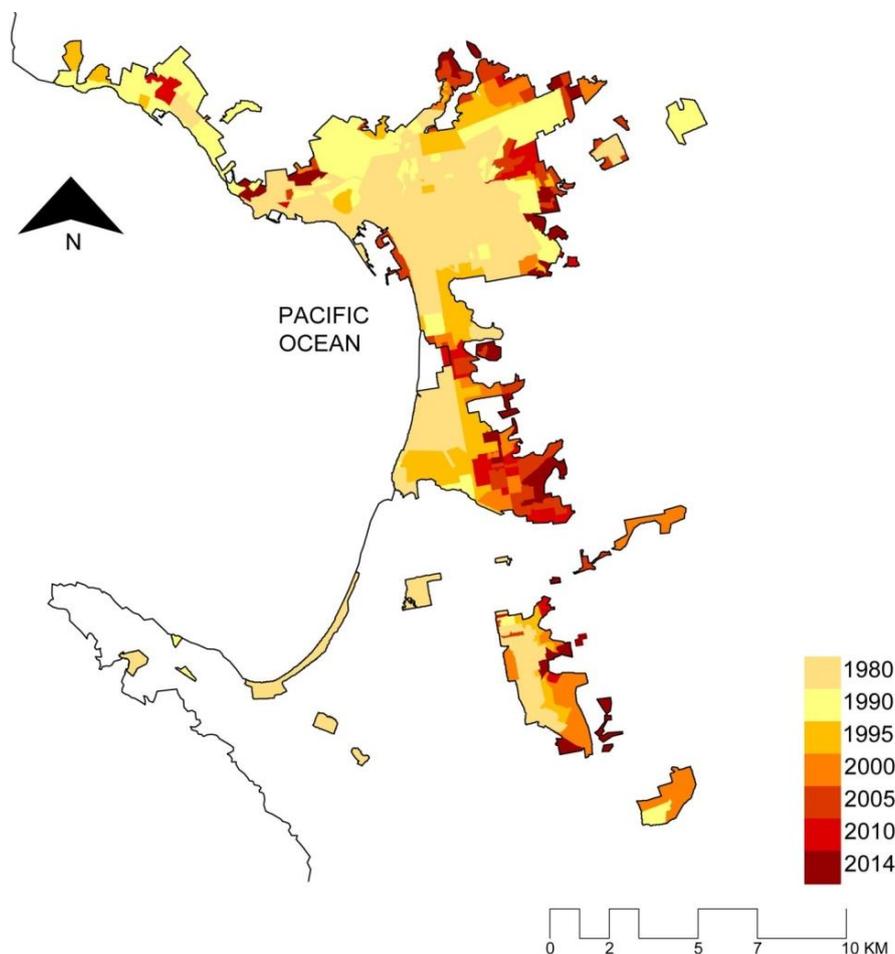


Figure 3.18 Urban growth of Ensenada since 1980.

Source: Made by the author

Urban sprawl's relationship to negative economic, environmental, and social consequences is nothing new. The advantages of living in a compact city instead of sprawl are substantial. Taking this into account, the importance of evaluating if cities present this form becomes apparent. Part of the problem lies in deciding whether a city can be defined as sprawling or not. Population density is related, but is not the only determinant factor; the city's form is also involved. Measurement of urban sprawl becomes problematic in absence of any accepted metrics by which to quantify it. Some authors measure sprawl in terms of land use patterns, commuting times and leapfrog development to draw conclusions (Barnes et al., 2001). Other authors decide to take a more statistical approach, as with the development of an index called the Shannon entropy, used to evaluate to what degree a city is compact or sprawling (Alabi, 2009; Deka, Tripathi, & Khan, 2011; Joshi & Bhatt, 2011; Sun, Forsythe, & Waters, 2007; Yeh & Li, 2001).

The Shannon entropy value created by Claude E. Shannon in 1948 is not exclusively used for quantifying urban sprawl. The entropy value can be used in several different areas for determining

other factors of interest, e.g. the most likely target candidates for a drug. The definition of entropy in this context can be summarized as the following:

“Entropy can be used to indicate the degree of urban sprawl by examining whether land development in a city or town is dispersed or compact. If it has a large value, then urban sprawl has occurred.”

(Yeh & Li, 2001, p. 84)

It can be inferred that a change in Shannon entropy over time indicates if the city is progressing towards more compact or dispersed land development. Different formulas for the calculation of Shannon Entropy exist, but they provide the same insight. Different authors have taken these formulas and used them in developing the index.

Box 3.4 Shannon entropy's formulas

Some examples are as follows, where H_n is Shannon entropy:

$$H_n = \sum_i^n P_i \log\left(\frac{1}{P_i}\right) \quad (\text{Yeh \& Li, 2001, p. 84})$$

$$H_n = -\sum P_i \ln(P_i) \quad (\text{Mohammadi et al., 2012, p. 83})$$

Where:

- n is the number of equal zones in the city, meaning they are of the same form and are equidistant from each other.
- P_i is the ratio of developed area in a specified zone (X_i) and the total built up area of all the zones: $P_i = \frac{X_i}{\sum_i^n X_i}$

Each method gives Shannon entropy values varying from zero to $\log(n)$ and $\ln(n)$ respectively; values closer to the maximum level indicate that the city is experiencing increased urban sprawl.

This value is more useful when converted to relative entropy (ranging from zero to one) for comparison with other cities: $H'n = H_n / \log(n)$.

There is no defined scale for determining what range of entropy values is acceptable. Results should be compared with other case studies for the purpose of estimating this range and gaining greater insight from those results.

Calculating Shannon entropy involves manipulating the maps provided by different sources, which becomes problematic due to the inconsistency of boundaries and scale. AutoCAD software was used to calculate the areas of different buffer zones, but first maps were oriented and adjusted to a common scale to achieve the greatest consistency possible. When some boundaries still did not match, the boundaries of previous years were respected in order to maintain some consistency. Maps obtained from IMIP and INEGI are considered to have greater validity than the other sources, and are therefore favored in the case of disparities among maps.

For this particular case study it was decided to use 12 circles of 2 kilometer radius each to divide the city (Figure 3.19). The built up area of the city is not very extensive, but due to the

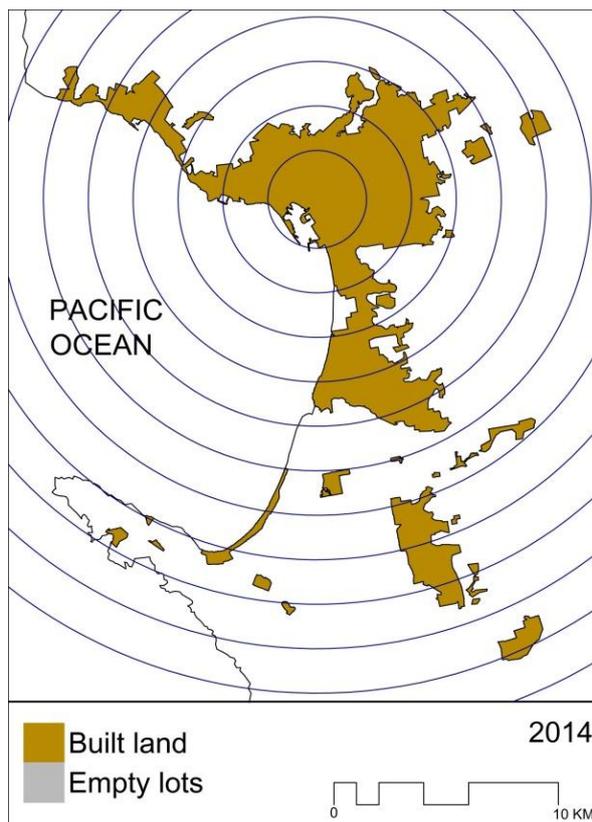


Figure 3.19 Buffer zones (12) for year 2014.

presence of leapfrog development and the shape of the city (large and slender) more circles were needed to achieve complete coverage. Some zones had almost no build-up at all. From this step in analysis, the status of urban sprawl’s development may be observed. In Annex 6 and Annex 7 the maps with the buffer zones and the calculations made are presented. Only the year 2014 is shown in this text (Table 3.8). The results of this process are described in the Findings chapter.

Table 3.8 Shannon Entropy calculation for 2014

| 2014 | | | | |
|-------|---------|------------|----------|--------------|
| Zones | Xi | Pi | 1/Pi | Pi*Log(1/Pi) |
| 1 | 13.0125 | 0.13309148 | 7.5136 | 0.1166 |
| 2 | 23.5515 | 0.24088406 | 4.1514 | 0.1489 |
| 3 | 17.3086 | 0.17703186 | 5.6487 | 0.1331 |
| 4 | 11.0139 | 0.11264985 | 8.8771 | 0.1068 |
| 5 | 11.9626 | 0.12235313 | 8.1731 | 0.1116 |
| 6 | 4.2949 | 0.04392811 | 22.7645 | 0.0596 |
| 7 | 3.4425 | 0.03520979 | 28.4012 | 0.0512 |
| 8 | 4.1807 | 0.04276008 | 23.3863 | 0.0585 |
| 9 | 5.3346 | 0.05456214 | 18.3277 | 0.0689 |
| 10 | 1.5863 | 0.01622463 | 61.6347 | 0.0290 |
| 11 | 1.7685 | 0.01808817 | 55.2848 | 0.0315 |
| 12 | 0.3145 | 0.0032167 | 310.8779 | 0.0080 |
| Σ= | 97.7711 | | | |
| | | | Hn= | 0.9239 |
| | | | H'n= | 0.8561 |

3.5.2.2. DENSITY VARIABLES

The population density variable has been a subject of discussion for its relationship with high car ownership ratios since the beginning of studies on the subject by authors as: (Buehler, 2011; Cervero & Kockelman, 1997; Cervero & Radisch, 1995; Greenwald & Boarnet, 2001; Hess, Vernez Moudon, & Logsdon, 2001; Jabareen, 2006; Naess, 2003; Newman & Kenworthy, 1989; Stead & Marshall, 2001).

Other authors argue the employment density variable also substantially affects car dependence. More jobs in an area will lead to shorter and less frequent trips. The question of whether this is relevant to car dependence and, if so, how important of a factor it is relative to others, has been a popular area of discussion (Aditjandra et al., 2013; Andrew, 2010, 2010; Badland et al., 2012; Bagley & Mokhtarian, 2001; Bento, Cropper, Mushfiq Mobarak, & Vinha, 2001; Buehler, 2011; Cao et al., 2007a; Holden, 2006; Kenworthy & Laube, 1999; Lawrence & Pivo, 1994; Leck, 2006; Naess, 2003; Nolon & Bacher, 2007; Scott, McEldowney, Tyley, & Smyth, 2005; Stradling, Meadows, & Beatty, 2000).

Table 3.9 Density variables

| Year | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|---|---------|---------|---------|---------|---------|---------|
| Population | 169,426 | 192,550 | 206,700 | 260,075 | 392,124 | 441,841 |
| Area (Km ²) | 58.05 | 69.28 | 79.55 | 87.26 | 91.5 | 97.77 |
| Population density (inhabit/km ²) | 2918.54 | 2779.30 | 2598.33 | 2980.45 | 4285.56 | 4519.14 |
| Employment density (jobs/km ²) | 1493.32 | 1653 | 1611.17 | 1506.71 | 2258.82 | 2244.72 |

Source: Made by the author with data from INEGI, IMIP and GOBCC.

Because there is no population density data for the municipal head of Ensenada, figures were calculated from population data from INEGI's database and the urban area data previously calculated above (Sprawl Speed). The employment density was assumed to be uniform due to the lack of information regarding employment by area. An increase is observed in both variables.

3.5.2.3. MIX LAND USE

As mentioned in previous chapters, land use mix is an important factor in terms of producing a sustainable city. In order for the city to have the characteristic of "mixed land use" different services must be available in small areas; Jabareen (2006) explained that diversity in certain area of land uses, i.e. services close to housing such as stores, schools, and jobs, are important.

Cervero and Kockelman (1997) explained the importance of diversity and developed a dissimilarity index which "gauges the degree to which uses abutting or diagonal to each hectare were different" (Cervero & Kockelman, 1997, p. 8). The value fluctuates between 0 and 1.0; values closer to the maximum indicate a higher degree of mix in the area. Even when no significant relationship between dissimilarity index and mobility was found, this index proved to be a better predictor and measuring metric than other indexes such as entropy.

Hess et al (2001) made a critique of different measurements of land use mix, including dissimilarity index and entropy index for land use. They found that entropy is a weak indicator of spatial interaction of different uses.

It can be difficult to change physical observations to numerical data, as when determining a number to represent urban speed. In this case, in order to measure the diversity of the city the dissimilarity index is used.

Box 3.5 Calculation of dissimilarity index

The dissimilarity index calculation was made as follows:

Each map is divided with a grid (parcels with the same grid). Each parcel receives a value depending on some lineaments (from zero to eight) and an average is taken. The number given to every parcel depends on how many different land uses apart from the one in the parcel are present; i.e. if the parcel is surrounded by the same land use as its own, the value given will be zero. Then an average is made from all the parcels to get an index for the whole city. Undeveloped land and the coast are not considered as different land uses.

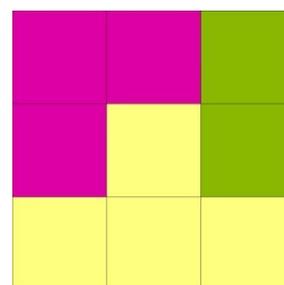


Figure 3.20 Example of parcels (value =2).

Source: Based on the work of Cervero and Kockelman (1997)



Figure 3.21 Grids in the center of the city (2005)

Source: Compiled by the author from IMIP.

One of the smallest parcels in the city of one hectare is initially selected. With Autodesk AutoCAD software a grid was drawn with a size of 100 by 100 meters. The grid aligned with the blocks of the city center. As explained in Box 3.5, several values are calculated, and an average is made. For this particular variable only three maps were available for the years 1995, 2005 and 2014, in .

For Ensenada, the maximum value given in a parcel was for three different uses which were not common in any of the studied years. The most common value given was zero due to homogeneity in the city, which is largely housing.

3.5.3. TRANSPORT VARIABLES

3.5.3.1. ROAD AND INTERSECTIONS

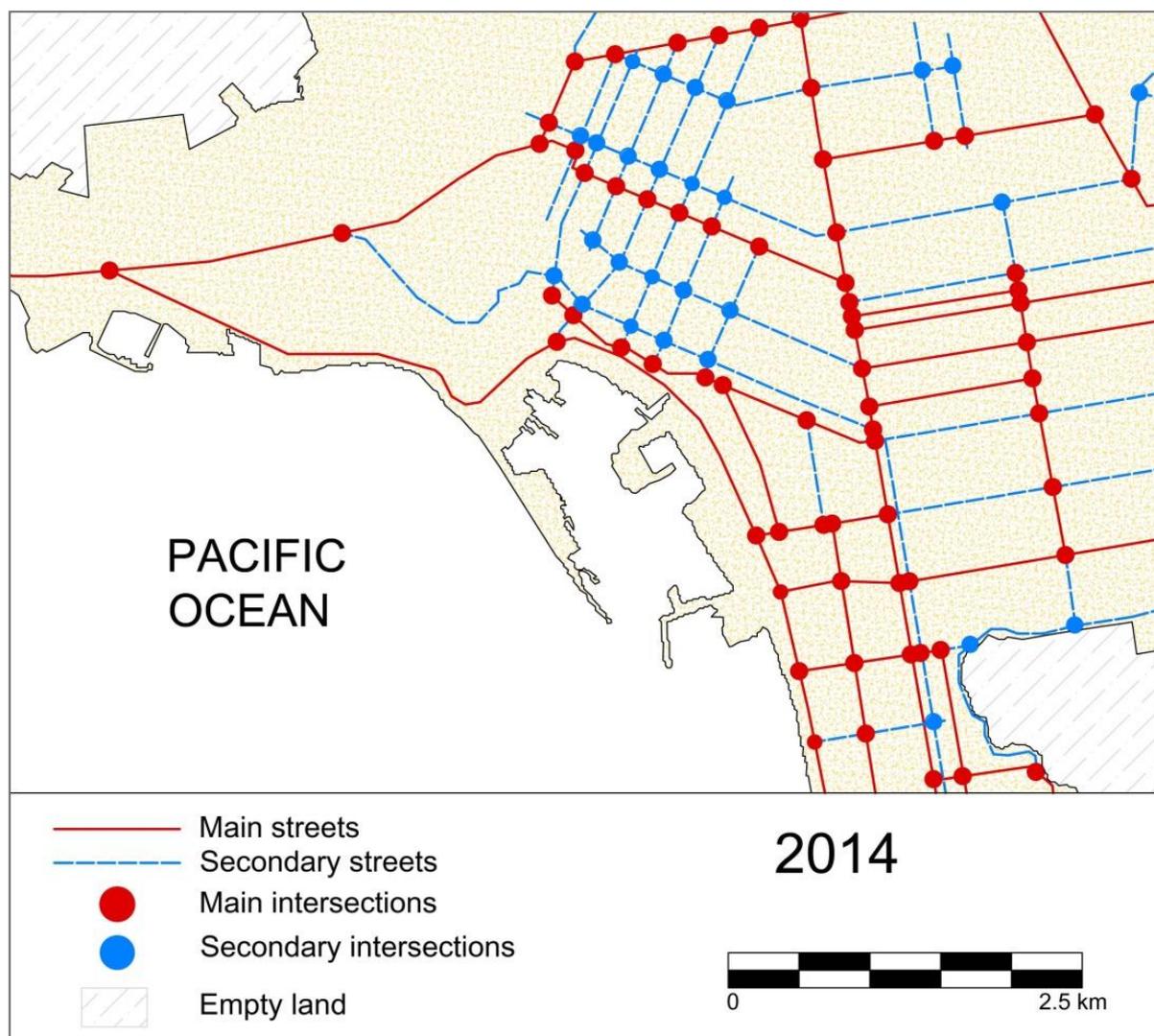


Figure 3.22 Street network and intersections in center zone 2014

Source: Made by the author based on IMIP (2007)

Road infrastructure variables are the most closely associated with government performance. How influential are these variables? Normally, common conception is that more roads and less accessibility to public transportation will lead to a car dependent city. Several authors have approached this topic and have confirmed these variables to be of great importance (Aditjandra et al., 2013; Badland et al., 2012; Bento et al., 2001; Cullinane, 2003; Naess, 2003; Newman & Kenworthy, 2006; Stead & Marshall, 2001; Stradling et al., 2000; van de Coevering & Schwanen, 2006).

Data specifying the lengths of streets was not directly available. Calculations were made with the actual street network of Ensenada, with different urban sprawl maps developed for each year

used as city boundaries. The selection of main and secondary streets is taken from IMIP maps (Annex 5), as this institution already set which streets are categorized as main, secondary, and alleys.

Streets considered are those inside the area of urban sprawl; streets connecting suburbs are not considered. It was possible to derive four different variables using street lengths, population, and area data.

Connectivity was calculated from the street network previously created with primary and secondary streets. The main nodes in this case are for two cases: intersections of primary streets and intersections of a primary and secondary street. The secondary nodes are defined as intersections of secondary streets. The two classes of nodes then are divided by the total area of the city to create two connectivity variables. Figure 3.22 provides an example of the street network made for every year in the whole city.

Table 3.10 Street Variables

| Year | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|---|--------|--------|--------|---------|---------|--------|
| Length of primary streets (km) | 88.62 | 97.9 | 101.86 | 104.87 | 107.49 | 108.32 |
| Length of secondary streets (km) | 72.13 | 89.04 | 94.48 | 100.98 | 110.18 | 114.63 |
| Primary streets per person (m) | 0.4603 | 0.3771 | 0.3335 | 0.3056 | 0.2741 | 0.2452 |
| Secondary streets per person (m) | 0.3746 | 0.343 | 0.3093 | 0.2943 | 0.281 | 0.2595 |
| Primary streets per km² | 1.526 | 1.413 | 1.28 | 1.201 | 1.174 | 1.107 |
| Secondary streets per km² | 1.2426 | 1.2853 | 1.1877 | 1.15733 | 1.20425 | 1.1725 |
| Main nodes per km² | 1.6882 | 1.7898 | 1.5713 | 1.46688 | 1.47543 | 1.3808 |
| Secondary nodes per km² | 0.7063 | 0.7361 | 0.7668 | 0.75636 | 0.76504 | 0.7773 |

Source: Compiled by the author

Using an economic transportation approach, two variables were included: the price of public transportation for a single trip and the price of a liter of gasoline. All values are in MXN. For the year of 1990, prices were converted due to the change in the currency.

Table 3.11 provides a summary of the variables that will be used for modeling.

Table 3.11 Summary of variables

| No. | Variable | Year | | | | | |
|---------------------------------|---------------------------------------|---------|---------|---------|----------|---------|----------|
| | | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
| <i>Socioeconomic</i> | | | | | | | |
| 1 | Average income per year | 43,972 | 45,699 | 48,648 | 66,530 | 86,505 | 98,404 |
| 2 | Average age | 24 | 25 | 26 | 29 | 28 | 30 |
| 3 | Percentage of men | 50.20% | 50.40% | 50.00% | 50.10% | 50.37% | 50.42% |
| 4 | Household size | 4.3 | 4.1 | 3.9 | 3.7 | 3.6 | 3.4 |
| <i>Urban Form</i> | | | | | | | |
| 5 | Shannon Entropy | 0.7798 | 0.7875 | 0.8432 | 0.8468 | 0.8503 | 0.8561 |
| 6 | Population density | 2918.54 | 2779.30 | 2598.33 | 2980.45 | 4285.56 | 4519.14 |
| 7 | Employment density | 1493.32 | 1653.08 | 1611.17 | 1506.71 | 2258.82 | 2244.72 |
| 8 | Dissimilarity Index | ND | 0.07863 | ND | 0.060766 | ND | 0.055039 |
| <i>Transportation variables</i> | | | | | | | |
| 9 | Primary streets per capita (m) | 0.5231 | 0.5085 | 0.4928 | 0.4032 | 0.2741 | 0.2452 |
| 10 | Secondary streets per capita (m) | 0.4258 | 0.4625 | 0.4571 | 0.3883 | 0.2810 | 0.2595 |
| 11 | Primary streets per km ² | 1.52665 | 1.41319 | 1.28049 | 1.20181 | 1.17477 | 1.107909 |
| 12 | Secondary streets per km ² | 1.24258 | 1.28534 | 1.18774 | 1.157327 | 1.20425 | 1.172521 |
| 13 | Main nodes per km ² | 1.68815 | 1.78984 | 1.57132 | 1.466877 | 1.47543 | 1.380776 |
| 14 | Secondary nodes per km ² | 0.70627 | 0.73614 | 0.7668 | 0.756359 | 0.76504 | 0.777326 |
| 15 | Single ticket bus price | 3 | 4 | 4.5 | 5 | 8 | 10 |
| 16 | Price per gasoline liter | 1 | 2.24 | 5.27 | 6.47 | 8.76 | 13.04 |
| <i>Dependent variable</i> | | | | | | | |
| | Cars per 1000 inhabitants | 230 | 249 | 250 | 263 | 283 | 295 |

FINDINGS

With all variables quantified and linear regression analysis completed as described in the previous chapter, interpretation of results may now be discussed. The following is an interpretation of the established model with a discussion of initial hypotheses.

4.1. DESCRIPTIVE ANALYSIS OF VARIABLES

This section serves as a brief description of each established variable. The results of the model will be interpreted in the next section.

Table 4.1 Car ownership rate

| Year | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|---------------------------|------|------|------|------|------|------|
| Cars per 1000 inhabitants | 230 | 249 | 250 | 263 | 283 | 295 |

Source: Made by the author with data from INEGI and IMIP

Car ownership is a previously described dependent variable. It is important to observe the development of this variable with respect to time in particular. As the Table 4.1 shows, Ensenada’s car ownership rate has been increasing with time, an expected outcome considering the constant growth of the city. The quantity of cars has increased almost threefold in the last 24 years.

The city presents a near equal distribution in gender; a fluctuation in the number of men in recent years caused a minor shift in gender distribution, but the ratio remains approximately equal. The average age in the city started at 23 years in 1980 and currently sits at 30 years. The city remains relatively young despite the increase; the rise in recent years is due to increased life expectancy throughout the country (Figure 4.1).

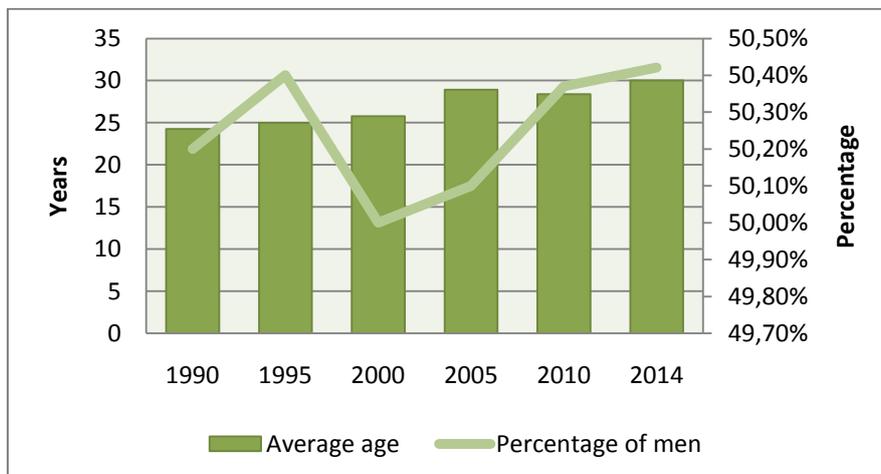


Figure 4.1 Changes in gender ratio and average age in the city

Source: INEGI

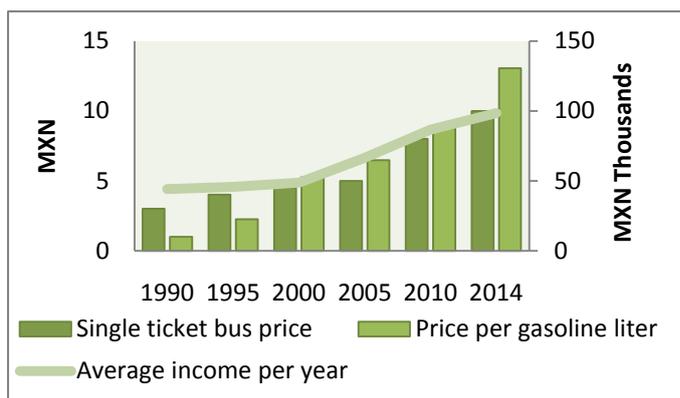


Figure 4.2 Comparison between average income, prices for public transportation, and fuel (MXN).

Source: INEGI, GOBBC and Mexican Newspapers

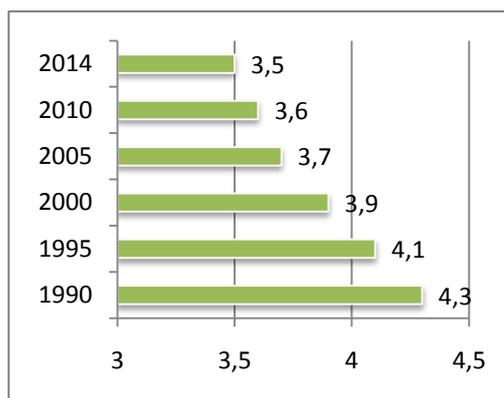


Figure 4.3 Average household size

Source: INEGI

The economy of the city has experienced growth, especially in the last fourteen years. However, the fact that average income has grown has to be compared with increases in living costs. The price of transportation, such as bus fares and fuel, also increased. Most surprising is that at the beginning of the time range examined a liter of fuel was approximately 50% cheaper than using the public transportation system. After 2000 fuel became more expensive, but the difference was not particularly substantial; currently a liter of gasoline is priced at around one US dollar. The price of a bus ticket is now almost ten times more expensive than it was in 1980; compared with the average annual income growth of a little more than two times, these figures are quite concerning (Figure 4.2).

The average members per household have been decreasing; now families have fewer children or none at all. There has also been an increase in the presence of shared housing (among friends or students). It appears that in the foreseeable future, the average household size will continue decreasing (Figure 4.3).

The urban speed of the city was previously calculated using the Shannon entropy formula. The results are in Table 4.2. Considering the range of these values is from zero to one, these results indicate the city is becoming less compact relative to previous years. The biggest change in the index is in the years 1995 to 2000. Afterwards the index has not fluctuated significantly but is still increasing gradually. The general stability of this value in recent years is a positive indicator of improvement, but ideally this value would be in decline.

| 1990 | 1995 | 2000 | 2005 | 2010 | 2014 |
|--------|--------|--------|--------|--------|--------|
| 0.7797 | 0.7874 | 0.8432 | 0.8468 | 0.8503 | 0.8560 |

Source: Compiled by the author

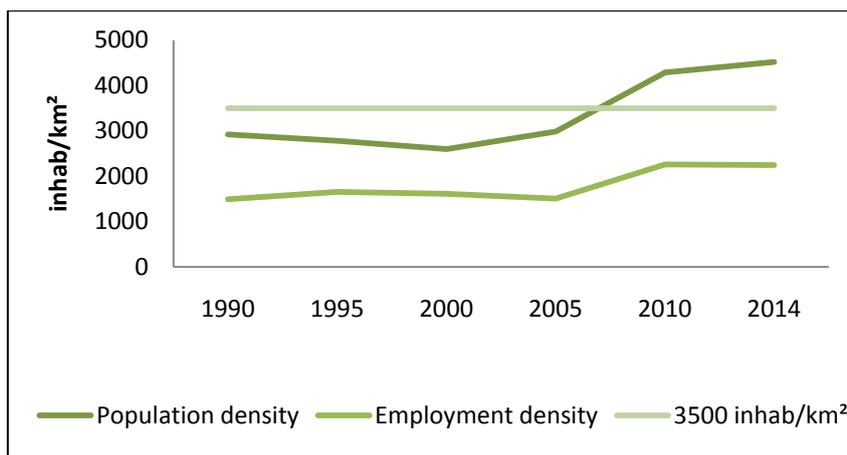


Figure 4.4 Comparison of population density and employment density

Source: Compiled by the author

The calculated dissimilarity index calculated is represented in Table 4.3. The variation of the index each decade does not seem significant. Still, it is a decrease during time, meaning that the city has less diversity in land mix compared to previous years.

Table 4.3 Dissimilarity Index results

| Year | 1995 | 2000 | 2014 |
|------|--------|--------|--------|
| DI | 0.0583 | 0.0561 | 0.0559 |

The rapid population growth of the city has led to a decrease in the available streets per capita (Figure 4.5). Continued construction of additional streets is not sufficiently compensating for rapid population growth, in terms of population growth per road constructed. This does not strictly mean that the city currently has a poor street network. This can help determine whether the street network (construction priority on roads) is a variable to consider in car ownership. The proportional decrease is more significant in principle avenues compared with secondary streets; both variables have dropped to almost half their initial value over the examined time period.

The connectivity of streets has decreased over time, as illustrated in Figure 4.6. All variables are expressed in units per area (km²); these variables are related to transportation speed growth in the city. The only variable that is not decreasing is the density of secondary nodes.

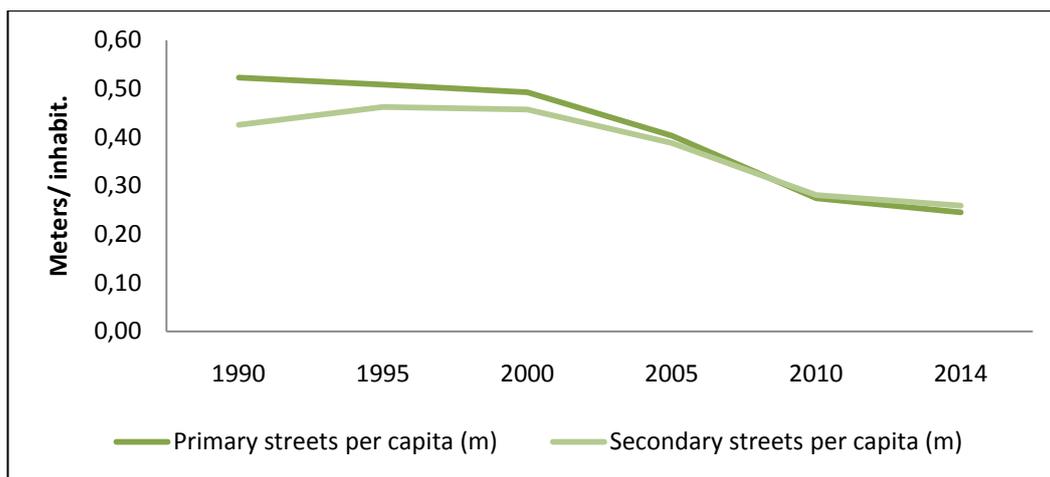


Figure 4.5 Road infrastructure per capita

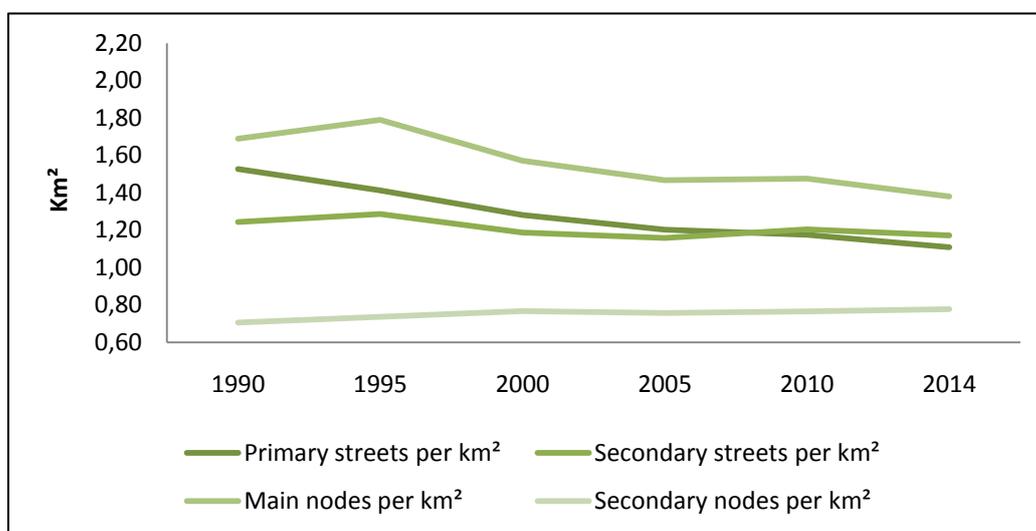


Figure 4.6 Road infrastructure per area

4.2. INTERPRETATION

After computing all relevant data through software, regression analysis was performed for each variable and the dependent variable of car ownership. The IBM SPSS statistics software produced the results summarized in Table 4.4. In Figure 4.7 is an example of the linear regression graph; in Annex 9 are the rest of the graphs for the other variables.

The linear regression model presents sixteen variables for three areas of interest (socioeconomic, urban form, and transportation). Each variable is shown with its standard error, the standard coefficient B, and their significance value (p-value). As explained in depth in chapter 3, the significance rate will be 5% (p-value). Larger values will be considered to have marginal significance or be rejected from the model. The standard coefficient will indicate if the impact is positive or negative on the dependent variable; a positive relationship indicates that both variables' slopes increase in the same direction.

From the sixteen variables, twelve are considered significant, one is marginal, and three are not significant. The percentage of men in the socioeconomic section, dissimilarity index, and the secondary nodes per km² in the transportation section are discarded due to a high p value (>5%).

Table 4.4 Results of the linear regression model by IBM SPSS statistics software

| No. | Variable | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | 95.0% Confidence Interval for B | |
|---|---------------------------------------|-----------------------------|------------|---------------------------|--------|------|---------------------------------|-------------|
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound |
| Dependent variable: Cars per 1000 inhabitants | | | | | | | | |
| Socioeconomic | | | | | | | | |
| 1 | Average Income per year | .001 | .000 | .974 | 8.550 | .001 | .001 | .001 |
| 2 | Average age | 9.143 | 2.169 | 0.903 | 4.216 | .014 | 3.122 | 15.164 |
| 3 | Percentage of men | 69.327 | 58.949 | .507 | 1.176 | .305 | -94.341 | 232.995 |
| 4 | Household size | -69.639 | 9.116 | -0.967 | -7.639 | .002 | -94.948 | -44.329 |
| Urban Form | | | | | | | | |
| 5 | Urban Sprawl Speed | 562.628 | 206.752 | .806 | 2.721 | .053 | -11.409 | 1136.665 |
| 6 | Population density | .025 | .007 | .885 | 3.803 | .019 | .007 | .044 |
| 7 | Employment density | .059 | .016 | .883 | 3.767 | .020 | .015 | .102 |
| 8 | Land Use Mix | -1697.9 | 1382.850 | -.775 | -1.228 | .435 | -19268.6 | 15872.863 |
| Transportation | | | | | | | | |
| 9 | Primary streets per person (m) | -293.122 | 48.594 | -.949 | -6.032 | .004 | -428.039 | -158.205 |
| 10 | Secondary streets per person (m) | -536.744 | 91.971 | -.946 | -5.836 | .004 | -792.097 | -281.390 |
| 11 | Primary streets per km ² | -140.416 | 28.180 | -.928 | -4.983 | .008 | -218.656 | -62.175 |
| 12 | Secondary streets per km ² | -277.244 | 208.664 | -.553 | -1.329 | .255 | -856.587 | 302.100 |
| 13 | Main nodes per km ² | -127.935 | 44.946 | -.818 | -2.846 | .047 | -252.726 | -3.144 |
| 14 | Secondary nodes per km ² | 768.589 | 253.029 | .835 | 3.038 | .038 | 66.069 | 1471.109 |
| 15 | Single ticket bus price | 8.711 | 1.006 | .974 | 8.659 | .001 | 5.918 | 11.504 |
| 16 | Price per gasoline liter | 5.245 | .717 | .965 | 7.319 | .002 | 3.256 | 7.235 |

Source: Compiled by the author.

The results are different from what was expected based on the initial hypothesis; from examined literature, significant p-values were expected in all variables. Most of the variables are related to the dependent variable of car ownership, but some of them had an impact opposite to expected behavior. Results indicate that socioeconomic variables play an important role in car ownership rates in the city of Ensenada. Of the four socioeconomic variables only one did not demonstrate a significant relation to car ownership (gender) while the others had the expected impact. Additionally, significant variables for urban form and transportation did not all exhibit the expected behavior.

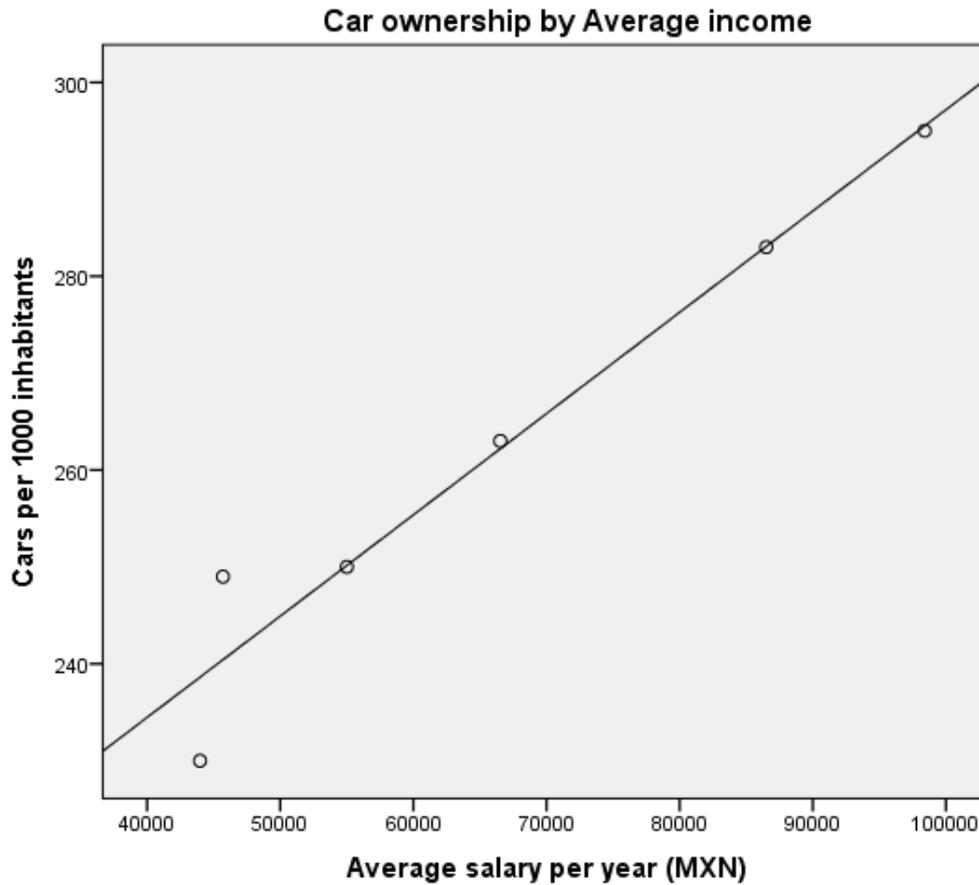


Figure 4.7 Linear regression of average salary and car ownership variables

Source: Generated with SPSS

The socioeconomic variables indicate the following:

1. The average annual income variable has a strong association with the independent variable car ownership, and a positive and B value. This means that the income has a substantial effect on the slope of car ownership, pushing it to increase. A wealthy city suggests citizens with more economic privilege to travel by private means.
2. The age variable showed a significant relationship with car dependence; as the average age increases the dependent variable grows equally. This variable may be related to employment, i.e. younger people who still do not work, have less working years (lower salary), or through different factors are less inclined to buy a car.
3. The gender variable is not relevant to the car ownership slope. The equality in gender ratio suggests that in the city both genders are similarly inclined to drive. This rejects any supposition that women, due to their household activities, tend to drive less.
4. The household size is strongly related with a negative B value, meaning that the drop in members per household is contributing to the rise of car registration. An average household will have at least one car; consequently, decreasing the number of members per household will not necessarily correspond to a direct decrease in the number of cars per family.

Urban Form variables:

5. The Shannon entropy value is positively related with a marginal significance to car ownership. As the value rises (the maximum value of entropy is 1.0) the car ownership rate grows. Ensenada's sprawl is comparable with US cities, the country with the most motorized cities in the world. High sprawl is conducive to a more motorized city. The presence of leapfrogs and the inconsistency of city growth lead to increased travel distances, sometimes in areas without public transportation services or even sufficient road infrastructure.
6. Population density on the other hand appears directly related, but with an unexpectedly positive relationship. Density in the city is growing with time, and contrary to several authors' statements, car ownership continues growing. This can be linked specifically to the urban sprawl of the city. Even the highest densities in the city are not helping to reduce the car ownership rates due to the presence of other sprawl-related factors such as leapfrogs.
7. The employment density rate is growing and affecting the car ownership in the same matter as population density. The presence of more jobs in the city is linked with average wealth levels, but the distribution of employment is an issue. The location of jobs is important, but due to the lack of information on this specific subject, this variable assumes an equal distribution in the city.
8. Dissimilarity index did not have a considerable relationship with car ownership ratio. The slope of the index did not fluctuate much during time. The mix land use has remained the same with a small slope leading to even less mixed land uses. The lack of more data made difficult to establish the relationship between land use mix and the increase of autos.

Transportation variables:

9. The primary and secondary streets per capita (meters) variables are significant in a negative aspect. The proportional decrease of the available primary and secondary streets per person is worsened by increasing car ownership. Less street availability per capita implies increased traffic congestion in the city, a common factor towards discouraging people from driving.

This suggests that incentive to drive provided by other variables is outweighing the impact of increased congestion.

10. The number of primary streets per km² exhibits a significant negative relationship. The ratio of streets per area is decreasing, contributing towards a positively sloped car ownership rate over time. This result contradicts research suggesting that more road infrastructure should lead to more car dependent cities.
11. The number of secondary streets per km² is not a significantly relevant variable to car ownership. The secondary streets are for more local use, while primary streets, with a much greater importance towards the overall connectivity of city transportation, have a significant impact on car ownership.
12. The price of a single bus ticket price has a strong positive relationship, meaning that as the price increases so does car ownership. A user always considers what is more affordable or comfortable; if the public transportation option is not affordable or is proportionally excessively priced; they will look for some other options, usually private transportation.
13. Gasoline prices have a strong relationship with car ownership. The rise in prices in the last several years is directly related to the rise in the car ownership variable. Contrary to the expectations of many authors, the rising price of gasoline is not stopping the increase in car ownership. But as shown in Figure 4.2 at the beginning of the time frame of interest (1990) the price of gasoline was proportionally extremely affordable compared with public transportation and perhaps created a tendency towards car ownership which continues despite increasing fuel prices.

DISCUSSION

This chapter is an interpretation of the obtained results described in the findings chapter, and serves as a discussion about the interaction between analyzed variables and car dependence. Some assumptions and speculations are based on the city's characteristics, as previously described in the case study sub-chapter. Analysis under the developed model produced results confirming and rejecting different claims made by previous researchers while largely supporting some of this study's hypotheses and allowing the development of recommendations for improvement.

What are the implications of these results for this particular mid-sized city? As mentioned before, Ensenada is a typical example of a medium size city in Mexico. The city follows the common demographic trends of the average city in the country from salaries to urban development, according to SEDESOL (2012).

Analyzing the collective results of the model, the socioeconomic variables as a group appear to have the biggest impact on the city, though one of the variables did not show significance to car ownership. The impact of the urban form and transportation variables seems to be increasing, which at least in theory would help to reduce the high car ownership ratio. However, as mentioned before it seems the economic variables have more significance. Additionally, the rates of urban growth and the price of public transportation continue to increase.

5.1. FEEDBACK TO PREVIOUS STUDIES BASED ON THE STATUS OF ENSENADA

Of the socioeconomic variables analyzed, the variables which behaved as expected were income, age and household size. As a group, socioeconomic factors proved most influential on car dependence, with all but the gender variable behaving as expected. These results support claims by Van de Coevering and Schwanen (2006), who concluded that socioeconomic variables are strongly related to car dependence, not only transportation and urban form factors.

As the data shows, Ensenada is becoming wealthier in terms of income earned by the average worker. This supports the work of Owen et al (2007), which found a negative relationship between the two variables. Stradling et al (2000) also found income to be a strong factor in influencing travel behavior. This variable does not work alone, but rather works in conjunction with other variables such as age and employment density. As explained in the chapter before, these variables have been growing with time, and are strongly linked with car ownership and income.

Present-day Ensenada has a growing working-age population and more jobs available per area, increasing the labor force. However, this factor should not necessarily be taken as negative; a wealthier city is one of the main objectives of politicians and municipality leaders. Therefore the implication of this variable is not strictly that higher income is negatively influencing the modal split. Several other factors such as the costs of living, the affordability of private transport and public transportation contribute towards the state of car dependence. As Camagni et al (2002) suggest, the

affordability of cars is also a factor in the modal split; as described before, the proximity to the USA border creates opportunities in the city (with often negative consequences) for some citizens to acquire used cars at lower costs compared with new cars in the city.

Currently the average working person in Ensenada is earning 98,404 MXN annually (circa 8,000 USD); this salary is considered in the average range for Mexico. Considering the costs of acquiring and maintaining a car, the average salary is not particularly high, yet the average citizen owns a car or has access to one. Then why are Ensenada's citizens deciding to spend their income on a car or even two in some families? Is it really a matter of necessity? It is probable that socio-cultural factors are involved, such as personal preferences and desired lifestyle. The economic status that an average citizen of Ensenada wants to achieve could be summarized in two main goals: to live in their own house in a suburban neighborhood as indicated by a survey (GOBBC, 2008), and to own a car as proof of social status. Measuring preferences can be imprecise as the perceptions of each citizen influence the outcome. Due to the lack of reliable data, these variables could not be included. However, this model considers other numerical results which could lead to methods for addressing the car dependence situation (i.e. urban sprawl).

The income variable is not straightforward to analyze, as several consequences from a changing variable must be taken into account simultaneously. The fact that the average salary is rising does not automatically imply a wealthier city; an overview of lifestyle costs should concurrently be considered. In this paper, gasoline and public transportation costs were included, but the percentage of income dedicated to commuting (private and public) should also be considered. The fraction of salary spent on private transportation by citizens could determine whether it is indeed a matter of necessity or a personal preference made possible by economic status. Regardless, from a broader perspective Ensenada's economic growth is indeed increasing the car ownership ratio.

Ensenada is becoming a city with an increasingly older population, but this trend is quite typical due to rising life expectancy in recent years, along with a decrease in the average number of children per family. This model claims that the rise of the average age in the city by almost 5 years encourages a modal split favoring private transportation. This contradicts the statement by Leck (2006) that age is not an important factor compared with population and employment densities.

Conversely, in agreement with these results, Zegras et al (2008) explain that the comfort of cars makes them favorable among the elderly, contributing to the impact of population age on modal split. The results of the analyzed model in conjunction with this notion suggest that if Ensenada's average age increases, car ownership will also increase. Despite the rising average population age, Ensenada remains a young city, with the average age of citizens at 29 years. This implies that the majority of the population is in the early stages of working or has been in the work force for only a few years. Ensenada's increasing average age will likely contribute to higher car ownership largely due to the relationship between age and work with better incomes. The change in people's lifestyles throughout their life is also relevant; the increasing average age in the city means more people with frequent work-related trips and better economic status. Fortunately, as Stradling (2000) states, a city with a younger population is easier to influence towards a public transportation-oriented modal split. Still, the limitation of this variable comes in determining how specific age groups commute; average age certainly appears to be a factor towards car dependence, but exactly which age group corresponds to this relationship may be uncertain. More specific useful information would include

the fluctuations of these age groups and their modal splits; this could provide further insight into how age is altering car ownership level.

Social changes occurring across the country have also occurred in Ensenada, such as shifts in women's activities and the average family size. Gender was not found to be a significant factor to the modal split in Ensenada. It is clear that there are differences between the genders in aspects such as lifestyle, economic status, etc., and from some perspectives, women tend to travel less due to their particular routines, such as one dedicated to housework and the care of children. In this case any fluctuation of the ratio of men to women should not impact the car ownership ratio. Gender distribution appears irrelevant in the case of this city, suggesting that people here commute equally despite their gender, contradicting the work of Owen et al (2007) and Curtins and Perkins (2006). With increasing equality between the genders professionally and in fields of study, it is likely that for this case study the question is one of profession and activities rather than gender.

One driving force of social change is the gradual decrease of the average Mexican family size, likely linked with changes in women's activities. This adjustment has an impact on car ownership in terms of density and cars per persons. This is because an average Mexican family has at least one car regardless of size; access to a car is imperative to the average family. In the event of increasing family sizes, a corresponding increase in the ratio of cars per person would intuitively be expected as growing families acquire additional vehicles on average. A more in-depth analysis of the structure of the family and their activities, such as how many members usually work or study, would provide valuable insight into how family size influences the ratio. A family with only one economically active member, for instance, is not the same as another family with both parents working. The same applies to the age of the children; in Mexico teenagers are allowed to drive beginning at age sixteen. The young are generally more dependent on their parents for their commute.

While the shrinking average family size is generally expected to correspond to lower population densities, in this case there does not appear to be such a trend. This may be due to new housing developments, which are considerably smaller than older lots.

The urban form of the city reveals a problem related to its urban speed. The results of Shannon entropy analysis indicate that the city is growing, and a lack of proper planning seems to be affecting how and where the growth is occurring. These results were expected based on previously consulted literature and analysis of city maps over time, which themselves suggested Ensenada was experiencing significant sprawl. According to the results of Ensenada's Shannon entropy, the city is becoming more sprawled with time. This behavior is similar to that of cities such as Calgary (Canada) and Setubal and Sesimbra in Portugal, which use the same approach to measure urban sprawl. The irregular growth of the city is reflected in this index, but in recent years the urban speed has decreased compared with previous years; regardless, outlooks for the future are not promising. There are several reasons for the slowdown. One possible factor would be the topography of the city making continued construction in the periphery unviable; this is a natural obstacle for urban sprawl. As Barnes et al (2001) concluded, topography influences the urban sprawl as some spaces become increasingly impractical to develop. This factor could be the reason for the gradual increase in Shannon entropy in recent years. Another factor may be the disproportionate costs of developing in the periphery, as it is no longer viable for development by either private enterprises or the government.

Shannon's entropy results coincide with the statements claiming that there is indeed a connection between a sprawled city and travel behavior (Badland et al., 2012; Cao, Mokhtarian, & Handy, 2007b; Cervero & Radisch, 1995; Chin, 2002; Crane & Chatman, 2003; de Abreu e Silva, Golob, & Goulias, 2006; Kenworthy & Laube, 1996a; Khattak & Rodriguez, 2005; Naess, 2003). Contrary to what other authors such as Bagley and Mokhtarian (2001) and Boarnet and Sarmiento (1996) have claimed, urban sprawl is significant in modern cities, as in the case of Mexican mid-sized cities.

This study confirms the Mexican studies conducted by SEDESOL presented in the paper "The Expansion of cities from 1980-2010". This would mean that, as presented in that paper, most Mexican cities are experiencing sprawl, and therefore share similarities with Ensenada's travel behavior. Nevertheless further research on each city should be conducted. This study does show mid-sized cities of Mexico as car dependent.

The statement by Chin (2002) is corroborated by this research, showing Ensenada's sprawl is leading to a more motorized city. Naess (2003) recommends avoiding urban sprawl to reduce car orientated cities. The speed of urban growth of Ensenada is directly related to the lack of public services such as roads and public transportation coverage in some areas.

The population densities in the city are variables which are not affecting car ownership as was expected. Analyzed alone, these variables would contradict the claim by authors that lower densities decrease car ownership values, as stated by Newman and Kenworthy (1989). Ensenada's population densities are growing with time, which was a recommendation by authors. Even with these conditions, car ownership values keep increasing. The new developments on the periphery of the city are increasing in density, and it is likely that the location and the type of these neighborhoods is a primary reason for increasing car ownership. The type of the new neighborhoods in Ensenada, called social houses, could fit the description of Cao et al (2009), explaining also that these new developments have a modal split that is more car orientated.

The map in the case study chapter given by IMIP of 2007 shows that population density in the city is higher in the periphery, which brings some consequences. Widespread need to commute to the CBD combined with the lack of coverage of public transportation affect the traveler's decision. This may indicate that the densities of Ensenada are not well distributed.

Kenworthy and Newman's (1989) statement that low densities create more car use is a bit simplistic. It does not consider other factors, such as neighborhood type, socioeconomic factors, and the presence of urban sprawl. There is little benefit from a dense city if there are underdeveloped areas in the center that force people to commute between gaps.

This result concurs with the work of Litman (1999), stating that densities are not a main factor. As Buehler (2011) found, the USA has more car trips than Germany even when the densities are lower in the former. Other factors must be taken into account; for example, as Culliane (2003) explains Hong Kong's high densities are not the main reason for the low car ownership; it was an economical approach from the government which influenced ownership rates.

Kenworthy and Newman (2006) believe that around 3500 inhabit/km² is the minimum population density required to support a sustainable public transportation system. Ensenada surpassed that density years ago. This high density does not seem to be substantially lowering car ownership in the city. Perhaps the conditions of Ensenada are demanding higher densities that have

yet to be reached. The lack of accurate data for some areas could be a factor. This means that in some areas of the city, population density is lower than the average calculated. Employment densities also have an important negative effect on car ownership. Jabareen (2006) describes the ideal city as a compacted one. However, as Van Wee (2011) explained, having a compact city will not necessarily decrease the average citizen's commute length or frequency due to the availability of better jobs at further distances. Ensenada's increasing jobs per unit area is not a complete solution. Due to insufficient data, this study assumes a uniform employment density throughout the city, which in reality is inaccurate, especially in the periphery. Leck's work (2006) relates how population and employment play important roles, but in the case of Ensenada these two variables are not necessarily behaving in the manner Leck would predict. Other characteristics of the city could be driving increasing car ownership despite these two last variables performing ideally for a sustainable mode split.

As with the population variable, the employment density variable would become more valuable if it were more specific, detecting some high points (CBD) and the types of jobs by area. Concentration of the same type of jobs will contribute to people commuting from greater distances. Making conclusions based on an assumed uniform employment density is additionally imprecise due to the assumption that the city is polycentric; in the case opposite to these assumptions, variable results would be interpreted differently. It is also assumed that the increasing number of jobs in the city is linked with the income variable. Increased employment consequently increases the number of persons with a need to commute frequently. Ideally the city will have more uniform job opportunities per area, but as Van Wee (2011) explained, even under these conditions non-work related trips may remain problematic.

Many authors have recommended increasingly diverse mixed land use as a method for contributing towards a beneficial shift in the modal split. However, this model does not provide any support for these statements; there seems to be no definitive relationship between the degree of land use mix and car ownership levels based on the analyzed data. This research consequently contradicts statements by several researchers (Cao, Mokhtarian, & Handy, 2009; Cervero, 2002; Cervero & Kockelman, 1997; Cervero & Radisch, 1995; de Abreu e Silva et al., 2006; Holden, 2006; Jabareen, 2006; Kenworthy & Laube, 1996b; Kockelman, 1991; Krizek, 2003; Lawrence & Pivo, 1994; Marshall & Banister, 2000; Nolon & Bacher, 2007). Still, these ideas should not be discarded solely on the grounds that the dissimilarity index is decreasing without the desired slope. Determining if the dissimilarity index of the city is simply too low should be a priority in order to provide a clear statement. A different approach should be used to dismiss the validity of this variable. The fact that there is no significant change over time makes conclusive analysis difficult; therefore, an examination of citizens' perception of the quality of land use should be conducted.

Proper management of these urban form variables can contribute towards a solution. More specifically information can give better detail on why the behavior of the city is car orientated. When considering the two density variables, we must either conclude that they have negligible influence on car dependence relative to the other variables analyzed in the model, or a more in-depth study as previously described must be conducted to better quantify their impact.

The road and public transportation infrastructure plays a substantial role in determining the modal split of the city. In recent years, Ensenada's road infrastructure has been expanding physically, but is proportionally decreasing in terms of area per capita. As previously discussed, some authors

agree that the condition of road infrastructure alters the modal split of a city (de Abreu e Silva et al., 2006; Hanson, 2002; Kenworthy & Laube, 1996b; Naess, 2003; Newman & Kenworthy, 1999). This intuitively results from the available infrastructure's impact on the decision of how to commute. Of course this decision is also based on economic conditions; the user will compare his or her options in terms of costs, speed, and comfort. In virtually all cases, private transportation will be favored under conditions where the costs of private and public options are comparable due to variables such as comfort, commuting times and flexibility.

Based on these statements on infrastructure, it was expected that Ensenada's decreasing road infrastructure availability would slow the car ownership growth rate. This was the first hypothesis from the literature review; however, the decrease of available infrastructure has not been enough to stop the general population from continuing to purchase more cars. Just as with the number of streets per capita, the number of streets per unit area continues to decrease with time. Together, these two variables correspond to the urban speed of the city.

The connectivity of the city, primarily determined by the quality and quantity of main and secondary intersections, has displayed similar behavior. Decreasing connectivity with time is a result of insufficient road expansion and connection, as observed in city maps (Annex 5). With high traffic congestion resulting from worsening connectivity, car use is expected to be increasingly discouraged.

The design and quality of streets and sidewalks is important; the lack of pavement, small sidewalks, and streets' slopes discourage pedestrians from walking or cycling. The topography of the city plays some role, but Ensenada is largely flat. The lack of bicycle infrastructure has also caused frequent accidents, potentially discouraging commutes by bicycle over safety concerns. The lack of pavement causes difficulty walking in some areas during and even after the rain, causing minor flooding and mud buildup.

Analysis of the state of the transportation system as a whole indicates the following:

- Infrastructure growth is not catching up with the population growth of the city.
- Main intersections are incomplete and remain disconnected from some streets. There are gaps between secondary and main streets which are connected by alleys.
- The high rate of urban sprawl is affecting the connectivity of the city.
- Less connectivity not only affects car drivers, but also represents fewer available routes for buses.

The fact that road infrastructure is decreasing as car ownership increases is not a direct contradiction to statements such as those by Hanson (2002), which state that prioritization of road development by the government would lead to car dependent cities. For this statement to be refuted in this case, a more economic analysis of the government budget would be necessary to determine what percentage of the government's budget is invested into road infrastructure. Other factors to consider in determining how the municipality of Ensenada balances prioritization of road infrastructure and explicit improvement of public transportation include the price of obtaining a license, ease of obtaining a car, parking prices, taxes, etc., as well as policies governing car companies and road costs. With this data, reaching a conclusion concerning Kenworthy and Laube's

statement (1996) regarding the close association between road provision and parking with car ownership ratios may become more viable.

These infrastructure variables are directly linked to public transportation. Urban sprawl continues to affect the areas in the city's periphery with a lack of public services; some lack adequate roads or population densities, leading to slower buses which may be forced to traverse dirt roads. In some cases, no viable routes exist to allow buses to reach these areas.

Ensenada's public transportation system as described in the case study chapter is integrated by five companies. With the authorization of the government, these companies have raised the ticket price enormously. As one may expect, the increase in the price of public transportation is leading to a car dependent city and fewer public commuters. Influencing a traveler's decision on their mode of commute relies on prices, availability, and comfort. The increase in bus fares compared with income growth is a concern among users, as the 5 companies intend to raise the toll by about 33% (from 10 to 13.5 MXN). Comparing the quality of the public transportation in Ensenada with other cities of Mexico such as the capital city would not be particularly insightful, as the economic conditions in the capital city are substantially stronger than in Ensenada (El Universal Magazine, 2014). The metro system in Mexico City, for example, charges a fare of 3 MXN which remains valid for any metro connections taken, while the buses cost up to 10 MXN depending how much you intend to travel. By comparison, Ensenada is significantly less affordable; when considering that the average user may purchase four tickets per day, the impact of the fare price increase is multiplied. Discrepancies between the two cities are naturally expected, as the average income in the capital is significantly higher, but the price of the public transport should be lower in Ensenada.

The low quality of the public transportation service relative to its price presents a major disadvantage against the private alternative. A bus ticket remains at nearly the same price as one liter of gasoline, which would provide much more flexible travel opportunities when fueling a car than a single ticket. The limited schedule of the bus system could also be a factor in its declining usage.

At the government level, the routes currently being commissioned largely overlap, as indicated by IMIP (2007); this is partially aligned with the interests of public transportation companies seeking to extend routes in areas with the most potential passengers. The fact that the government is allowing this is a problem. Some routes overlapping while other areas lack sufficient public transportation is a major weakness in the system. The limited hours of operation are also a notable flaw; the last bus runs until 11 p.m., leaving night-shift workers with no alternative to commuting by car. It is logical to conclude that the high prices of a bus ticket combined with the weaknesses of the public transportation system are negatively affecting car ownership levels.

The expected consequence of a rise in the gasoline price should be a decrease in the car ownership ratio, as some authors explain (Hanson, 2002; Zegras, Eran, Hebbert, & Coughlin, 2008). It seems that the rising prices are not sufficiently encouraging people to stop buying cars or to sell off their existing cars; it may be that the price has not risen to levels where the average Ensenada citizen is unable to afford a car anymore. Tolerance for high gas prices is increased by the similarly priced public transportation options available.

The current state of gasoline prices could be causing drivers to make fewer trips by car or may be having an impact on the household economy, even if it has not yet substantially influenced the

car ownership ratio. For rising gas prices to cause a greater reduction in car use, affordable public transportation is necessary as well. If a person decides to change their mode of transportation, it will be because there are other affordable options. Currently the price of gasoline in Mexico is even higher than in the US; again considering the difference in average income between the two regions, conditions in Ensenada are concerning.

In summary, as Newman and Kenworthy (1999) have concluded, many factors including economic and transportation conditions along with population densities and employment densities are relevant to the issue of car dependence, and must all be considered simultaneously in order to produce effective and practical proposals for improvement.

5.2. RECOMMENDATIONS

Based on the development of Ensenada's condition over the last 24 years, some recommendations can be offered. As explained before in subchapter 5.1, failing to consider all aspects of the problem would lead to an incomplete plan of action. The following suggestions together should lead to reductions in the growth of the car ownership ratio. Urban planners must make a practical selection of these options based on costs and a reasonable time frame. These recommendations are based on the numerically supported final model, but some recommendations are based on assumptions which may render numerical support increasingly unreliable while still maintaining relevance based on the case study.

1. Ensenada's growing average income, along with other city conditions such as age and employment availability, encourages the purchase of additional cars. Controlling income or regulating purchasing patterns is not a viable or arguably ethical solution; ultimately, the goal of government is to provide better quality of life to its citizens. An awareness campaign informing people of the economic advantages of commuting less by car, for example, could have some impact. A campaign focused primarily on personal finances rather than bigger picture issues such as environmental benefits could more effectively influence the population. The campaign should target the working class, with flyers or posters placed in city centers which an abundance of people commute through, and with the cooperation of some companies these flyers could be delivered directly to employees. While people are interested in saving money, there is an extent to which comfort takes priority over savings. However, in order to convince the population that the alternatives to private transportation are worth favoring, the public transportation system must compete favorably against the cost of continuing to commute by car, as discussed further in a later recommendation.
2. While Ensenada's average age remains relatively young, the steadily increasing average implies a growing elderly population which tends to travel less through the public transportation system. The relative wealth of the elderly allows for a higher car ownership rate than the population in general. As private transportation becomes increasingly attractive relative to the alternative, facilitations for the elderly would be necessary to encourage a substantial shift. The youngest age range of drivers is also an important target demographic, as these drivers will generally be easier to influence than others (Stradling et al., 2000).

- a. Economic approach: The current 50% discount in bus fares for the elderly appears to be insufficient, considering that they live on retirement funds and the high initial price of a bus ticket. An approach towards appealing to this group would be the introduction of an integrated ticket with a bigger discount. The different firms managing retirement plans should be responsible for delivering a card valid for unlimited access on the public transportation system. This ticket can be financed with the same retirement fund and with the support of the state. With the pass provided to retirees, public transportation becomes a persistent economic alternative without the decision to pay for bus fare. Younger citizens are more likely to be persuaded to make a change in their modal split. Though similar discounts exist for students (50%), complaints of drivers not honoring discounts and the exclusion of weekends limit the popularity of the bus system. Similarly to retirees, students should be provided with an annual ticket valid for the duration of their study period. Coordination is needed between the government and the schools and institutions which manage the funding and distribution of the annual passes for the elderly and students respectively. The government may expect resistance from citizens who feel they are being forced to pay extra pension taxes or tuition for a service they will not use. The extra tax must be presented with the justification that a regular or even occasional user of the public transportation system would be receiving a major discount by using their pass over paying fare on every use. The availability of a “free” public transit option once the pass is acquired will make any commute by car the explicitly more expensive option, decreasing its appeal for most purposes.
 - b. Accessibility for the elderly: Buses are currently largely inaccessible to citizens with disabilities and the elderly. The elderly age group is particularly relevant to this case study; normally this group is characterized by better economic standing and mobility disabilities which make buses generally unattractive to them compared to the convenience of private transportation. Buses must strive to accommodate the elderly; Ensenada’s buses currently lack priority seating for the elderly and disabled near the front and sufficient space for wheelchair passengers. It is similarly difficult for passengers with walkers to board the buses. For the blind, there are no audio indicators of the current location of the bus. Implementation of these services would improve accessibility. Without improvements to accessibility, efforts to increase the affordability of public transportation will have little impact on these people.
3. The decreasing average Mexican family size cannot be effectively regulated; in fact many campaigns already exist for family planning. Attempting to alter the family structure is not particularly relevant to this study. Problems relevant to car dependence arise in cases of families where all members have access to a vehicle, as is common with families with teenagers. It is common for working parents to provide driving-age teenagers with their own car to accommodate different schedules between family members. It is necessary to control the number of cars per family, but adding taxes to additional cars per household can be problematic due to the implied logistics. Collecting taxes from citizens who purchase additional cars (and who therefore are more likely to have better economic standing) then using collected funds to improve the public transportation system may be a reasonable proposal. Alternatively, more expensive licenses for teenagers could have a similar impact

on larger families. An additional measure towards reducing the number of teenage drivers is to implement stricter policies for granting them licenses. Combined with recommendation number 2.a, under which teenagers/students would commute for free (with taxes already paid on tuition fees) through public transit, parents would have decreased incentive to provide them with their own vehicles.

4. Changing population densities is difficult in terms of both time and costs, and the current trend is to keep constructing in the periphery to avoid the new costs of urbanization. Opportunities may lie in the empty spaces available in the city's inner areas. Ensenada needs an infill development approach to develop a more compact city. The empty spaces are well connected with the city's center, and some are big enough for housing development projects. As can be seen in Figure 3.5, there are some bigger areas in the city which are viable for further development, as well as other smaller areas which may be used for the construction of individual structures. There are a few bigger empty lots which could support the development of sub centers (malls, industry, etc.). Mid-sized lots may be used for housing developments such as apartment complexes. Infill construction projects designed for these unused lots should be increasingly vertical in order to increase population and employment densities simultaneously. Current designs for social houses are not optimal for these empty spaces; development of vertical construction projects (i.e. apartments) along with small malls. The problem with apartments is a lack of incentive for citizens to form a family heritage there, but this may be remedied with construction in more favorable locations and more efficient use of available area may also allow improvements in the size of the average house. An additional change which may also be applied in this design is to limit each household to a single parking space.
5. While difficult, changing the structure of employment distribution throughout the city is another viable option.
 - a. Employment arrangements may not be fully controlled by the government effectively, but the government may be able to guide people towards finding jobs in the vicinity of their homes. The government may arrange employment fairs, with employers prioritizing applicants partially based on their proximity. The government may also fund the creation of a web service to serve as an interface for workers to exchange their jobs if they share an interest in doing so, and the nature and income of both jobs are comparable. It could be a viable system for teachers, secretaries, etc. A similar system is already in place for public schools when enrolling their students, as students may choose their school based on proximity.
 - b. The government should also promote more urban centers. As illustrated by the IMIP map (Annex 8), there are some unconsolidated sub-centers which have not yet fully developed. A focus on properly developing these sub-centers would lead to better and denser job opportunities. As mentioned in recommendation 4, use of empty lots is an opportunity for infill in areas otherwise dominated by housing projects.
6. Addressing urban sprawl: Reducing the urban speed of the city will directly influence car ownership levels. This does not imply a stop to emerging urbanization in the city; it is also related to increasing urban density.
 - a. Controlling the sprawl of Ensenada means directly applying reforms to the construction policies. Policies governing construction of social housing should be

prioritized, as these structures are most common in the city's periphery. In cases where it is unable to fund proper urban development, the government may consider adopting a policy of selling some to private owners instead. Private businesses acquiring these properties would expect similar or likely improved profits relative to what could be made in the outer areas of the city. The problem largely lies in the suburban and horizontal construction of social housing. Ensenada is becoming sprawled due to the lack of vertical construction, as most structures are limited to one or two levels, and few apartments exist relative to the abundance of houses.

- b. Implementation of restrictions on construction permits: in certain areas of the city, construction permits may be granted depending on the project's ability to produce a certain quantity of jobs, sufficient population density, and accessibility of public services. Alternatively, projects which do not meet these requirements may be granted a permit with an associated tax to help fund proper development elsewhere.
7. Because the land use mix is not relevant according to the selected model, a solid foundation for a land use recommendation could not be developed. Urban planners should not dedicate resources to improve land use mix unless more solid supporting data is found, particularly with respect to its relation to mitigated car ownership ratios.
 8. Decreases in roads per area and per capita throughout Ensenada should lead to reduced car use. However, it is also possible the degrading road network is causing increasing congestion and commute times without sufficiently discouraging car use. This outcome would also be a result of insufficient availability of buses in some areas. The lack of road infrastructure also corresponds with the lack of sidewalks and bicycling infrastructure. Some improvements should be made:
 - a. Pedestrian-friendly streets. In the periphery of Ensenada, some districts have a lack of pavement, making walking an unattractive option. Future construction of streets should be designed to better accommodate pedestrians. In some parts of the city the sidewalks are approximately 2 meters wide, and are normally obstructed by cars. Additionally, in the majority of the city the citizens are responsible for their sidewalk (in front of their houses), resulting in paths which are uneven throughout neighborhoods. The government should integrate sidewalks into road construction projects as a common practice.
 - b. Bike lanes: As previously discussed, addressing car dependence is an issue of giving travelers more viable options. Bicycle lanes could be implemented in some primary streets where sufficient space is available; the removal of diagonal parking spaces, for example, would provide the required space for a bike lane. Local streets with low traffic could be converted to one-way streets, removing a car lane for conversion to a bike lane and possibly providing enough space for sidewalks. Education in the schools concerning safety while riding bicycles would help expand cycling while helping to address increasing related accidents.
 - c. Conversion of parking spaces: Nonessential parking spaces could be replaced either by bike lanes or wider sidewalks. The lack of parking spaces should at least lead to some reduction in car usage and ownership.

9. The most important area that Ensenada should focus on is the public transportation system. To change the modal split of citizens, other viable options should be present. In order for citizens to commute in better conditions, the following improvements should be considered:
- a. Reduction of fares to a level significantly more affordable than the cost of a commute by car. As mentioned previously, an economic approach is important to influence people's travel behavior. Their economic status can be a limitation; giving the citizens better economic options over a car is more viable than a push approach such as implementing taxes or increased road tolls. A bus fare price reduction of at least 20% should be made. Bus companies should strike a sustainable balance between their profits and how they manage their prices, with the government advising them on how to invest and administrate their resources.
 - b. Improve the commuting times of public transportation in the city. A survey conducted by IMIP (2007) found that people normally wait between 6 to 10 minutes (with 25% waiting more than 10 minutes) not including time spent walking to the bus stop. If it is not possible to increase the number of buses per route, a reliable time schedule in some new mandatory bus stations (few currently exist) should be implemented at the minimum.
 - c. Avoidance of additional overlapping routes. As IMIP (2007) mentioned, there are 23 routes that overlap by around 50%; a better use of these resources can decrease transit costs while improving the speed of the public transportation system and general traffic. Future bus routes should be more extensively planned with more involvement of the government.
 - d. The poor quality of the buses is a problem as well. Even if the price of bus fare drops low enough to be economically favorable over cars, many will continue to prefer private transportation if the buses are not properly maintained. The buses are old (IMIP, 2007), and while the companies are responsible for maintenance it seems there is a lack of supervision and enforcement.
 - e. Regulation of the different bus companies. In order to apply all the recommendations above for the public transport system, some changes must be made at a political level. The lack of transparency and proper paperwork from the different companies demonstrate a lack of structure. If there is a need for a change in the ticket price and to improve bus routes, the government should be more involved and have control over the granted routes.
 - f. Integrated tickets: As mentioned before, some age groups should have access to annual tickets. Normal passengers should also have some incentives to buy a ticket at a certain discount or with an alternate payment plan, such as paying by month or year or only paying for some routes, for example.
10. The fuel price is a variable that affects car travelers, but in this case it seems that the rise in fuel prices is not substantially discouraging the average driver. Urban planners should not focus on fuel taxes in order to reduce the car ownership level. It seems that the economic level of the city prevents fuel prices from affecting car dependence. A push measure as a first step is not recommended in the city.
11. Road pricing: This alternative involves directly economically affect the average private commuter. After the recommendations above are implemented, a new status quo of the city should develop. If pull measures prove insufficient, a push approach can be implemented.

There are several approaches to implement road pricing measures, as in the examples of London, Oslo, Singapore, etc. A more thorough study would be necessary to determine the appropriate approach for Ensenada, but an initial recommendation is to avoid aggressive economic measures. This study suggests that such measures could have worse consequences than the car ownership rates they attempt to reduce. Road tolls are unlikely to be particularly effective; if, for example, a high price is set to travel through the CBD, citizens are likely to reroute their commutes or otherwise avoid fees whenever possible. If tolls are set for travel through designated areas, exemption for residents would be recommended.

The recommendations presented above are based on the results of the analytical model and complemented with the city's current characteristics. The approach towards formulating these suggestions favors pull measures to incentivize citizens to change their modal split. Furthermore, an aggregated model should be developed to complement these results and recommendations; a re-evaluation of the city after initial implementations are made would also be necessary in order to decide if a push measure is appropriate or necessary. The recommendations made above cannot be implemented all together. Some of them are easier to implement, and therefore three phases are suggested. As can be seen in Figure 5.1 some recommendations will be implemented initially, and the final phase would be implemented after a reevaluation of the city.

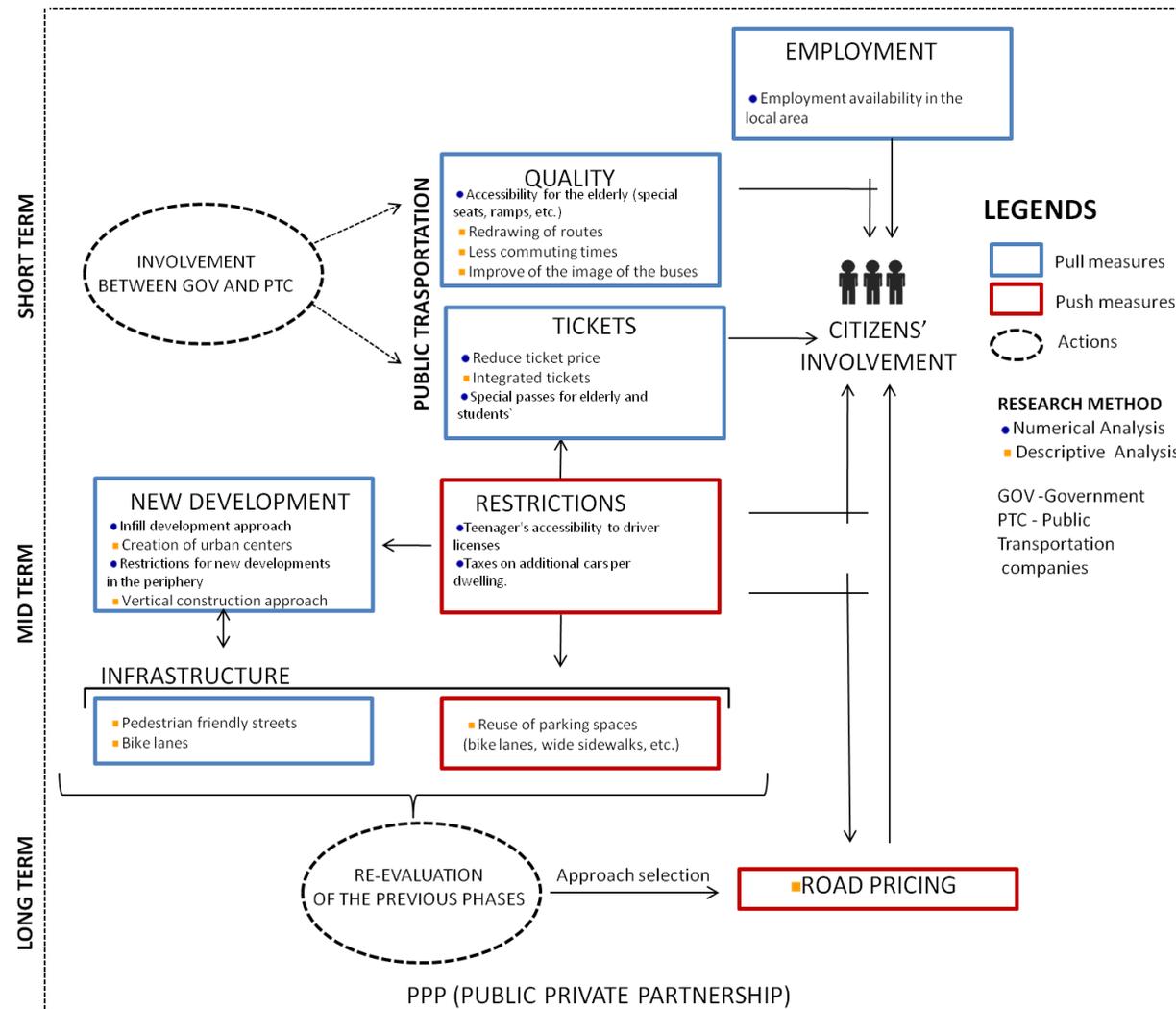


Figure 5.1 Implementation scheme for recommendations

Source: Compiled by the author.

CONCLUSIONS AND FURTHER WORK

The developing potential of middle sized cities compared with bigger cities makes them increasingly important. These cities may be placed on a path towards becoming either a sustainable city or a megacity with the common corresponding problems of mobility. This research aimed to determine whether specific characteristics of a mid-sized city are related to an increase of car ownership. It is important to detect and understand the factors leading to car dependence. The social and environmental consequences of high automobile use warrant a dedicated study towards reducing its causes.

This research focused on three areas of interest: urban form, transportation, and socioeconomic factors. The initial hypothesis predicted that all selected variables were related in some form, and specific interactions were anticipated.

Using a linear regression model, it was possible to measure if the analyzed variables are in fact relevant to the problem. The study reveals some contradictions to prior statements and hypotheses. These results do not necessarily indicate that the previous statements are incorrect; the city's characteristics may have not yet developed to the necessary stage to substantially affect car dependence.

The hypothesis was that the three areas were directly related, with corresponding variables negatively affecting car ownership levels. This hypothesis was partially confirmed, though one variable was found to be of minimal significance and others were found to have a relationship to car dependence contradictory to what was expected.

A drop in a city's population and employment densities was assumed to correspond to increased car ownership levels. Densities in Ensenada are increasing along with car ownership, but this does not definitively indicate causality between the two. The model should be interpreted in context of previously conducted research on the subject. It may be the case that densities in Ensenada have not reached the minimum levels necessary for a significant relationship to emerge. Kenworthy and Newman (2006) believe that a minimum density of around 3500 inhabitants per square kilometer is suitable for public transportation, but a density range suitable for cycling and walking is uncertain. It may be that Ensenada has yet to reach such a density.

Urban growth rates can represent an even more significant factor towards car ownership rates. Even when a city is becoming denser in terms of population and job availability, the presence of leapfrogs is often substantial enough to net an increased average commute distance.

The socioeconomic category of factors had stronger influence than expected, despite the gender distribution variable proving to be of little to no significance on car ownership. Income, age, and household size varied directly with car ownership. A gradual increase in the city's average population age appears to be part of this relationship, as a more mature population will in theory represent a higher average income. Social changes such as household size are not easily regulated. It may be assumed that families currently include more teenagers than in previous years.

In regard to transportation factors, the connectivity of the city is decreasing, which in theory should lead to reduced car ownership levels. The decrease in connectivity is not only relevant to

automobile traffic, but also to pedestrian and cyclist traffic. Economic factors also played an important role; public transportation is becoming exceedingly expensive, and remains largely inaccessible to the elderly (the most important age group for a potential modal shift). Gasoline price increases have not provided sufficient motivation for most citizens to refrain from continuing to purchase cars. Similar pricing between fuel and public transportation fares can be a decisive factor in the decision between private and public transportation. All these factors are collectively influencing car ownership levels.

From a general perspective, some of the city's variables indicate consistency with basic recommendations for reducing car dependence on matters of urban form and road infrastructure. However, the city presents increasing densities and low priority towards improving roads. The issue falls on how exactly these factors are evolving. Without any more specific data on densities per area, it is quite difficult to make any assertions with certainty, but it seems that densities are not well distributed. Urban sprawl is another substantial factor, as dense settlements with the presence of leapfrogs obligate residents to commute by car. Physical aspects of Ensenada's general development trends, combined with increasing bus fares, allow private transportation to remain the preferred method of commute.

A push system may not be ideal, as regulations and fees may not be respected, and considerable expenditures may be necessary for implementation. A pull approach should be considered; the integrated tickets and investments into changing the infrastructure to be more pedestrian and cyclist focused should lead to favorable results. This may be combined with an effort to increase awareness of public transportation options, as some of the better options in public transportation are often underutilized. The lack of consideration of each of these relevant factors is problematic in plans for Ensenada's development. Proper urban planning is needed, integrating several areas of concern into a viable roadmap for improvement. Focusing on a single aspect of the problem will lead to inevitably weak solutions.

The following recommendations for the city favor a pull approach:

1. Inform citizens about the economic advantages of travel by public transportation over travel by car.
2. Regarding age groups:
 - a. Offer special ticket pricing for students and the elderly.
 - b. Improve accessibility for the elderly through improvements in infrastructure.
3. Regulation of cars per household and increased restrictions for teenagers' licenses.
4. Improve population densities by infill development.
5. Employment:
 - a. Inform citizens about available jobs in their living area and possibilities to move to others jobs in their area.
 - b. Improve urban sub-centers and create new ones in available empty lots.
6. In terms of urban sprawl:
 - a. Promotion and government facilitation of construction inside the city
 - b. Restriction of construction in the periphery.
7. Infrastructure:
 - a. Pedestrian-friendly streets
 - b. Bike lanes

- c. Remove of some parking spaces.
8. More in-depth investigation concerning mixed land use's impact on the city's development.
9. Public transportation system
 - a. Reduction of bus ticket prices.
 - b. Improve commuting times.
 - c. Redrawing of routes.
 - d. Improve the image and quality of buses.
 - e. Increased supervision and control over the bus companies.
 - f. Integrated tickets (use for multiple rides and across different companies).
10. Avoid use of taxes on gasoline to discourage car use (due to substantial data to support this action).
11. Road pricing.

This research focused on a quantitative approach, numerical findings gathered and interpreted by previous studies, and the city profile. The lack of information regarding the population's personal preferences and cultural background limited this study, as with some vague or incomplete data (neighborhood data). An aggregated model should be constructed in order to more fully understand the conditions which lead to a car orientated city.

The analysis conducted throughout this research can serve as a guideline for future studies on other mid-sized cities in Mexico with similar characteristics, particularly those with similar economic activity and proximity to the US border.

Every country has its cultural differences; these differences have a strong influence on travel behavior. For instance, the general preference towards private over public transportation may be an issue of maintaining a symbol of economic status. Understanding the actual motivations behind the decision to commute by car will enable more insightful analysis. A sociological approach would be fitting for complementing this type of study. Few previous studies focus on examining the personalities of citizens. Other studies concerning personal preferences have been conducted in other countries, but do not provide relevant usable data for this study due to differences between cultures. Even within a single country, people among different cities have different ways of thinking. The study of the urban form and variables such as socio-economic and transportation factors is just the first step towards understanding this behavior.

Besides the culture factor, people must be seen as individuals. The preferences of the individual provide unique motivations and perspectives.

This could lead to the development of a better action plan to ensure that if an economically sustainable public transportation option is available, people will use it. Ultimately it may be the case that the preferences and culture of a population are stronger factors than even physical infrastructure.

REFERENCES

- Aditjandra, P. T., Mulley, C., & Nelson, J. D. (2013). The influence of neighbourhood design on travel behaviour: Empirical evidence from North East England. *Transport Policy*, 26, 54–65.
- Alabi, M. O. (2009). Urban sprawl, pattern and measurement in Lokoja, Nigeria. *Theoretical and Empirical Researches in Urban Management*, 4(13), 158–164.
- Andrew, A. (2010). Pedestrian Priority Addressing Car Dependency-Purposes and Benefits. Retrieved from <http://www.seiofbluemountain.com/upload/product/201010/2010dthy01a13.pdf>
- Badland, H. M., Oliver, M., Kearns, R. A., Mavoa, S., Witten, K., Duncan, M. J., & Batty, G. D. (2012). Association of neighbourhood residence and preferences with the built environment, work-related travel behaviours, and health implications for employed adults: Findings from the urban study. *Social Science & Medicine*, 75(8), 1469–1476.
- Bagley, M. N., & Mokhtarian, P. L. (2001). The impact of residential neighborhood type on travel behavior: A structural equations modeling approach. University of California Transportation Center. Retrieved from <http://escholarship.org/uc/item/12q634n2>
- Barnes, K. B., Morgan III, J. M., Roberge, M. C., & Lowe, S. (2001). Sprawl development: its patterns, consequences, and measurement. Towson University, Towson, 1–24.
- Bento, A. M., Cropper, M. L., Mushfiq Mobarak, A., & Vinha, K. (2001). The Impact of Urban Spatial Structure on travel demand in the United States. Retrieved from http://are.berkeley.edu/courses/envres_seminar/s2002/bento.doc
- Blumenberg, E., Taylor, B. D., Smart, M., Ralph, K., Wander, M., & Brumbagh, S. (2012). What's Youth Got to Do with It? Exploring the Travel Behavior of Teens and Young Adults. Retrieved from <https://escholarship.org/uc/item/9c14p6d5.pdf>
- Boarnet, M. G., & Sarmiento, S. (1996). Can Land Use Policy Really Affect Travel Behavior? A Study of the Link Between Non-Work Travel and Land Use Characteristics. University of California Transportation Center. Retrieved from <http://escholarship.org/uc/item/95h07239>
- Brindle, R. (2003). Kicking the habit (Part 2): What are the real options for reducing “Car Dependence”? *Road & Transport Research*, 12(4), 34–40.
- British Embassy in Mexico. (2013). *Desarrollo Orientado al Transporte*.
- Brueckner, J. K. (2000). Urban sprawl: diagnosis and remedies. *International Regional Science Review*, 23(2), 160–171.
- Brueckner, J. K., & Fansler, D. A. (1983). The Economics of Urban Sprawl: Theory and Evidence on the Spatial Sizes of Cities. *The Review of Economics and Statistics*, 65(3), 479.
- Brueckner, J. K., Mills, E., & Kremer, M. (2001). Urban sprawl: Lessons from urban economics. *Brookings-Wharton Papers on Urban Affairs*, 65–97.
- Buehler, R. (2011). Determinants of Automobile Use: A comparison of Germany and the U.S. *Transportation Research Record: Journal of the Transportation Research Board*, 2139, 161–171.
- Camagni, R., Gibelli, M. C., & Rigamonti, P. (2002). Urban mobility and urban form: the social and environmental costs of different patterns of urban expansion. *Ecological Economics*, 40(2), 199–216.
- Cao, X., Mokhtarian, P. L., & Handy, S. (2007a). Do changes in neighborhood characteristics lead to changes in travel behavior? A structural equations modeling approach. *Transportation*, 34(5). Retrieved from <http://escholarship.org/uc/item/49393360>
- Cao, X., Mokhtarian, P. L., & Handy, S. (2009). The relationship between the built environment and nonwork travel: A case study of Northern California. *Transportation Research Part A: Policy and Practice*, 43(5), 548–559.
- Cao, X., Mokhtarian, P. L., & Handy, S. L. (2007b). Do changes in neighborhood characteristics lead to changes in travel behavior? A structural equations modeling approach. *Transportation*, 34(5). Retrieved from <http://escholarship.org/uc/item/49393360>
- Cervero, R. (2002). Built environments and mode choice: toward a normative framework. *Transportation Research Part D: Transport and Environment*, 7(4), 265–284.
- Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: density, diversity, and design. *Transportation Research Part D: Transport and Environment*, 2(3), 199–219.

- Cervero, R., & Radisch, C. (1995). Travel Choices in Pedestrian Versus Automobile Oriented Neighborhoods. University of California Transportation Center. Retrieved from <http://escholarship.org/uc/item/7cn9m1qz>
- Chin, N. (2002). Unearthing the roots of urban sprawl: a critical analysis of form, function and methodology. Centre for Advanced Spatial Analysis. Retrieved from <http://eprints.ucl.ac.uk/249/>
- COPLADE. (2014). Comité de Planeación para el Desarrollo del Estado de Baja California. Retrieved September 29, 2014, from <http://www.copladebc.gob.mx/>
- Crane, R. (2000). The Influence of Urban Form on Travel: An Interpretive Review. *Journal of Planning Literature*, 15(1), 3–23.
- Crane, R., & Chatman, D. G. (2003). Traffic and Sprawl: Evidence from U.S. Commuting, 1985 To 1997. *Planning & Markets*, 6(1).
- Crane, R., & Crepeau, R. (1998). Does Neighborhood Design influence Travel. Retrieved from <http://www.uctc.net/papers/374.pdf>
- Cullinane, S. (2003). Hong Kong's low car dependence: lessons and prospects. *Journal of Transport Geography*, 11(1), 25–35.
- Curtis, C., & Perkins, T. (2006). Travel behavior: a review of recent literature. Working Paper. Retrieved from http://urbanet.curtin.edu.au/local/pdf/ARC_TOD_Working_Paper_3.pdf
- De Abreu e Silva, J., Golob, T., & Goulias, K. G. (2006). The effects of land use characteristics on residence and employment location and travel behavior of urban adult workers. Retrieved from <http://eden.dei.uc.pt/~camara/files/iTEAM/LandUseEffects.pdf>
- Deka, J., Tripathi, O. P., & Khan, M. L. (2011). Urban growth trend analysis using Shannon Entropy approach-A case study in North-East India. *International Journal of Geomatics and Geosciences*, 2(4), 1062–1068.
- De Winter, J. C. F. (2013). Using the Student's t-test with extremely small sample sizes. *Practical Assessment, Research & Evaluation*, 18(10), 2.
- El Universal Magazine. (2014, January). Cinco estados concentran los salarios más elevados. Retrieved November 23, 2014, from <http://www.eluniversal.com.mx/finanzas-cartera/2014/impreso/cinco-estados-concentran-los-salarios-mas-elevados-107715.html>
- Frenkel, A., & Ashkenazi, M. (2008). Measuring urban sprawl: how can we deal with it? *Environment and Planning B: Planning and Design*, 35(1), 56–79.
- Frost, J. (2012). A Tribute to Regression Analysis | Minitab. Retrieved October 9, 2014, from <http://blog.minitab.com/blog/adventures-in-statistics/a-tribute-to-regression-analysis>
- GOBBC. (2008). Programa sectorial de vivienda del estado de baja California. GOBBC.
- Greenwald, M. J., & Boarnet, M. G. (2001). The Built Environment as a Determinant of Walking Behavior: Analyzing Non-Work Pedestrian Travel in Portland, Oregon. Center for Activity Systems Analysis. Retrieved from <http://escholarship.org/uc/item/9gn7265f>
- Handy, S., Cao, X., & Mokhtarian, P. (2005). Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transportation Research Part D: Transport and Environment*, 10(6), 427–444.
- Hanson, M. (2002). Car dependence—an unsustainable mode of consumption. *Paths to Sustainability*, 77–88.
- Hasse, J. E., & Lathrop, R. G. (2003). Land resource impact indicators of urban sprawl. *Applied Geography*, 23(2-3), 159–175.
- Hess, P., Vernez Moudon, A., & Logsdon, M. (2001). Measuring Land Use Patterns for Transportation Research. *Transportation Research Record*, 1780(1), 17–24.
- Holden, D. (2006). The relationship between land use and car dependence and its application for land use planning policy in Sydney. In *Proceedings, 29th Australasian Transport Research Forum, Gold Coast, Queensland*. Retrieved from http://www.atrf.info/papers/2006/2006_Holden.pdf
- IMIP. (2005). PDUCP-E2030-abreviado.pdf.
- INEGI. (2014). Instituto Nacional de Estadística y Geografía. Retrieved September 29, 2014, from <http://www.inegi.org.mx/>
- INEGI. (n.d.). National Institute of Statistics and Geography. Retrieved August 25, 2014, from <http://www.inegi.org.mx/>

- Jabareen, Y. R. (2006). Sustainable Urban Forms: Their Typologies, Models, and Concepts. *Journal of Planning Education and Research*, 26(1), 38–52.
- Jaeger, J. A. G., Bertiller, R., Schwick, C., & Kienast, F. (2010). Suitability criteria for measures of urban sprawl. *Ecological Indicators*, 10(2), 397–406.
- Johnson, M. P. (2001). Environmental impacts of urban sprawl: a survey of the literature and proposed research agenda. *Environment and Planning A*, 33(4), 717–735.
- Joshi, J. P., & Bhatt, B. (2011). Quantifying Urban Sprawl: A Case Study of Vadodara Taluka. *Geoscience Research*, 34–37.
- Kenworthy, J. R., & Laube, F. B. (1996a). Automobile dependence in cities: an international comparison of urban transport and land use patterns with implications for sustainability. *Environmental Impact Assessment Review*, 16(4), 279–308.
- Kenworthy, J. R., & Laube, F. B. (1996b). Automobile dependence in cities: an international comparison of urban transport and land use patterns with implications for sustainability. *Environmental Impact Assessment Review*, 16(4), 279–308.
- Kenworthy, J. R., & Laube, F. B. (1999). Patterns of automobile dependence in cities: an international overview of key physical and economic dimensions with some implications for urban policy. *Transportation Research Part A: Policy and Practice*, 33(7), 691–723.
- Khattak, A. J., & Rodriguez, D. (2005). Travel behavior in neo-traditional neighborhood developments: A case study in USA. *Transportation Research Part A: Policy and Practice*, 39(6), 481–500.
- Kockelman, K. (1991). *Travel Behaviour as a Function of Accessibility, land use mixing, and land use Balance: Evidence from the San Francisco Bay Area*. University of California, Berkeley. Retrieved from http://www.ce.utexas.edu/prof/kockelman/public_html/mcpthesis.pdf
- Krizek, K. J. (2003). Operationalizing Neighborhood Accessibility for Land Use-Travel Behavior Research and Regional Modeling. *Journal of Planning Education and Research*, 22(3), 270–287.
- Laran, J. (2014). *Quantitative Data Analysis: A Versatile and Beneficial Process*. Retrieved from <https://www.udemy.com/blog/quantitative-data-analysis/>
- Lawrence, F., & Pivo, Gary. (1994). Relationships between land use and travel behavior in the Puget Sound Region, 1994. Retrieved from http://architecture.arizona.edu/sites/default/files/faculty_papers/Relationships%20between%20land%20use%20and%20travel%20behavior%20in%20the%20Puget%20Sound%20Region,%201994.pdf
- Leck, E. (2006). The Impact of Urban Form on Travel Behavior: A Meta-Analysis. *Berkeley Planning Journal*, 19(1). Retrieved from <http://escholarship.org/uc/item/20s78772>
- Litman, T. (1999). The costs of automobile dependency. Victoria Transportation Policy Institute. Retrieved from <http://www.vtpi.org/autodep.pdf>
- Marshall, S., & Banister, D. (2000). Travel reduction strategies: intentions and outcomes. *Transportation Research Part A: Policy and Practice*, 34(5), 321–338.
- Masoumi, H. E. (2012). Urban sprawl in Iranian cities and its differences with the western sprawl. *Spatium*, (27), 12–18.
- Masoumi, H. E. (2014). urban Sprawl in mid-sized cities of MENA, evidence from Yazd and Kashan in central Iran. *Management Research and Practice*, 6(2), 25–41.
- Milakis, D., Vlastos, T., & Barbopoulos, N. (2008). Relationships between urban form and travel behaviour in Athens, Greece. A comparison with Western European and North American results. *EJTIR*, 3(8). Retrieved from http://www.ejtir.tbm.tudelft.nl/issues/2008_03/pdf/2008_03_02.pdf?origin=publication_detail
- Mohammadi, J., Zarabi, A., & Mobaraki, O. (2012). Urban Sprawl pattern and effective factors on them: the case of Urmia, Iran. *Journal of Urban & Regional Analysis*, 4(1).
- Mokhtarian, P. L., & Cao, X. (2008). Examining the impacts of residential self-selection on travel behavior: A focus on methodologies. *Transportation Research Part B: Methodological*, 42(3), 204–228.
- Naess, P. (2003). Urban Structures and Travel Behaviour. Experiences from Empirical Research in Norway and Denmark. In *Urban Structures and Travel Behaviour* (pp. 155–178). Retrieved from http://www.ejtir.tbm.tudelft.nl/issues/2003_02/pdf/2003_02_03.pdf
- Newman, P., & Kenworthy, J. (1989). *Cities and Automobile Dependence: An International Sourcebook*.

- Newman, P., & Kenworthy, J. (1996). The land use—transport connection: An overview. *Land Use Policy*, 13(1), 1–22.
- Newman, P., & Kenworthy, J. (1999). *Sustainability and cities: overcoming automobile dependence*. Island Press. Retrieved from http://books.google.com/books?hl=en&lr=&id=pjatbiavDZYC&oi=fnd&pg=PR13&dq=%22to+see+how+this+has+caused+three+types+of+cities+to+develop+as%22+%22cities+today+have+sections+that+retain+historical+walking%22+%22of+destinations+by+walking,+but+this+is+rare+in+U.S.+or+Australian%22+&ots=BaHXoPxszy&sig=_jlkjAIVUAoXEQz-C836Mh6Bo-I
- Newman, P., & Kenworthy, J. (2006). *Opolis: An International Journal of Suburban and Metropolitan Studies*. *Opolis*, 2(1). Retrieved from <http://escholarship.org/uc/item/2b76f089.pdf>
- Newman, P., & Kenworthy, J. R. (2011). "Peak Car Use": Understanding the Demise of Automobile Dependence. Retrieved from <https://blogs.otago.ac.nz/amc/research/files/2011/07/Newman-Peak-Car-Use.pdf>
- Newspaper El Vigia. (2012). Ensenada en un bache. - El Vigia. Retrieved November 26, 2014, from <http://www.elvigia.net/columnas/bitacora/2012/2/15/ensenada-bache-126485.html>
- Newspaper El Vigia. (2014). Aumentan ciclistas; y también accidentes - El Vigia. Retrieved November 26, 2014, from <http://www.elvigia.net/general/2014/1/28/aumentan-ciclistas-tambien-accidentes-148423.html>
- Nolon, J. R., & Bacher, J. A. (2007). Transit Orientation Reduces Car Dependency. Retrieved from <http://digitalcommons.pace.edu/lawfaculty/671/>
- ONU HABITAT, & SEDESOL. (2011). *Estado de las Ciudades de México 2011*. SEDESOL.
- Owen, N., Cerin, E., Leslie, E., duToit, L., Coffee, N., Frank, L. D., ... Sallis, J. F. (2007). Neighborhood Walkability and the Walking Behavior of Australian Adults. *American Journal of Preventive Medicine*, 33(5), 387–395.
- Papa, E. (2009). Measuring Urban Sprawl with GIS: Study Case of Naples and Bari Metropolitan Areas. In *Representation of geographical information for Planning* (pp. 109–118). Bologna, Italy: Societa Editrice Esculapio.
- Reduced car dependency. (n.d.). In *Inquiry into sustainable urban design for new communities in outer suburban areas*. (pp. 153–216). Retrieved from <http://www.cycle-helmets.com/vic-park-sustainability.pdf>
- Schwanen, T., & Mokhtarian, P. L. (2005). What affects commute mode choice: neighborhood physical structure or preferences toward neighborhoods? *Journal of Transport Geography*, 13(1), 83–99.
- Scott, M., McEldowney, M., Tyley, T., & Smyth, A. (2005). Urban form and reducing the demand for car travel: insights from Belfast. In *Planning and environmental policy*. University College Dublin. Retrieved from <http://www.ucd.ie/gpep/publications/archivedworkingpapers/2005/05-02.pdf>
- SEDESOL. (2012). *The Expansion of the Cities 1980-2010*. Mexican Federal Government. Retrieved from http://padrondemedios.segob.gob.mx/work/models/SEGOB/swbpress_Content/3309/09_REDES_DE_CIUDADES.PDF
- Spears, S., Boarnet, M. G., & Handy, S. (n.d.). *Technical Background on the Impacts of Land Use Mix Based on a Review of the Empirical Literature*. Retrieved from http://arb.ca.gov/cc/sb375/policies/mix/lu_mix_bkgd120313.pdf
- Stat Trek. (2014). Regression Slope Test. Retrieved October 9, 2014, from <http://stattrek.com/regression/slope-test.aspx>
- Stead, D., & Marshall, S. (2001). The relationships between urban form and travel patterns. An international review and evaluation. *European Journal of Transport and Infrastructure Research*, 1(2), 113–141.
- Stradling, S. G., Meadows, M. L., & Beatty, S. (2000a). Helping drivers out of their cars Integrating transport policy and social psychology for sustainable change. *Transport Policy*, 7(3), 207–215.
- Stradling, S. G., Meadows, M. L., & Beatty, S. (2000b). Helping drivers out of their cars Integrating transport policy and social psychology for sustainable change. *Transport Policy*, 7(3), 207–215.
- Sudhira, H. S., Ramachandra, T. V., & Jagadish, K. S. (2004). Urban sprawl: metrics, dynamics and modelling using GIS. *International Journal of Applied Earth Observation and Geoinformation*, 5(1), 29–39.
- Sun, H., Forsythe, W., & Waters, N. (2007). Modeling Urban Land Use Change and Urban Sprawl: Calgary, Alberta, Canada. *Networks and Spatial Economics*, 7(4), 353–376.
- Sykes, A. O. (1993). *An introduction to regression analysis*. Retrieved from http://chicagounbound.uchicago.edu/cgi/viewcontent.cgi?article=1050&context=law_and_economics
- Tsai, Y.-H. (2005). Quantifying urban form: compactness versus "sprawl." *Urban Studies*, 42(1), 141–161.

Urban Planning for Reduced Car Use. (2007). Technical Administration and City Planning Office. Retrieved from http://www.polisnetwork.eu/uploads/Modules/PublicDocuments/HandBook_Short_version_Lund.pdf

Van de Coevering, P., & Schwanen, T. (2006). Re-evaluating the impact of urban form on travel patterns in Europe and North-America. *Transport Policy*, 13(3), 229–239.

Van Wee, B. (2011). Evaluating the impact of land use on travel behaviour: the environment versus accessibility. *Journal of Transport Geography*, 19(6), 1530–1533.

Williams, K. (2005). Spatial planning, urban form and sustainable transport: An introduction. *Spatial Planning, Urban Form and Sustainable Transport*, 1–13.

Yeh, A. G.-O., & Li, X. (2001). Measurement and Monitoring of Urban Sprawl in a Rapidly Growing Region Using Entropy. *Photogrammetric Engineering and Remote Sensing*, 67(1), 83–90.

Zegras, P. C., Eran, B.-J., Hebbert, F., & Coughlin, J. (2008). A Comparative Study of Baby Boomers' Travel Behavior and Residential Preferences in Age-Restricted and Typical Suburban Neighborhoods. Retrieved from <http://web.mit.edu/czegras/www/Zegras%20et%20al%20Boomers%20Focus%20Groups.pdf>

ANNEXES

Annex 1 Car ownership, urban and population growth in the 62 middle size cities in Mexico

| City | Autos per inhabitant | Population growth (times) | Urban growth (times) |
|----------------------------|----------------------|---------------------------|----------------------|
| Tlaxcala-Apizaco | 0.19 | 3.79 | 57.14 |
| Matamoros | 0.18 | 2.05 | 8 |
| Cuautla | 0.12 | 3.14 | 21.8 |
| Tepic | 0.21 | 2.43 | 5.28 |
| Orizaba | 0.12 | 2.04 | 6.45 |
| Irapuato | 0.54 | 2.31 | 7.76 |
| Nuevo Laredo | 0.17 | 1.89 | 5.11 |
| Mazatlan | 0.2 | 1.91 | 5.1 |
| Puerto Vallarta | 0.16 | 6.66 | 21.39 |
| Minatitlan | 0.13 | 1.64 | 3.89 |
| Coatzacoalcos | 0.21 | 1.67 | 7.84 |
| Colima-Villa de Alvarez | 0.21 | 2.79 | 6.93 |
| Monclova | 0.17 | 1.86 | 5.47 |
| Cordoba | 0.15 | 2.02 | 4.77 |
| Zacatecas-Guadalupe | 0.26 | 2.21 | 7.99 |
| Victoria | 0.23 | 2.18 | 6.27 |
| Obregon | 0.24 | 1.83 | 4.02 |
| Tehuacan | 0.11 | 2.62 | 9.02 |
| Ensenada | 0.46 | 2.4 | 3.74 |
| Uruapan | 0.76 | 2.25 | 4.12 |
| Mochis | 0.3 | 2.09 | 3.73 |
| Zamora-Jacona | 0.17 | 1.68 | 5.16 |
| Piedad-Penjamo | 0.16 | 1.48 | 7.49 |
| Tulancingo | 0.21 | 3.38 | 23.3 |
| Campeche | 0.34 | 1.78 | 4.73 |
| Cordova y Ordoñez | 0.63 | 2.5 | 8.11 |
| La Paz | 0.63 | 2.35 | 2.07 |
| Heroica Nogales | 0.36 | 3.24 | 6.2 |
| Tula | 0.26 | 3.57 | 23.89 |
| Guaymas | 0.17 | 1.46 | 9.15 |
| Chilpancingo de los Bravo | 0.59 | 2.92 | 17.39 |
| San Francisco del Rincon | 0.12 | 2.74 | 7.28 |
| Piedras Negras | 0.22 | 2.25 | 11.43 |
| Ciudad del Carmen | 0.21 | 2.34 | 12.77 |
| Tehuantepec | 0.08 | 2.28 | 3.84 |
| Salamanca | 0.28 | 1.66 | 6.68 |
| San Luis Rio Colorado | 0.53 | 2.06 | 3.27 |
| San Cristobal de las Casas | 0.14 | 3.76 | 19.36 |
| Tianguistenco | 0.17 | 4.06 | 15.52 |
| Chetumal | 0.67 | 2.76 | 3.65 |
| Playa del Carmen | 0.2 | 203.42 | 4.35 |

D. Roque

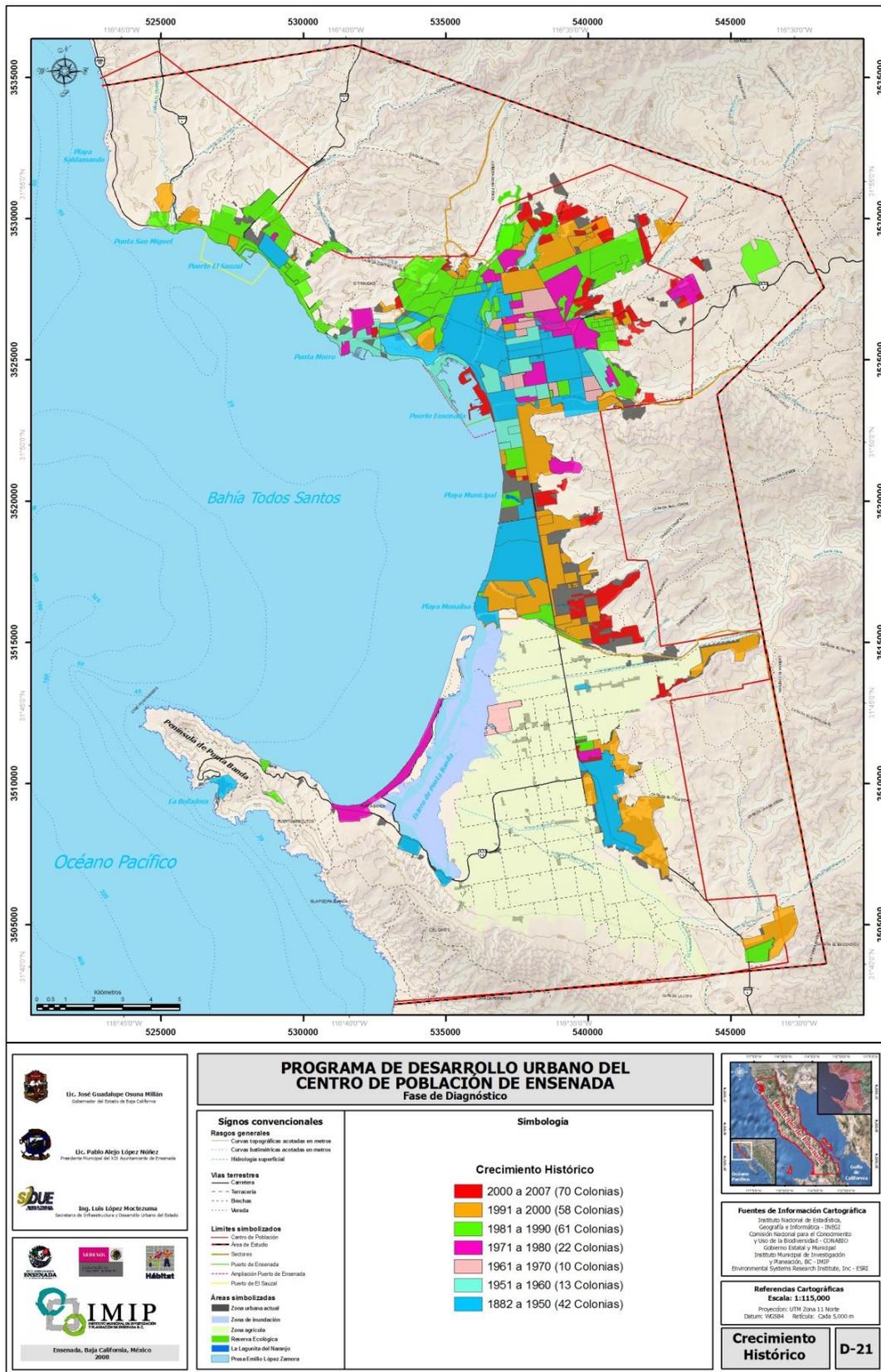
Car Dependence Factors in Mid-Sized Cities

| | | | |
|----------------------------|------|-------|-------|
| Tecoman | 0.1 | 1.59 | 6.03 |
| Ocotlan | 0.12 | 2.39 | 6.28 |
| Manzanillo | 0.36 | 3.59 | 21.37 |
| San Juan del Rio | 0.25 | 5.11 | 38.71 |
| Lazaro Cardenas | 0.19 | 3.44 | 31.74 |
| Rioverde-Ciudad Fernandez | 0.12 | 1.32 | 34.5 |
| Ciudad Acuña | 0.13 | 3.45 | 5.7 |
| Cabo San Lucas | 2.62 | 30.25 | 73.49 |
| Fresnillo | 0.25 | 2.24 | 4.79 |
| Ciudad Valles | 0.22 | 1.9 | 5.82 |
| Teziutlan | 0.1 | 4.88 | 35.12 |
| Iguala de la Independencia | 0.21 | 1.79 | 17.97 |
| Delicias | 0.26 | 1.8 | 4.93 |
| Cuauhtemoc | 0.22 | 2.62 | 22.67 |
| Navojoa | 0.19 | 1.81 | 6.16 |
| Acayucan | 0.08 | 2.17 | 2.91 |
| Guanajuato | 0.26 | 2.25 | 10.58 |
| Moroleon-Uriangato | 0.17 | 1.45 | 6.99 |
| Tuxpam de Rodriguez Cano | 0.16 | 1.93 | 10.74 |
| San Juan Bautista Tuxtepec | 0.06 | 3.62 | 11.72 |
| Hidalgo del Parral | 0.23 | 1.39 | 4.69 |

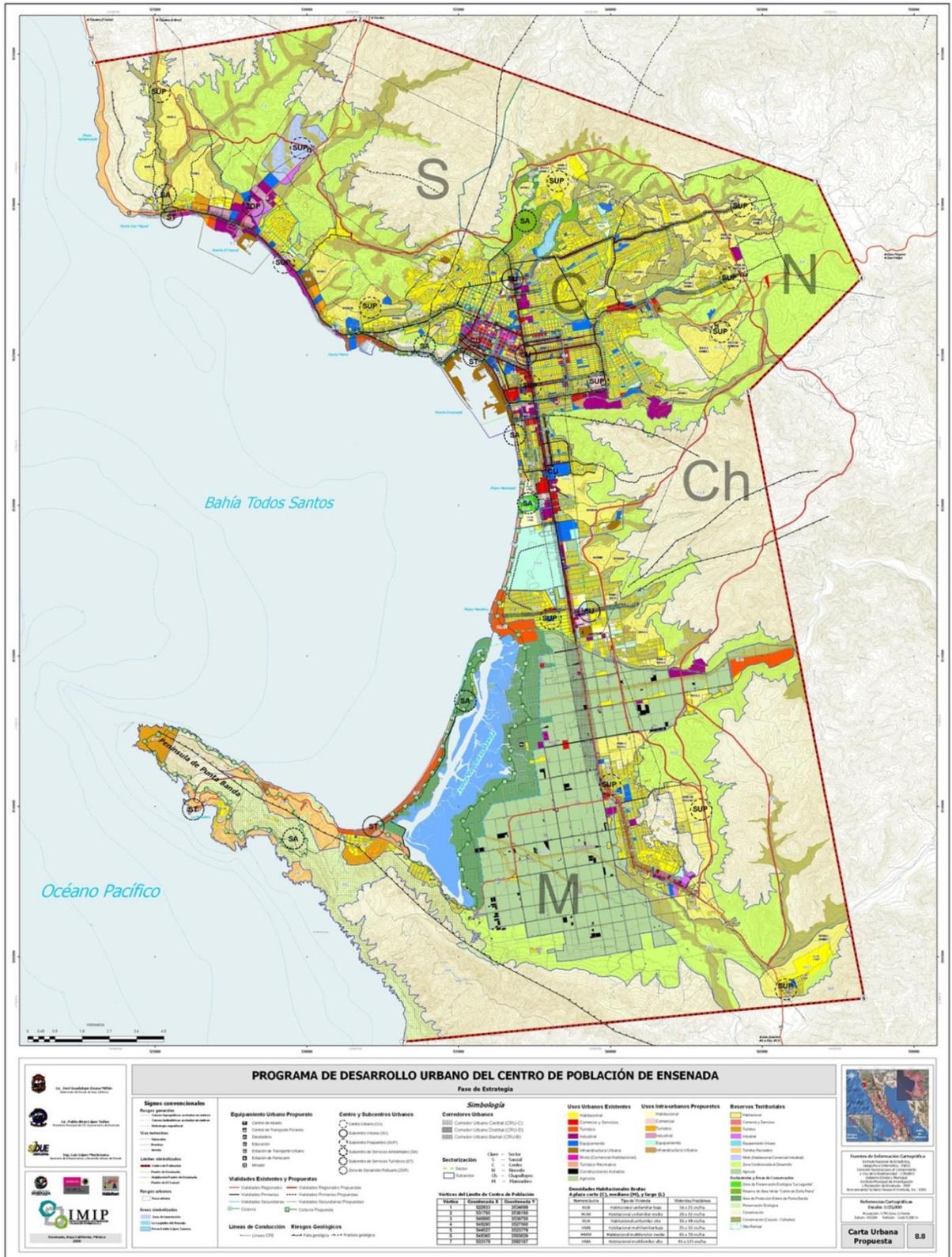
Annex 2 Quantity of cars and motor vehicles in the municipality of Ensenada

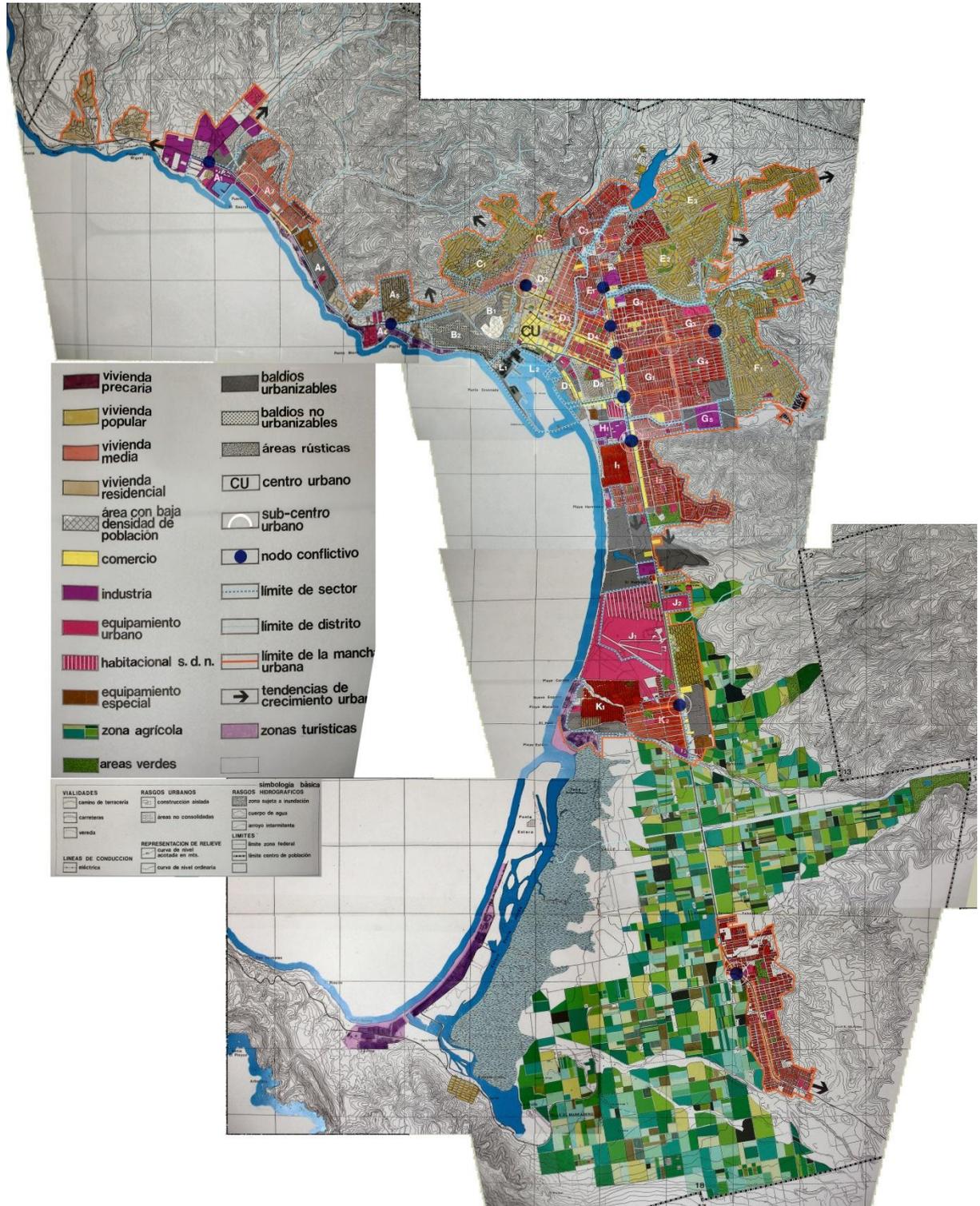
| Year | Cars | Motor vehicles | Year | Cars | Motor vehicles |
|-------------|-------------|-----------------------|-------------|-------------|-----------------------|
| 1980 | 56,448 | 69797 | 1997 | 74644 | 113299 |
| 1981 | 63,434 | 77428 | 1998 | 63053 | 96669 |
| 1982 | 65,254 | 80525 | 1999 | 75869 | 109884 |
| 1983 | 72,543 | 92339 | 2000 | 84848 | 105580 |
| 1984 | 74,720 | 95109 | 2001 | 96890 | 121346 |
| 1985 | 76,917 | 98071 | 2002 | 106340 | 132356 |
| 1986 | 69,932 | 90458 | 2003 | 104924 | 151367 |
| 1987 | 64,468 | 86308 | 2004 | 99655 | 142710 |
| 1988 | 64,725 | 86767 | 2005 | 108779 | 155677 |
| 1989 | 70,223 | 93961 | 2006 | 116447 | 165905 |
| 1990 | 71,999 | 98126 | 2007 | 123574 | 175593 |
| 1991 | 79,200 | 107939 | 2008 | 128842 | 183331 |
| 1992 | 78,287 | 107052 | 2009 | 131972 | 187375 |
| 1993 | 78,239 | 107493 | 2010 | 74705 | 105298 |
| 1994 | 78,545 | 108073 | 2011 | 76397 | 107827 |
| 1995 | 60,139 | 88958 | 2012 | 87487 | 122970 |
| 1996 | 65,011 | 97799 | 2013 | 92059 | 129241 |

Annex 3 Urban growth of Ensenada from 1980 to 2007 (IMIP).

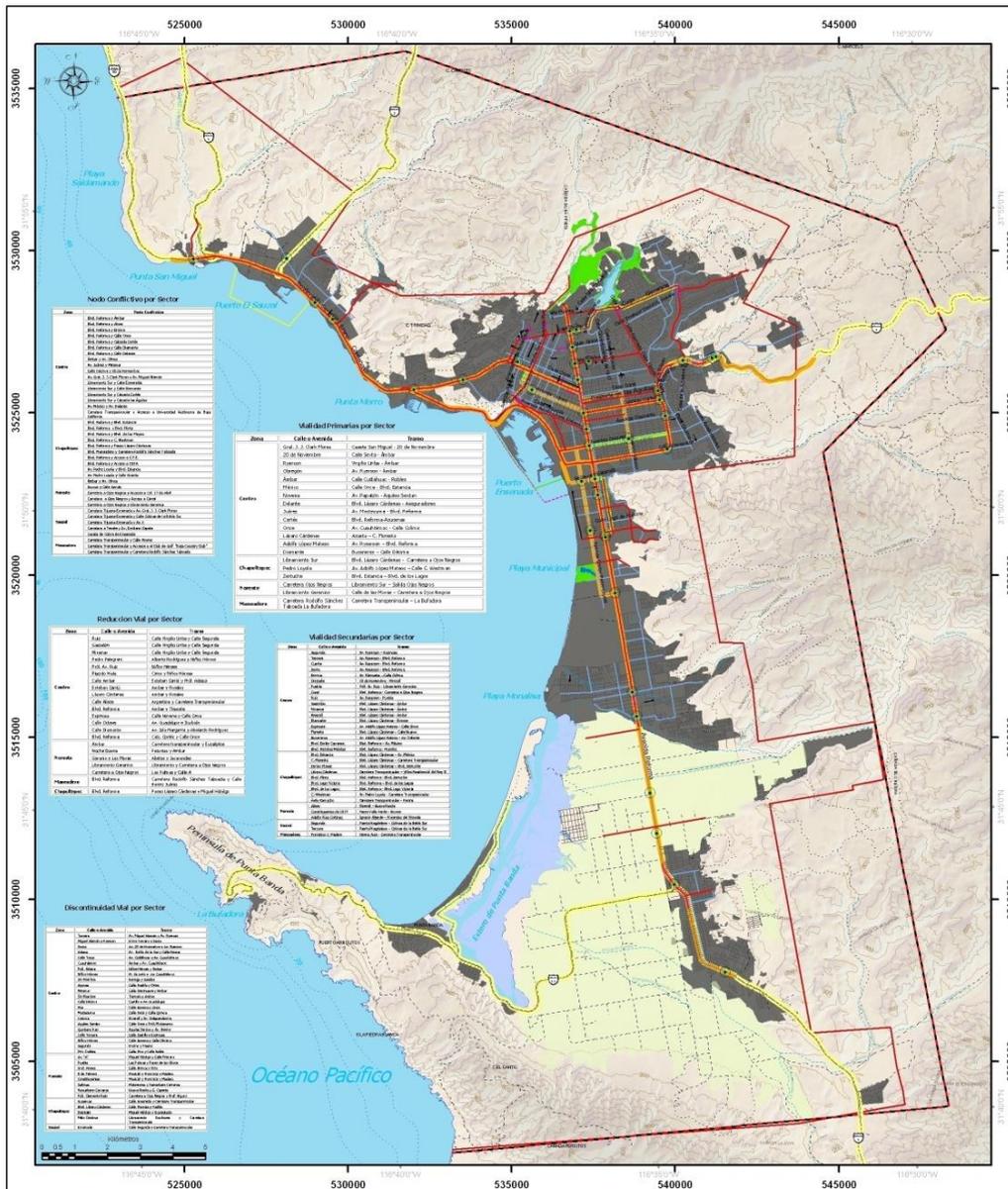


Annex 4 Land use maps (2005 y 1995).





Annex 5 Street's network, main and secondary streets (IMIP 2005)



Lic. José Guadalupe Ocasio Millán
Gobernador del Estado de Baja California

Lic. Héctor Alvaro López Núñez
Presidente Municipal del Ayuntamiento de Ensenada

Ing. Luis López Múzquiz
Secretario de Planeación y Desarrollo Urbano del Estado

PROGRAMA DE DESARROLLO URBANO DEL CENTRO DE POBLACION DE ENSENADA

Fase de Diagnóstico

Fuentes de Información Cartográfica
Instituto Nacional de Estadística, Geografía e Informática - INEGI
Comisión Nacional para el Desarrollo Urbano y la Infraestructura - CONADEU
Gobierno Estatal y Municipal
Instituto Municipal de Investigación y Planeación, S.C. - IMIP
Environmental Systems Research Institute, Inc. - ESRI

Referencia Cartográfica
Escala: 1:115,000
Proyección: UTM Zona 11 Norte
Datum: WGS84 - Mérida: Cota 5,000 m

Signos convencionales

Rasgos generales

- Carretera topográfica acotada en suaves
- Carretera hidrológica acotada en suaves
- Hidrología superficial

Vías terrestres

- Carretera
- Buscador
- Wells

Limites simbolizados

- Centro de Población
- Área de Estudio

Áreas simbolizadas

- Zona urbana actual
- Zona de Invasión
- Zona agrícola
- La Laguna del Maraje
- Primo Emilio López Zamora

Simbología

Enlaces Viales

- Nodos Viales
- Discontinuidad Vial
- Reduccion Vial
- Corredor Didual
- Corredor Central

Validades

- Validades Primarias
- Validades Secundarias
- Validades Regionales

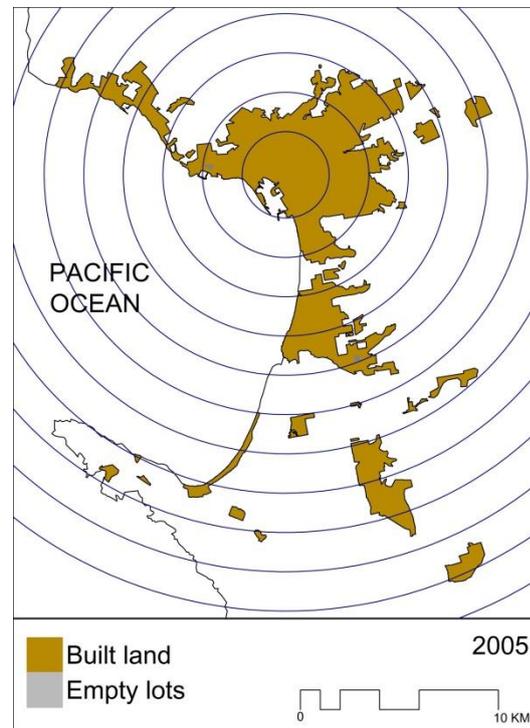
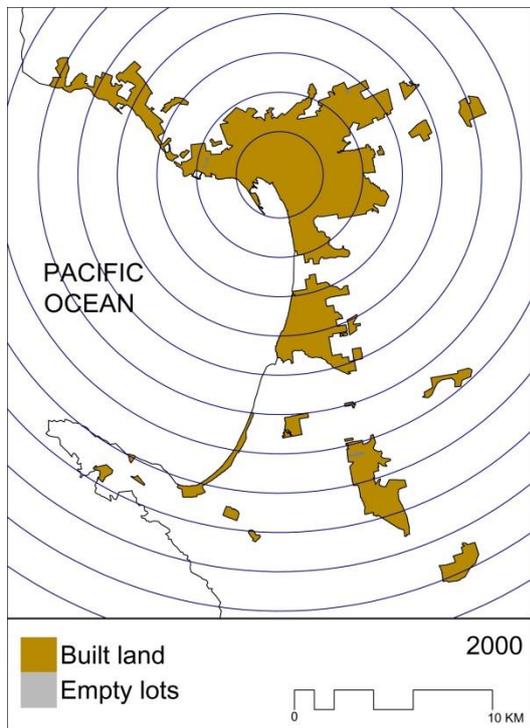
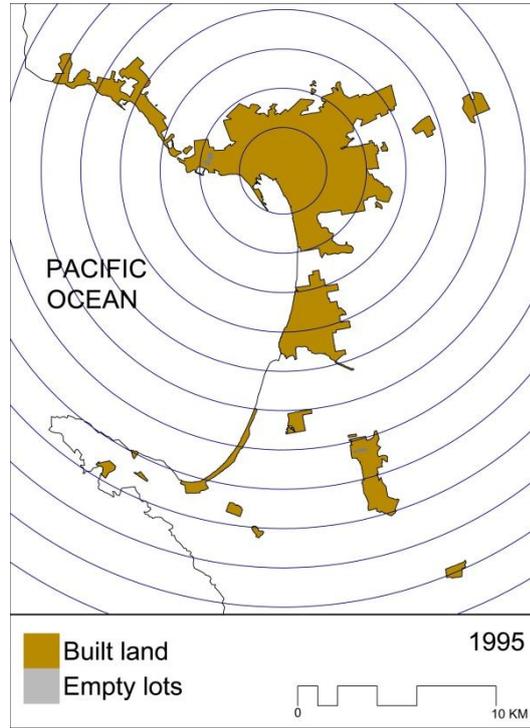
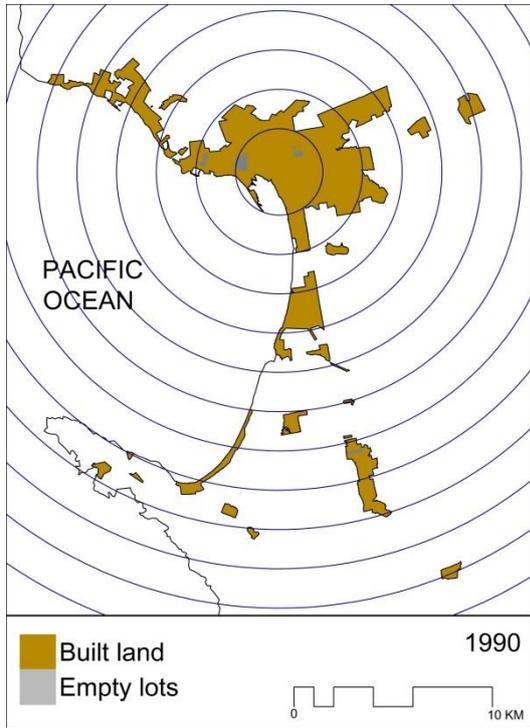
Mapas de Validades

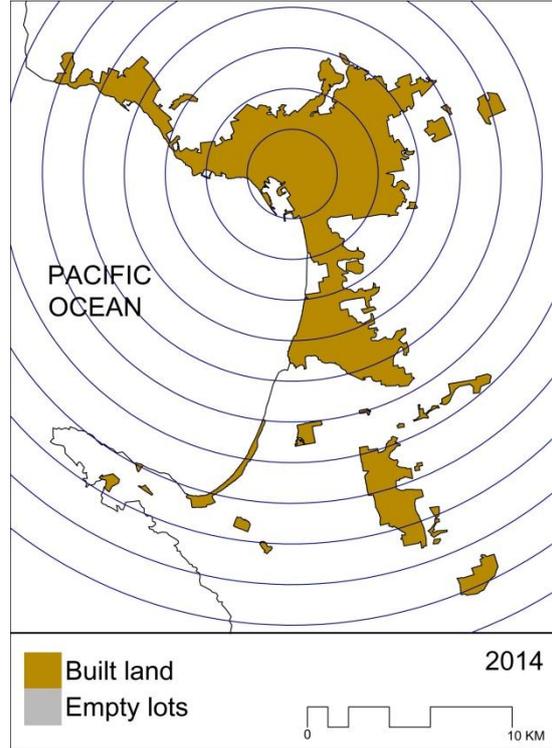
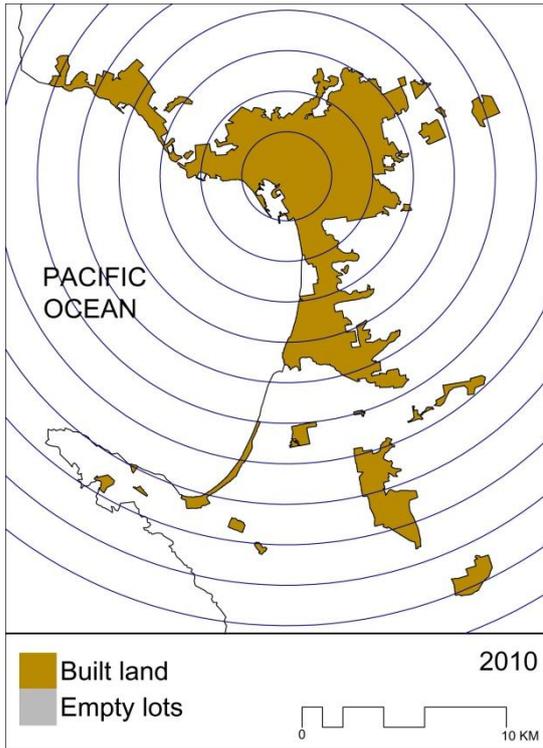
Mapa de Validades Primarias por Zona

Mapa de Validades Secundarias por Zona

Mapa de Validades Regionales por Zona

Annex 6 Buffer zones for Shannon entropy calculations





Annex 7 Shannon entropy calculations (1990, 1995, 2000, 2005 and 2010)

| 1990 | | | | |
|-----------|---------|------------|----------|--------------|
| Zones | Xi | Pi | 1/Pi | Pi*Log(1/Pi) |
| 1 | 11.9911 | 0.20655898 | 4.8412 | 0.1415 |
| 2 | 18.6607 | 0.32144967 | 3.1109 | 0.1584 |
| 3 | 7.0479 | 0.1214073 | 8.2367 | 0.1112 |
| 4 | 6.6548 | 0.11463575 | 8.7233 | 0.1078 |
| 5 | 4.4679 | 0.07696415 | 12.9931 | 0.0857 |
| 6 | 1.523 | 0.02623524 | 38.1167 | 0.0415 |
| 7 | 1.4391 | 0.02478997 | 40.3389 | 0.0398 |
| 8 | 2.386 | 0.04110129 | 24.3301 | 0.0570 |
| 9 | 3.1351 | 0.05400531 | 18.5167 | 0.0685 |
| 10 | 0.2187 | 0.00376733 | 265.4399 | 0.0091 |
| 11 | 0.3574 | 0.00615658 | 162.4278 | 0.0136 |
| 12 | 0.17 | 0.00292842 | 341.4806 | 0.0074 |
| $\Sigma=$ | 58.0517 | | | |
| | | | Hn= | 0.8415 |
| | | | H'n= | 0.7798 |

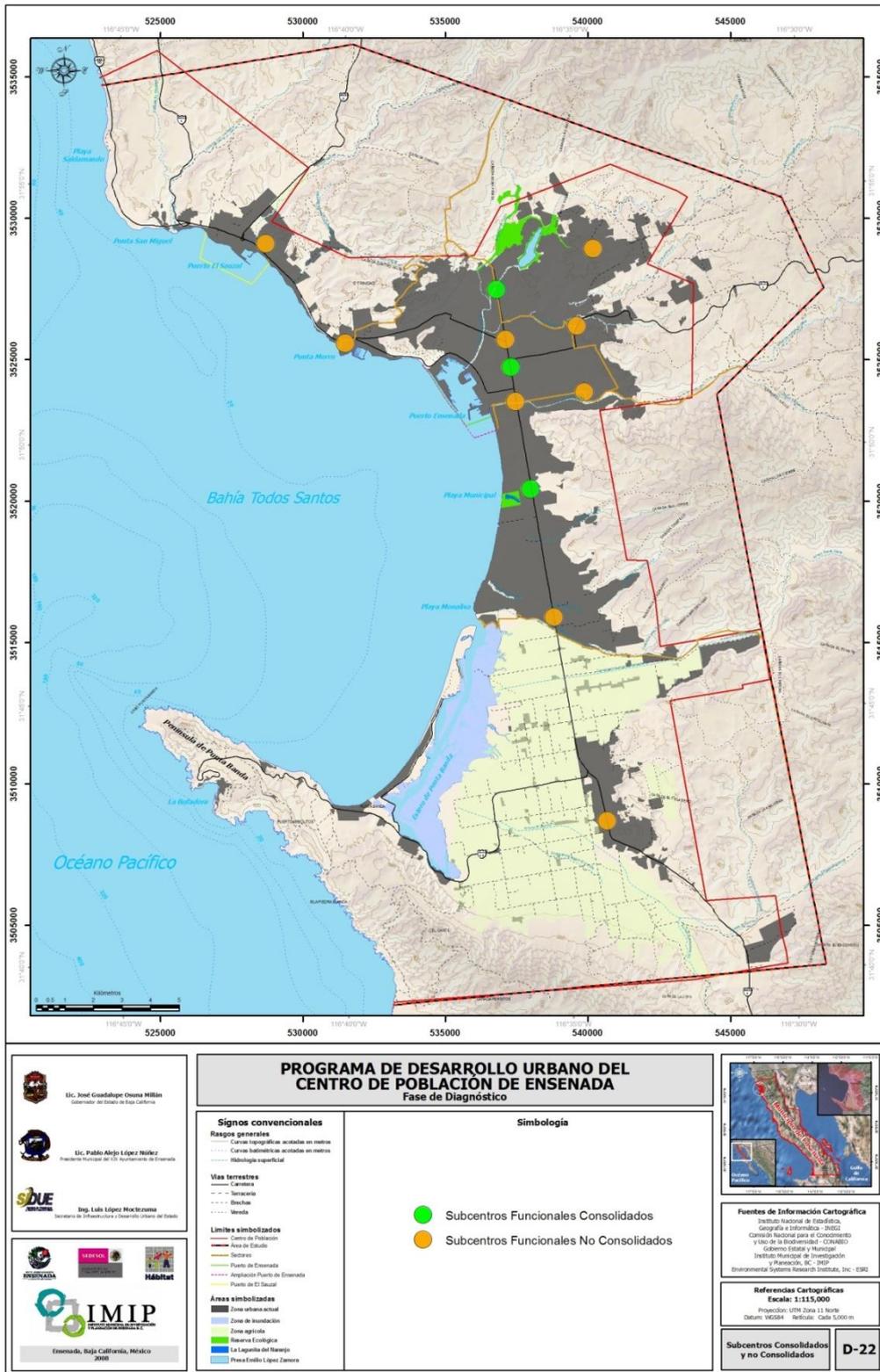
| 1995 | | | | |
|-----------|---------|------------|----------|--------------|
| Zones | Xi | Pi | 1/Pi | Pi*Log(1/Pi) |
| 1 | 12.4724 | 0.18002887 | 5.5547 | 0.1341 |
| 2 | 22.1952 | 0.32036952 | 3.1214 | 0.1584 |
| 3 | 8.8477 | 0.1277093 | 7.8303 | 0.1141 |
| 4 | 7.5138 | 0.10845554 | 9.2204 | 0.1046 |
| 5 | 7.1284 | 0.10289261 | 9.7189 | 0.1016 |
| 6 | 1.8405 | 0.02656611 | 37.6419 | 0.0419 |
| 7 | 1.9339 | 0.02791426 | 35.8240 | 0.0434 |
| 8 | 2.8897 | 0.04171045 | 23.9748 | 0.0576 |
| 9 | 3.7123 | 0.05358401 | 18.6623 | 0.0681 |
| 10 | 0.2187 | 0.00315676 | 316.7810 | 0.0079 |
| 11 | 0.3574 | 0.00515878 | 193.8444 | 0.0118 |
| 12 | 0.17 | 0.00245381 | 407.5294 | 0.0064 |
| $\Sigma=$ | 69.28 | | | |
| | | | Hn= | 0.8498 |
| | | | H'n= | 0.7875 |

| 2000 | | | | |
|-----------|---------|------------|----------|-------------------------|
| Zones | X_i | P_i | $1/P_i$ | $P_i \cdot \log(1/P_i)$ |
| 1 | 12.4724 | 0.15678496 | 6.3782 | 0.1262 |
| 2 | 22.3241 | 0.28062626 | 3.5635 | 0.1549 |
| 3 | 10.6475 | 0.13384495 | 7.4713 | 0.1169 |
| 4 | 9.1302 | 0.11477166 | 8.7130 | 0.1079 |
| 5 | 8.1264 | 0.10215334 | 9.7892 | 0.1012 |
| 6 | 2.3252 | 0.02922905 | 34.2125 | 0.0448 |
| 7 | 2.9627 | 0.03724278 | 26.8508 | 0.0532 |
| 8 | 3.487 | 0.04383352 | 22.8136 | 0.0595 |
| 9 | 5.0177 | 0.06307526 | 15.8541 | 0.0757 |
| 10 | 0.9748 | 0.01225377 | 81.6075 | 0.0234 |
| 11 | 1.7685 | 0.02223102 | 44.9822 | 0.0367 |
| 12 | 0.3145 | 0.00395344 | 252.9444 | 0.0095 |
| $\Sigma=$ | 79.551 | | $H_n=$ | 0.9100 |
| | | | $H'_n=$ | 0.8432 |

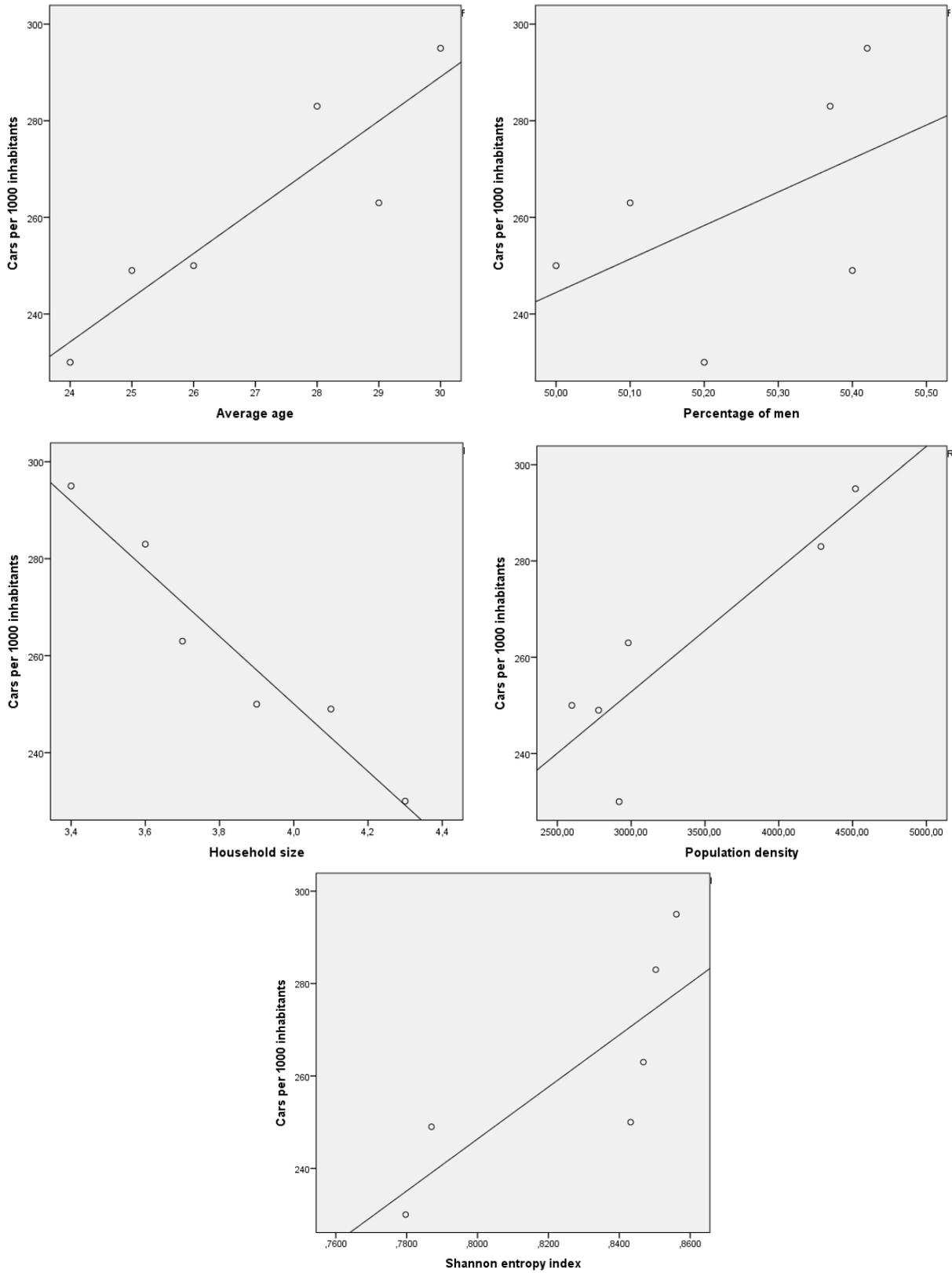
| 2005 | | | | |
|-----------|---------|------------|----------|-------------------------|
| Zones | X_i | P_i | $1/P_i$ | $P_i \cdot \log(1/P_i)$ |
| 1 | 13.0125 | 0.14912297 | 6.7059 | 0.1232 |
| 2 | 22.9113 | 0.262563 | 3.8086 | 0.1525 |
| 3 | 13.7155 | 0.15717933 | 6.3622 | 0.1263 |
| 4 | 10.1077 | 0.11583402 | 8.6330 | 0.1084 |
| 5 | 9.388 | 0.10758628 | 9.2949 | 0.1042 |
| 6 | 3.245 | 0.03718763 | 26.8907 | 0.0532 |
| 7 | 3.2141 | 0.03683352 | 27.1492 | 0.0528 |
| 8 | 3.5901 | 0.04114247 | 24.3058 | 0.0570 |
| 9 | 5.0182 | 0.05750846 | 17.3887 | 0.0713 |
| 10 | 0.9748 | 0.01117119 | 89.5160 | 0.0218 |
| 11 | 1.7685 | 0.02026697 | 49.3414 | 0.0343 |
| 12 | 0.3145 | 0.00360416 | 277.4569 | 0.0088 |
| $\Sigma=$ | 87.2602 | | $H_n=$ | 0.9139 |
| | | | $H'_n=$ | 0.8468 |

| 2010 | | | | |
|-----------|---------|------------|----------|-------------------------|
| Zones | X_i | P_i | $1/P_i$ | $P_i \cdot \log(1/P_i)$ |
| 1 | 13.0125 | 0.14221482 | 7.0316 | 0.1205 |
| 2 | 22.9113 | 0.25039973 | 3.9936 | 0.1506 |
| 3 | 15.1978 | 0.16609817 | 6.0205 | 0.1295 |
| 4 | 10.1531 | 0.11096418 | 9.0119 | 0.1060 |
| 5 | 11.0934 | 0.1212408 | 8.2480 | 0.1111 |
| 6 | 3.8683 | 0.04227701 | 23.6535 | 0.0581 |
| 7 | 3.3849 | 0.03699389 | 27.0315 | 0.0530 |
| 8 | 3.6758 | 0.04017316 | 24.8922 | 0.0561 |
| 9 | 5.1413 | 0.05618975 | 17.7968 | 0.0703 |
| 10 | 0.9775 | 0.01068319 | 93.6050 | 0.0211 |
| 11 | 1.7685 | 0.0193281 | 51.7381 | 0.0331 |
| 12 | 0.3145 | 0.0034372 | 290.9345 | 0.0085 |
| $\Sigma=$ | 91.4989 | | $H_n=$ | 0.91764 |
| | | | $H^n=$ | 0.85031 |

Annex 8 Centers and sub-centers according to IMIP



Annex 9 Linear regressions' graphs



D. Roque

Car Dependence Factors in Mid-Sized Cities

