Longitudinal correlations of car ownership with socio-economics, urban form, and transport infrastructure in Latin America: Example from Ensenada, Mexico

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Abstract. Car-orientated modal splits represent problems for the city in economic, environmental and social terms. The implementation of policies and other measures can fail if the causes are not well recognized. Mid-sized cities in Mexico are not well-represented in studies where only the capital and other bigger cities are studied. This research aims to recognize those causes focusing on northern mid-sized cities in Mexico. The approach involves numerical work (linear regression) complemented with a descriptive analysis of the city. The analysis takes on such areas of consideration as socio-economic factors, land-use variables and the street network of the city. Of the 16 variables, almost all presented a relationship with car ownership levels, but not all behaved as expected. The final part of the research is a reaction to the previous studies and recommendations to change the city from car-orientated to one with a sustainable modal split.

Contents:

1. Introduction

As cities grow, several problems in different areas appear. An unsustainable modal split is well characterized by being motorization-dependent; a characteristic well present in most growing cities, mostly in the developing world. Therefore, there is a need to investigate the causes. There is a large body of literature ranging from urban form to urban sociology targeting the circumstances of human decisions regarding personal car use as the main topic. Many studies have obtained well-supported results and cities have decreased their dependence on cars. Several guidelines and researches propose the same path to a certain extent; an accepted view is providing higher densities, mixed uses and accessible public transportation. The developing world indeed presents motorization rates comparable with industrialized countries, but with differences in culture, lifestyle, economy, etc. Then, is it correct to assume that the same triggers are in place, or even worse, to assume that the same solutions can be used? When it comes to the developing world some questions are still present; assuming that cities behave in the same manner will be a grave mistake. The investigations within the developing world are references, mostly from bigger cities and economic centres. Of course, some factors are relevant in both worlds and this research aims to find out the factors applicable to Mexican mid-sized cities.

Most of the research in the international context and on Mexico is made with a descriptive analysis approach. There is a lack of numerical analysis, which can better support the investigation. Descriptive analyses can bring some insights but the researchers must be careful with the analysis and personal believes. The dominance of studies on bigger cities with a descriptive approach, as the literature review shows, is not applicable to all cities. The current guidelines and research do not represent the majority of cities in Mexico and it is a mistake to assume that they can be that easily implemented; these guidelines can be used as a reference but further and in-depth research in these cities must be done. Applying a generalised solution for accomplishing sustainable mobility is a mistake that municipalities should not make.

Latin American cities present motorization rates that have been increasing dramatically during the past two decades, is the driver being the poor public transportation system. Researches of Mexican cities are dominated by the capital city, followed by some other big cities, what is not surprising due to the importance of the capital. According to the population size, currently there are 62 mid-sized cities in Mexico (SEDESOL, 2012). The importance of these cities lies on their growth, some of them grow faster and have comparable or bigger motorization rates than the capital. Even in an economic crisis, the country, presents a high motorization rate among Latin American (Hidalgo, Huizenga, 2013) and developed countries with the same GDP (Medina Ramirez, Veloz Rosas, 2012). From 1980 to 2010, the number of cars went from 5 to 32 million (Martinez Salgado, 2011). Mid-sized cities are even different amidst themselves due to different characteristics such as location, weather, economic activities, etc.

This research aims to detect factors that are related to the increase of car ownership levels. The research is focused on a specific location, the north of Mexico, in cities catalogued as mid-sized by the government (100,000 to 500,000 inhabitants by SEDESOL, 2012). The cities are in proximity to the US border, which brings access to cheaper cars for the citizens. The paper starts with a review of the current knowledge and guidelines in the area at the international, Latin American and national level. The methodology comprises two approaches: descriptive and numerical. The interpretation of the results will be a combination of these two findings. The descriptive part is collection of data regarding the city and a description of different areas relevant to mobility in the case study. The numerical part takes the same case study and analyses with statistics a time frame of 24 years (intervals of 5 years) with linear regression. The analysis is orientated towards three focus areas: land use, street network and socio-economic factors. In total, 16 variables

are formulated in the three above-mentioned categories. The comparison of the results and previous studies gives feedback on the similarities of this case study with bigger cities. The recommendations are based merely on the findings divided into stages of implementation.

2. Car ownership in Mexico

Several points must be considered for sustainable mobility to be reached as a goal. The dependence on cars is caused by several factors, for example the urban form has been proved to be a powerful driver. Socio-economic factors are also relevant, specially income (Brueckner, Fansler, 1983; Stradling, Meadows, Beatty, 2000; Leck, 2006), others are based on personal preferences placed above the other factors, meaning the user is the one who decides even when the environment is suitable for commuting without a car. Regardless of the fact that all of these pieces of research being based on the developed world (which means that this factor can vary), some similarities can still be found. Gwillian (2010) states, there are clear differences between policies in the developing countries and the industrialized countries, and they are affected more by the presence of cars due to poor management and road infrastructure; their environment policies are also weak. But there are also similarities, as Hanson (1989) explains, Mexico follows the example of the industrialized countries: urban sprawl, low densities and dependence on motorized trips and a decrease in traditional travel modes.

Both in the developed and the developing world, income has been a factor connected with car ownership levels. Dargay and Gately (1999) found a strong connection between income and car ownership levels. Button et al. (1993) stated that in the developing countries, as the economy gets stronger and the citizens receive better incomes, they present a car use growth similar to industrialized countries; Moctezuma Navarro (2012) examined the effects of income but using the minimum wage. Guerra (2015) found that in the case of Mexico City there was a strong relationship between the increase of income and possibilities to own a car. Other authors also state this relationship in Mexico but at national level or

in the capital (Moctezuma Navarro, 2012; SEMOVI, 2014). Studies on the national level also shown the GDP to be correlated to car ownership (Clear Air Institute, 2012; Medina Ramirez, 2012; Moctezuma Navarro, 2012). Such studies stated that the country presents motorization rates higher than other countries with a lower GDP.

Other economic factors include prices in different aspects such car accessibility, gasoline and public transportation (PT). Subsidies on fuel prices are a trigger to encourage people to commute (Clear Air Institute, 2012) and therefore taxation of gasoline is not the best approach (Parry, Timilsina, 2010). On the other hand, changes in fuel price have no effect on car use (Crotte et al., 2008). The price of public transportation is relevant, as some authors claimed (Sánchez-Flores, Romero-Torres, 2014) though others claimed there is no effect (Crotte et al., 2008). Access to affordable cars is relevant (Clear Air Institute, 2012; Medina Ramirez, 2012) especially in cities near the US border (Martinez Salgado, 2011); as Islas Rivera et al. (2011) stated, the introduction of used cars has changed the motorization rates in the country.

When income and accessibility to cars are present as the authors above mention, some measures to reduce the use of cars can be counter-productive. Eskeland and Feyzioglu (1997) stated that the ban (Mexico City) on cars one day per week did not function due to the households deciding to buy a second car (old and more contaminant) in order not to be affected by the restriction. Public transportation characteristics play an important role; the quality, price, and time can be associated with people's commute choices (Crotte, Graham, Noland, 2011; DINAMIA, 2014; Sánchez-Flores, Romero-Torres, 2014; SEMOVI, 2014). Differences between genders and their travel behaviour are also relevant: Brennan (2000) found in the case of Puebla, Mexico that women travel more than men due to the different lifestyles. The role of the built environment of the city in defining car ownership rates, as stated before, has been relatively shown in international studies. At Mexican level, not much is stated. Guerra (2015) found that people from central locations are inclined to drive more, and the periphery to use PT. But this statement is linked more to the fact that wealthier populations live in central locations.

Density is a variable commonly cited as a related factor: since the study of Newman and Kenworthy (1989), several authors have proposed that high densities are an asset to achieve sustainable transportation. Guerra (2013) found that in the case of Mexico City, higher population number and job densities decrease the probability of driving, and that this relationship is getting stronger over time (Guerra 2014). Martinez Salgado (2011) and Moctezuma Navarro (2012) stated that the increase in population was one of the reasons of the increasing motorization rate in the country, followed by low population densities (Medina Ramirez 2012). The connectivity of the city is also another aspect to take to consideration, sometimes it can even be a bad solution to congestion, as in the case of the capital, which had doubtful results from the construction of the second floor of the beltway, which just led to more cars on the streets (Clear Air Institute, 2012). Guerra (2014) stated that street densities and street proximity of households are related to the use of cars. Medina Ramirez (2012), Clear Air Institute (2012), Moctezuma Navarro (2012), and SEMOVI (2014) pointed out that in order to reduce the use of cars, the infrastructure such as roads and parking availability must be taken into account. Medina Ramirez (2012) pointed to the importance of reducing the use of cars, and mentioned some factors such as urban sprawl and the lack of mixed land uses. Another related statement is that of Baranda Sepulveda et al. (2013) that the necessity to travel is originated by the location of services, therefore zoning policies and the promotion of infill development need to be accounted for.

3. Methodology and findings

Different methodologies can be used to analyse or tackle a problem such as car ownership; some researchers choose a descriptive approach or interpret numerical results of statistics methods. Empirical results are tested numerically, so if the data is reliable, the results are accurate. The existence of trustable data has always been a problem that can limit the numerical approaches. This study is not an exception either. A descriptive work has its strengths; therefore, this study complements empirical work

with a descriptive part. The first part is a description of the current status of the city, where relevant information about the city is collected from different entities; this part brings a status quo in terms of PT, changes in the urban form, living preferences and other connected data. The descriptive part complements the numerical findings. In the second part, the empirical work is based on developing 16 variables from governmental data.

The numerical part of this research uses simple linear regression analysis, which is conducted by SPSS IBM. This method is selected due to its capability to provide clear results, such as the level of correlation between the two factors and the type of relationship (positive or negative). The results are described because the numerical results by themselves do not give a complete answer. The decision regarding which one is the dependent variable is the responsibility of the researcher. It is made on the basis of previous works; for example, several papers state that drops in population density increase the motorization rates. Using a confidence level of 95% the p-values for each regression are interpreted as follows: 0% to 1% is highly significant, 1% to 5% is significant, 5% to 10% is marginally significant, and above 10% is not significant. The case study comes from one of the 62 mid-sized cities located at the border.

3.1. Case study

Ensenada is located at the Northwest of Mexico, in the peninsula of Baja California by the Pacific Ocean. The whole county (*Municipio* in Spanish) has almost 52,000 km² but the municipality is only around 90 km². The municipality of Ensenada is classified by SEDESOL (2012) as mid-sized due to its population. It has approximately 440,000 inhabitants and is expected to become an intermediate city in less than 15 years (COPLADE, 2014). The city was born in the harbour in the central zone, where also all tourism activities are found. This zone is characterized by low population densities and the dominant uses here are commercial and retail, such as stores, restaurants and hotels. The city is divided into 5 zones as showed in Figure 1. As mentioned, the oldest part of the town is the 'Central Zone', zone which presents parking problems and some conges-

tion due to the location of the main boulevard. The other main centre is in the zone of Chapultepec, where housing projects have been implemented in the last two decades; moreover, this zone presents deficient connectivity and therefore it is not consid-ered as a consolidated centre (Instituto Municipal de Investigacion y Planeacion - IMIP, 2010). The Sauzal zone until now has been a previously industrial zone that has been developed; other ones have failed due to the poor connectivity (IMIP, 2010).
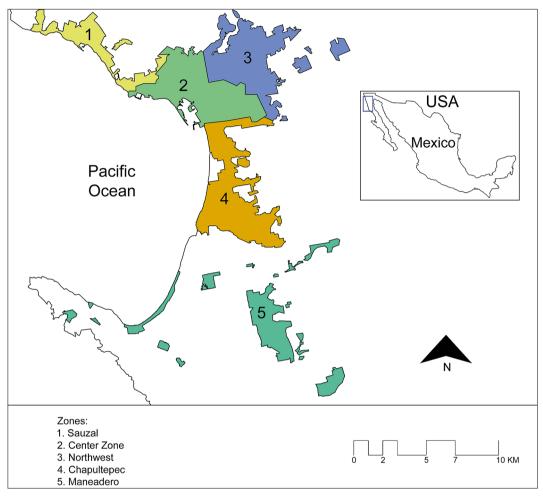

Fig. 1. Location and zones of Ensenada

Source: Adapted by the author from various sources

Even when it is not considered a border city by the government, the fact is that the proximity to the US border affects the city in some factors, such as the presence of illegal cars coming from the USA (due to their affordability). There is no precise data regarding the number of these cars and therefore it could not be taken into consideration for this re-search. Densities are not well distributed, the urban form of the city includes leapfrogs; inside the urban area approximately 11% lots are empty. The shape of the city due to its topography and the coast is thin and large (north to south). The urban form of the city has changed over time. The oldest parts of the city are characterized by housing areas with lots be-tween 200 and 250 m², wide streets and horizontal construction. The implementation of social hous-es brought a change in densities of the periphery where all projects of this type are constructed due to space requirements. Mostly, the new social houses are located in the Northeast Zone and Chapultepec.

On the other hand, citizens' living preferenc-es are involved. There is an inclination of the cit-izens to single detached homes instead of vertical constructions (apartments). The stronger aspects that affect people when deciding to buy a home are price- and size-related rather than those regard-

ing access to public transportation or accessibility to the city centre (Gobierno de Baja California - GOBBC, 2008). How people commute in the city has become problematic; the city presents motorization rates higher than the capital (ONU HABITAT and SEDESOL, 2011), which can be attributed to the accessibility to cheaper used cars.

The size, poor quality and unevenness make the sidewalks unfriendly to walk in. The streets also present potholes, affecting the flow of cars; and in the rainy season they prevent people from walking due to puddles. Combined with the lack of bike lanes and the streets' conditions it has brought about some incidents in the city lately (Newspaper El Vigia, 2014). The public transportation of the city is solely based on buses. There are six private companies which operate the bus network of the entire city. According to a report regarding the year 2007 made by Instituto Municipal de Investigacion y Planeacion (IMIP) (2010), there is a cover of 100 percent of the city area if a 300-metre radius is considered, which seems very enthusiastic.

There are 95 planned routes but only 65 operate due to arguments of the bus companies that these routes are not profitable enough for them. Related to this is the pressure of the transport companies to increase the bus ticket price, claiming that their finances are in the red. This has brought complaints from the users, who claim that the ticket price was already high in 2007 (2 percent of the users). With the data from IMIP (2010), it was calculated that in 2007 the bus users with the lowest income levels spent between 10 and 25 percent of their salaries on bus tickets. The report of IMIP states that the vehicles are old and a considerable percentage of the citizens think that the quality is not adequate. 58 percent of PT users are women. The lack of adequate planning of the routes has brought the overlapping of several routes operated by different companies. In some areas (centre), the intervals between buses are around 5 minutes, but in the periphery the waiting time can be up to 30 minutes.

3.2. Data

The numerical study consists in gathering the data in order to develop 16 variables. The variables come from three areas: urban form, socio-economic factors and street network. The data was primarily gathered from government sources (for accuracy and legitimacy) and from alternative sources consulted in the absence of more official documents (inquiring citizens, reports, etc.). The data obtained dates between the year 1990 and 2014 in 5-year intervals (except for the last interval). Inter- and extrapolation was used to account for the missing data from some years. The dependent variable: car ownership levels (cars per 1000 inhabitants) is tested against the 16 variables in order to measure correlation between them.

The number of vehicles and population was available from Instituto Nacional de Estadística y Geografía (INEGI). The socio-economic data, maps and street network data was obtained from INEGI and IMIP, complemented with Google Earth. After the compilation of the raw data, it was transformed to more meaningful units to be compared and tested with the dependent variable. The socio-economic variables did not need much developing from the raw stage. Income was directly available from the government, expressed as income in Mexican Pesos (MXN) per year. Average age also was directly available, except for 2014 which was interpolated. In the case of the variable of gender ratio, a percentage was obtained using the quantity of men compared with the total population. Household size was obtained from INEGI, except for 2014 for which as previously, interpolation was used. Prices of gasoline and bus ticket prices were obtained from newspapers and inquiries of citizens. Except for one year, the data needed to develop the urban form variables were gotten from IMIP. The data of the missing year was collected from Google Earth.

It can be difficult to determinate if a city is sprawled or how fast it is sprawling. There are studies which prefer to do descriptive work and determinate if the city is sprawled using some characteristics. In numerical terms, Shannon entropy has been used by different authors to give a value to the city (Yeh, Li, 2001; Sun et al. 2007; Alabi, 2009; Deka et al. 2011; Joshi, Bhatt, 2011). The range fluctuates from zero to one, where one is a sprawled city. However, there are no ranges to claim which index is adequate, therefore comparing the index change over time can be useful. In this study, Shannon entropy shows how fast the city has sprawled during the target duration of time. There are differ-

ent expressions of the formula, in this case formula (1) was used. Circles with a distance of two kilometres were drawn on the city map, centred on the downtown, and the areas located between the circles were measured.

$$Hn = \sum_i^n Pi \log\left(\frac{1}{pi}\right) Hn = \sum_i^n Pi \log\left(\frac{1}{pi}\right) \quad (1)$$

Where $PiPi$ is the proportion of built-up area in the zone (Xi) and $HnHn$ is the entropy value.

The other calculated index is the dissimilarity index which calculates the degree of how mixed the land uses are in the city. Cervero and Kockelman (1997) developed this index, which fluctuates from 0 to 1, where zero means a homogeneous land. The calculation of the dissimilarity index is made by dividing the city in equal parcels (100x100 meters in this case). Each parcel receives a value depending on how many different uses this parcel has. Then an average is calculated for all the parcels and divided by the total number of land uses. For this variable, only three maps were provided based on the existing land use maps of 1995, 2005, and 2014. The mix of land uses is assumed to encourage city dwellers to walk and cycle in order to reach nearby destinations; thus, a neighbourhood with a high mix of land uses may provide a quality against personal car use, at least for local trips.

Fig. 2. Parcels and grid for the estimation of the Dissimilarity Index in Ensenada

Source: IMIP 2007

There is no population density data for the municipality of Ensenada, hence figures were calculated from the population data from INEGI's database and the urban area data previously calculated above (Sprawl Speed variable). Employment density was assumed to be uniform due to the lack of information regarding employment by area. Both densities are increasing, which in theory is a good sign for the city.

The street network configuration was analysed using 6 variables: streets per capita, streets per area and nodes per area (all of them divided into primary and secondary). Road infrastructure represents the availability for drivers, and at the same time how walking-friendly they are (main and secondary streets, respectively). It is assumed that better-connected street networks can encourage residents to walk or cycle. The availability is represented by area and per capita. Data specifying the length of streets was not directly available. The selection of main and secondary streets is taken from IMIP maps, as this institution already determines which streets are categorized as main, secondary, and alleys. Nodes were calculated from the street network previously created with primary and secondary streets. There are two cases of main nodes: 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.

4. Results

Table 1 summarizes the variables after the calculations previously explained. The car ownership levels showed an increase over time, what supports the problem statement; mid-sized cities are suffering from higher motorization rates.

Table 1. Summary of the variables

No.	Variable	Year					
		1990	1995	2000	2005	2010	2014
	Socioeconomic						
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	50.2%	50.4%	50%	50.1%	50.4%	50.4%
4	Household size	4.3	4.1	3.9	3.7	3.6	3.4
5	Single ticket bus price	3	4	4.5	5	8	10
6	Price per gasoline litre	1	2.24	5.27	6.47	8.76	13.04
	Built Environment						
7	Urban Speed	0.7798	0.7875	0.8432	0.8468	0.8503	0.8561
8	Population Density	2918.54	2779.30	2598.33	2980.45	4285.56	4519.14
9	Employment Density	1493.32	1653.08	1611.17	1506.71	2258.82	2244.72
10	Land Use Mix	ND	0.0786	ND	0.06076	ND	0.05503
	Connectivity						
11	Primary streets per capita (m)	0.5231	0.5085	0.4928	0.4032	0.2741	0.2452
12	Secondary streets per capita (m)	0.4258	0.4625	0.4571	0.3883	0.2810	0.2595
13	Primary streets per km²	1.52665	1.41319	1.28049	1.20181	1.17477	1.107909
14	Secondary streets per km²	1.24258	1.28534	1.18774	1.157327	1.20425	1.172521
15	Main nodes per km²	1.68815	1.78984	1.57132	1.466877	1.47543	1.380776
16	Secondary nodes per km²	0.70627	0.73614	0.7668	0.756359	0.76504	0.777326
	Dependent variable						
	Cars per 1000 inhabitants	230	249	250	263	283	295

Source: Authors' calculations

The socio-economic data of the city shows aging of the inhabitants; the average age increased from 24 to 30 between 1990 and 2014. Increasing employment density is related to that fact. More people are working because the city has more people of working age. Population densities are also increasing over time according to almost the same pattern as employment density. The average income has increased two times in the studied period but compared with the increases of other expenses, such as gasoline and ticket price, it is not a considerable growth. At the beginning of the study period, the PT ticket price was two times more expensive than a litre of gasoline; at present, it is almost equal. The structure of the family has changed, decreasing by almost one member. A fluctuation in the number of men in recent years caused a minor shift in gender distribution, but the ratio remains approximately equal.

The urban form of the city has changed considerably but not for the better. The urban speed of the city shows that Ensenada is becoming sprawled compared to the years before. The biggest change in the Shannon entropy index is during the years 1995 to 2000; afterwards the index still continues to increase but not with significant growth. The changes in the dissimilarity index are not that significant, but the index is considerably low. The decrease over time shows that the city has even less diversity compared to previous years. The street network of the city fared badly in all the variables, all of them have been decreasing except one: secondary nodes per area. The decrease can be linked with the fast urban growth of the city, as Shannon Entropy Index showed.

All these variables were processed by the IBM SPSS software. The results of the linear regression analysis are illustrated in Table 2. These results show that almost all the variables are significant, using the previously established p-values three variables were insignificant: gender, land use mix and secondary streets per area. The only variable with marginal significance is urban sprawl speed. Socio-economic factors are significant and present positive relationships except for the household size with a negative value. Both densities are significant and present positive relationships. The street configuration of the city presented high significance with negative relationships except for the secondary nodes per area.

Table 2. Summary of the variables

No.	Variable	Unstandardized Coefficients		Standardized Coefficients	t	p-value	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
5	Single ticket bus price	8.711	1.006	.974	8.659	.001	5.918	11.504
6	Price per gasoline litre	5.245	.717	.965	7.319	.002	3.256	7.235
	Urban Form							
7	Urban Sprawl Speed	562.628	206.752	.806	2.721	.053	-11.409	1136.665
8	Population Density	.025	.007	.885	3.803	.019	.007	.044
9	Employment Density	.059	.016	.883	3.767	.020	.015	.102
10	Land Use Mix	-1697.9	1382.850	-.775	-1.228	.435	-19268.6	15872.863
	Transportation							
11	Primary streets per person (m)	-293.122	48.594	-.949	-6.032	.004	-428.039	-158.205
12	Secondary streets per person (m)	-536.744	91.971	-.946	-5.836	.004	-792.097	-281.390

13	Primary streets per km²	-140.416	28.180	-.928	-4.983	.008	-218.656	-62.175
14	Secondary streets per km²	-277.244	208.664	-.553	-1.329	.255	-856.587	302.100
15	Main nodes per km²	-127.935	44.946	-.818	-2.846	.047	-252.726	-3.144
16	Secondary nodes per km²	768.589	253.029	.835	3.038	.038	66.069	1471.109

Source: Author's calculations

5. Discussion

Every numerical variable represents an effect on the dependent variable, but interpreting the numerical variable alone can lead to misleading interpretations. Therefore, together with the descriptive work, numerical analysis gives better interpretations. The performance of the variables was in its majority confirming the findings in existing international and national literature. The three areas showed a connection to the changes in car ownership levels. The socio-economic area had strong relationships but not all the variables showed the expected relationship. The increase in average income related with an increase in cars is not a surprising result, especially with the high accessibility to cars due to the proximity to the border. Ensenada presents similarities to Mexico City (Guerra, 2015) and OECD countries (Dargay, Gately, 1999). Even when the statements of Clear Institute (2012), Moctezuma Navarro (2012) and Medina Ramirez (2012) are in the same path, they are made on a different scale, namely at the national level, and are too general and imprecise when using GDP or minimum wage.

Although the effects of average household income on car ownership is near to zero, another economic variable, namely bus ticket price positive and significant influence. The bus ticket price is becoming higher and citizens spend a considerable percentage of their income on buses. Gasoline price is correlated to vehicle ownership; this increase has not stopped the motorization of the city. The citizens, from the point of view of consumers, state that the prices of buses compared to quality and commuting time are not efficient for them; therefore, they decide for the car. The fact is that the citizens will prefer comfort when the prices are the same, and the conditions of PT are not adequate to compete with the cars' flexibility. Contrary to what Crotte et al. (2008) stated, there is a relationship, and it is a factor to be considered, as Sanchez Flores and Romero Torres (2014) stated. The different surveys showed a clear disadvantage of using PT for the citizens compared with the car use affordability.

Other variables show an evolution in the city; the average age is increasing together with more people working and smaller families. The relation with age can be justified due to older people having a better economic status than younger people; and the elderly clearly have a problem with access to PT in the city. Then the increase in average age should be taken as a trigger of more motorized travels. The fact that gender is not relevant in this study could mean that in the city women and men have similar lifestyles with respect to working and commuting, but the survey of Instituto Municipal de Investigacion y Planeacion – IMIP (2007) shows a slight tendency towards women using the PT. The decrease in the household size by almost one member has a strong negative effect. A family can easily increase the number of cars as the members increase, but the number will hardly decrease if there are less members (depending also on the structure of the family, i.e. working people, teenagers, etc.).

The urban form of the city has changed with time, but the effects of the land use change seem to be twofold: density are increasing but the uncontrolled growth seems to have negative effects on personal vehicle ownership. Urban sprawl of the city has an important role here, the externalities of sprawl are well known: the costs of infrastructure and increasing commuting distances. Motorization is of marginal significance, this means that the leapfrogs and the shape of the city indeed represent an unsustainable urban form as Medina Ramirez (2012) points out. The relationship between population and employment densities is already stated in other works, higher densities lead to less motorized cities. In the case of Ensenada, the increasing densities are not bringing a change to the motorization rates, which merely contradict statements such as Newman and Kenworthy's (1999). With a closer look, the fact becomes clear that densities are in-

creasing on the urban periphery and that the centre remains with low densities and homogeneous land use results in a misleading interpretation of the numerical result. It means that even when the densities are increasing, they may seem not to cause less car use if they are not well distributed. Employment density behaves similar to population; therefore, the distribution is important and the lack of consolidated urban centres is a disadvantage. The city does not present changes in the land use mix over time but shows a uniform index for land use mix. It then does not present an adequate distribution of services which Medina Ramirez (2012) recommends.

The street network of the city shows a decrease in the majority of the variables, but this should not be taken as a representation of the government not prioritizing the road construction anymore. The urban sprawl and leapfrogs of the city clearly intervene in the street variables. The new infrastructure is not compensating for the rapid growth leading to a decrease in connectivity. In other words, the presence of traffic congestion will continue and increase in the future. On the one hand, this should discourage car users but this also affects other areas such as buses trapped in congestion, and less space available in the streets for bikers. The decrease of secondary streets per capita and by area means less availability of streets friendly to pedestrians, which are more used to commute by bike and on foot. The lack of pedestrian streets and their bad quality as the descriptive work showed is a clear proof of why people decide to use cars. After a rain, streets are not optimal to use for walking or cycling.

If the city wants to reduce the motorization rates, some implementations based on the descriptive and numerical results can be done. It seems quite obvious that the conditions of PT including quality, price, and image are highly effective on how people tend to own and perhaps use personal cars. A full restructuring of the PT system is required. As age is a related variable, the elderly people seem a target group to consider; infrastructure for the elderly (ramps, special seats, etc.) such as passes and special tickets need to be especially designed based on the current shortcomings. In the same area, students also should be able to pay with a student card provided by the educational institutes. Increasing the PT ticket price is the most problematic aspect as the descriptive and numerical work found; the gov-

ernment along with the bus companies should take action to reduce it or keep it affordable for consumers. An increase will lead to a decrease in the number of users, which eventually will lead to an economic crisis for the bus companies. Based on the descriptive work (surveys of the state), it can be said that reducing commuting times and redrawing routes are important factors for car ownership. The overlapping routes that IMIP calculated are a reason for congestion in some streets and the misuse of resources. The lack of planning in the planned routes has led to this, therefore the redrawing can be significantly effective.

As income is a factor to consider, when citizens earn extra money, they decide to invest in the access to a first or second car. Not many users are aware of the externalities caused by preferring the car over PT. An awareness campaign showing people how much of their income they can save if they commute by bus instead of car will have more effect on them than the typical campaigns of environment awareness. In order to implement the idea, changes must be made to the PT fare system e.g. the bus ticket price reduction. Even when densities did not have the expected effect as explained before, actions regarding the two density-related variables should not be left aside. Information about jobs available in the area for some types of jobs can be viable; of course, not all the jobs can be arranged, for example the specialized jobs in some employment centres such as Sauzal (where the main activity is fishing).

Due to the results of the analysis of the urban sprawl speed variable, an infill development should be taken in consideration. An opportunity is found in the 10 percent of empty lots in the city; with a vertical construction approach, the densities in the central zone should increase and lead to the densification of this district. Restrictions on constructions in the periphery and stronger control of the new constructions, taking to consideration the creation of jobs opportunities for urban centres, high population densities and access to public services: if these characteristics are not fulfilled, the state should consider not allowing new developments. The decrease in the family size while maintaining the number of cars is a problem, implementing a push measure can be recommended in this case. Some taxes can be applied to the acquirer of a second and third car.

The performance of the street connectivity variables conveys different things, for example that pedestrian-friendly streets are needed. The condition of the sidewalks mentioned in the descriptive part means that people can be discouraged to walk, as also in the numerical part the decrease of availability of secondary streets means less streets that the citizens use to walk and cycle (main streets are used by cars). What is linked is the implementation of bike lines which can be provided from the spaces already allocated to parking lots (mostly in the central zone).

Finally, road pricing as the final push measure can be implemented, mostly due to income variable. The recommendations follow an order of importance, time of implementation and costs. After the second stage, it is recommended to do a re-evaluation on how these recommendations have affected the motorization rates and the decision can be made if the road pricing is adequate and exactly what type can be introduced in this city. Different stakeholders are involved, and the participation from private companies, such as the bus companies, is vital. Still these recommendations are based on the empirical work of this research, which had some limitations. Conduction of research using disaggregate data would lead to more complete and accurate recommendations. Another aspect should be the development of a tool, based on data from different cities in the country. It will aim to discover which cities indeed are similar in factors for commuting by car, and then give a better perception for new policies.

6.   Conclusions

As many studies, manuals and reports showed, variables regarding land use, socio-economic factors and the street network are indeed related to the increment of cars per inhabitants. The importance of identifying exactly which ones are vital because there is no one general formula of how to achieve sustainable transportation. Applying general guidelines imply the risk of failure, misuse of resources on implementations that do not have a strong relation to the problem. This research used a combination of descriptive work with a numerical analysis

to provide a more complete answer. Together, the results were in some areas different from the guidelines that some of the literature presented. The existing literature have a strong focus on large cities. Without further research similarities with small and medium-sized cities cannot be hypothesized or proved. This research brought results comparable and similar to bigger cities, which means that mid-sized cities behave similarly to larger cities.

Socio-economic factors are strong in persuading citizens how to commute, as income and the bus ticket price showed. The price of gasoline has still not reached the point which would affect the citizens to decide to change the commuting mode; probably due to the similar cost of commuting between car and PT (where the quality of the second is lower compared with the comfort of the car). Changes to the profile of citizens such as age and household size were also relevant due to the changes of their lifestyles; therefore, a necessity of an empirical approach to studying these age groups is felt.

Differences are also shown as the increasing densities in the city are not helping; the implementation of increasing densities just due to the international guidelines can lead to a contra-productive result, meaning that recommendations should be more detailed including the circumstances and place of increasing densities. In other words, densification policies and strategies can be different for the city centre and suburbs. This study showed that the need for densification of the central city is stronger than that of the periphery of the case-study city. The presence of urban sprawl is more important in this case; therefore, the infill development is more recommendable than the increase of densities in the new developments. The street connectivity relationship with the increase of car ownership levels comes from the lack of availability of pedestrian streets. The possibilities to walk and cycle after a period of rain are minimal and should be tackled.

Mid-sized cities of Mexico are experimenting sprawl, as this research and other national studies found (SEDESOL, 2012), socio-economic factors are present and should be taken into account to propose measures such as the ones stated in this research.

It is necessary to obtain more detailed information about mid-sized cities which are following to some extent the trends of bigger cities. Only with

research on this kind of cities, planning and policy-related guidelines can be used, and not only be used merely as a general formula to prevent car-orientated modal splits.

In general, this study emphasizes the importance and necessity of attention to the monitoring of socio-economic factors such as household income, household size, gender, age, etc., as well as the land use factors as a long-term approach to control car ownership. The search for transportation solutions has received a large part of the efforts towards promoting sustainable transportation, while the above issues can also have a share in easing mobility challenges in developing countries like Mexico, especially in the less-studied context of mid-sized cities.

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