

## **Transport and Greenhouse Gas Emissions. Mitigation Measures.**

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### **Abstract**

This paper presents a comparative analysis of transportation-driven GHG emissions as well as a set of mitigation measures in four mid-sized Argentinian cities. Passenger and freight transport were considered as part of the mobility system. Information was gathered through origin/destination surveys and data provided by freight companies with urban destinations.

According to the results of a research project, 36.98% of the population in the Metropolitan Area of Buenos Aires produces 70.12% of all CO<sub>2</sub> emissions. All 19 Argentinian cities with 200,000 inhabitants (30.82% of the population) produce 15.18% of emissions. The remaining 32.19% of population living in cities with less than 200,000 inhabitants generates 14.70% of emissions. This difference enables planners to identify potential GHG mitigation areas.

This research aimed at identifying those behaviours which determine local environmental situations as well as those potential changes in behavioural patterns which could lead to a higher GHG-reduction efficiency in major urban agglomerations.

The distribution of emission data also varies according to transport type with the predominance of private transportation, which accounted for 68.56% of CO<sub>2</sub> emissions; public passenger transport accounted for 18.72%, freight transportation for 11.69% and service transportation for only 1.03%.

**Keywords:** energy efficiency- emission GHG- urban transportation- road transportation

### **1. Introduction**

This paper presents different indicators of energy consumption and greenhouse effect gas emissions (GHG) produced by the movement of people and goods in and out of the Metropolitan Area of Buenos Aires (MABA) and of four other Argentine cities, namely, Rosario, La Plata, Mendoza and Córdoba. Estimates for cities with over 2,000 inhabitants are also included. It is important to note that Argentina has a total

surface of 2,700,000 km<sup>2</sup> and a population of approximately 40,000,000 inhabitants, 85% of which lives in cities.

The movement of people and goods accounts for 32% of the country's final energy consumption, almost 100% of which corresponds to fossil fuels (only 0.35% to electricity). Eighty-four percent of this 100% is consumed by the motor vehicle sector and 35.6% of this sector's energy is used up on Argentina's 231,095 km. of highways and roads. That is to say, 6,494,809 TOE/year are consumed, 66% of which are accounted for by freight transport and 34% by passenger transport. When breaking down passenger transport into two groups: massive (buses) and non-massive means (taxis, rental vehicles and private cars), passengers' usage of energy is distributed as follows: 11% and 23%, respectively. This sector generated 6.494.809 tonnes of oil equivalent (TOE) on roads (35,6%) and 11.758.170 TOE in cities (64,42%). (Bravo, V., 1999) Out of the total energy used in cities, 44 % corresponds to the Buenos Aires Metropolitan Area, 51 % to cities with over 200, 000 inhabitants, 1% to cities with approximately 100.000- 200.000 inhabitants and the rest (4%) is distributed among cities with around 50.000- 2.000 inhabitants. Out of the total emissions produced in the country's transport corridors, 45 % is concentrated at 200 km. from access roads to large cities, especially, Buenos Aires and Rosario, both of which are harbour cities.

This study was based on the concept that a city is a system, beyond delimited jurisdictions and appropriate legislation, which integrates both urban and rural settings through transport activities and means. In the midst of this context, the movement of people and goods is regarded as a complex system where several economical, social and cultural aspects interact and where transport plays the key role of articulating the population's diverse activities and transportation needs. Transportation, mostly petrol-dependant, its private and public management activities, the different social sectors' transport habits, and the lack of an urban planning process to integrate transportation with land usage, turn it into one of the main factors that cause contaminating emissions and is responsible for turning urban settings unsustainable. (Giacobbe, N. et all, 2007)

Transport problems resulting from urban sprawl, incoherence in the localization of diverse activities and vehicle overuse require complex systemic solutions that could be difficult to implement in the short term. Such solutions must be provided by an integrated urban planning and mainly by the state's regulatory policies to revert cities' sprawl tendency while also privileging compactness over sprawling, multimodality over the hegemony of motor transport and collective transport over private transport means.

The methodology that emerged from the aforesaid concepts was applied to tackle, from the demand standpoint, the technical and spatial aspects of transportation, aiming at the definition of a competent political jurisdiction and priority mitigation measures. Such demand is analyzed by breaking down information on roads and cities, using an equilibrium equation to equal such information to each energy source's supply, presented in the 2003 National Energy Balance of the National Energy Secretariat, as the main criterion for information consistency. Another criterion also used was the analysis of time series for each concept in the balance to

discover emissions' tendencies and the realization of prospective projects. Expert judgments and estimates based on the Adjustments category in the National Energy Balance (BEN, from its name in Spanish) were used to estimate confidence levels of transport flows and fugitive emissions data.

Table 1 illustrates sources, data collection methods and confidence levels.

The collected information made possible the formulation of 4 possible mitigation measures, whose results were analyzed in terms of three different scenarios: mean (or tendency based), low and high, defined in relation to the following information:

- a) Population growth determined through increase rates resulting from five national censuses (1950-2001)
- b) Evolution of trips generated in cities and transport corridors
- c) Main macroeconomic variables: variation percent of Gross Domestic Product (GDP) and Consumer Price Index (CPI), annual average of dollar exchange rate and GDP per capita.

## **2. Interurban Transport System Analysis**

### **2.1 Analysis Methodology**

The national road network covers 231,095 km, 13.5% (31,153 km) of which are national pavement roads, 16,7% provincial pavement roads (38,537 km) and 69.8% (161, 405 km) non-pavement roads (Figure 1)

The methodology was based on the analysis of:

- a) The annual average daily traffic (AADT<sup>1</sup>) in 10% of the total kilometres of the highest traffic flow road network and of 50% of total fuel consumption -42% corresponds to national pavement roads, 48 % to provincial pavement roads and 10% to earth and gravelled roads- (Table 2).
- b) The AADT per 100 km sections calculus aiming at the comparison of each road's information regardless of the length of each analyzed corridors
- c) Urban periphery sections were excluded;
- d) Calculation of emissions according to vehicle types, considering their make and model, broken down in terms of the number of units in the vehicle park for the different transport means and types of engine and fuel (petrol, diesel or CNG) and kilometres covered. The mean number of kilometres covered was used as an adjustment variable to establish fuel consumption values per vehicle, the addition of which had to coincide with the consumption values provided for each energy source included in the National Energy Balance. The consumption of the network as a whole –excluded from this study- was estimated considering a consumption equal to 50% of the average value per 100 km. of the analysed roads, emerging from the difference in AADT between studied roads and the rest<sup>1</sup>.

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<sup>1</sup> Information obtained from permanent censuses carried out by both the Provincial and National Department of Transport including volume, type, speed and directionality of vehicles, according to the provincial and national pavement system and the non-pavement system from different sources belonging to either state or public organisms.

e) Estimates of emissions attained by multiplying fuel consumption (TJ) by their respective emission factors included in the LEAP programme (Ch. Heaps, 2004).

## **2.2. Findings**

The above-described methodology shed light on the following consumption TOE values as well as the associated CO<sub>2</sub> emissions. Subsequently, the obtained indicators were extrapolated to the total number of roads and the findings were made compatible with the supply indicated in the National Energy Balance.

In 2003, National roads accounted for the highest energy consumption, reaching 59% of the total (6,494, 809 TOE), while 39% was consumed in provincial roads and 2% in earth roads. Out of the total used fuel, 80% was diesel, 17% petrol and 3% CNG, clearly revealing the high incidence of freight transport on CO<sub>2</sub> emissions.

This information was broken down in 100 Km. sections, revealing that the road network portions where the greatest concentration of vehicle flow and emissions are found correspond, in general, to those kilometres close to large city access roads (Figure 2). The country's total road fuel consumption (6,494,809 TOE) is equal to 0.18 TOE/inhabitants<sup>2</sup> and 0.53 Tn/year/inhab. of CO<sub>2</sub>.

As regards fuel consumption concentration per 100 km sections, emission values show great diversification depending on the affected population. As to the Buenos Aires Metropolitan Area surroundings, with a population of 14 millions of inhabitants, CO<sub>2</sub> emissions reach 2.5 Tn/inhab.(Figure 3).

Emissions by type of transport vary in the different roads, ranging from 62% to 74% produced by freight transport and from 15% to 19% resulting from passenger transport (cars and buses). CO<sub>2</sub> emissions' spatiality determines their concentration and highest rates per inhabitant.

## **3. City Transport System Analysis**

### **3.1. Analysis Methodology**

In 2003, 87.4% of the country's population was urban (32,254,868/ 37,600,000 inhab.). Table 3 shows urban population distribution by city size.

The transport system was analysed by breaking down the following variables: massive and non-massive passenger motor transport, service and freight motor transport, energy consumption per transport mode and GHG emissions in a city (La Plata city), defined as the baseline city and whose information was obtained through in situ surveys across all variables. The transport systems in Mendoza, Rosario, Córdoba and Neuquén were studied on the basis of existing surveys and through the

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<sup>2</sup> Country population in 2003: 37,000,000 inhabitants

application of baseline city indicators, adjusted by data provided by qualified informants. As far as the rest of the cities with over 2,500 inhabitants are concerned, they were also studied by the application of obtained indicators, adjusted by conducting opinion polls among qualified informants. A summary of the information building process is shown in Figure 4.

Consumption and GHG emissions data was obtained as follows: “Baseline city” indicators were adjusted to the characteristics of the four cities under study. Such indicators were extrapolated to the rest of the cities, adjusted by secondary information and data provided by qualified informants, and grouped into 5 categories:

1. Metropolitan Area of Buenos Aires with, approximately, 11 million inhabitants;
2. Large agglomerates: 7 cities whose population ranges from 500,000 to 1,300,000 inhabitants and 11 province capitals whose populations range from 200,000 and 500,000 inhabitants;
3. Cities with 100,000-200,000 inhabitants;
4. Cities with 50,000-100,000 inhabitants;
5. And cities with less than 50,000 inhabitants.

### **3.2. Baseline City Analysis**

La Plata city together with its metropolitan area (MALP), with a population of 735,692 inhabitants, was defined as the “baseline city” because it presented accurate information regarding the variables indispensable for the study: passenger, freight and service transport and average kilometres covered by each of these. Baseline information for passenger transport is shown in Table 4.

The following services were surveyed: deliveries, ambulances, solid waste collection, telephony, postal, gas, electricity, drinking water, urban police, and other official and private services. Data on freight transport were gathered from secondary information in addition to surveys carried out in the industry sector, regional markets and supermarkets. Fuel consumption was estimated on the basis of vehicle characteristics and distances covered. Table 5 summarizes annual fuel consumption in POE and CO<sub>2</sub> gas emissions in tons.

Out of the total amount of energy consumed, 45.4% is used by private cars, which accounts for 52.4 % of emissions. Massive transport is responsible for 29% of total CO<sub>2</sub> emissions and freight transport produces 13.3 % (Figure 5).

Information on trips corresponding to the cities of Buenos Aires, Córdoba, Mendoza, Rosario and Neuquén was collected by means of surveys or estimated through the application of simulation models. Energy consumption data for freight and service transport were determined by the extrapolation of “baseline city” indicators, adjusted by secondary information and information provided by qualified informants of each of the four studied cities (Table 6).

This data allow us to present indicators related to both kilometres covered per inhabitant and massive and non-massive transport per year in cities with over 500,000 inhabitants (Table 7).

Information about massive and non-massive motor vehicle trips in the 19 cities with over 200,000 inhabitants is displayed in Figure 6.

Table 8 shows fuel consumption indicators and CO<sub>2</sub>/inhabitant emissions with data estimates for freight and service transport across cities on the basis of extrapolations made from baseline city information and that of the four large cities analyzed.

Differentiated indicators are verified hinging on each city's population level. While MABA registers a higher rate of CO<sub>2</sub> emissions per inhabitant resulting from passenger transport, energy consumption per inhabitant in this area is lower than in cities with over 200,000 inhabitants (0.44 TOE/inhab. versus 0.61 TOE/inhab., respectively). Indicators of the different variables are presented in Figure 7.

At present, this data is being compared with information that is being gathered in other cities in the country by the workgroup responsible for this study as well by others. Such data collection will enable fine tuning both the methodology and indicators presented in this study.

#### **4. Mitigation Measures**

Proposals for mitigation measures in the transport sector are a complex issue. Unlike other sectors, there are barriers for their application due to the multiplicity of actors and transportation behaviours, further hindered by political and business sectors. Implementation of these measures in specific urban areas or roads requires particularized studies to turn them suitable for each specific situation.

The following mitigation measures were analysed in terms of cost-benefit relations and short and middle term implementation criteria: i. Incorporation of new technology (such as the incorporation of new trams or engine changes), ii. Modal transference (shift from private car to bus or bicycle) iii. Good practices, iv. Differentiated timetables for freight transportation.

Modal transference was studied for: a) freight transportation in corridors, studying the shift from truck to train b) city passenger transport, considering the shift from private cars to public transport and, in some cases, c) changes in technology, contemplating the proposal to implement a rigid urban mode.

The introduction of technology changes was analyzed for cities and corridors, mainly considering the implementation of engine improvements.

Good practices were studied for both cases.

The CO<sub>2</sub> reduction indicators for each measure were evaluated: a) for the baseline city and the four analyzed cities, introducing the necessary adjustments to baseline city indicators; b) across all cities extrapolating the results to the rest of the cities grouped into four population levels; c) for corridors.

Measures were assessed in terms of three scenarios that consider three different situations: a mean scenario i.e. based on tendencies; an optimistic scenario and a pessimistic one.

This article presents the mean scenario constructed in terms of the following hypotheses: a) population growth based on increase rates estimated from historical evolution; b) an economy slowdown during 2008-2011; c) a stable period during 2011-2015, according to indicators shown in Figure 8.

#### **4.1. Analysis of Mitigation Measures in Cities**

Aiming at determining the measures' impact on compact or sprawl urban areas the following was explored: a) the baseline city (micro region of La Plata – AMLP) was studied in depth in terms of passenger, freight and service transport, b) the four cities with over 500,000 inhabitants were studied in terms of passenger transport. The resulting indicators were extrapolated to the rest of the cities grouped into four population levels and according to geographical, socio-spatial and socio-economic attributes

Three selected areas of the baseline city were studied in terms of socio-professional categories, population density, land use and degree of compactness/sprawl in order to achieve a more representative coverage, encompassing: i. two neighbourhoods with a sprawled periphery with dissimilar characteristics (consolidation degree, population, and equipment and service coverage) ii. a consolidated and compact urban neighbourhood. The resulting data were extrapolated to the rest of the cities, in relation to consolidation and density levels. The disparity between the areas' inhabitants was not considered determinant since the trip/km variable was itself regarded as an analytical category.

The first analyzed area was Villa Elisa (20 inhab/hectare - 11,595 inhabitants) with middle- and upper –middle socio-economic groups, and presenting a higher density enclave (200 inhab/ha) occupied by housing of social interest, situated 20 km from the La Plata urban centre and connected by both highway and railway. Even though this area displays a disperse urbanization, it also boasts of a certain degree of consolidation among a set of daily activities which imply rationality of movements, proximity to primary educational system, everyday purchase shops, newspapers and primary healthcare system.

Table 9 shows annual transportation (1,815,708 annual trips), consumption and emissions that account for 0.6 TOE/year/inhab and 2,169 Tn of CO<sub>2</sub>.

The second area (Villa Elvira with approximately 28,661 inhabitants and 27 inhab/hectare) is located 9 km from the centre and connected by a medium traffic flow road; it includes a housing group of social interest with 100-150 inhab/hectare and registers a 27% population growth. Its inhabitants pertain to middle – lower-middle socioeconomic classes, some of which present unmet basic needs. The 8,677,094 annual trips made in Villa Elvira represent 23,393 TOE/year of energy consumption and 7,138 Tn of CO<sub>2</sub> (Table 10).

The third area is an urban centre with 183,855 inhabitants (with an average density of 66 inhabitants per hectare). It is a highly multifunctional area that includes educational, health (all levels of complexity), cultural and leisure activities (cinemas, theatres, museums, exhibitions). It also hosts the provincial, commercial and services

administration headquarters. It registers the highest demand for trips. A hundred and seventeen million trips are made in this area resulting in an energy consumption of 107,514 TOE and 32,716 tons of CO<sub>2</sub> per year (Table 11).

This information allowed analyzing the impact these measures would produce by the year 2030 considering the following variables in each scenario: i. Population increase, based on the tendency of the past 20 years (4.5% yearly in Villa Elisa, 2.7 % yearly in Villa Elvira and 0.15% yearly in the central area). ii. Availability of vacant lots; iii. Increase of trips, estimated by applying the trips/inhabitants indicator; iv. Covered kilometres, calculated by considering urban expansion and the km/inhabitant indicator; v. Freight transportation, estimated in relation to the GDP calculated for the mean scenario.

The following findings were obtained: i. the incorporation of new technologies (incorporation of a new tram line) would imply a 0.92% reduction of CO<sub>2</sub> emissions by the year 2012 and a reduction of 1.07% by 2030. The modal transference of 15% of private car trips to public transport would reduce emissions in 2.19% by 2012 and in 4.6% by 2030 (Table 12).

The adoption of good practices represents one of the measures providing the greatest savings, that is to say, a reduction of 27.4% of the emissions produced by public transport and of 17.4% of those produced by freight transport could be attained by the year 2030 (Figure 9).

In order to optimise the impact of each measure, the different areas were affected by an emission reduction coefficient that is variable in terms of geographic characteristics, population (consolidated periphery, periphery in expansion and central area) and transportation (mode and type of predominant vehicle). In this sense, the incorporation of new technologies specified in the tram project was only applied in the urban centre.

The modal transference was applied to the three areas for private cars. The adoption of good driving practices was applied to the three areas and its efficacy was proven by means of pilot studies in which savings of up to 20% were reported. Finally, the implementation of a timetable for freight transport was only applied to the urban centre.

The CO<sub>2</sub> reduction per trip produced by each measure is quantified for the different years considered and the results obtained by applying the LEAP programme (Ch. Hearp, 2004) are shown in Figures 10

In sprawled out areas (Villa Elisa and Villa Elvira), the application of good practices and modal transference present a lower level of efficacy than in compact networks (urban centre). In sprawled out areas, the impact of these two measures is more relevant in the case of Villa Elvira, where a greater distance between the mitigation curve and the reference curve is reported.

The application of the good practices and timetable change measures applied to freight transport produce a greater reduction. The modal transference and



incorporation of new technologies measures, whose results are inferior to those expected, should be further studied in more complex scenarios in order to fully grasp their potential.

Furthermore, measures aimed at mitigating the effects of GHG emissions are more effective when applied to cities' compact areas.

The indicators obtained in the baseline city for passenger transport broken down by compact and sprawled areas and for freight transport for the entire city, allowed adjusting the indicators in terms of energy savings in the four analyzed cities, depending on each city's features (socio-spatial, socio-economic, transport management: public or private; and transport means according to size) to determine each measure's feasibility as regards the consumption-emissions relation. The indicators, made compatible according to the above criteria, were extrapolated to the rest of the country's cities grouped into four population levels for the mean scenario constructed considering: a) population growth based on increase rates estimated from historical evolution; b) an economy slowdown during 2008-2011; c) a stable period during 2011-2015, according to indicators shown in Figure 8.

Only the application of the good practices measure was analyzed among cities with a population level of 4. For the Metropolitan Area of Buenos Aires (MABA), the incorporation of new technologies was not considered due to the absence of a concrete plan. Such measure was not analyzed either in level 3 cities, as opposed to level 2 cities, where such measure was analyzed through the incorporation of new motor technologies, specially, for the public transport units. This is a first approximation that only provides an overall idea of each measure's effects, which should be the basis for particularized studies aiming at the assurance of the adequacy and efficacy of each measure.

## **4.2. Mitigation Measures in Cities and Roads**

The measures that proved to be more effective on roads were: a) good practices, b) maximum speed control and c) modal transference from trucks to railways, all of which accounted for annual CO<sub>2</sub> reductions in roads of 1,6% and 5,7% and 10,3%, respectively, as opposed to approximately 22%, the estimated percentage of emissions that would be produced without the application of mitigation measures.

On the basis of the increase of emissions calculated for 2015 in the mean scenario for cities and corridors (Table 14), reductions are estimated by applying the different measures (Table 15).

When comparing both scenarios, the following is unveiled: i. the evaluation of these measures would cast more substantial results over a longer period of time; ii) the same measure produces different results depending on the application area. This is verified by the application of good driving practices, which account for an approximate variation of 1.5% in emissions when it comes to corridors, whereas in cities, the measure brings about a far more important reduction percentage (11%). As

springs from the conducted analysis, an approximate reduction of 12 to 15% of CO<sub>2</sub> yearly emissions could be possible by 2015 if a policy at national, provincial and municipal levels were implemented aiming at the application of different measures in line with each region's features.

Considering the relation between the CO<sub>2</sub> reduction and its marginal cost amongst the analyzed scenarios with a discount rate of 10% for each analyzed measures, the results shown in Table 16 were obtained.

Judging by these results, the application of good practices account for highly appealing economic benefits, the only requirement being that drivers take specific courses when obtaining their driver's license. The implementation of this measure only hinges on the existence of a federally enforced legislation, through a national entity that would eliminate all existing institutional barriers and promote strategic alliances with provincial and municipal organizations as well as with non-governmental associations that deal with these issues. The application of this measure casts the best results in cities that present the most serious bad driving practices.

Speed control in interurban corridors is the next most important measure. In order for this measure to be implemented, an analysis of institutional barriers should be conducted, the cost of which is by no means comparable with the savings it would bring about. The application of this measure would bring about important positive externalities since it would entail restructuring the administration with the inclusion of qualified personnel.

Despite the high marginal costs estimated, the modal transference from truck or other motor vehicles to railway for freight transport and interurban passenger transport is a key factor in a country with long distances, in the light of a sustainable development programme over a period of 25 years. The application of this measure would not only produce a profitable return on investment but it would also imply important externalities for the emerging social development, especially, in the less prosperous areas of the country. The same holds true when it comes to applying these measures in cities. This assertion is verified in a new technologies' incorporation project carried out in one of the analyzed cities.

The control of loading and unloading timetables is of the utmost importance to reduce urban centres' emissions in cities with over 200,000 inhabitants, but it requires specific studies on each sector's characteristics and institutional barriers, as well as the execution of alliances among all possible stakeholders.

Despite the fact that the modal transference measure fails to cast very good results in this study because of the short evaluation period (2015), it undoubtedly implies highly beneficial externalities for cities' sustainable development in terms of urban functioning, improved life quality, reduction of transport costs and enhanced spatial organization.

At present, important changes, such as the promotion of projects aiming at the transport system's rationalization through the introduction of more sustainable

technologies in different cities in the country, have taken place at a governmental level.

A study conducted in the baseline city allowed estimating that the restructuring of the current transport system would enable an annual fuel saving of around 40% and a CO<sub>2</sub> emissions' reduction of approximately 52%, through the incorporation of a tram and the implementation of urban policies to promote public transport (car usage was estimated to drop by 15% over the next 15 years). These changes would imply average marginal costs of 35 USD/CO<sub>2</sub> ton by the end of the period and of between 7 and 5 USD/CO<sub>2</sub> ton in four years' time<sup>3</sup>.

To sum up, the way information was broken down proved to be adequate to assess the overall level of emissions' reductions across cities based on the extrapolation of results. Consequently, the data obtained based on the disaggregated demand were adequately correlated with the supply data from the National Energy Balance with a

### **Concluding notes**

In the absence of specialized information, the described methodology became a key central support for proposing various mitigation measures.

As for the research outcomes, it is apparent that: 1. Polluting emissions along road networks are concentrated within 100 kilometers around the Metropolitan Areas of Buenos Aires and Rosario, which house international harbors. 2. Highest CO<sub>2</sub> emissions in cities are generated by private automobiles (an average of 53.4%), followed by passengers' public transportation (29%) and, to a lesser extent, by freight transport (13.3 %) and services (5.4%). Per capita CO<sub>2</sub> emissions are much higher in Buenos Aires Metropolitan Area – where they vary between 1,2 and 0,16 ton/year/inh. - than in the remaining analyzed cities.

Regarding mitigation measures, we verified that those which may provoke the highest emissions' reductions in the shortest time are also those which imply lowest initial costs, such as (a) good driving practices ( by 2030, these might reduce emissions produced by passengers' transport by 27.4% and those produced by freight transport by 17.4%. However, this measure is not as relevant in highway transit); (b) arranging freight transport's timetable also generates an important emissions' reduction.

However, these measures that reduce the adverse effects of urban transport on environment are necessary but not sufficient ones. When individual automobile transportation is currently viewed as the prevailing option for covering ever wider distances between increasingly disperse, mono-functional and deconcentrated/decentralized urban spaces, the Urban/Regional Planning is probably the most significant tool for controlling greenhouse effect produced by the combination of these territorial models and consumption patterns. This is still a significant battle ahead.

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<sup>3</sup> According to studies conducted in the Research Unit # 6B, IDEHAB, FAU, UNLP. Year 2005.

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## Tables

Interurban transport				
Activity	Transport Mode	Source of information	Procedure	Quality of Findings to be Obtained
Passengers	Car	Reports on national roads' traffic issued by the National Department of Roads	Extrapolation to provincial roads based on previous studies	Average Confidence Level (due to database quality)
	Bus	Statistical reports on interurban passenger transport within national jurisdiction	Extrapolation to the total based on an estimate of existing bus traffic for the year 1999	Average Confidence Level (due to database quality)
	Railway	Available statistical reports	-----	Absolute Confidence Level
Freight	Motor transport	Reports on national roads' traffic issued by the National Department of Roads	Extrapolation to provincial roads based on previous studies	Average Confidence Level (due to database quality)
	Railway	Available statistical reports	-----	Absolute Confidence Level

**Table 1. Interurban transport: Illustrates sources, data collection methods and confidence levels.** Source: author's elaboration

Consumption and CO2 emissions- Interurban corridors in Argentina							
Roads	Total Roads Analysed			Total in the country			Percentages
	Total Km.	TOE	Total Ton of CO2/Year	Total Km.	TOE	Total Ton of CO2/Year	
National pavement system	12,925	2,857,887	8,608,592	31,153	3,843,968	9,205,028	48%
Provincial pavement system	3,36	686,463	2,022,848	38,537	2,575,422	9,380,899	49%
Earth and gravelled roads (total of the country)	3,888	23,681	54	161,405	75,419	491,797	3%
<b>Total</b>	<b>20,174</b>	<b>3,568,031</b>	<b>10,631,493</b>	<b>231,095</b>	<b>6,494,809</b>	<b>19,077,723</b>	<b>100%</b>

**Table 2. Roads' Estimated Fuel Consumption in TOE and CO2 Emissions in Tn.**  
Source: author's elaboration/ Statistical yearbook 2003. National Department of Transport.

Areas	2003 population	
	Total	%
MABA	11,833,639	36.7
Between 500,000 and 1,300,000 inhab.	6,332,127	19.6
Between 200,000 and 500,000 inhab.	3,784,825	11.7
Between 100,000 and 200,000 inhab.	1,332,298	4.1
Between 50,000 and 100,000 inhab.	2,596,522	8.0
Less than 50,000 inhab.	6,375,457	19.8
<b>Totals</b>	<b>32,254,868</b>	<b>100.00</b>

**Table 3. Urban Population Distribution by City Size**

Source: author's elaboration

Kilometres Covered and Transport Mode Partition - La Plata- 2003							
Transport Modes	Trips	Percentages	Km. Covered		Consumption		
			daily	annual	Petrol	Diesel Fuel	CNG (Compressed Natural Gas)
Cars	364,096	35%	1,274,335	465,132,395	337,686,119	43,024,747	84,421,530
Taxis	74,585	7%	15	5,293		4,332	961
Rental Cars	45	4.37%	9	3,193		2,614	580
Motorcycles	55,425	5.39%	193,986	70,804,902	70,804,902		
Others	88,093	8.56%	308,325	112,538,569		112,538,569	
Public Transport	309,032	30.04%	121,542	44,362,733		44,362,733	
School Transport	30	2.92%	2	852		852	
Interurban Transport	43,076	4.19%	51,457	18,781,776		18,781,776	
Train	19,408	1.89%	1,325	483,667		483,667	
<b>TOTAL</b>	<b>1,028,715</b>	<b>100%</b>	<b>1,950,996</b>	<b>712,113,380</b>	<b>408,491,021</b>	<b>219,199,289</b>	<b>84,423,070</b>
<b>Population</b>	<b>735,692</b>						
<b>Trips per inhabitant</b>	<b>1.51</b>						
<b>Urban area (km2)</b>	<b>1,162</b>						

**Table 4. Number of trips distributed across transport modes for the Metropolitan Area of La Plata.** Source: author's elaboration.

Type of Transportation	Annual Covered Km.	%	Fuel Consumption per year in TEP	%	CO2 Emissions in Tn	%
<b>Passengers</b>						
Massive	70,928,175.92	6.88	38,638.11	34.00	94,379	29
Non-Massive	801,000,297.42	77.75	51,600.15	45.41	170,573	52.4
<b>Freight</b>	112,966,806.50	10.96	17,662.50	15.54	43,245	13.3
<b>Services</b>	45,376,587.92	4.40	5,734.99	5.05	17,503	5.4
<b>Total</b>	<b>1,030,271,868</b>	<b>100.00</b>	<b>113,635.75</b>	<b>100.00</b>	<b>325,699</b>	<b>100.00</b>

**Table 5. MALP Energy Consumption and CO2 Emissions.** Source: author's elaboration.

Agglomerates	Population	%	Urban surface	Total annual trips						Trips per inhabitant	Trips per Km2
				Total	%	Massive	%	Non-massive	%		
MABA	11,944,104	73.8	3880	25,327,928	83.5	7,299,729	28.82	18,028,198	71.2	2.12	6527.8
Greater Rosario	1,171,995	7.2	1890	1,014,732	3.3	417,525	41.15	597,207	58.9	0.87	537
Greater Córdoba	1,340,107	8.3	562	1,634,087	5.4	759,98	46.51	874,107	53.5	1.22	2908
Greater Mendoza	1,024,420	6.3	14712	1,330,584	4.4	527,005	39.61	803,579	60.4	1.30	90
Greater La Plata	705,909	4.4	16167	1,028,715	3.4	401,516	39.03	627,198	61.0	1.46	64
<b>Total</b>	<b>16,186,535</b>			<b>30,336,046</b>		<b>9,405,755</b>		<b>20,930,290</b>			

**Table 6. Population, Urban Surface and Number of Motorized Trips in the Four Analyzed Cities.** Source: author's elaboration / OD surveys

Agglomerates	Population	km/inhab/year	Trips per inhabitant	km/inhab/year	POE/Inhab/year	CO2/Inhab/year
MABA	11,944,104	5361.47	21.205	5361.47	0.4327	12.378
Greater Rosario	1171995	889.82	0.8658	889.82	0.0758	0.2198
Greater Córdoba	1340107	1106.53	12.194	1106.53	0.0933	0.2706
Greater Mendoza	1024420	1197.68	12.989	1197.68	0.1114	0.3213
Greater La Plata	705909	1394.61	14.573	1394.61	0.1278	0.3753
<b>Total</b>	<b>16186535</b>					

**Table 7. Fuel Indicators (in POE) and CO2 Gas Emissions (in Tn.) per Year/Inhabitant.** Source: author's elaboration / O-D surveys

Total national consumption and CO2 emissions per cities' population level. Year 2003									
City	Population	Passenger transport CO2 emissions		Fuel consumption		Freight and service transport CO2 emissions			
		Passenger Total CO2	Total per inhab.	Passenger transp.	Consumption per inhab.	Freight transp.	Emission per inhab.	Service transp.	Emission per inhab.
MABA	11,833,639	14,783,863.35	1.25	5,168,154.73	0.44	1,051,828.07	0.09	36,317.21	0.003
Cities with over 200,000 inhab.	9,862,457	2,515,086.74	0.26	6,008,076.15	0.61	622,108.48	0.06	88,110.34	0.009
Cities with 100,000 to 200,000 inhab.	1,332,298	308,316.33	0.23	100,589.06	0.08	85,284.32	0.06	13,549.82	0.010
Cities with 50,000 to 100,000 inhab	2,596,522								
Cities with less than 50,000 inhab.	6,375,457	1,475,388.76	0.23	481,349.68	0.08	408,111.81	0.06	64,840.07	0.010
<b>TOTAL</b>	<b>32,254,868</b>	<b>19,082,655</b>		<b>11,758,170</b>		<b>2,167,333</b>		<b>202,817</b>	

**Table 8. Energy consumption and CO2 emissions for Argentinean cities according to population level.** Source: author's elaboration

Consumption and Emissions. Villa Elisa. 2003						
Transport Mode	Fuels	Annual Trips	Travellers km/year	Consumption/year TOE	CO2 (Tn./year)	CO2(Tn./trips/year)
Car	Petrol	1.011.000				
	Diesel	129.000				
	GNC	253.000				
		<b>1.393.000</b>	<b>2.498.056</b>	<b>115</b>	<b>532</b>	<b>0,000382</b>
Motorcycles	Petrol	184.000				
Others(Small tracks)	Gas Oil	184.000				
Public Transpor	Gas Oil	<b>3.172.542</b>	<b>430.826</b>	<b>235</b>	<b>573</b>	<b>0,000181</b>
Train	Diesel Oil	41.000				
<b>TOTAL</b>		<b>4.974.542</b>		<b>577</b>	<b>1.175</b>	<b>0,000236</b>

**Table 9. Baseline Year Consumption and Emission for Villa Elisa.** Source: author's elaboration based on O-D survey projections, 1994. FAU-UNLP

Consumption and Emissions Villa Elvira. 2003						
Transport Mode	Fuels	Annual Trips	Travellerskm/ year	Consumption/ye ar TOE	CO2 (Tn/year)	CO2 (Tn/trip/year)
Car	Nafta	4.632.935				
	Diesel	593.475				
	GNC	1.161.425				
		<b>6.387.835</b>	<b>10.152.307</b>	<b>650</b>	<b>2.162</b>	<b>0,000339</b>
Motorcycles	Nafta	1.806.333				
Others(Small tracks)	Gas Oil	380.253				
Public Transpor	Gas Oil	<b>6.628.453</b>	<b>935.406</b>	<b>5.098</b>	<b>1.245</b>	<b>0,000188</b>
<b>TOTAL</b>		<b>15.202.874</b>	<b>11.087.712</b>	<b>5.748</b>	<b>3.407</b>	<b>0,000224</b>

**Table 10. Baseline Year Consumption and Emissions for Villa Elvira.** Source: author's elaboration based on Survey O-D projections, 1994. FAU-UNLP.

Consumption and Emissions. Urban centre 2003						
Transport Mode	Fuels	Annual Trips	Travellerskm/ year	Consumption/ye ar TOE	CO2 (Tn/year)	CO2 (Tn/trip/year)
Car	Nafta	23.381.183				
	Diesel	2.996.336				
	GNC	5.841.027				
		<b>32.218.546</b>	<b>144.725.296</b>	<b>6.657</b>	<b>30.826</b>	<b>0,000957</b>
Motorcycles	Nafta	4.536.008				
Others(Small tracks)	Gas Oil	1.891.004				
Public Transpor	Gas Oil	<b>66.632.654</b>	<b>32.000.000</b>	<b>17.440</b>	<b>42.592</b>	<b>0,000639</b>
Train	Gas Oil	261.897		0	1	
<b>TOTAL</b>		<b>105.540.109</b>	<b>176.725.296</b>	<b>24.097</b>	<b>73.419</b>	<b>0,000696</b>

**Table 11. Baseline Year Consumption and Emissions for the Urban Centre.** Source: author's elaboration based on Survey O-D projections, 1994. FAU-UNLP.

Emission Reduction Percentage by Mitigation Measures. La Plata District				
Año	1. Incorporation of new technologies	2. Modal transference	3. Good practices	4. Timetable for freight transpor
2008	0,88%	0,60%	0,00%	0,73%
2012	0,92%	2,19%	3,63%	1,55%
2015	0,97%	2,98%	11,50%	6,83%
2020	1,02%	3,77%	19,37%	12,11%
2030	1,07%	4,56%	27,24%	17,39%

**Table 12. Emission Reduction Percentage by Mitigation Measure (2008-2030).** Source: author's elaboration

Analysed mitigation measures / Coefficients of CO <sub>2</sub> emissions reduction						
City Population Level	Periods	Measure 1 - incorporation of new technologies	Measure 2 - modal transference	Measure 3 - good practices	Measure 4 - timetable for freight transp.	Total measures
MABA – Level 1	2008		1.21	3.24	6.83	11.28
	2012		1.82	3.92	1.55	7.29
	2015		1.57	11.32	0.73	13.62
More than 500.000 inhab. - level 2	2008	1.44	1.21	3.24	6.83	12.72
	2012	0.78	1.82	3.92	1.55	8.07
	2015	-0.08	1.57	11.32	0.73	13.54
Between 500.000 and 100.000 inhab. Level 3	2008		1.21	3.24	6.83	11.28
	2012		1.82	3.92	1.55	7.29
	2015		1.57	11.32	0.73	13.62
Less than 100000 inhab. Level 4	2008			3.24		3.24
	2012			3.92		3.92
	2015			11.32		11.32

**Table 13. CO<sub>2</sub> reduction percentages in each population level per analysed measure.**  
 Source: author's elaboration. Source: author's elaboration

Mean baseline scenario- CO <sub>2</sub> emissions in Tons/Year									
	2008			2012			2015		
Cities	massive	non massive	Freight t.	massive	non massive	Freight t.	massive	non massive	Freight t.
MABA	3,662,468	13,412,516	2,487,266	4,056,184	14,854,362	2,754,647	4,454,907	16,314,545	3,025,429
More 500.000 inhab	557,786	2,042,696	378,805	601,014	2,201,005	408,162	642,063	2,351,334	436,040
500.000 to 100.000 inhab.	237,301	1,088,763	201,904	311,423	1,140,479	211	323,351	1,184,159	219,595
Less than 100.000 inhab	565,791	2,072,014	384,242	575,693	2,108,275	390,966	580,471	2,125,773	394,211
<b>Total cities</b>	<b>5,083,347</b>	<b>18,615,990</b>	<b>3,452,217</b>	<b>5,544,314</b>	<b>20,304,120</b>	<b>3,765,271</b>	<b>6,000,792</b>	<b>21,975,812</b>	<b>4,075,275</b>
Roads									
<b>Total countries roads</b>	<b>2,350,466</b>	<b>7,253,524</b>	<b>14,366,900</b>	<b>2,795,602</b>	<b>8,627,212</b>	<b>17,087,733</b>	<b>3,167,287</b>	<b>9,774,230</b>	<b>19,359,608</b>
<b>TOTAL</b>	<b>7,433,813</b>	<b>25,869,514</b>	<b>17,819,118</b>	<b>8,339,916</b>	<b>28,931,332</b>	<b>20,853,004</b>	<b>9,168,079</b>	<b>31,750,042</b>	<b>23,434,883</b>

**Table 14. Baseline Mean Scenario for Cities and Interurban -Corridors in Argentina.**  
 Source: author's elaboration

Mean baseline scenario- CO <sub>2</sub> emissions in Tons/Year									
	2008			2012			2015		
Cities	massive	non massive	Freight t.	massive	non massive	Freight t.	massive	non massive	Freight t.
MABA	3,249,335	11,899,561	2,206,698	3,760,578	13,771,809	2,553,895	3,847,970	14,091,851	2,613,245
More 500.000 inhab	486,847	1,782,909	330,629	552,54	2,023,484	375,242	555,110	2,032,897	376,988
500.000 to 100.000 inhab	263,765	965,948	179,129	288,727	1,057,363	196,081	279,297	1,022,829	189,677
Less than 100.000 inhab	547,47	2,004,920	371,800	553,152	2,025,726	375,058	514,755	1,885,110	349,582
<b>Total cities</b>	<b>4,547,419</b>	<b>16,653,338</b>	<b>3,088,256</b>	<b>5,154,997</b>	<b>18,878,383</b>	<b>3,500,876</b>	<b>5,197,132</b>	<b>19,032,688</b>	<b>3,529,491</b>
Roads									
<b>Total countries roads</b>	<b>2,291,917</b>	<b>7,072,843</b>	<b>14,009,028</b>	<b>2,652,748</b>	<b>8,186,365</b>	<b>16,214,557</b>	<b>2,921,402</b>	<b>9,015,430</b>	<b>17,856,669</b>
<b>TOTAL</b>	<b>6,839,335</b>	<b>23,726,181</b>	<b>17,097,284</b>	<b>7,807,744</b>	<b>27,064,747</b>	<b>19,715,434</b>	<b>8,118,534</b>	<b>28,048,118</b>	<b>21,386,161</b>

**Table 15. Mean Mitigation Scenario for Cities and Interurban Corridors in Argentina.**  
 Source: author's elaboration



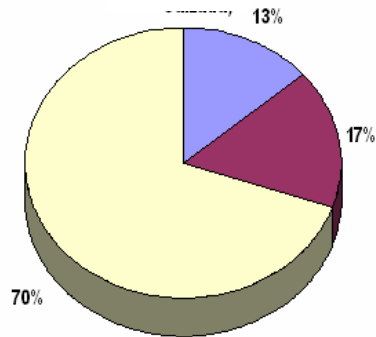
Measures	CO <sub>2</sub> Emissions reduction 2003- 2015 (in Millions of Tons/Year)	Marginal cost of emission reduction (Discount Rate of 10%)	Application of recommendation
Interurban corridor M1- Good practices	0.17	9	YES
Interurban corridors M2- Speed control	0.59	10	YES
Cities R1- M3 Good practices	0.75	15	YES
Cities R1- M4 Timetable for freight transport	0.50	17	YES
Cities R4- M3 Good practices	0.10	24	YES
Cities R3- M3 Good practices	0.06	28	YES
Cities R2- M3 Good practices	0.11	30	YES
Cities R2- M4 Timetable for freight transport	0.08	31	YES
Interurban corridors M3- Modal transference	0.78	82	NO
Cities R3- M4 Timetable for freight transport	0.04	156	NO
Cities R3- M2 Modal transference	0.02	419	NO
Cities R2- M2 Modal transference	0.03	1084	NO
Cities R2- M1 New technologies	0.02	2470	NO

**Table 16. Emission mitigation measures in interurban corridors and cities in Argentina listed according to marginal cost with a discount rate of 10% (U\$\$/Ton CO<sub>2</sub>).** Source: author’s elaboration

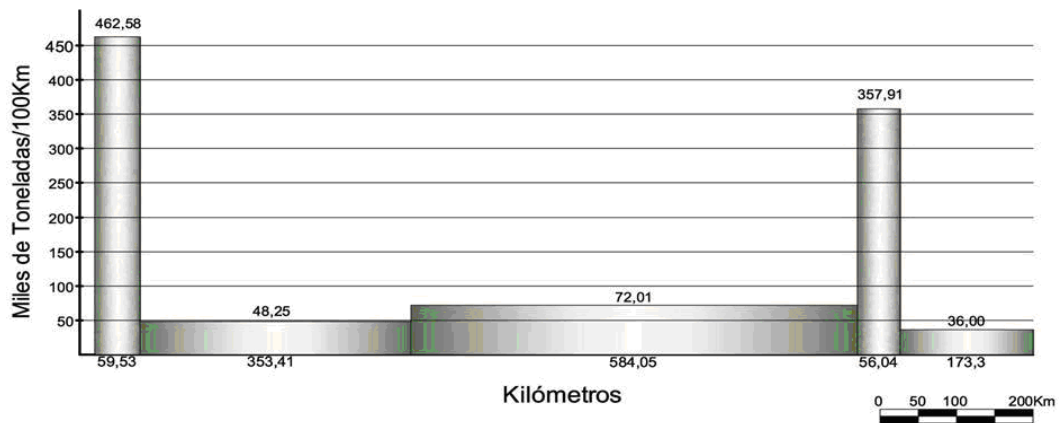


**Figures**

**Figure 1. Road Network Distribution by Jurisdiction and Road Surface Type**  
 Source: author’s elaboration

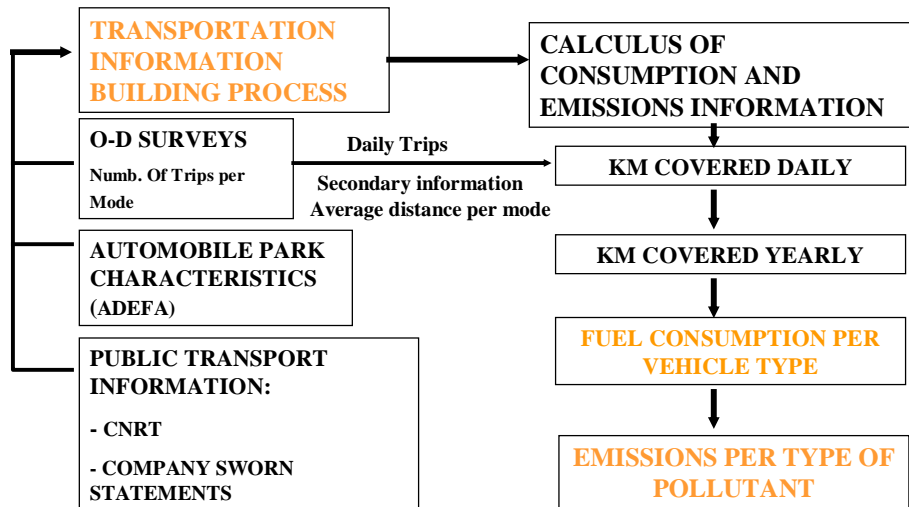


**Figure 2. Annual CO2 emissions in Thousands of Tn/ 100 km of National Road 7.**  
 Source: author's elaboration

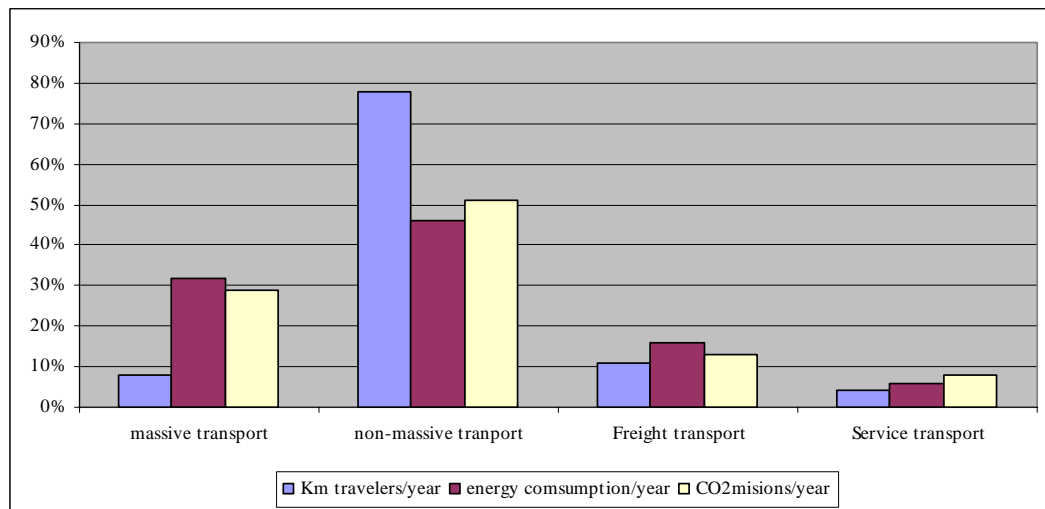


**Figure 3. Concentration of CO2 Emissions in Roads.**  
 Source: author's elaboration

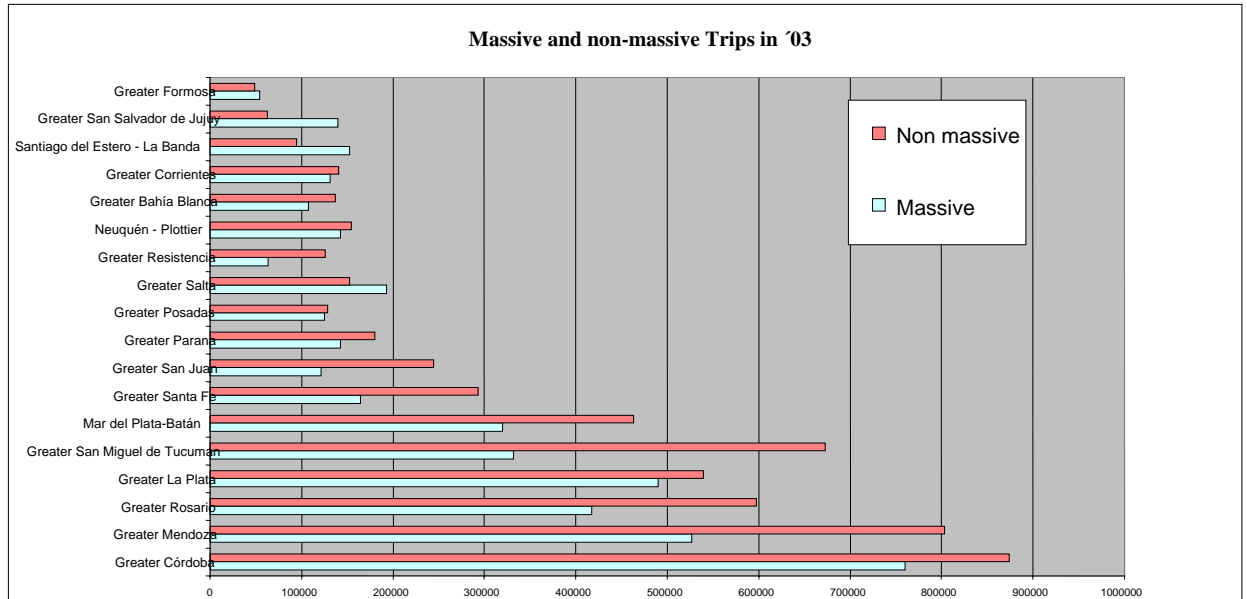
### Information Building Process



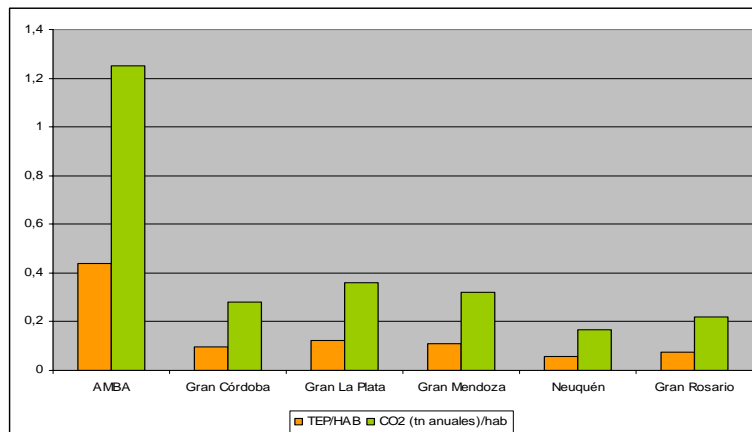
**Figure 4. City Transport Information Building Process** Source: author’s elaboration



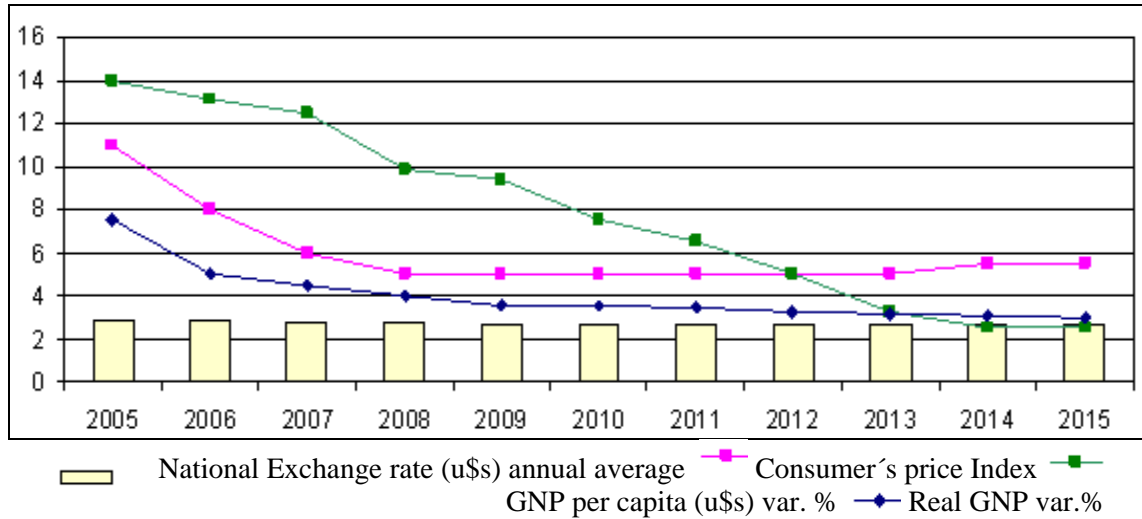
**Figure 5. Comparison between Percentages of km Covered, Consumption and CO2 Emissions.** Source: author’s elaboration



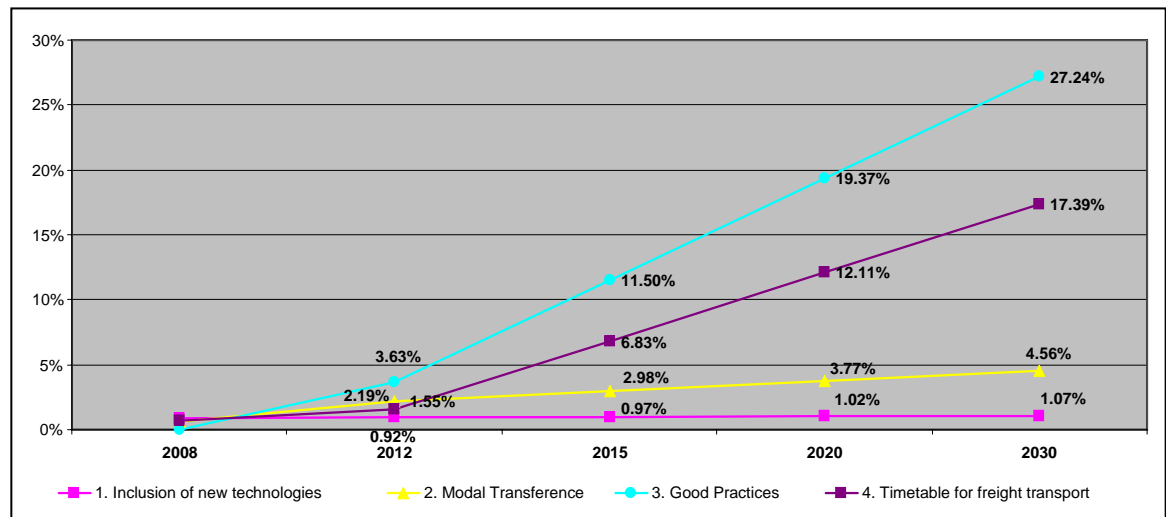
**Figure 6. Massive and Non-massive Motor Vehicle Trips in the 19 Cities with over 200,000 Inhabitants. Source: author's elaboration**



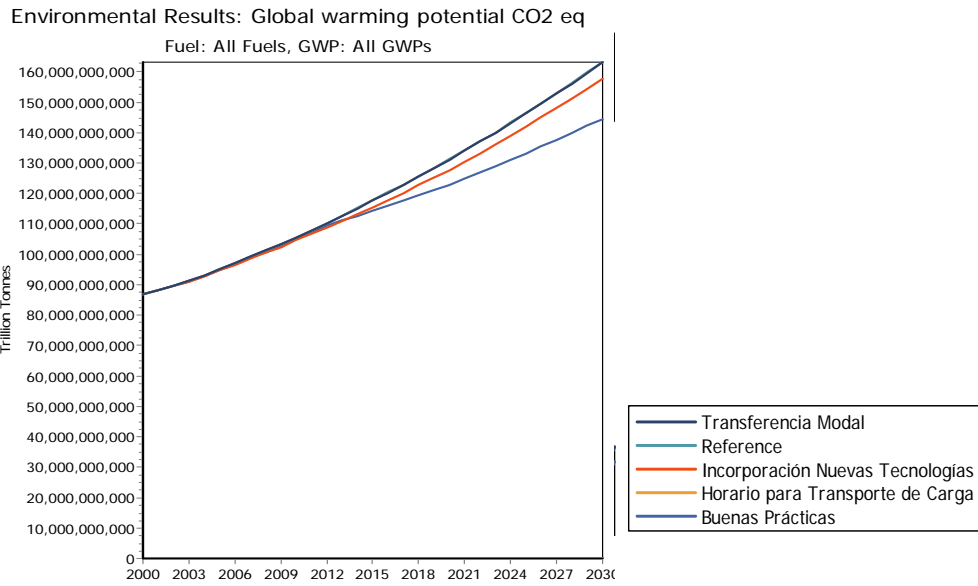
**Figure 7. Fuel Consumption and CO2 Emissions in Percentages for the Five Analyzed Cities. Source: author's elaboration**



**Figure 8. Tendencies of Main Variables in the Mean Scenario.** Source: author's elaboration



**Figure 9. CO<sub>2</sub> Emissions Reduction Percentage by Mitigation Measure. (2008-2030).** Source: author's elaboration



**Figure 10. Measures' impact on the urban centre.** Source: author's elaboration by use of the LEAP programme.