B−6 GREEN VEHICLE SCENARIOS IN MAJOR CITIES IN LATINAMERICA

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This paper proposes future transport scenarios for the potential reducion of GHG and air pollutant emissions when green vehicle technologies and alternative fuels are introduced in passenger automobiles, in 5 major urban areas in Latin America –Mexico City, Sao Paulo, Bogota, Lima and Santiago- by 2030. The Base Scenario considers that automobiles are fuelled by gasoline with no change in its composition but there are improvements in the current technology, in terms of fuel efficiency. Alternative scenarios (Green Transport) involve the introduction of new technologies and fuels –HEV, PHEV, BEV, FCV, Flex Fuel- based on specific conditions at country and city level, suitable for comparison purposes. The future vehicle fleet was calculated using historical data as well as the scrappage rate and new vehicle sales and is supposed to be the same for both scenarios. An additional analysis regarding the relationship between GDP per capita and vehicle ownership was also conducted. By using a bottom-up model and local emissions factors, mitigation of –CO_2, CO, NO_X, SO_X, HC, VOC, PM10- emissions were calculated for all the scenarios.

Key Words: *Green Vehicle, Alternative fuels, Passenger Automobile, tranport scenarios.*

1. INTRODUCTION

In the last few decades, Latin American countries have experienced a rapid growth reflected in a rising population and increasing migration to the cities. CAF (Banco de desarrollo de America Latina) reported that urban population in Latin America goes up to 80% and it is expected to reach 90% by 2030[1)–3)]. This rapid urbanization rate has increased transport demand and encouraged vehicle ownership which directly affects air quality and CO2 emissions. Dargay et al[4)] showed the positive relationship between vehicle ownership and income and pointed out that in developing countries, vehicle ownership increases as income raises until reaching a country-specific saturation level, still far in these countries. In the specific context of developing countries, Mazini et al[5)] analyzed the potential reduction of CO_2 emissions in passenger LDV (Light Duty Vehicle) in Mexico City from 2000 to 2030 and pointed out that if the motorization rate continuously increases, the vehicle fleet will become slighly less than double. Therefore, it is expected that a rapid increase in vehicle stock (~6% a year for Latin America[1)]) and travel demand will take place in the developing world. However, besides a growing vehicle ownership, Latin American vehicle fleet is modified by the addition of new vehicles to a fleet of aging old and poor maintained cars rather than the substitution of old vehicles for new ones increasing environmental burden[3)].

To counteract the environmental harm caused by a growing vehicle fleet and 100% dependency on fossil fuels, a set of alternative solutions have been considered and are grouped into three different strategies[6)]: 1. To avoid long and unnecessary motor vehicle trips, 2. To shift individual motorization towards transit, biking and walking, and 3. To improve vehicle and fuel technology. A mix of these measures matches the objectives of a sustainable urban transporation.

Based on these statements, the purpose of this research is to determine atmospheric emissions during vehicle operation in 5 major cities in Latin America: Mexico City, Sao Paulo, Bogota, Santiago and Lima. Vehicle and fuel technologies were only considered in this study. The calculation was based on a modeled vehicle fleet projected up to 2030 and future vehicle emissions were determined.

2. SCENARIO DEVELOPMENT

A prospective approach, using scenarios, aims to represent a possible evolution of vehicle fleet and its impact to support decision making[5),6)].In this research, a scenario-based approach was used to determine the potential emission reduction by the introduction of new vehicle technologies and fuels into the vehicle fleet. Two different scenarios were developed and applied to 5 Latin American cities as shown in Fig 1.

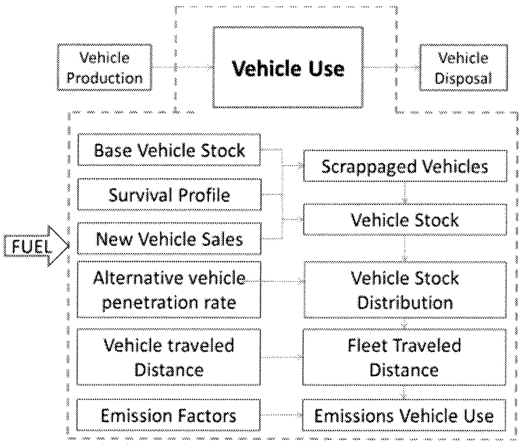

Fig 1. Methodology for scenarios calculation during vehicle operation[8)].

All scenarios were constructed and simulated in LEAP (Long-Range Energy Alternatives Planning Systems) which has been designed as an environment modeling tool for the evaluation of energy systems at national/regional level [8)]. This model has low initial data requirements and then, it is suitable for being used in the developing countries [5)].

(1) Scenarios

a) Baseline Scenario: Business As Usual (BAU)

For the BAU scenario, all automobiles run with gasoline in Internal Combustion Engine Vehicles (ICEV) with no change in gasoline composition. Improvement in fuel efficiency is considered based on the technological development of current devices and policy makers' intentions. **Table 1** summarizes the scenario assumptions.

b) Alternative Scenario: Green Vehicle (GRE)

As for the GRE scenario, new technologies are available on the market and are expected to be introduced into the new vehicle sales based on the different aspects: 1) electricity generation mix by country, 2) policies, 3) manufacturers and 4) other studies about future trends, technology maturity, infrastructure, etc.

(2) Future vehicle stock

The evolution of the on-road gasoline vehicle fleet can be estimated by Eq (1) :

$$N_{m,y,v} = S_{m,v} F_{m,y-v} \tag{1}$$

Where N is the stock or number of vehicles existing in a particular year, S are the sales and F is the survival profile of vehicle type m after a year y, of model year v (vintage).

The survival profile F is estimated by $F(t) = F(t-1)\, e^{Kt}$ where: $K = \frac{\ln F(t) - \ln(F(t-1))}{t}$. The value of constant K is obtained based on the age distribution of gasoline vehicles per city in different years. Vehicle stock was calculated for each city and considered same for all the scenarios.

Table 1. Scenario Assumptions

	BASE SCENARIO	ALTERNATIVE SCENARIOS
Title	Business As Usual (BAU)	Green Transport (GRE)
Target Year	2030	2030
Common Assumptions	• Passenger vehicles: Automobiles SUVs and Pickups based on data availability per city. • Vehicle stock is calculated and projected to 2030 and is considered the same. • Vehicle sales are assumed to be the same and are calculated based on historical data. • Other interventions such as Traffic Control Managament are not considered.	
Specific Assumptions	• All vehicles run with gasoline. • There is no change in gasoline composition.	• New technologies are available in the market: Hybrid Electric Vehicles (HEV), Plug-in Hybrid Electric Vechiles (PHEV), Battery Electric Vehicles (BEV), Flex Fuel Vehicles (FFV) and Fuel Cell Vehicles (FCV)

The relationship between vehicle ownership and GDP per capita was also calculated. The relation is obtained from Eq $V_t^* = \gamma e^{\alpha e^{\beta GDP_t}}$. Where V_t^* is Long-run equilibrium level of the vehicle per capita ratio. GDP is the income per capita, γ is the saturation level and α and β are negative parameters defining the curvature of the function. A delay parameter must be also included to take into account the time lag in adjustment to the increase of GDP per capita, as shown is -$V_t = V_{t-1} + \theta(V_t^* - V_{t-1})$, where θ is the speed of adjustment and the range of -θ $0 < \theta < 1$ [4]. However, this model is used only for comparison purposes and its results are not actually used during the scenarios simulation.

(3) Air emissions calculation

Annual emissions of air pollutants can be estimated by Eq (3) and Eq (4). The target pollutants are: carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), total hydrocarbons (HC), volatile organic compounds (VOC), and particulate matter smaller than 10 µm (PM10). Carbon dioxide (CO_2) is calculated as the main greenhouse gas (GHG), based on Eq 5.

a) Distance-based emissions

Eq 2 is shown as follows:

$$Emissions_{t,y,v,p} = Stock_{t,y,v} \cdot Mileage_{t,y,v} \cdot EmissionFactor_{t,v,p} \cdot EmDegradation_{t,y-v,p} \quad (2)$$

where *'Stock'* is the number of vehicles in a particular year, *'Mileage'* is the annual distance traveled per vehicle and *'EmissionFactor'* is the emissions rate for pollutant p for new vehicles of vintage v. *'EmDegradation'* is the factor representing the change in the emissions factor for pollutant p as a vehicle ages[9].

b) Energy-based emissions

Eq 3 is shown as follows:

$$Emissions_{t,y,v,p} = EnergyConsumption_{t,y,v} \cdot EmissionFactor_{t,v,p} \cdot EmDegradation_{t,y-v,p} \quad (3)$$

where *'EnergyConsumption'* is estimated by the below Eq. 4:

$$EnergyConsumption_{t,y,v} = Stock_{ty,v} \cdot Mileage_{t,y,v} \cdot FuelEconomy_{t,y,v} \quad (4)$$

where *'FuelEconomy'* is considered as the fuel use per unit of vehicle distance traveled.

3. RESULTS

(1) Vehicle Stock

The estimated passenger vehicle fleet size by 2030 is summarized in **Table 2**. The base year was selected regarding the available data. Bogota's vehicle fleet increased 2.87 times from 1.07 million units in 2009 to 3.072 million vehicles in 2030; leading the list with the fastest growth. This can be explained by the average age of vehicles.

Table 2. Comparison of vehicle stock base year and 2030

City	Base Year	Vehicle Stock [thousand units]	
		Base Year	2030
Mexico	2002	2.906	5.324
Sao Paulo	2010	5.440	10.190
Bogota	2009	1.070	3.072
Santiago	2012	1.394	2.127
Lima	2003	851	1.407

As for the vehicle ownership method, the model was run for Mexico City and shows that the vehicle fleet will reach 5.9 million of vehicles.

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