Environmental impact due to automobile use[♦]

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Abstract

The first goal of this article is to analyze the effect of household composition on the projection of the automobile fleet due to demographic changes that have been occurred. In order to determine this effect, the projection of the number and composition of Brazilian households (Fioravante, 2009) is used to make the projection of the automobile fleet a function of mortality, fertility and nuptiality rates. The observed number of automobiles is compared with projected fleet to determine the magnitude of demographic effects on automobile fleet and measure the environmental impact due to automobile use. Between 2000 and 2050, the population will rise 3.1%; while the number of households will rise 37.8%. The forecasted fleet of Belo Horizonte will rise until 2035, reaching 743214 automobiles. In 2007, the observed fleet already corresponded to 730468 automobiles, indicating the additional effect of others variables, for example, the economical ones. However the environmental impact did not occur with the same intensity, because some old vehicles were substituted by new ones that have lower emission of pollutants.

Key words: automobile, household projection, ProFamy

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1. Introduction

The household is influenced by transformations that occur in the population and can be related to economical and cultural values of society referring to familial life and also to demographic components: fertility, mortality and migration. According to Vos & Palloni (1989), the demographic factors are determinants for the rules of household formation/dissolution and for the availability of kin that can cohabitate in a household. For example, the fertility determines the level of reproduction, the distribution of children and indicates how the average number of siblings responds to this behavior, i.e., the number of siblings that each child will have opportunity to live together (Cavenaghi & Goldani, 1993). Even a cultural rule has been strictly followed; variations of the demographic rates will contribute to the variability in the household formation (Hammel, 1984).

The fertility has had a fast and widespread decline in Brazil, the number of offsprings per woman, at the end of reproductive period, reduced from 6.2 children to 2.4 children between 1940 and 2000 (Simões, 2006). At the same time, the life's expectancy at birth was around 60 years in 1950, but it has increased almost 10 years during the last fifty years (Saad, 2006).

According to Stockmayer (2004), different household structures imply different household sizes; for example, fewer people per household imply an increase in the number of necessary housing units. Depending upon how those units are constructed, they can have large impacts on the environment once they can require more land, more building materials, and more infrastructures to support new neighborhoods, for example, the collect of garbage by trucks. So the declining rates of the population can't be considered the only solution to reduce the environmental impacts, because the number of households has increased more than the number of people (Hogan, 2005). Besides that it's necessary to consider the consumption pattern that has been changing. Brazilian people have substituted their consumption goods at time intervals shorter than in the past (Rydkewski, 2007). Ten years ago, the cellular telephone and the computer were substituted by new ones every three years and every five years respectively; but they have been now substituted every year and every two years respectively. Surprisingly, the automobile was substituted by a new one every eight years, but it has been substituted every four years nowadays.

Considering that the automobile has a significant contribution to the pollutants emissions at the metropolitan areas (Companhia de Tecnologia de Saneamento Ambiental, 2008), the projection of the number of automobiles was calculated for the period from 2000 to 2050. For this projection, it was used the projection of household composition because this composition is

associated with the automobile ownership (Fioravante, 2008; Pfeiffer & Strambi, 2005; Prskawetz, Leiwen & O'Neill, 2004). In this manner, it is possible to analyze the effect of demographic changes on the increase of the number of automobiles.

Prskawetz, Leiwen & O'Neill (2004) observed that demographic characteristics of the households can produce important effects to the overall demand of the automobiles, through the combined effects of differences of the automobile demands (based on the household type) and changes of the population composition in the future (also based on the household type). Considering the household head, both the automobile ownership and the automobile use have the similar standard: there is an increase until the intermediate ages and a decrease after these ages. The household size affects directly the automobile ownership and use; part of this effect reflects the age effect. According to Prskawetz, Leiwen & O'Neill (2004), this can be explained as follows: households of smaller size are most likely of being commanded by younger or older persons than by persons with intermediate ages; once the automobile ownership and use are low for younger and older persons. Fioravante (2008) used the logistic regression model to analyze the association between the social-economic and demographic variables (specifically age and sex of household head, household size, household income) and the number of automobile per household in Belo Horizonte (Brazil), using the census data of 2000. Household income is an important variable, but age and sex of household head are also important, besides the household size.

The available data related to the pollutant emissions of carbon monoxide and hydrocarbons for the automobile fleet (Dutra, 2007; Brasil, 2006) were primordial to analyze the environmental impact of automobile use in Belo Horizonte (Brazil).

2. Methodology

It was used a multidimensional model developed by Yi (1991) to project the number and composition of households in Belo Horizonte by household size, marital status and age of reference person. This model considers the interdependence between demographic events, because it analyzes the familial dynamic and the demographic processes that occur into the familial context. For this model, it is necessary to prepare the input data standard schedules: probability of surviving, mortality rates at open-ended age interval, age-sex-specific rates of marital/union status transitions, age-parity-specific fertility, net rates of leaving parental home,

net rates of external migrations; besides the summary measures, for example, life expectancy at birth and fertility rates.

The data of demographic census of 1991 and 2000 and of PNAD's (household survey) of 2004 and 2005 were used to estimate, among numbers of rates, those related to the rates of marital transitions and the event of leaving parental home respectively. The projection of household composition in Belo Horizonte was obtained by Fioravante (2008) who used the ProFamy software developed by Zeng Yi.

For the household projection until 2050, three hypotheses were adopted: the mortality rates will decrease after 2000, the general fertility rate will be maintained constant and equal to 1.49 children, and the number of net migrants will be maintained null after 2010. At the first moment, the negative rates of net migration were maintained constant after 2000; however the reduction of the number of habitants became improbable. Since the rate of net migration is negative and the fertility rate is below the reposition level, it is reasonable to think that the net migrant number will be null in the future, because the city will become more attractive, since the city hall will have a better condition to offer good services.

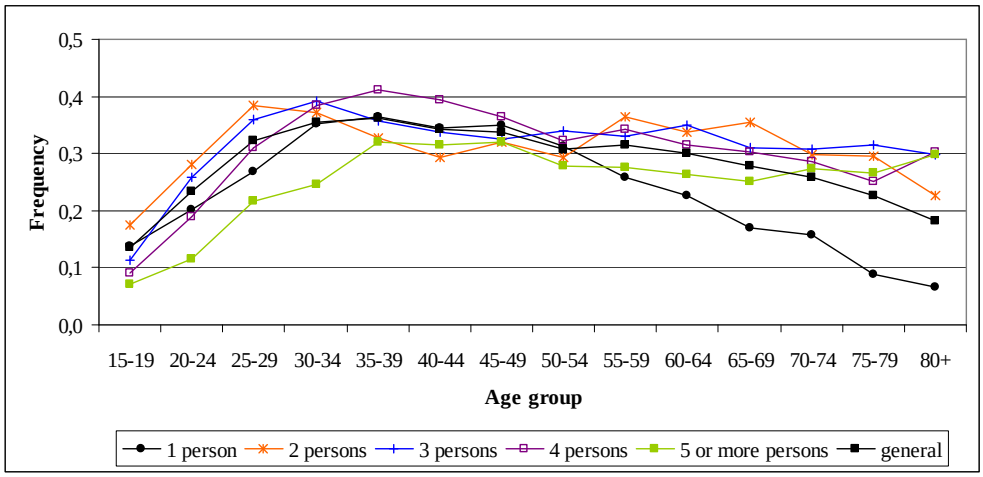
The frequencies of automobiles by age of the reference person and size of household were calculated using the census data of 2000. These frequencies were multiplied by the composition of households projected from 2000 to 2050, as it can be visualized in the following equation:

$$Total\quad of\quad automobiles^{k} = \sum_{i=15}^{100}\sum_{j=1}^{5+}\left(\frac{Total\quad of\quad automobiles}{Total\quad of\quad households}\right)_{ij}^{2000} * \left(Total\quad of\quad households\right)_{ij}^{k}, \qquad (1)$$

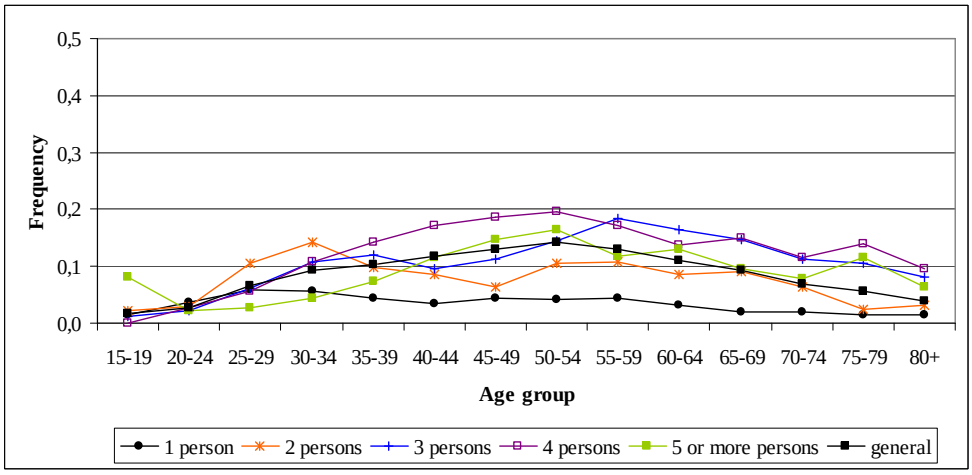
where indexes "i" and "j" represent the age of the reference person and size of household, respectively, every quinquennium "k". The first term of the multiplication represents the observed frequency of automobile ownership in 2000 by household; the second term represents the number of households of size "j" and whose reference person belongs to group of age "i". In 2000, the frequencies of households that had one automobile, two automobiles, three or more automobiles corresponded to 31.6%, 9.9% and 2.6%, respectively.

The frequencies by size of household and age group of reference person can be visualized in the Graphic 1.

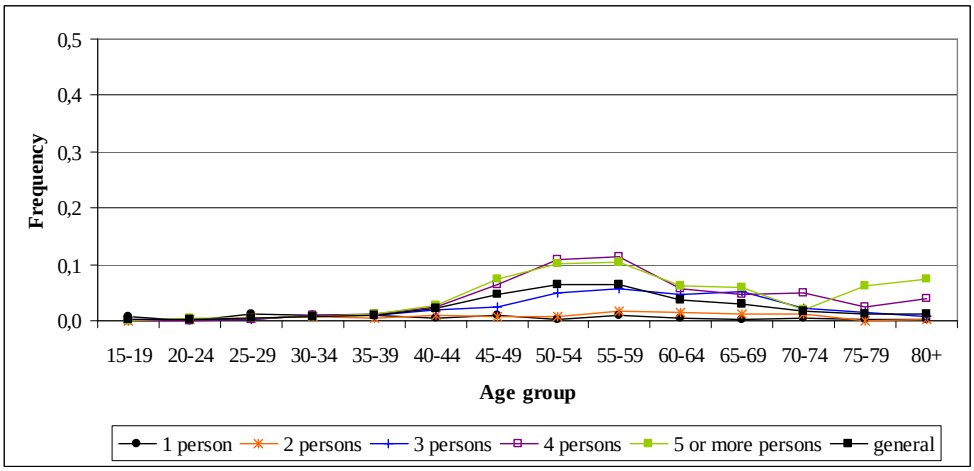
Graphic 1: Frequencies of households that have automobiles per age group of the reference person and size of household, Belo Horizonte, Brazil, 2000



a) One automobile per household size



b) Two automobiles per household size



c) Three or more automobiles per household size

Note: considering all the number of automobiles per household size (zero, one, two, three or more), the sum of frequencies is equal 1 for each age group.

Source: Demographic census of 2000, IBGE.

For the households that had one automobile, two automobiles, three or more automobiles, the general frequencies increase until group of age 35-39, 50-54, 55-59, respectively. Among the households with one person of age between 25 and 29 years, 27% of them had one automobile, 6% had two automobiles, 1% had three or more automobiles. This means that, amongst the households whose reference person belongs to the age group of 25-29, 34% of them had one or more automobiles.

The methodology most usual to calculate the emission of pollutants combines the variables: 1) total of automobiles of each type of fuel and year of manufacture, 2) factor of emission of the new automobiles, 3) factor of deterioration of the used automobiles, 4) the average number of kilometers driven by the owners of automobiles, as can be visualized at the following equation:

$$Emission = \sum_{fuel} \sum_{x=0}^{10+} N_{fuel,x} * FE_{fuel,x} * FD_x * D_x \ , \qquad (2)$$

where $N_{fuel,x}$ represents the number of automobiles of each type of fuel and age "x" (the year of the database supplied by the Transit Bureau minus the year of manufacture of the automobile); $FE_{fuel,x}$ represents the factor of emission of the pollutant by the automobile of each type of fuel and age "x"; FD_x represents the factor of deterioration of the used automobile of age "x"; D_x represents the average number of kilometers driven by the owners of automobiles of age "x" per day. The equation calculates the total of each pollutant that is emitted by the automobile fleet per day, i.e., considering the use of all the automobiles in the same day.

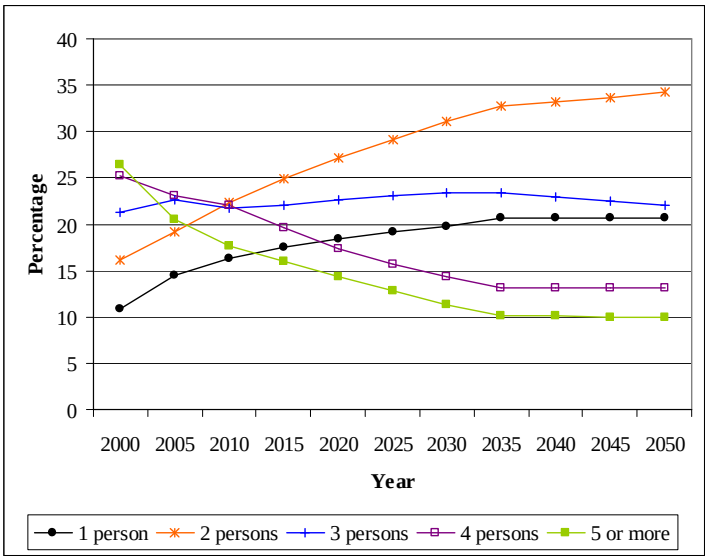
The emission of each pollutant represents the total of pollutant launched into the atmosphere by all the automobiles of the fleet in Belo Horizonte per day. In spite of the fact that the emission calculated does not correspond completely to the reality, this methodology has the advantage of comparing the potential of emission of each fleet, because it considers the distribution of fleet by age as well as the average number of kilometers driven by the owners.

3. Results

Between 2000 and 2050, considering the hypotheses that the mortality rates will decrease, the total fertility rate will maintain 1.49 children by woman and the number of net migrants will be equal zero after 2010, the population will rise 3.1%; while the number of households will rise 37.8%. In 2050, Belo Horizonte will have a big proportion of married

people, aged 65 or older, probably due to the lower mortality rates that can be contributing to the old couples to live together for a long time. From 2000 to 2050, the number of households of size one will rise from 10.9% to 20.7% and the households of size two from 16.2% to 34.2%; while the proportion of households of size three will be remained practically constant (23%) and decreasing the proportion concerning the biggest households (Graphic 2).

Graphic 2: Distribution of households by size, Belo Horizonte, Brazil, from 2000 to 2050

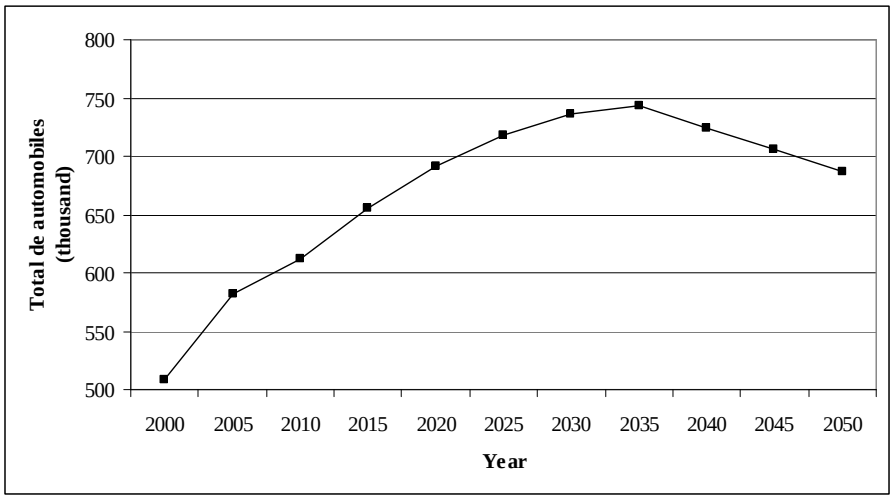


Source: Demographic census of 2000 (IBGE).

In a generalized manner, it can be said that the smaller households tend to have older reference persons throughout the period of projection. According to Kobrin (1976), the households of size two tend to be an empty nest, i.e., a household comprised of an older couple whose child left the household.

To evaluate the influence of the change of the household composition, the standard of automobile ownership observed in 2000 was used. The projected fleet of Belo Horizonte will rise until 2035, reaching 743214 automobiles, as can be visualized in the Graphic 3. After 2030, the proportion of small households (households comprised of one or two people) becomes bigger every quinquenium. Since a great part of these households are comprised of older people, the projected automobile fleet diminished after 2035, because the automobile ownership by old people is smaller than by young people.

Graphic 3: Projected total of automobiles, Belo Horizonte, Brazil, from 2000 to 2050



Source: Demographic census of 2000 (IBGE) and database supplied by the Transit Bureau of Minas Gerais state.

Table 1 shows the projected number of households and automobile fleet since the year 2001 until 2007 as well as the observed number of automobiles.

Table 1: Projected number of households and automobiles, Belo Horizonte, Brazil, 2001-2007

Year	Projected number(1)		Observed number of automobile(2)
	Household	Automobile	
2001	664438	536060	532747
2002	673774	541680	552626
2003	684079	547343	580706
2004	693940	552561	601962
2005	702907	557010	628303
2006	710758	560678	673301
2007	717199	564430	730468

1) Demographic census of 2000 in starting year, IBGE.

2) Transit Bureau of Minas Gerais state.

The increase of the projected automobile fleet is smaller than the increase of the observed fleet for the period from 2000 to 2007. The recent increase of automobile fleet has been attributed to the economic development and the easiness of financing the purchase of new or used automobiles. However, the increase of the environmental impact doesn't have the same intensity, because the increase of the automobile fleet in Belo Horizonte is due to the acquisition of new automobiles, whose factors of pollutant emissions are lower than the factors of the used automobiles (Brasil, 2006). The total emission of carbon monoxide by the automobile fleet of

Belo Horizonte in 2007 (186.3 ton/day) is about 74% of that in 2000 (250.4 ton/day). The total emission of hydrocarbons by the automobile fleet of Belo Horizonte in 2007 (21.6 ton/day) is about 78% of that in 2000 (27.6 ton/day).

4. Conclusion

In general lines, the results are in congruence with literature about the subject. Considering the hypotheses that the mortality will reduce, the total fertility rate will maintain 1.49 children by woman and the number of net-migrants will be equal zero after 2010, the population in Belo Horizonte will rise 3.1%; while the number of households will rise 37.8%. The population pyramid will have a reduction of the base, i.e., a reduction of the proportion of young people. In 2050, Belo Horizonte will have a big proportion of married people, aged 65 or older, probably due to the lower mortality rates that can be contributing to the old couples to live together for a long time. From 2000 to 2050, the number of households of size one will rise from 10.9% to 20.7% and the households of size two from 16.2% to 34.2%; while the proportion of households of size three will be remained practically constant (23%), and decreasing the proportion concerning the biggest households.

To evaluate the influence of the change of the household composition, the standard of automobile ownership observed in 2000 was used. The forecasted fleet of Belo Horizonte will rise until 2035, reaching 743214 automobiles. In 2007, the observed fleet already corresponded to 730468 automobiles, indicating the additional effect of others variables, for example, the economical ones.

From 2000 to 2050, it was used the same frequencies of automobiles per household composition observed in the demographic census of 2000. However, the results indicated the necessity of actualizing those frequencies what it will be possible with the data of demographic census of 2010. The constant frequency of automobile per household ignores that the youngest generation will have a greater necessity of the automobile in the future than the younger generation nowadays. On the other hand, the limitation of flow of automobiles on the streets, because of this extraordinary growth of the fleet of automobiles, can reduce the utility of the automobile. Due to limitation of flow of automobiles or economic factors, the increase of motorcycle fleet in Belo Horizonte has been bigger than the automobile fleet since 2000. According to Transit Bureau database, the number of motorcycles increased from 48415 to 113928 motorcycles between 2000 and 2007.

Between 2000 and 2007, the potential of the environmental impact caused by the automobile fleet diminished due to both emission of carbon monoxide (-26%) and hydrocarbons (-22%). This happened because part of the increase of the fleet was compensated by the reduction of the number of old automobiles that present the biggest emission factors. This last analysis can be considered an example of the model considered by Boserup (1981) that incorporates the technology level component in relation to the model considered by Malthus for the theory of the development.

For the future, a big reduction of the pollutant emission is not expected because of the technology limitation of the motors that uses alcohol, gasoline or diesel. A possible solution is to invest in public transportation or to use a new kind of fuel, for example solar energy. Besides the atmospheric pollution and the global heating, areas with vegetation and areas destined to the population conviviality have been reduced or eliminated to keep the flow of the vehicles at a satisfactory level.

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