Original Research Article

VEHICULAR FLEET EXPANSION AND ACCIDENTS VARIATION NUMBERS: A CONTRIBUTION TO THE ANALYSIS OF THE D.PEDRO I-TAMOIOS EXPORTER ROAD AXIS

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ABSTRACT

Aims: This paper aims to analyse the evolution of the fleet of vehicles on the D. Pedro I Export Corridor Axis, in the period 1998-2016 and its potential relationship with vehicle accident mortality rates with two municipalities cut by this route - Atibaia and Caraguatatuba.
Study design: The focus was to investigate to what extent the intensification of the current fleet can be related as a factor directly responsible for the increase of the occurrence of accidents, using as an indicator for this measurement the mortality rate due to accidents of Traffic.
Place and Duration of Study: Study realized in São Paulo State, Brazil, for 36 months, from July 2015 to July 2018. The data used and analysed to diverse indicators were from 1998 to 2016.
Methodology: The methodology for the analysis of the intensification of the current fleet in the studied region was based on the comparison between the evolution figures of the fleets and the mortality rates due to transport accidents. In this way, all values were arranged on an identical horizontal axis (referring to the years), to show possible correlations.
Results: The relationship between the circulation fleet increase and the increase of accidents represents the negative impact of the processes of social and environmental changes that are occurring in the region. These processes link urbanisation, risks and vulnerability due to the lack of adequate urban planning and road safety infrastructure that exposes the population of these municipalities to a higher risk of accidents.
Conclusion: The data on the evolution of vehicle fleet in the exporting Corridor unequivocally evidences an accelerated urbanisation process, while mortality rates indicate the absence or inefficiency of public sector-oriented police and the health of the population, which hinder this process and may indicate negative impacts on society as a whole.

Keywords: Vehicle fleet, Mortality rates, Vehicle accidents, Exporter Road Axis, São Paulo, Brazil

1. INTRODUCTION

The Export Hub Campinas - São Sebastião is a corridor to transport, through highways, import and export products of the Campinas region and of the entire Interior of São Paulo State, which arrive at Viracopos International Airport and to receive and distribute goods arriving by São Sebastião Port [1-2]. Its composition includes three important state highways: Dom Pedro I Highway (SP-65), Carvalho Pinto Highway (SP-70) and Tamoios Highway (SP-99). The location of the three highways can be identified in Figure 01.

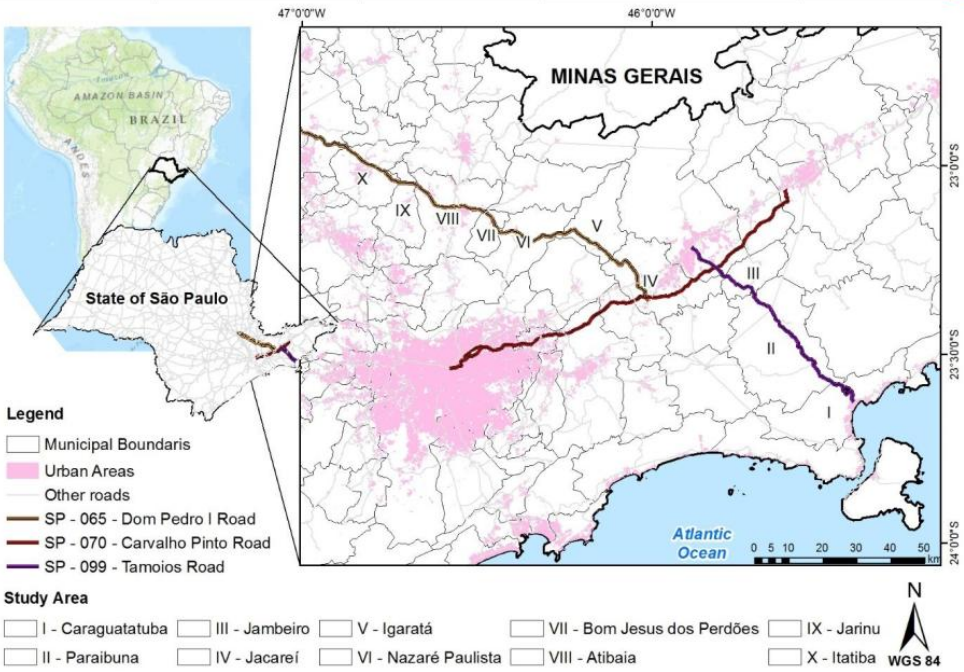

Figure 1: Location of highways belonging to the Campinas - São Sebastião export corridor

Source: Seixas et al (2016) [33]

As can be seen in Figure 1, the axis connects the interior of São Paulo state (SP-65 left end) with the São Paulo coast (SP-99 right end), making it possible to flow products and the same occurs in in the opposite direction, that is, from the coast to the interior of the state.

Atibaia is located in the central region of SP-65 - municipality VIII, while Caraguatatuba is on the right-hand end of SP-99 - municipality I (Figure 01). The analysis of the transformations occurring in municipalities located in different portions of the export corridor allows to investigate the influence of the dynamics of this corridor in the promotion of changes with a similar profile in both municipalities.

1.1 The Road Axis, Transport and Accident Mortality: a brief analysis

The transport sector, responsible for the movement dynamics of people and cargoes, is closely related to the promotion of various social and environmental impacts, of different natures. Among the most evident and most approached by authors who deal with this subject, we highlight factors such as air pollution, accidents, congestion and noise [3-4-5]. It can also address greenhouse gas emissions [4-5] and the generation of solid waste [3-4]. It is a series of problems that directly affect people's lives, including deaths and different and significant pressures on health sectors, facilitating the perception of these impacts by society [6].

Other effects caused by the transportation sector also represent important socio-environmental issues, such as the intensive use of natural resources (oil, metals, etc.), land use and occupation and the so-called "barrier effect", a phenomenon whose impact on life occurs indirectly [3-4]. The "barrier effect" is indicated as the effect caused by the presence

of elements in the urban environment, natural or not, capable of preventing or restricting the displacement and movement of people. These elements may be, for example, an extensive real estate development, a broad avenue or a large river. Some authors consider the understanding of "barrier effect" also applies to the existence of vast distances between different locations [7].

Also noteworthy is the reduced accessibility facing socially disadvantaged populations. The difficulty of mobility faced by these groups reduces their ability to participate in social activities satisfactorily; contributing directly to a scenario of social exclusion [8].This lack of accessibility generates a scenario of spatial and temporal population segregation. It is possible to identify a direct link between high vulnerability groups and the lack of access to urban equipment's that these people face. In this way, this impediment to accessibility can contribute directly to the quality of life reduction of those whose process of displacement is substantially restricted [7].

Another critical effect to be considered is the participation of the transport sector as one of the leading human activities associated with the emission of greenhouse gases (GHG) and climate change. For some authors [9], emissions and removals of GHG are compartmented in 4 main sectors - Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry and other Land Use (AFOLU); and Waste, and the transport scope being configured as a category belonging to the Energy sector [9]. Other authors [10] who work directly with a more significant number of more specific emission sources suggest six primary sources: "transport", "agriculture", "energy (electricity and heating) "Industrial processes and product use", "residential" and "residues", and the large-scale biomass burning was not considered in this case because it was not contained in the database used by some authors [10]. In an author case [11] three main categories of emission sources were considered, one of them being the "production and use of energy", within which the transport sector resides as a subcategory.

Regarding the issue of accidents, it should be pointed out that most of the occurrences on the road occur in urban areas, much in function of the complex driving environments and the large number of vulnerable users who use these urban roads [12-13-14]. As for the factors that contribute most to the occurrence of road accidents, issues such as inexperience, lack of ability and risk behavior, alcohol and drug use - in the case of collisions involving young drivers - and reduced visual capacity, cognitive and mobility - in the case of older drivers must be considered [15-16-17-18-19]. In addition, one can also point to the issue of speed as one of the variables most strongly related to the occurrence of accidents [20], as well as the increase in cargo fleets, especially of trucks, and of passenger vehicles [21] and by the construction of new highways and even duplication of already existing highways [3] facts observed in a significant way in the study area of this work.

In this article, the main objective was to investigate to what extent the intensification of the circulating fleet can also be related as a factor directly responsible for the increase of the occurrence of accidents, using as a substitute indicator for this measurement the mortality rate due to accidents of Traffic.

2. METHODOLOGY

The basic methodology for the analysis of the intensification of the current fleet in the studied region was based on the comparison between the evolution figures of the fleets and the mortality rates due to transport accidents. In this way, all values were arranged on an identical horizontal axis (referring to the years), in order to show possible correlations.

Concerning the mortality rates due to transportation accidents in Atibaia, Caraguatatuba and São Paulo state, they were obtained directly from the website of the State System for Data Analysis-SEADE [22]. Regarding the rates for Brazil, the calculations were made based on the absolute numbers of deaths due to transportation accidents at the Department of Information Technology of the Brazilian Unified Health System (SUS/DATASUS) [23], dividing them by the total population of Brazil in each year, according to the World Bank [24], and multiplying the result by 100,000 to match the base of municipalities' rates (deaths per 100,000 inhabitants).

Finally, data from the Dom Pedro I Highway fleet were obtained through the Department of Roads-DER [25-26] and the former concessionaire (DERSA) responsible for the administration of the highway during part of the period analysed [27]. In the case of the municipalities examined, the values referring to the current fleets were obtained from São Paulo State Environmental Agency-CETESB [28].

The data provided by the Highways Department of São Paulo State (DER), referring to Dom Pedro Highway's fleet, are in the format of Average Daily Volume (ADV), that is, they represent the annual average of the number of vehicles that went through each toll over the course of a day. For each toll, two ADVs are available, one for each direction of the highway.

The data treatment procedure to estimate the annual circulating fleet on the highway involves, firstly, the sum of the ADVs referring to the two directions of the Itatiba toll. Then the value found - which represents the average annual number of vehicles travelling at that point on the highway for one day - was multiplied by the number of days in a year (365).

The data provided by CETESB for the state of São Paulo's circulating fleets show values that reflect the number of new vehicles sold, subtracting the estimate number of vehicles that left circulation by scrapping. These figures are presented by year (from 1977 to 2016), by vehicle type (gasoline car, ethanol car, flex-fuel car, etc.) and by municipality (Atibaia, Caraguatatuba, etc.).

The estimation of the current fleet of the two municipalities reflects the sum of these values (new vehicles sold minus scrapped cars) for each city, from 1977 to the year corresponding to the estimated value. In the case of the state fleet, the estimate reflects the sum of the values of all 645 municipalities in the state.

3. RESULTS AND DISCUSSION

3.1 Variation of the circulating fleet and the mortality rate due to traffic accidents

Air pollution refers to vehicular emissions linked to pollutants harmful to human health, such as carbon monoxide (CO), hydrocarbons, nitrogen oxides (NOx) and others [29], representing critical environmental impacts of local and regional character. The emission of Greenhouse Gas (GHG) in the transport sector (mainly CO2 - carbon dioxide), mostly from the burning of fossil fuels, is related to global impacts such as climate change and global temperature rise [30-31].

Regarding the region of this study, it has presented in the last decades a significant increase in the circulation of vehicles. It can be observed that, for the period 1998 to 2016, this increase was practically 100% in the Dom Pedro I Highway, according to Figure 2, which shows the current fleet counted in one of the highway tolls (Itatiba toll).

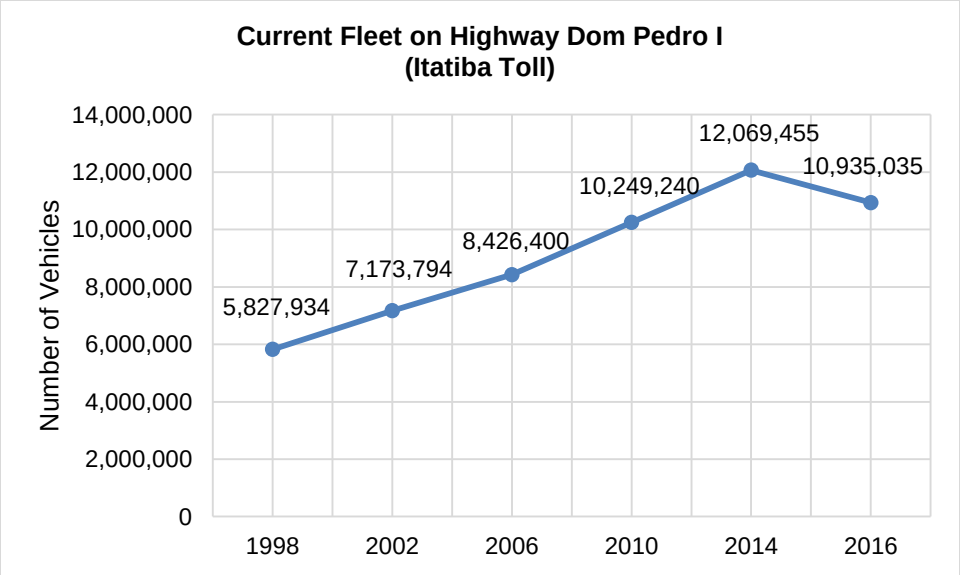

Figure 02: Current Fleet on Highway Dom Pedro I (Itatiba toll)

Source: DER, 2019; DER, 2014; DERSA, 2013 [25-26-27]

It is noted that the intensification of the circulating fleet observed on the highways may be related to a much greater percentage increase in the number of vehicles circulating within the municipalities transposed by these highways. Two symptomatic examples are the municipalities of Atibaia and Caraguatatuba, transposed by the Dom Pedro I and Tamoios highways, respectively, whose circulating fleets grew almost 700% in the same period analysed, as shown in Figure 3 and Figure 4 for São Paulo state.

There is a drop in the highway fleet in the period from 2014 to 2016 that seems to coincide with the reduction of the increase of vehicles in Atibaia and Caraguatatuba. This period is also marked by the intensification of the economic recession in Brazil and can be related to this fact a consequent reduction of the purchase of vehicles, reduction of the number of vehicles in the cities, reduction of the number of trips and of vehicles in the highways. This hypothesis will be discussed later, in the light of an economic indicator that can contribute to its validation - evolution of the total Brazilian GDP.

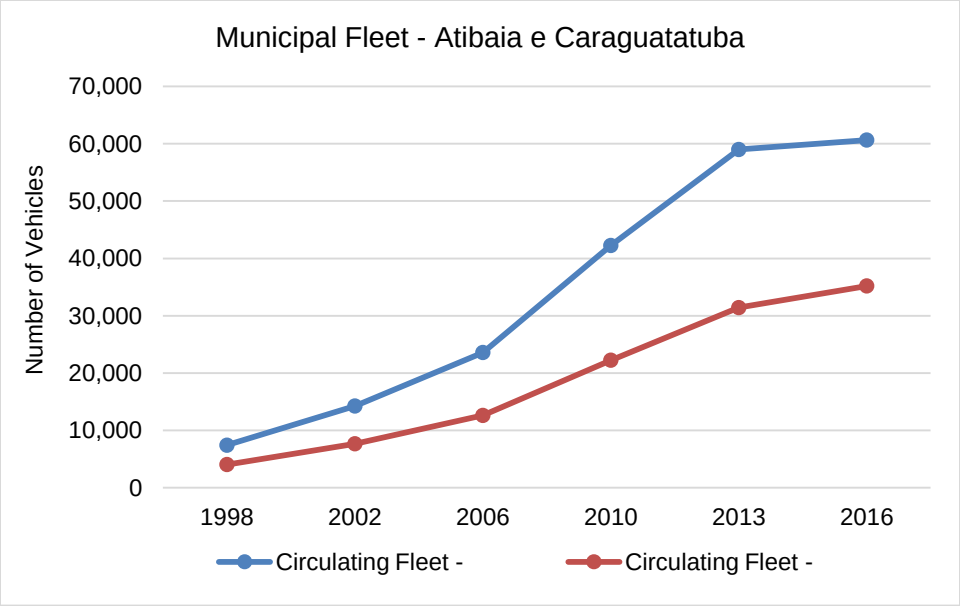

Figure 3: Circulating fleet in the municipalities of Atibaia and Caraguatatuba

Source: SÃO PAULO, 2019 [28]

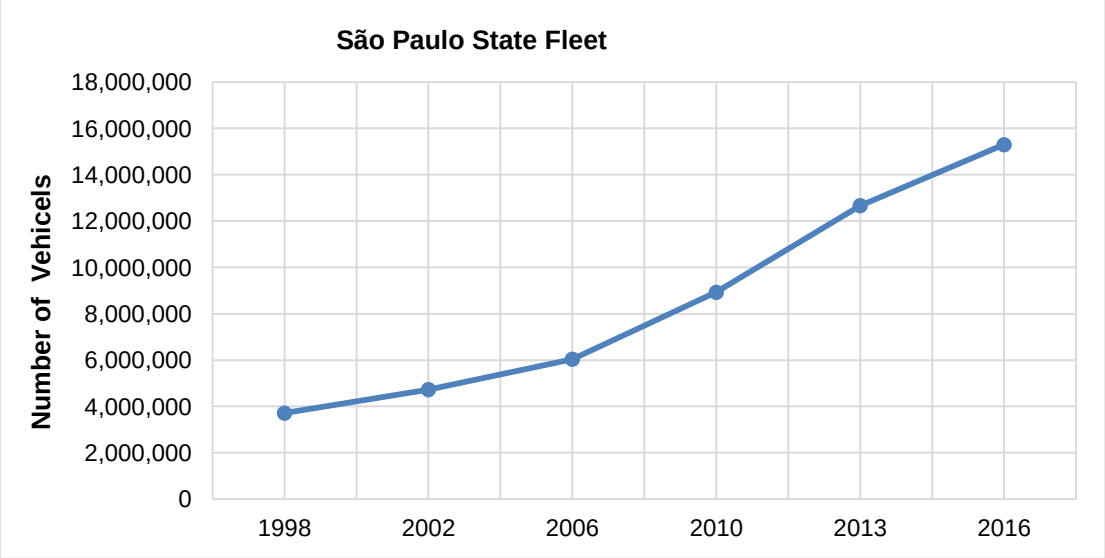

Figure 4: São Paulo State Fleet

Source: SÃO PAULO, 2019 [28]

This exponential growth of the current fleets within the municipalities belonging to the study area has a direct impact on the intensification of socioenvironmental problems related to urbanisation, industrialisation and the transport sector mentioned previously, such as air pollution, accidents, congestion, noise, solid waste generation and others. Among the main possible correlations to be built from the increase in the current fleets is the evolution of death rates caused by transport accidents. Figure 5 shows the mortality rate due to

transportation accidents per 100,000 residents of the municipalities of Atibaia and Caraguatatuba, which are directly related to the expansion of the highways and consequently to the increase of the fleet.

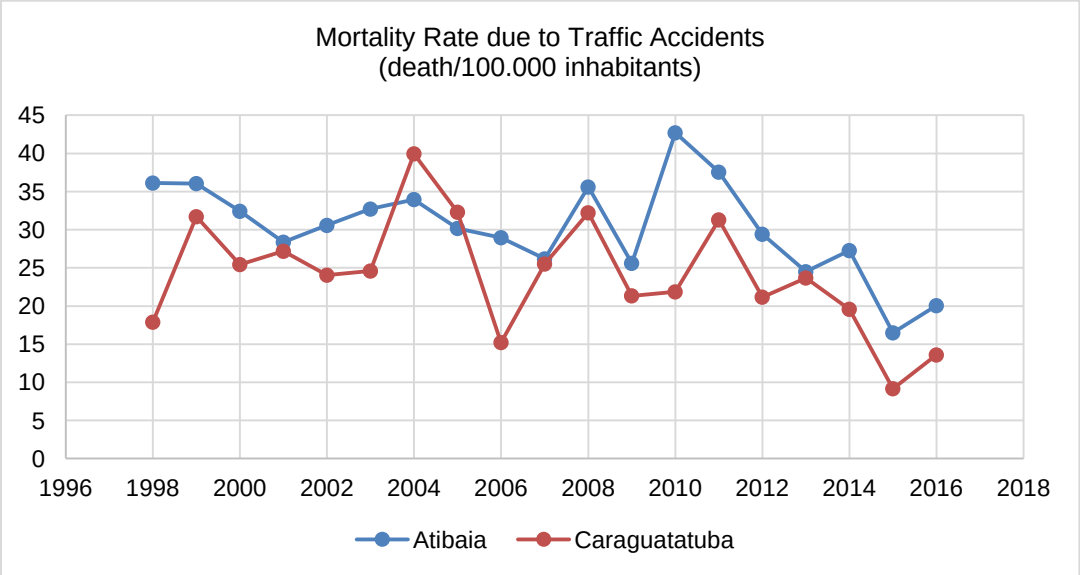

Figure 5: Mortality rate due to traffic accidents - Atibaia and Caraguatatuba.

Source: SEADE, 2019 [22]

The mortality curves for transportation accidents in the analysed municipalities do not behave precisely according to the evolution of their current fleets, as shown when crossing the information from Figure 5 with Figure 3. This behavior is natural to the extent that other variables, in addition to the existing fleet volume, also influence the mortality rate due to transportation accidents, for example, public policies to promote traffic accident prevention. However, there is a specific period of analysis that seems to allow the construction of a stronger correlation. The three evolution curves of the current fleet (Dom Pedro Highway, Atibaia and Caraguatatuba Municipalities) showed their central intensification as of 2006, a variation similar to that observed in the mortality rates due to transportation accidents (Atibaia and Caraguatatuba municipalities), which also significant increases from 2006 and 2007.

Figure 6 shows the evolution of mortality rates due to transportation accidents in the state of São Paulo and Brazil. Brazil's traffic accident mortality rates were calculated from the absolute number of traffic accident deaths in the country [23] and the size of the Brazilian population each year [24].

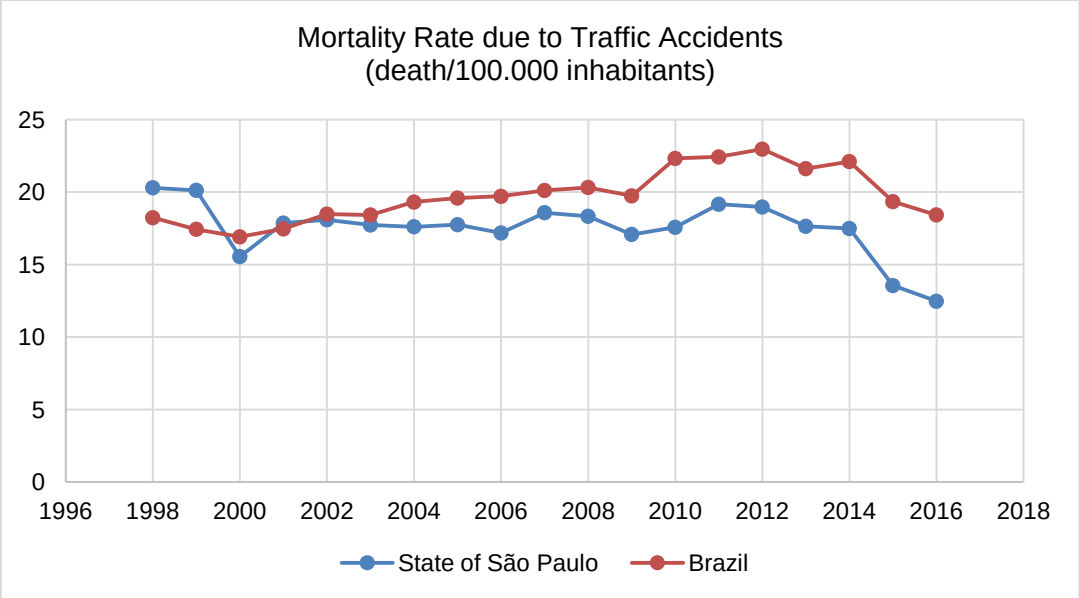

Figure 6: Mortality rate due to traffic accidents - State of São Paulo and Brazil

Source: SEADE, 2019; DATASUS, 2019; World Bank, 2019 [22-23-24]

Comparing the four curves (Figure 7), it is noted that the municipality of Atibaia has higher rates than the state and the country in almost the entire period analyzed, while Caraguatatuba is surpassed by them in some moments (1998, 2006, 2014 and 2015).

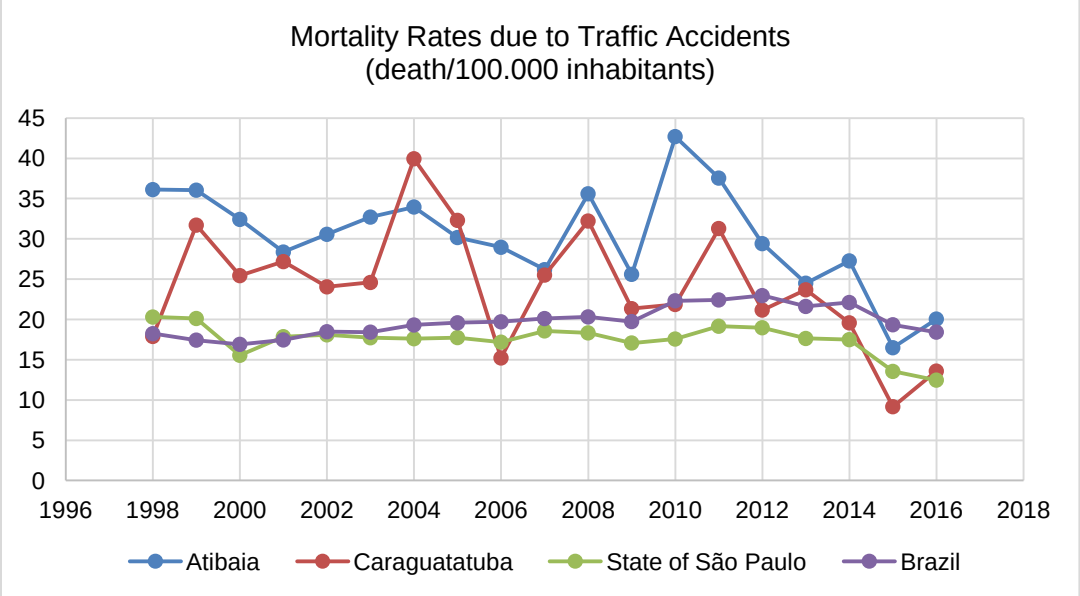

Figure 7: Mortality rate due to traffic accidents, Atibaia, Caraguatatuba, State of São Paulo and Brazil

SEADE, 2019; DATASUS, 2019; World Bank, 2019 [22-23-24]

Analysis of the data collected in the research allows inferring that, during the period investigated, there are no public policy measures that have resulted in a relative reduction of the mortality rate involving traffic accidents in Atibaia and Caraguatatuba. The principal reduction in the mortality rate of the series, observed since 2014 (in both cities, state and country - Figure 7), seems to have another motivation, as it finds a direct correlation with the reduction in the intensification of the circulating fleet in the cities (Figure 3) and with the decrease of the circulating fleet in the Dom Pedro Highway (Figure 2) - reductions also started in 2014. And this decrease in the number of vehicles circulating in the cities and on the highway, in turn, can be explained by the reduction in economic activity in the country, which, after 2014, shows the worst results in the series (-3.8% in 2015 and -3.6% in 2016 - Figure 8) [32].

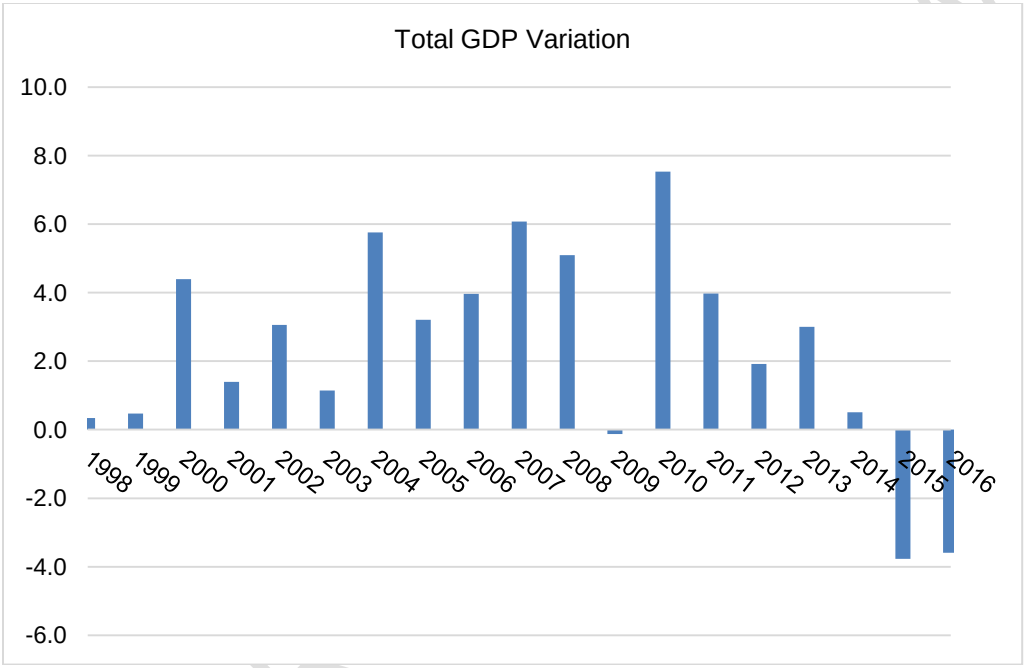

Figure 8: Evolution of the total Brazilian GDP variation

Source: Based on IBGE, 2019 [32]

Thus, the only significant reduction in road traffic fatalities observed in the series seems to be justified in reducing the number of vehicles added to the streets of the two cities from 2014, coupled with the poor economic performance identified in the country in 2015 and 2016.

4. CONCLUSION

The scenario of the study region has environmental and economic importance, related to the diversity of natural resources existing in these localities. On one hand, the north coast presents offshore reserves of natural gas and oil, as well as transport infrastructure, with the port of São Sebastião. It is located in the Serra do Mar, which constitutes an essential continuous fragment of the Atlantic Forest, considered one of the biodiversity hotspots. Although preservation efforts can be identified, it is recognized, due to the development model adopted, environmental issue conflicts with the construction and expansion of the road and port network and hydrocarbon exploration and production activities.

The model of economic development of the region results in population growth, urbanisation and disordered occupation where the new tourist developments and construction of vacation homes have been intensified. At the same time, the duplication of the highways Fernão Dias and D. Pedro I is related to the occupation process in the whole area, which has intensified drastically, allowing diverse impacts. The population increase has occurred in all municipalities in the region, especially in Atibaia, Itatiba, Jarinú and Bom Jesus dos Perdões. The duplication of the Fernão Dias - Dom Pedro I roadway facilitated that the residents of these municipalities, carry out their professional activities in the Metropolitan Region of São Paulo [33-34].

The data on the evolution of vehicle fleet in the exporting Corridor unequivocally evidences an accelerated urbanization process, while mortality rates for two of the municipalities - Atibaia and Caraguatatuba - considered exemplary in all the towns studied, indicate the absence or inefficiency of public sector-oriented police and the health of the population, which hinder this process and may indicate negative impacts on society as a whole [35].

In this sense, considering the data analysed, one of the factors that drew attention was the intensification of the death rate due to accidents occurring from 2006 and 2007 in Caraguatatuba and Atibaia, coinciding with the acceleration of the growth of the current fleets of both municipalities and the Dom Pedro I highway. This correlation seems to confirm the potential influence that the expansion of the vehicle fleet has on the mortality rate due to traffic accidents.

The correlation between these two variables - number of vehicles circulating and mortality rate due to traffic accidents - has been more evident since 2014. This year, mortality rates fall significantly in both municipalities analysed at the same time that the intensification of the fleet circulating in these cities is also drastically reduced. As of this year, Brazil also faces the worst economic performance of the series studied, helping to explain the reduction of the increase of vehicles in these cities.

However, it is noted that the variation of these mortality indices does not follow the pattern of change of the current fleets throughout the analysed period. It is evident that other factors also contribute to the role of determinants capable of influencing the mortality rate due to traffic accidents in a city, in addition to the size of its circulating fleet. In this sense, authors [20] highlight the strong correlation between speed factor and collision occurrence, indicating that this variable-speed pattern - can be used indirectly to measure safety levels [20].

To reduce the frequency and severity of collisions, it is often sought to reduce vehicle speeds using Traffic Calming Measures (TCMs) [20]. These measures are configured as engineering interventions in road infrastructure, such as "raised intersections, raised pedestrian crossings, horizontal deviations of the travelled lane and reducing the lane width" [14].

Thus, the Export Corridor reflects several of the socio-environmental contradictions that are emblematic of regional and local policies and speculative interests, which do not adequately consider the sustainability of regional natural resources, especially water resources, and do not allow management and use of natural resources in a sustainable way that promote the environmental and life quality of the population.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

All authors read and approved the final manuscript.

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