ROAD SAFETY DEVELOPMENT IN BRAZIL IN TERMS OF FATALITIES AND MOBILITY DATA

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ABSTRACT

In road safety studies, the index which relates the number of traffic fatalities with the distance traveled by road transport vehicles (mobility level) is considered more appropriate than the indexes related to the population and fleet (traditionally used in the country). In addition, it is important to know the behavior of this parameter for the different traffic modes (automobile; motorcycle, truck, bus, pedestrian, and cyclist), so that improvements or setbacks may be identified. Thus, the aim of this research is to calculate the fatality rates in relation to the distance traveled for each traffic mode in Brazil during the 2004-2008 period. The method required the processing of information on the annual traffic deaths and on previous researches on the exposure estimation in the country. The results reveal that, besides the overall fatalities per billion-kilometer rate reduction trend, the risk for motorcycle occupants and pedestrians is increasing for most types of accidents studied. Furthermore, the motorcyclists' death risk resulted more than 4 times the one for automobiles.

RESUMO

Em avaliações no âmbito da segurança viária, o índice que relaciona o número de mortes no trânsito à distância percorrida pelos veículos de transporte rodoviário (nível de mobilidade) é considerado mais adequado que os índices em relação à população e à frota (tradicionalmente usados no país). Além disso, é importante conhecer o comportamento desse parâmetro para os diferentes modos de transporte (automóvel, motocicleta, caminhão, ônibus, pedestre e ciclista). Dessa forma, o objetivo da presente pesquisa é calcular os índices de mortes em relação à distância viajada para o Brasil para cada modo de transporte no período 2004-2008. O método exigiu o tratamento de informações referentes às mortes anuais no trânsito e a pesquisas anteriores sobre a estimativa da exposição no país. Os resultados revelam que, apesar de uma tendência geral de redução da taxa de mortes por bilhão de quilômetro, o risco para ocupantes de motocicleta e pedestres está aumentando na maioria dos tipos de acidentes estudados. Adicionalmente, o risco de morte do motociclista resultou mais de 4 vezes o de um ocupante de automóvel.

Keywords: Fatality per billion-kilometer rate; Road safety; Traffic mode; Death Risk; Brazil

Number of words: 3,882

1. INTRODUCTION

1.1 Brazil's fleet growth

In last recent years, Brazil is undergoing a period of intense economic growth. In 2011 the country became the seventh place among the largest economies in the world, reaching a GDP (Gross Domestic Product) of 2.1 trillion dollars (IBGE - Brazillian Institute of Geography and Statistic, 2011). The changes resulting from this process directly affect the transportation system issues and, consequently, the road safety, mainly due to the large increase in motor vehicle fleet. Notably, motorcycles fleet grew at a much higher rate than other motorized modes, 83.68%, from 2004 to 2008 in the country (Table 1).

Table 1: Motor vehicle fleet in Brazil from 2004 to 2008

Year	Fleet (million vehicles)				
	Automobiles	**Motorcycles**	**Trucks**	**Buses**	**Total**
2004	28.85	7.12	1.88	0.49	38.35
2005	30.48	8.16	1.97	0.52	41.12
2006	32.31	9.45	2.05	0.55	44.35
2007	34.64	11.16	2.15	0.59	48.54
2008	37.30	13.08	2.28	0.63	53.29
Growth (2004 to 2008)	**29.27%**	**83.68%**	**21.02%**	**28.17%**	**38.95%**

Source: DENATRAN - National Department for Traffic (2011), adapted.

In a significant part, this increment of the motorized vehicle fleet all over the country is composed by young and/or inexperienced drivers, who are leaving the dependence of the saturated transit system and beginning to act as individual motor vehicle users. Motorcycle conductors are, for example, most of the times, facing real traffic conditions for the first time in their lives, as their training and examinations is held in a confined test environment, totally isolated from real traffic situations.

By the same time, life expectancy in Brazil is also increasing, and fewer drivers are ceasing to conduct. Consequently, a crescent portion of the population is interacting through a system with serious problems regarding roads, vehicles and traffic education.

1.2 General data on traffic fatalities

The impacts of this development are reflected in the increasing and unbroken trend in the number of traffic deaths, which in 2008 amounted to almost 40,000 (DATASUS - Department of Data Processing of the Health Care System, 2011). In the graph of Figure 1, the growth in the number of traffic deaths in the country during the 2004-2008 period is showed. The death rates per 100,000 inhabitants and per 100,000 vehicles are also included on the figure.

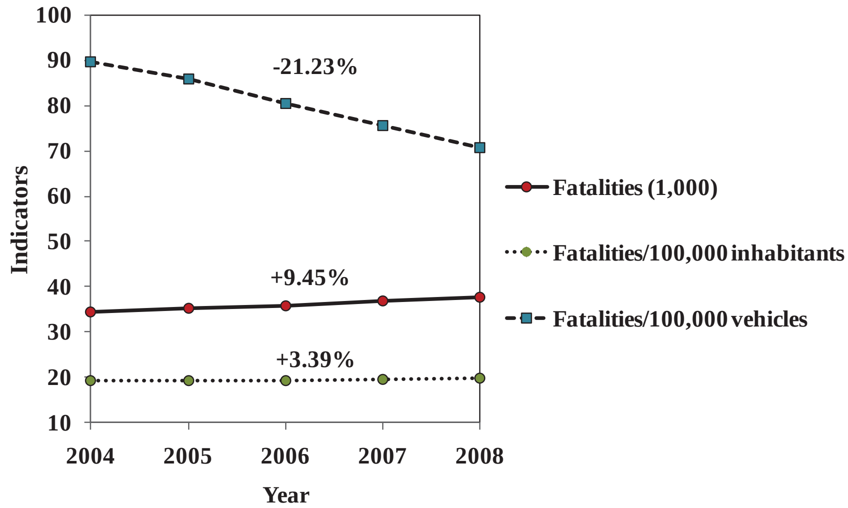

Figure 1: Number of traffic fatalities and fatalities rates (per inhabitant and per vehicle)
Source: DATASUS (2011); DENATRAN (2011); IBGE (2011), adapted.

Though, it is known that the use of inhabitants and fleet death rates may present misleading results when used for traffic safety comparisons. The death per population rate is strongly affected by the motorization rate, i.e. countries with low motorization rates tend to have a lower rate per inhabitant (an example is the fact that many African countries exhibit smaller indexes than Nordic European ones, somewhat that makes no sense in terms of road safety engineering). The index in relation to the fleet also presents problems since it is affected by the mobility level of individuals in a country, so that in places where the fleet travels a greater distance, the "per vehicle" rates tend to result higher (Thagesen, 1996; Ferraz, Raia Jr., & Bezerra, 2008).

Given this situation and the absence of a more reliable indicator for traffic safety evaluation in the country, (Bastos, 2011) presented a model adequate to Brazilian scenery to estimate the distance traveled by motorized road transportation vehicles. This parameter represents the denominator for the composition of the index of deaths per billion-kilometer, never estimated for Brazil so far. The model input information consisted on automotive fuel sales and fleet characterization. The results for both distance and index are exposed in Figure 2.

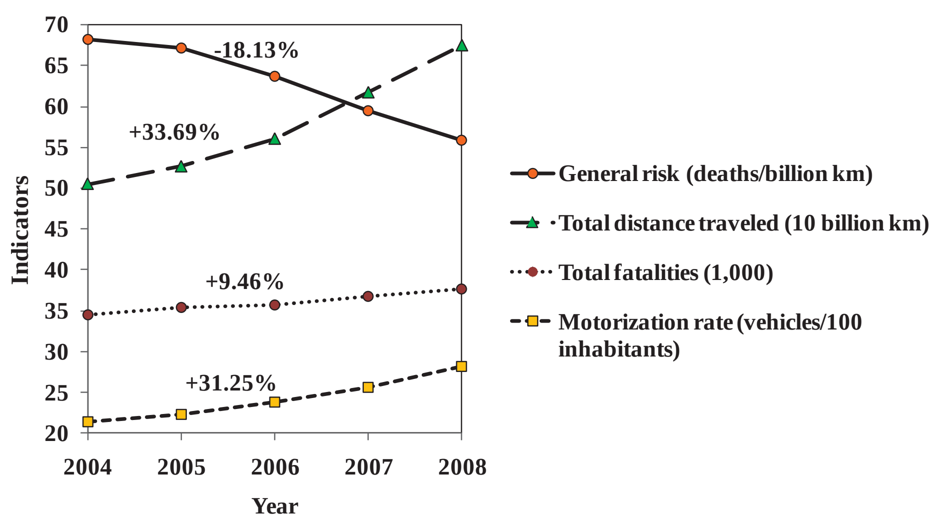

Figure 2: General traffic death risk, total distance traveled, number of traffic fatalities, and motorization rate
Source: BASTOS (2011); DATASUS (2011); DENATRAN (2011); IBGE (2011), adapted.

The numbers on Figure 2 point to a continued reduction in the rate, which decreased from 68.26 to 55.87 deaths per billion-kilometer in the country between 2004 and 2008 (a reduction of 18.15%). This is due to the increase on the mobility level (from 504.52 to 674.65 billion-kilometer traveled), a result of the increased fleet and economic growth (evidenced by the continuous gain on the motorization rate), and also of a minor raise in the absolute number of fatalities.

Thus, this reduction on the deaths per kilometer index may not be a result of real progress towards traffic safety, but a natural process attributed to the growth of motorization in the country. With motorization increase, the number of causalities occurs to raise, and also does the news reports on traffic death broadcasted by the media. This way, there's a natural reaction led by fear. Though, it might be one of the reasons that there is not a decrease as meaningful as the one obtained in countries with a high level of road safety investment. This type of process is slower, being the half-life time for the fatalities per billion-kilometer rate almost 20 years in Brazil.

1.3 Mobility estimative importance

The availability of an index that relates traffic fatalities with the level of exposure, leads to a more accurate diagnostic about the traffic safety situation. Through this index, the alarming situation of Brazil is revealed, being from 7 to 13 times the rate for highly developed countries (Figure 3). If the fatalities per inhabitant rate were mistakenly used, these differences would appear much smaller.

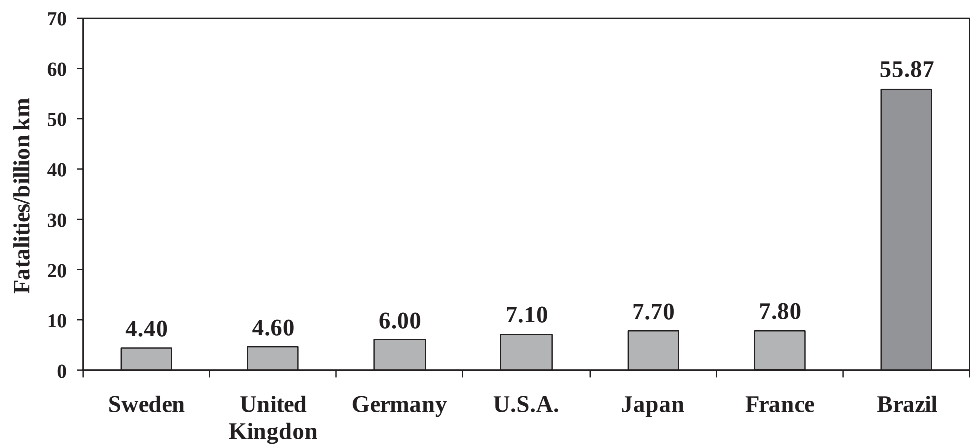

Figure 3: Fatalities per 10^9 kilometers rate in Brazil and some highly developed countries
Source: IRTAD - International Road Traffic and Accident Database (2010), international data for 2009; Bastos (2011), Brazilian data for 2008.

Nevertheless, to assess progress or setbacks on the safety situation, it is not enough to know the fatality rate in relation to exposure only. It represents an aggregate measure of many forms of exposure (Golob, Recker, & Alvarez, 2003). The main and most obvious of these forms is the traffic mode. If not disaggregated, a certain rates evolution patterns may be covered by the tendency of all data together (Stipdonk & Berends, 2008; Evans, 2004). Therefore, it is important to perform such analysis disaggregated by traffic modes (automobiles, motorcycles, trucks and buses).

1.4 Objective

The aim of this study is to present the fatalities rates in relation to the level of mobility disaggregated by transportation mode in Brazil over a five years period, 2004 to 2008. The main purpose is to describe the rates according to each traffic mode, so that there is no commitment on pointing causes for such results.

Despite the apparent decrease trend in the index shown in Figure 2, it does not necessarily means that the safety situation is improving, since the relationship between mobility and the number of accidents is not linear. For each subsequent increment in the mobility level, the impact in the number of accidents is smaller (Elvik, 2006; Elvik, Erke, & Christensen, 2009). In this case, there must be a clear distinction between what one wants to see (the increase of safety due to the reduction of the index) and what might actually be happening (a natural process of rate reduction without a real advance on safety).

Thus, this general trend should be investigated, and its variants need to be separated in order to seek a better comprehension of the safety changes. The availability of this type of data may contribute to planning targeted national traffic safety public policies.

2. METHOD

In the scheme in Figure 4 the method applied is summarized. The input information are based on DATASUS (the board that compiles the traffic fatalities data from all states and make it available for consultation) and Bastos (2011), which used some prior input information to build a national model. The output consists on the fatalities rates in relation to the mobility level for each traffic mode (or vehicle type): automobile; motorcycle; truck; bus; pedestrian; and cyclist.

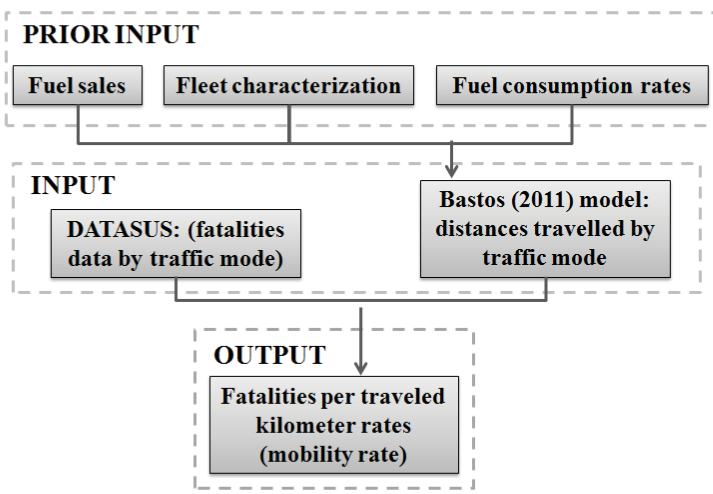

Figure 4: Method scheme

2.1 Data collection and initial procedures

As already mentioned, this research is based on a previous one in which the level of mobility or exposure of the road transportation system was estimated. A model to calculate the distances traveled by road vehicles with input information regarding the vehicle fleet characterization and the automotive fuels sales was developed, which was used to estimate the total distance travelled (Bastos, 2011). Traffic fatalities official data from the Ministry of Health regarding the period 2004-2008 fulfilled the model.

Vehicle fleet characterization included data about vehicle categories (automobiles, motorcycles, trucks, and buses) from the National Department for Traffic (DENATRAN), the different fuel consumption rates (in km/l) based on the National Institute of Metrology, Standardization, and

Industrial Quality (INMETRO), and the fuel type used by each category according to National Association of Motorized Road Vehicles Manufactures (ANFAVEA). Automotive fuel sales (ethanol, diesel oil, gasoline and natural gas) were also collected from the National Agency of Petroleum, Natural Gas and Biofuels (ANP). More details of this model can be checked out in Bastos (2011).

The risk stratification by transportation mode requires that fatalities and mobility data be obtained for each specific mode, as shown in Figures 5 and 6. In Figure 5 traffic fatalities distribution by road transportation mode is presented for the 2004-2008 period, in which the average distribution is: 29.52% automobile occupants; 34.14% motorcycle occupants; 4.41% truck occupants; 1.07% bus occupants; 23.37% pedestrians; and 7.50% cyclists. According to these data, motorcyclists respond to the major part of the traffic deaths in the country, followed by automobile occupants and pedestrians.

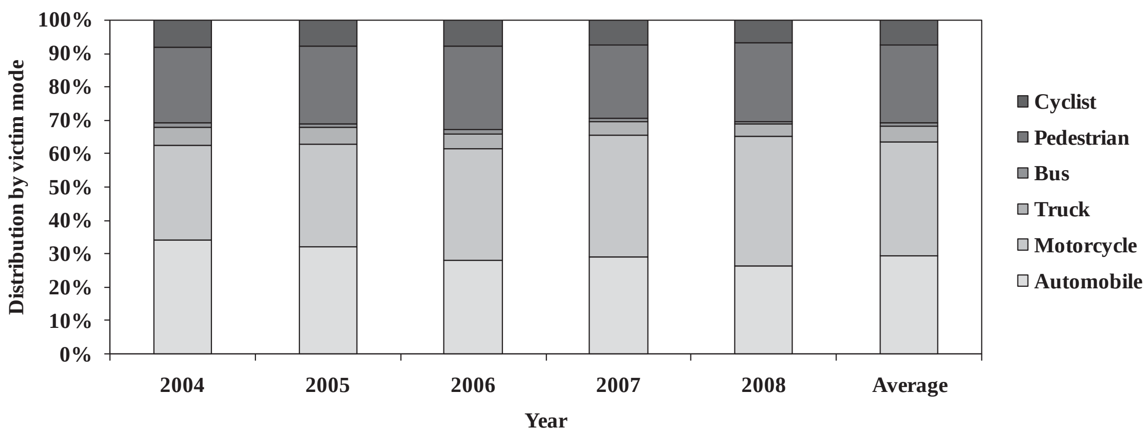

Figure 5: Distribution of the annual traffic fatalities in Brazil from 2004-2008

Source: DATASUS (2011), adapted.

In Figure 6, the average annual distance traveled by vehicle type can be checked. Again, it is important to focus on motorcycle numbers, that indicate a 40% (in average) higher mobility level in comparison with automobiles.

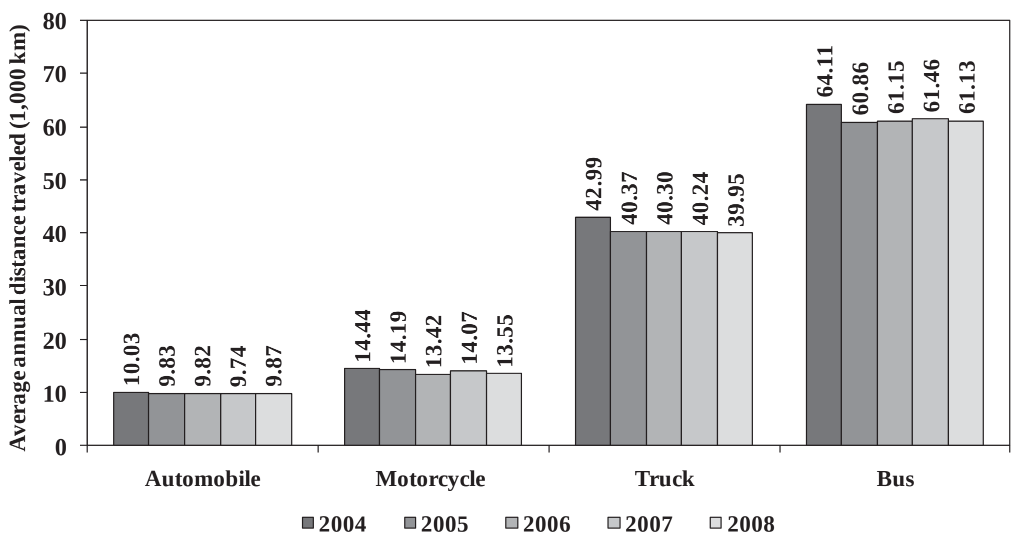

Figure 6: Average annual distance traveled by traffic mode in Brazil

Source: Bastos (2011).

2.2 Selection of the mobility parameter considered in each accident type

In this paper, following the procedures applied in Stipdonk and Berends (2008), the mobility level of the involved part that sustained fatal injury ("Victim" on Figure 7 squares) was considered for the index composition, no matter whose fault it was. The matrix in Figure 7 contains the guidance for the selection of the traffic mode mobility to be considered for each type of accident, determined by the "victim " and "2nd part" pair (victim x second part). For example, in an accident involving a motorcycle and a truck, the victim is the motorcycle occupant (motorcycle x truck), so it is the mobility of the motorcycle that should be taken into account in the index.

2nd part / Victim	Automobile	Motorcycle	Truck/Bus	None	Unknown
Automobile	*Automobile*		*Automobile*	*Automobile*	*Automobile*
Motorcycle	*Motorcycle*	*Motorcycle*	*Motorcycle*	*Motorcycle*	*Motorcycle*
Truck			*Truck*	*Truck*	*Truck*
Bus				*Bus*	*Bus*
Pedestrian	*Automobile*	*Motorcycle*	*Truck*		*All motorized*
Cyclist	*Automobile*	*Motorcycle*	*Truck*		*All motorized*

Figure 7: Guidance matrix for the selection of the traffic mode mobility to be considered for each type of accident

More unusual cases, such as an automobile occupant dead in a motorcycle accident are not covered by the research scope. These cases are represented by the blank frames on Figure 7. When the fatality happened in a single vehicle crash, the hypothetical second part is represented by the column "none" on the same figure. In the column "Unknown" are represented the fatality data in which only the mode of the victim was available, being the second part involved unknown. Fatalities data for trucks and buses are disaggregated only for the victim; when considering the second part they are presented together.

It is important to note that mobility data for non motorized modes are not available in Brazil. It required the use of a reversed index, in which motor vehicle mobility was taken as the exposure parameter to compose the rate, as can be checked out on Figure 7. Therefore, the resultant rate for pedestrian and cyclist fatalities is "fatalities per motor vehicle kilometers traveled". When the victim is a pedestrian or a cyclist, the mobility of all motorized modes together is considered (automobiles, motorcycles, trucks, and buses).

Therefore, the victims described on Figure 7 account for 71.89% of the 179,927 fatalities involving road motor vehicles on the five year period of study (33.52% with both the victim and the second part traffic modes known, and 38.37% with only the victim mode identified). Unfortunately, for some amount of reports, not even the traffic mode is known (24.87% of all fatalities); such data was excluded. The remaindering 3.24% deaths are not covered by this research also, because they do not fit in any of the categories listed on Figure 7 matrix.

This fault does not compromise general risk analysis, when all traffic deaths are accounted, since they involve at least one road motor vehicle. However, for disaggregated analysis, as performed in this paper, it reduces the sample size. It requires the belief on the premise that these reporting mistakes (when the traffic mode of the second part is unknown) have occurred in uniform proportions through all traffic modes considered and, consequently, comparative analysis are not affected.

3. RESULTS

The results are firstly presented individually, for each traffic mode considered (3.1 to 3.6 items). Then, in 3.7 item a comparison between the risk sustained by the motorized modes is performed.

3.1 Automobiles

The fatalities rates for accidents in which the victim was an automobile occupant are presented in Figure 8. The accidents are divided in: automobile total; automobile x automobile; automobile x truck/bus; single automobile; and automobile x unknown.

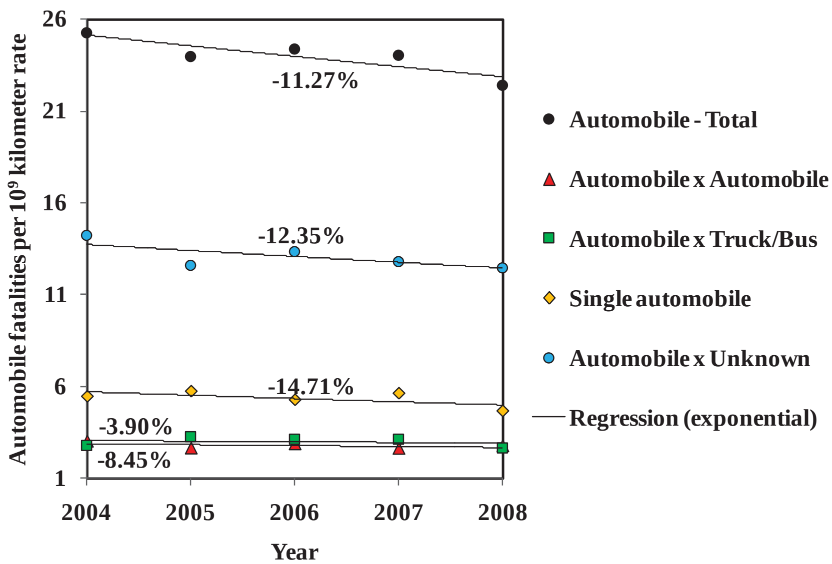

Figure 8: Fatalities per billion-kilometer of automobile occupants

The risk of death in automobile crashes appears to be decreasing, passing from 25.24 to 22.40 deaths per billion-kilometer traveled (reduction of 11.27% during the period). There is a great percentage of automobile fatalities which the traffic mode of the second part is unknown, although this tendency is diminishing along the period (-12.35%). The death occurrence in single automobile crashes, much more common in rural highways, is presented with an almost-two-times higher risk in comparison with the accidents with other automobiles or trucks/buses.

3.2 Motorcycles

In Figure 9 there are available the fatality rates for accidents in which the victim was a motorcycle occupant. The accidents are divided in: motorcycle total; motorcycle x motorcycle; motorcycle x automobile; motorcycle x truck/bus; single motorcycle; and motorcycle x unknown.

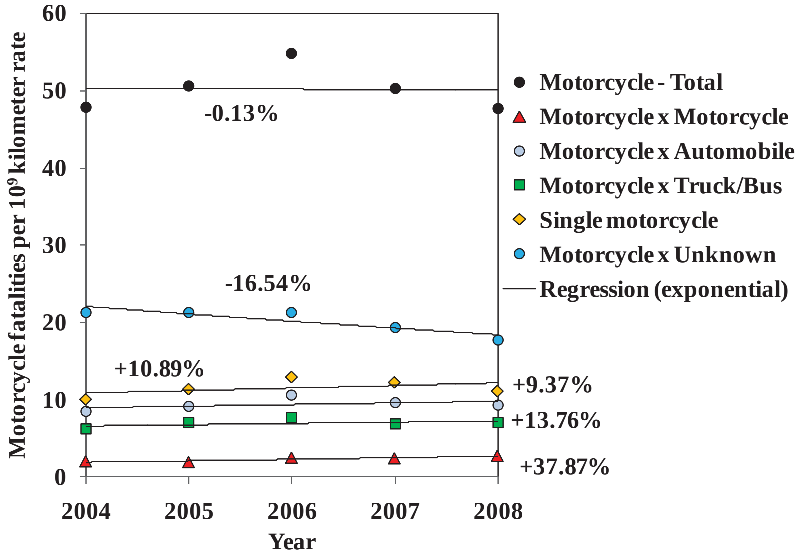

Figure 9: Fatalities per billion-kilometer of motorcycle occupants

The fatalities rate for motorcycle occupants had a strong increase until 2006, and then returned to almost the same baseline of 2004, about 47 fatalities per billion-kilometer. Indeed, segmented analysis shows noteworthy raises for deaths of motorcycle occupants in accidents with all the others traffic modes, outstandingly for “motorcycle x motorcycle” deaths (37.87% increase). The rate for “motorcycle x unknown” declined, probably due to improvements on data processing, being the corresponding fatalities classified according to the second part involved.

3.3 Trucks

The deaths per billion-kilometer rates for truck occupants are showed in Figure 10. The accidents are divided in: truck total; truck x truck/bus; single truck; and truck x unknown.

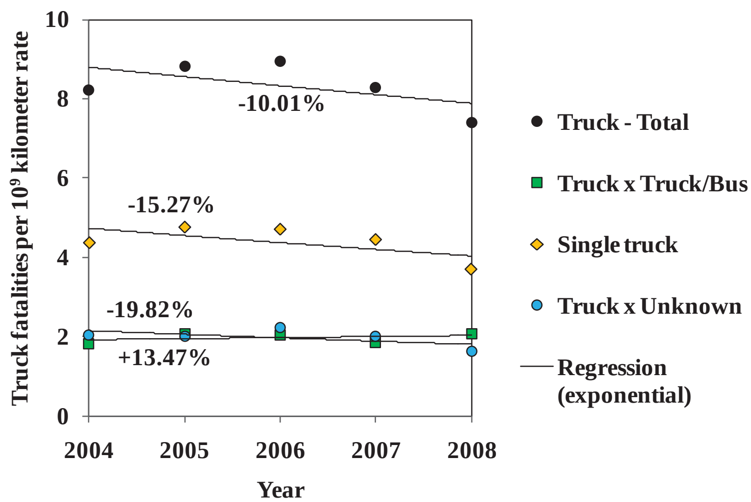

Figure 10: Fatalities per billion-kilometer of truck occupants

The death rate for truck occupants declined 10.01%, varying from 8.23 to 7.41. As observed for the other traffic modes, the rates of unknown second part fatalities are representative. Despite the general reduction trend, the fatalities in “truck x truck/bus” events increased about 13%.

3.4 Buses

In Figure 11 the fatalities rates for accidents in which the victim was a bus occupant can be observed. The accidents are divided in: bus total; bus x truck/bus; single bus; and bus x unknown.

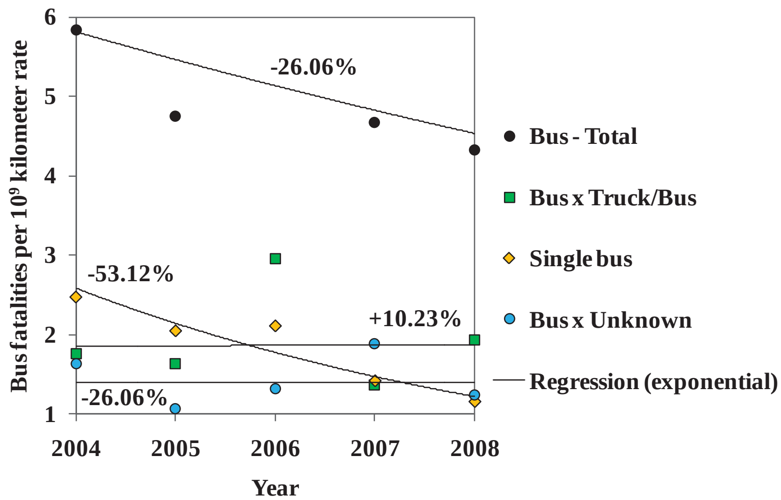

Figure 11: Fatalities per billion-kilometer of bus occupants

While the “bus x truck/bus” death rate rise 10.23%, the “bus x none” rate declined 53.12%. It resulted in a general pattern of 26.06% decrease of this mode fatality index. Proportionally, the number of death reports that the second part involved is unknown is the least of all traffic modes, indicating a better quality on the reporting procedures.

3.5 Pedestrians

The deaths of pedestrians per billion motor vehicle kilometers are available in Figure 12. The accidents are divided in: pedestrian total; pedestrian x motorcycle; pedestrian x automobile; pedestrian x truck/bus, and pedestrian x unknown.

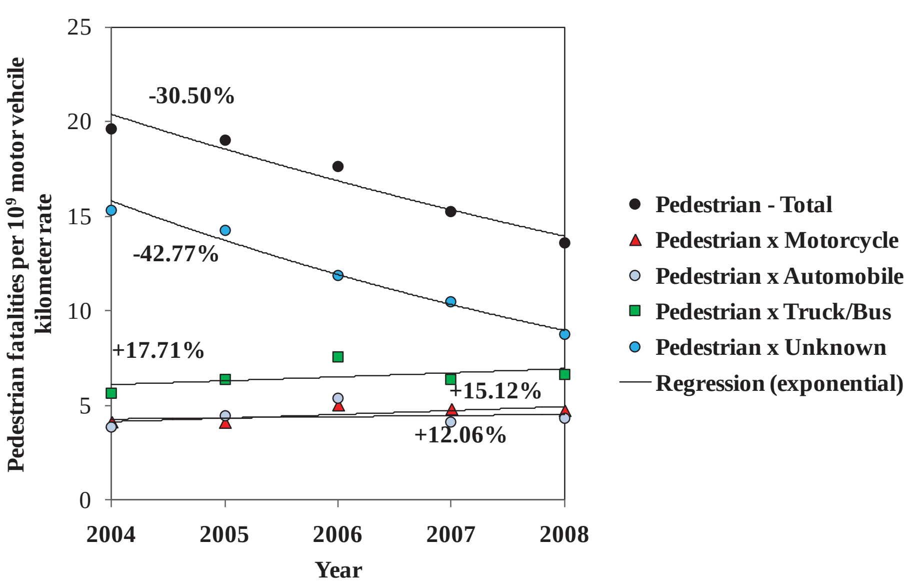

Figure 12: Pedestrian fatalities per billion motor vehicle kilometers rates

The lethality in all types of pedestrian in run over accidents is increasing during the study period, with the greater rise in pedestrian hit by truck/bus events, which is also the type with the higher death risk between the events with known second part, averaging 6.53 deaths per billion-kilometer traveled. Notwithstanding, influenced by the high rates of "pedestrian x unknown" deaths, the overall index reduced 30.50% in the five years period.

3.6 Cyclists

The cyclists deaths per billion motor vehicle kilometers are presented in Figure 13. The accidents are divided in: cyclists total; cyclists x motorcycle; cyclists x automobile; cyclists x truck/bus and cyclist x unknown.

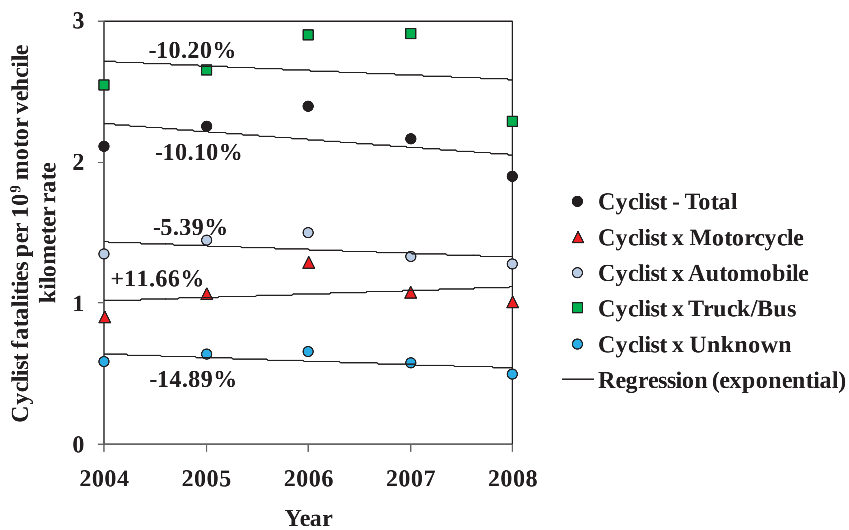

Figure 13: Cyclists fatalities per billion motor vehicle kilometers rates

The mortality in all types of cyclist in run over accidents decreased from 2004 to 2008 (overall reduction of 10.10%), with exception for the "cyclist x motorcycle" crashes, in which the risk of death increased almost 12%.

3.6 Fatality risk comparison

The risk comparison of the distinct traffic modes is performed in this paper through the ratio between the fatalities per billion-kilometer rate of each mode and the automobile's rate. Reasonable occupancy rates were estimated (there are no official data on the issue in the country) in order to obtain the fatalities per billion-passenger-kilometer rate, so that the different modes risk comparison could be carried out. The occupancy rates considered are:

- Automobile: 2 occupants/vehicle;
- Motorcycle: 1 occupant/vehicle;
- Truck: 1 occupant/vehicle;
- Bus: 15 occupants/vehicle.

The ratio's resulting values are presented in Table 2. The higher risk associated to the motorcycle usage is evident, with a risk, in average, 4.20 times higher than the one for automobiles along the years of the study. On the other hand, international researches, mainly in Europe, indicate higher relative risk for two wheeled motor vehicles, with values ranging from 10 to 30 times the risk for automobile's passengers (WHO - World Health Organization, 2004; Elvik, Hoye, Truls, & Sorensen, 2009).

Table 2: Ratio between the fatalities per passenger-kilometers rate of each traffic mode in relation to the automobile's rate

Traffic mode	2004	2005	2006	2007	2008
Automobile	1,00	1,00	1,00	1,00	1,00
Motorcycle	3,79	4,23	4,50	4,20	4,27
Truck	0,65	0,74	0,73	0,69	0,66
Bus	0,03	0,03	0,03	0,03	0,03

The local characteristics of motorcycle usage may contribute to the differences on the relative risk of these vehicles in Brazil and in Europe. It includes a higher annual distance traveled, that aggregates experience to the driving task, in accordance with the "universal law of learning" proposed by Elvik (2006): the ability to detect and control hazards increase uniformly as the amount of travel increases (accident rate per unit of exposure will decline as the amount of exposure increases). In Great Britain, for instance, according to the Department for Transport (2009), a motorcycle rider travels about 6,500km a year (2008 as base year), against 13,550 in Brazil; in other words, the average annual distance traveled by Brazilian motorcycle rider is 2 times longer than the distance traveled by a British user.

4. DISCUSSION

Despite an apparent reduction of the risk of death in all traffic modes, the results showed worrying figures, since this decline was already expected due to the great motorization increase in Brazil. The largest reductions occurred on the following types of fatalities (pattern - victim x second part):

- 56.43% pedestrian x unknown;
- 53.12% bus x none;
- 35.20% cyclist x unknown;
- 20.06% bus x unknown;
- 19.82% truck x unknown.

The decreases on the fatalities in which the second part is unknown point to improvements on the reporting system attributed to the traffic mode of the second part identification. Accordingly, advances throughout road safety can only be observed on "bus x none" fatalities. In contrast, the highest increases on the traffic deaths per mobility rate happened on the following types of fatalities (pattern - victim x second part):

- 37.37% motorcycle x motorcycle;
- 17.71% pedestrian x truck/bus;
- 15.12% pedestrian x motorcycle;
- 13.76% motorcycle x truck/bus;
- 13.47% truck x truck/bus.

Vulnerable road users, such as motorcyclists and pedestrians figure on the top of the safety deterioration ranking above. Motorcyclists and pedestrians are, respectively, the first and the third most common fatal victims on road accidents. Motorcycles have evidenced to be the most serious problem due to its low conspicuity, reduced mass and little stability.

5. CONCLUSIONS

It is known it would be helpful to have a longer period of analysis in order to identify other development trends with respect to road safety in Brazil. However, latest data are not available and data before 2004 does not follows the same standards and some information are missing.

The results indicate the need of special policies directed to motorcyclists; otherwise the situation tends to get worse, because of the great motorcycle's fleet growth, previously shown in this paper. Furthermore, pedestrians also deserve attention; despite the apparent protection given by Brazilian Traffic Code, these users still remain to sustain the impacts of a greater than ever motorization process.

Finally, it is essential to attempt for the quality of data on traffic fatalities. Much more accurate analysis could have been done if there were complete data regarding the traffic mode of both parts involved on the accident which resulted in one or more fatalities. Although, the quality of data seems to have increased from 2004 to 2008.

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