USE OF SECONDARY INDICATORS IN THE ANALYSIS OF RURAL ROADS "ACCIDENTABILITY" BY ROAD POLICE – A CASE STUDY IN BRAZIL

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ABSTRACT

This paper is based on a pilot study about comparative analysis of road safety indicators, such as – use of helmets, use of seat belts, drinking and driving, vehicle conditions and speeding – and road "accidentability". But, unfortunately data about speeding and driver experience was not available for this study. The segments of road that were selected are on the scope of Road Military Police of Jaú, State of Sao Paulo, Brazil. The period of analysis was from January 2008 to August 2009. The indicators were obtained through the database of infractions of the Road Military Police of the State of Sao Paulo. And the absolute number of accidents in these sections was obtained in the accident database from the same institution. The main objective was analyzed driver behavior of the segments under scrutiny, using the indicators developed. The results showed the relation among secondary road safety indicators and the number of accidents, victims and severity. This work also is a tentative to show the utility of secondary road indicators and the ways to obtain it with the tools at hand, the database from Road Military Police, with negligible costs and time consuming.

Keywords: indicators, road safety, accidentability

1. INTRODUCTION

The European Transport Safety Council (2001) defines a safety performance indicator as "any measurement that is causally related to crashes or injuries, used in addition to a count of crashes or injuries in order to indicate safety performance or understand the process that leads to crashes".

In general, the road safety level is often described in terms of final outcome information, for example 'the number of killed and injured persons" per population or fleet, using registered accident data. Although these output indicators are relevant, they do not give a total view on the road safety situation in a country and the factors influencing it.

Based on the analysis of road safety indicators, here it will be used data from the database of accidents and driving violations, we attempted to trace the profile of offenders' behavior, enabling the use of more effective preventive measures in the areas: education, legal efforts, and engineering, with the aim of reducing accidents.

2. METHODOLOGY

In this paper it was used information pertain to the accident database (BOATRV) and database of infractions (AI) from the Road Military Police of Jaú, in the periods of January of 2008 and July of 2009. The main objective was to have an overview of driver's behavior and a tentative of analysis of road accidentability with road safety indicators, in the segment under jurisdiction of the 3º Pelotão de Policiamento Rodoviário de Jaú, pertain to 1ª Cia. and to 2º Batalhão.

The use of the database, in the period of analyses, made possible crossing data, among databases and road safety indicators, what resulted in more proper policy in the management of road traffic by Road Military Police of Jaú.

3. ROAD SAFETY INDICATORS

The road safety indicators are used to measure the evidences that contribute or contributed to the occurrence of traffic accident. It is related to the vehicle conditions, driver behavior, driving offenses and others.

Accordingly to Diógenes (2004), a road safety indicator is any measure related to the incidence and/or severity of accidents, through them is possible evaluated the consequences

and to propose enhancements, providing means to take decisions in road safety sphere. They can be classified in:

- Primary indicators: are the impact indicators or statistical indicators, they can be defined as measures that are directed related with the problems of unsafe. For example, percentage of inexpedient drivers, alcohol usage, accidents with victims, percentages of fatal victims and etc.
- Secondary indicators: are factors related directly with accidents, like, driver behavior, legal aspects, legislation, enforcement, vehicular technology, speed, number of hours of Police enforcement and etc.

Utilization of road safety indicators

The primary road safety indicators are used by the majority of the countries, having variations in the denominators, represented by variables of exposure; in the definition of what is an accident, injured and fatality; in the way the data is desegregate. In Brazil accordingly to DENATRAN, they are:

- Index of fatal victims;
- Index of non fatal victims;
- Index of victims of traffic accidents; and others related always with fleet or population.

By ETSC (2001), the secondary indicators of safety had its use disseminate in the beginning of 90's, in Sweden and Finland the use of seat belts is monitored since 1966 and implemented a system of monitoring driver behavior in 1992 (LUUKKANEN**,** 2002). Other Nordic countries, Canada, United Kingdom, and USA have monitoring programs with behavior indicators.

In general, to monitoring safety concerning road-environment behavior are used techniques of audit and the indicators developed for this purpose, usually making references to the standards set for each country. Sweden is a reference in the development of a secondary indicator system linked to the goals of the National Safety Program in the period of 1995 to 2000, which comprise behavior indicators, road environment, vehicles and trauma management. (VAGVERKET[1],1999 apud DIÓGENES, 2004).

In Brazil until no secondary indicators are in use or developed to monitoring activities in road safety. This paper is an incipient attempted to do this, in a small scale using data from the area of coverage of jurisdiction of the 3º Peloton of Road Police of Jaú.

[1] VAGVERKET, The SNRA 1998 road traffic safety report, 1999 apud DIÓGENES, 2004.

Development of road safety indicators

The road safety indicators can be used to evaluate the improvements in road safety. However, the data collection is an expansive and sometimes is not viable to use a large number of indicators. Thus is important to establish selection criterions for the indicators to be used, which must follow the purpose whereby the indicators are being formulated, that is, if is for changes in attitudes or to fundament decision making process.

Campbell (2002 apud DIÓGENES, 2004), describes that indicators should be developed through a theoretical and conceptual model and summarizes four methodologies:

1. A process oriented to goals, where the goals and objectives are established, to create significant indicators to measure the reach of these goals is used the Swedish model (VAGVERKET, 1999).

2. Consultative process, where members of the government, traffic planners and users are consulted through their experiences can select indicators, this model is used by AUSTROADS[2] (2001 apud DIÓGENES 2004);

3. Revision process, which is similar to the process oriented to the goals, but formed by cyclic system, where the goals, objectives and indicators are review periodically;

4. Oriented process to casual factors, where are identified the main causes of accidents and selected potential indicators to measure the mitigation of the problem, chosen the most relevant to the organization strategies, ETSC 2001.

Source to obtain indicators

To collect information about possible road safety indicators, we used data from the documents used by the State of Sao Paolo Military Police, and are classified in Military Police Report (BOPM), Police Reports of Road Traffic Accident (BOTRAV), and Offenses violations (AI).

Police Reports of Road Traffic Accident (BOTRAV)

Police Reports of Road Traffic Accident (BOTRAV) is the document used by the Military Road Police in the State of Sao Paulo to register the road accidents occurred in the roads. Since July 2007, all information of accidents at Road Police in Jaú is electronically available.

The BOATRV differs from the Police Report used in the urban areas, and its use is exclusive to accidents occurring in roads. In some cases the two documents (BOPM e BOATRV), are

[2] AUSTROADS, Australian and New Zeland road system and road authorities national performance indicators, 2001 apud DIÓGENES, 2004)

used when the driver is under influence of alcohol. The BOATRV *r*egister the accident and BOPM register the crime of driving under influence.

The BOATRV, has the following basic information: general data (date, hour, day of week, city); type of accident; type of victims; accident localization; environmental conditions; vehicles description; damages in the vehicle; driver qualification; pedestrian and passenger victimized; draft of the accident occurrence.

Offenses violations

Offenses violations or infractions (AI), is the document elaborated by the Road Military Police (PMRv) when is found a traffic violation. It is made a notification which is transformed later in fine by the authority responsible, in this case is the Department of Roads (DER), of the State of Sao Paulo. The fine is a penalty impost to the driver by the authority accordingly the Brazilian Traffic Code (CTB, 1997).

4. CASE OF STUDY

The Road Military Police is a specialization of Military Police. In Jaú the Road Military Police has 25 police officers, responsible for the road surveillance. The segments of rural roads under jurisdiction comprises the cities of Jaú, Bocaina, Dois Córregos, Igaraçu do Tietê, Barra Bonita, Mineiros do Tietê, Pederneiras, Boracéia, Itapuí, Bariri and Itaju, and their respective access roads. They are around 300 km of roads, which only 57 km, belongs to the SP 225 (Road between Bauru x Jaú x Brotas), from km 210 to 153, that makes 19% of multilane roads, which are under private concession. Figure 1 in dash line and Table 1 shows the roads and limits of the jurisdiction of Road Military Police of Jaú.

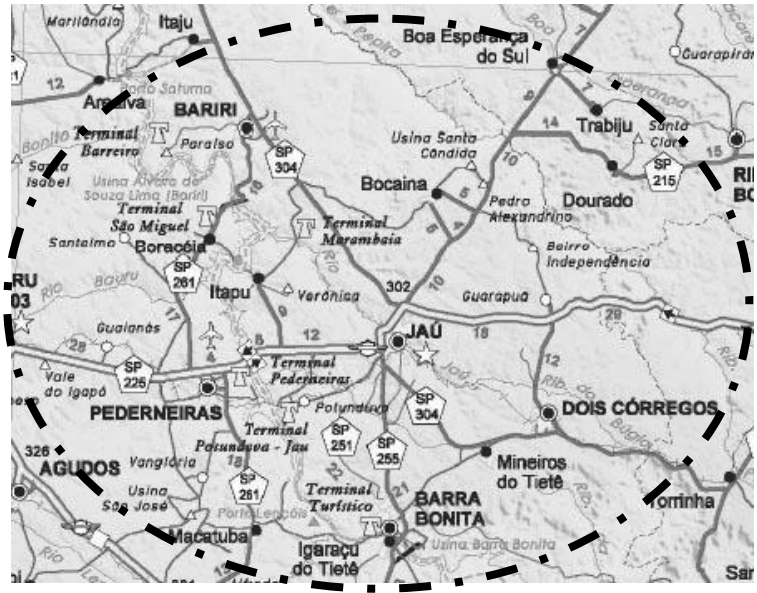

Figure 1: Area under jurisdiction of Military Road Police of Jaú.

Table 1 – The roads and limits of the jurisdiction of Road Military Police of Jaú.

SP[3]	Initial KM.	Final KM	Name
225	153+340	177+700	ENG. PAULO NILLO ROMANO
225	177+700	183+800	CONT. ANTONIO P. GALVÃO DE BARROS
225	183+800	210+000	CMT. JOÃO RIBEIRO DE BARROS
255	124+200	147+300	CMT. JOÃO RIBEIRO DE BARROS
255	155+800	169+950	DEP. OTAVIO PACHECO DE ALM. PRADO.
255	169+95	186+700	DEP. JOÃO LAZARO DE ALM. PRADO.
261	136+300	146+700	OSNI MATHEUS
261	151+000	183+500	PREF. CESAR AUGUSTO SGAVIOLI
304	256+964	280+850	DEP. AMAURI BARROSSO DE SOUZA
304	280+850	295+500	DEP. AMAURI BARROSSO DE SOUZA
304	302+900	352+400	DEP. LEONIDAS PACH. DE ALM. PRADO
159/225	000+000	010+875	FERNANDO DE OLIVEIRA SIMÕES
160/225	000+000	002+000	FERNANDO DE OLIVEIRA SIMÕES
195/225	000+000	007+950	ALBERTO MASSONI
138/255	000+000	005+171	BENEDITO MONTENEGRO
342/304	000+000	002+050	JOSÉ MASSON

Source: Polícia Militar Rodoviária de Jaú

The three documents already mention (BOPM, BOATRV and AI) can be used to obtain some indicators of road safety performance. Table 2 shows where we can find each type of indicator.

Table 2 – Sources to obtain road safety indicators

Indicators	AI	BOATRV	BOPM
Speed	X		
Driving under influence of alcohol	X	X	X
Seat belt usage	X		
Helmet	X		
Vehicle conditions	X	X	
Inexperiencie of the driver	X	X	

Source: Polícia Militar Rodoviária de Jaú

From the Table 2 we can realized that the AI is an important source of data, because it contains all the indicators that is necessary in this study, but as the AI are also made for other violations than traffic offenses is necessary to make a data mining.

Speeding

The enforcement of speeding is no longer performed by the police, because the only speed radar available is not operational, and, besides the lack of equipment, the number of police officers is not enough. Only on the roads under concession, in the case SP255, have surveillance with speed radar, although are under responsibility of outsourced company hired by DER[4]. In this study, unfortunately, this data was not available.

[3] This mean, that the road belongs to the State of Sao Paulo.
[4] DER – Highway State Agency.

Driving under influence of alcohol

In Brazil a new Law (Lei 11.705 and Decreto 6.488 from Federal Government) from 19/06/2008, establish zero tolerance to alcohol in the blood.

Due establish tolerances, the maximum limit is 0.1 milligrams of alcohol per liter of air expelled by the lungs, which is measure by breathalyzer. According with Ministry of Justice in 2008, were expended 70 millions of Brazilian real to buy 10,000 breathalyzers, which were distributed to the Police.

Between 0,1mg/l and 0,29mg/l of alcohol per liter of air expelled by the lungs, or between 2 dg/l e 5,99dg/l, decigrams of alcohol per liter of blood: fine of five times of the basic value, and seven points in the driver license (total allowed points per year is 21) and suspension of license. Over 0,3mg/l (or 6 dg/l): The same previous punishment, and arrested in flagrante offense, with a penalty ranging from six months to three year, and is a non-bailable offense.

When the driver is caught driving under influence of alcohol, he or she has three options: blow in the breathalyzer; if he or she refused, he or she is sent to Police Station, where is order an authorization to take a blood sample; if he or she refuses, is called a coroner to make a clinical exam.

The BOPM concern to indicators, is elaborated only when the driver had alcohol concentration in the blood equal or higher than 6 decigrams or 0.3 milligrams of alcohol per liter air expelled, because this situation configure offense conform article 306 of CTB5. Below this limit it is made only an administrative measure and actuation in art. 165 of CTB, the vehicle liberated to other driver in condition to drive.

Seat Belt

In Brazil, since 1988 due the CTB, the use of seat belt is mandatory, and is one of targets of enforcement by the competent agents.

Helmet

Also is mandatory since 1998 by the CTB. The helmet, also have standards and have to be certified by INMETRO, agency in Brazil which regulates standards and norms to be followed by manufactures.

Vehicle conditions

In Brazil there are an old car fleet, with a lot of cars without licensing or legal pendency, and some in bad conditions. This type of infraction is report on BOATRV, because, besides the

[5] Código de Trânsito Brasileiro - Brazilian Traffic Code.

normal surveillance made by Police, in every accident the conditions of the vehicles are verified. In CTB is establish vehicular inspection, but until more than 12 years after, the country do not have regulated the procedures, and only in the city of São Paulo it is in practice since of 2009.

Driver inexperience

Inexperience of the driver could be indentified in the BOATRV, in the data field for the date of the first drive license. However, should be necessary a separate analysis in each BOATRV, because in the statistical program use by the Road Police of Jaú there aren't this specific field.

In Brazil when the driver took his first driver license, he or she receives a permission to drive (PPD), like a driver license (CNH), at the end of one year the driver will receive a driver license, inasmuch as he or she, in this period, did not receive a fine for serious offense or recidivist in a non serious offense. Nowadays in Brazil there is a debate of forbidden drivers with PPD to drive in highways.

5. DATA ANALYSIS

Were analyzed data referring to the amount of infractions, using the report of AI, and accident occurred, using the data from BOATRV, in the roads under jurisdiction of the Road Police of Jaú, since January of 2008 until July of 2009.

Infractions

Table 3 shows according CTB (Brazilian Traffic Code edited on 1998), the articles and typify and its respective road safety indicator.

Table 3– Articles and typify according CTB, and respective indicator.

Article	Typify	Indicators
167	Not wearing seat belt	Seat belt
230 XVIII	Bad state of conservation and safety	Vehicle conditions
230 XXII	Defect of signalization and illumination	Vehicle conditions
165	Driver under influence of alcohol	Alcohol
244 I e II	Not wearing helmet or in discordance	Helmet
218 Inc I a	Speeding until 20% of the limit	Speed
218 Inc I b	Speeding over 20% of the limit	Speed

Source: Brazil, 1998.

In Table 4 is shown the number of official notifications of infractions send to drivers, referring to indicators for the 1º and 2 º semesters of 2008.

Table 4. Number of infractions per indicator.

Indicator	1º Sem 2008	2º Sem 2008
Speed	0	0
Alcohol	0	18
Seat belt	343	189
Helmet	14	28
Vehicle conditions	498	304
Driver inexperience	0	0

Source: Polícia Militar Rodoviária de Jaú

Unfortunately information regarding speed was not possible to obtain, due the lack of source. The following can be depicted from the table above:

1. Alcohol: we can see a slight increase. In accordance with the table, no register was made in the first semester, but it not means that none was been made, but at that time the breathalyzer was not delivered to the police, and the notifications made is at dependency of report, what demand some months. What no occurred in the second semester because the use of breathalyzer made notification process almost online.

2. Helmet: the articles 244 I and 244 II, encompass sundry situations of helmet irregularities, being the notifications of non use of helmet rare in most parts of Brazil, because is one of the main targets of police enforcement.

3. Seat belt and vehicle conditions – the decrease in the number of notification was due the decrease in the number of inspections of this kind, because of the lost of seven police officers at that time.

4. Driver inexperience – as mention before the database does not have this kind of information to be use at ease.

Making comparison between the 1º semester of 2008 and 1º Semester of 2009, we have the following numbers shown on Table 5:

Table 5 – Number of infractions per type of indicator.

Indicators	1º Sem 2008	1º Sem 2009
Speed	0	0
Alcohol	0	23
Seat belt	343	350
Helmet	14	15
Vehicle conditions	498	407
Driver inexperience	0	0

Source: Polícia Militar Rodoviária de Jaú

The indicators are subject a lot of flaws like the number of inspections or surveillance by the Police, that can vary from period to period These make one to raise a red flag. And new consideration must be made in this subject, to make possible an analysis. It is necessary to introduce the number of inspections realized by police to drivers and the number of official notifications received for these drivers inspected in comparison with other infractions not used as indicators. Police stop drivers for inspection randomly, so the official notification can

be said to be a random sample. In Table 6 are shown the number of vehicles stopped and number of vehicles that received an official notification (fine).

Table 6 – Number of vehicles stopped and that received an official notification

Number of vehicles	1º Sem 2008	2º Sem 2008	1º Sem 2009
Stopped	13047	12485	13187
Received Official Notification	3308	2644	2792
Percentage of official notification	25.35%	21.17%	21.15%
Total Infractions for indicators	855	539	795
Percentage of official notification indicator	6.55%	4.32%	6.03%

To improve the analysis it was used an index that was called index of infractions that is equal to the sum of infractions of total indicator per total number of vehicles stopped and will be denoted by Ψ. Also, for each indicator was calculated its own index, namely, $\Psi_{alcohol}$, $\Psi_{seat\ belt}$, Ψ_{helmet} , $\Psi_{vehicle\ condition}$ by total number of vehicle stopped. In Table 7 the same data of Table 5 is transcript with additional information of number of infractions reported by Police for each period and number of infractions per total of indicators and for each indicator.

Table 7– Number of infractions per type of indicator.

Indicators	1º Sem 2008	2º Sem 2008	1º Sem 2009
Speed	0	0	0
Alcohol	0	18	23
Seat belt	343	189	350
Helmet	14	28	15
Vehicle conditions	498	304	407
Driver inexperience	0	0	0
Total number of vehicle stopped	3308	2644	2792
Total Infractions for indicators	855	539	795
Ψ	6.55%	4.32%	6.03%
Ψ alcohol	-	0.14%	0.17%
Ψ seat belt	2.63%	1.51%	2.65%
Ψ helmet	0.10%	0.22%	0.11%
Ψ vehicle cond	3.82%	2.43%	3.09%

Source: Polícia Militar Rodoviária de Jaú

Accidents

Based on road accidents, the accidents count for the period of January of 2008 to July of 2009 are shown in Table 8.

Table 8– Accidents count in the period of January of 2008 to July of 2009.

Accidents	1º Sem 2008	2º Sem 2008	1º Sem 2009
PDO	189	203	223
With Victims	168	150	150
Total Accidents	357	353	373
Fatal Victims	8	13	10
Non Fatal Victims	349	340	363
Total Accidents	357	353	373
Victim non serious injured	192	195	172
Victim serious injured	72	52	56
Victim Fatal	9	16	10
Total Victims	273	263	238
Run over non fatal	4	1	0
Run over fatal	1	1	2

Source: Polícia Militar Rodoviária de Jaú

Analyzing the Table 8 it is possible to deduce:

1. The accidents with victims in this period of analysis had a tendency to reduce since the first semester of 2008, from 168 to 150 in the second semester of 2008 (when the breathalyzer began to be used) and first semester of 2009.

2. Comparing the first Semester of 2008 with the first semester of 2009, we have a reduction in the number of non serious and serious victims and a slight increase in fatal victims from 9 to 10. The accidents without victims also had a slight increase.

3. The total number of victims was reduced from 273 in the first semester of 2008 to 263 in the second semester of 2008, and to 238 in the first semester of 2009.

4. It is important to point out that in the second semester of 2008, in the months of July and August, four accidents with fatal victims occurred where six people died.

Comparison among secondary road safety indicators and accidents and victims

For a better visualization over relationship among number of accidents, number of victims and secondary road safety indicators, in Figure 2 it is represented the total number of accidents, total number of accidents with property damage only (PDO), total number of accidents with no fatal victim, the total number of accidents with fatal victims times 10, Ψ times 2,000, $\Psi_{alcohol}$ times 100,000, $\Psi_{seat\ belt}$ times 10,000, Ψ_{helmet} times 100,000 $\Psi_{vehicle\ condition}$ times 100,000; and in Figure 3 it is represented the total number of fatal victim times 10 for each semester, the total number of serious injured victim, the total number of non serious injured victim, Ψ times 10, $\Psi_{alcohol}$ times 100,000, $\Psi_{seat\ belt}$ times 1,000, Ψ_{helmet} times10,000, $\Psi_{vehicle\ condition}$ times 10,000.

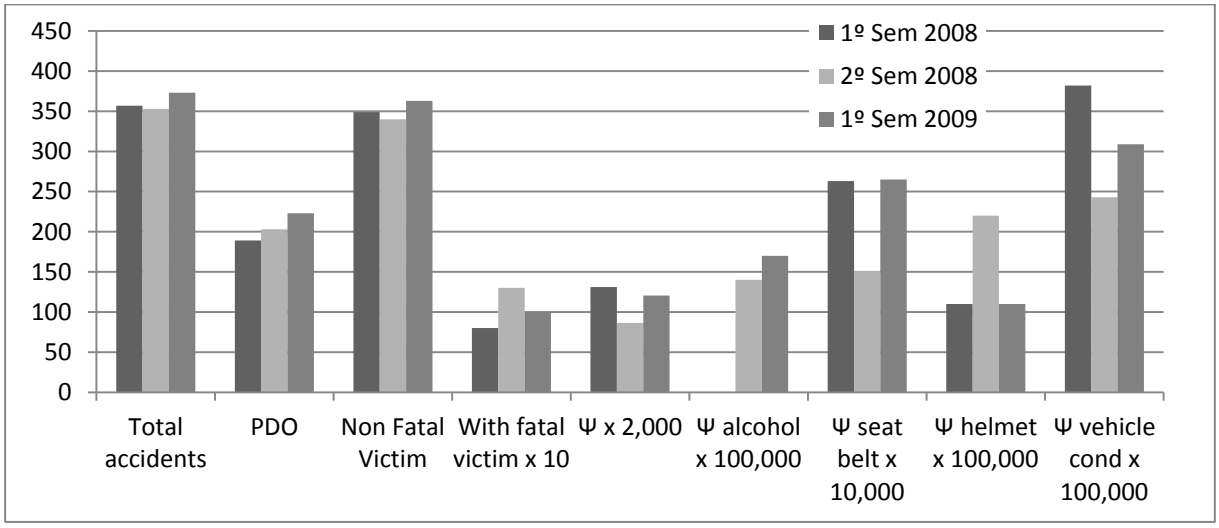

Figure 2: Comparison with total number of accidents, total number of PDO accidents, total number of accident with non fatal victim, number of accidents with fatal victims x10 and secondary road safety indicators.

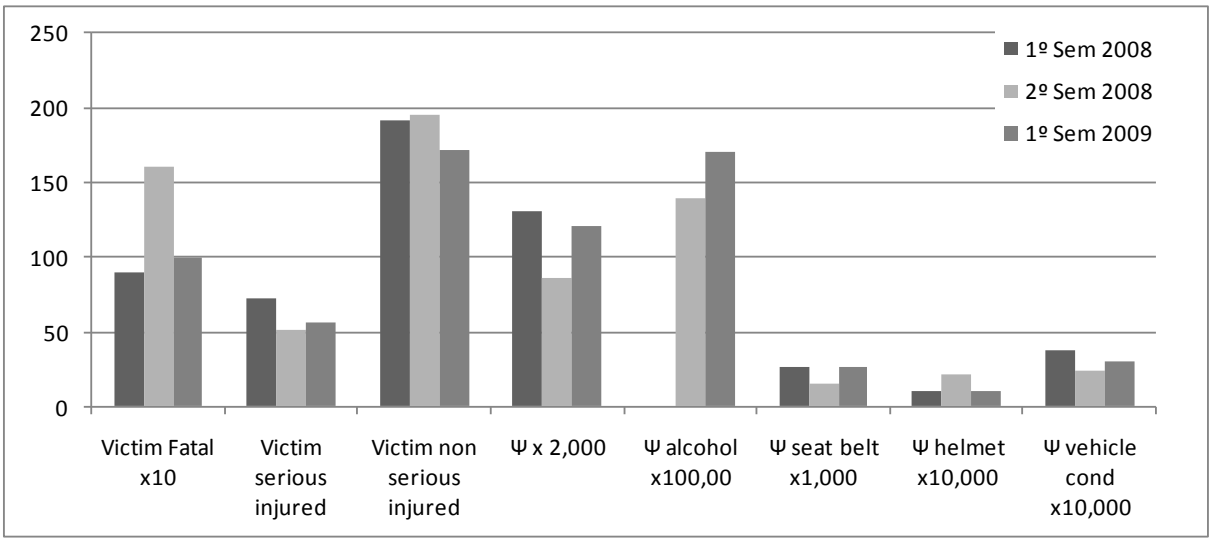

Figure 3: Comparison with total number of victim fatal x10, total number of victim serious injured, total number of victim non serious injured and road safety indicators.

It is possible to depict from Figures 1 and 2 the following:

1. The indicators Ψ,$\Psi_{\text{seat belt}}$,$\Psi_{\text{vehicle condition}}$ follow closely the tendency of the number of total accidents and total number of accidents with non fatal victims.

2. In relation to the total number of PDO accidents this tendency was not observed for the first semester of 2008, but for the second semester of 2008 and first semester of 2009 the tendency appear.

3. The indicator Ψ_{alcohol} only is available to the second semester of 2008 and first semester of 2009 and also show the same tendency of follow total number of accidents, non fatal accidents and PDO accidents (second semester of 2008 and first semester of 2009).

4. The indicator, Ψ_{helmet} follows closely the tendency of total accidents with fatal victim. This tendency also appears in regarding total number of fatal victim.

5. The indicators Ψ,$\Psi_{\text{seat belt}}$, $\Psi_{\text{vehicle condition}}$ follow the same tendency of total number of serious injured.

6. The indicators Ψ,$\Psi_{\text{seat belt}}$, $\Psi_{\text{vehicle condition}}$ follow opposite tendency of total victims non serious injured.

Of course that some indicators are more related with consequences of the victims as seat belt and helmet than to occurrence of accidents like alcohol, speeding, vehicle condition and driver inexperience. But a reckless behavior can be indicated also by the indicators related to consequences. And maybe this reckless behavior could have connection with occurrence of accidents.

6. FINAL CONSIDERATIONS

In developing countries like Brazil, where the motorization rates increase and population rates increase, only primary indicators could not give an overview of road safety in the country. Accident rates per vehicle and population will be constant or decrease only because in increases in the denominator. Thus the use of secondary indicators is a good policy to estimate road safety situation.

The use concomitant of primary and secondary indicators it is already practice in some countries of Europe, and in some parts of United States and Canada. But in Brazil, so far, this is the first work attempt to explore this subject.

Both primary and secondary indicators are fundamentals to identify (or a tentative to identify) the main causes of accidents and to formulate strategies, targets and measures to mitigate and prevent road accidents. For example, when a road behaviour (secondary) indicator revel an increase in drivers driving under influence of alcohol and the primary indicator show an increase in the number of accidents related to alcohol; the interpretation of these two indicators could lead to consider that more accidents are occurring because more drivers are driving under influence of alcohol. However, it does not indicate a direct relation between cause and consequence, but only a possible cause in the web of the causal factors. The secondary indicator is also useful to making following up with measures undertaken in road safety, to estimate its efficiency.

In this paper we tried to show that the use of indicators extracted from information about infractions, related to drivers behavior, that already exist in the database of Road Military Police in Jaú is a good start point for develop such indicators.

It was demonstrated that the indicators, from the period under scrutiny, follow the tendencies of the total number of accidents, total number of non fatal accidents, and in part follows the tendency of PDO accidents and victim serious injured. The indicator Ψ_{helmet} has a close tendency to the number of accident with fatal victims and number of fatal victims. Although, we do not have official data about the mode of transport of this victims, is well-known in Brazil that the number of fatal victims in road accidents is roughly composed by 50% of motorcycles. And this indicator could be an indication of this relationship.

Inasmuch as new studies about this subject arise, the improvement of methodology in the analysis of secondary road safety indicators will lead to a better comprehension over its interaction and relation with road safety.

The authors would like to point out some restrictions of this paper concerning of not have information about speeding infractions and driver experience. For developing more accurate and precisely secondary indicators from the Road Military Police database of infractions, some suggestions is presented as follow: incorporated the date of the first drive license in the

field of the search engine of the database and make a partnership with the agency that is responsible for speeding surveillance for incorporate this information in the database.

Furthermore, even with lack of indicators about speeding and driver experience this paper is a tentative to show the utility of secondary road indicators and the ways to obtain with the tools at hand, the database from Road Military Police, with negligible costs and time consuming. In other words, is a low cost measure to obtain road safety behavior indicator.

We hope that future works could overcome the flaws encounter in this paper, and improve the number of road safety indicators that can contribute to the progress of road safety in Brazil.

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