METHODOLOGY FOR PRIORITIZING ACTIONS FOR ROADWAY SAFETY

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RESUMO

Este artigo tem como objetivo propor um método para priorização de medidas de segurança em um sistema rodoviário, usando como estudo de caso a malha administrada pelo Consórcio Univias. Primeiramente, é realizada uma revisão bibliográfica mostrando o contexto dos acidentes de trânsito no Brasil. Faz-se um panorama entre o índice de acidentes existente no Univias em comparação ao contexto internacional. Além disso, é pormenorizado o perfil desses acidentes, detalhando-se suas ocorrências temporais, tipos, gravidade, e os veículos envolvidos. Descreve-se uma metodologia para seleção de pontos críticos a serem melhorados, de forma a fomentar a segurança, culminando com a seleção dos 19 principais locais de severidade do Univias. É descrito o tratamento dado a dois desses locais, mostrando o projeto e ações de engenharia efetuadas, inclusive com fotos de antes e depois. Por fim, confirma-se a eficácia do método, através da constatação da redução de sinistralidade.

Palavras chaves: segurança rodoviária; índices de acidentes; soluções de engenharia.

ABSTRACT

This paper aims to suggest a method for prioritizing security actions in a road system using as case study the net managed by Univias System. In order to achieve this aim, a literature review on the traffic accident context in Brazil is carried out. Through this, Univias index of accidents is compared with to what happen in the international context. The profile of these accidents is detailed with the description of the frequency occurrence, accident types and gravity, and involved vehicles. The methodology used in this study determined the critical points which must be ameliorated and the 19 accident locations. The treatments given to two of these locations are also presented as well as the project and effected actions of engineering, with before and later photos. Finally, the effectiveness of the method was confirmed by the accident reduction.

Keywords: safety; accident index; engineering solutions.

1 INTRODUCTION

The uncontrolled growth of urban areas and the increasing motorization of cities have been contributing to the proliferation of accidents which consequently increases the need for more effective traffic safety programs. In this context, the rates of traffic accidents have been used to describe the situation of traffic safety of countries, states and municipalities, and the obtained values were compared with international standard index. Considering the high importance of the subject, it is possible to say that the number of comparative studies in Brazil is still small.

In these circumstances, the general goal of this study is to compare accident and death rates in order to propose measures to reduce these numbers. This comparison is made between roads granted to Univias System, considering the performance of Federal Highways in the State of Rio Grande do Sul and the highways of European countries.

2 LITERATURE REVIEW

The World Health Organization defines accident as an event beyond the control of man, caused by an external force, which acts suddenly and leaves wounds on the body and the mind (Gold, 1998). According to Santos and Junior Ray (2006), the traffic accident is an event that occurs on public roads involving at least one vehicle, motorized or not, that normally circulates by a way designated for it, resulting in material, physical damages that, in some cases, may lead to the death of one or more involved.

Traffic accidents can be divided into three groups: accidents without casualties, accidents with injuries and fatal accidents. Accident without victim is the one that produces material damage without causing any physical harm on the people involved. The accident victim type causes any injury at least in one person involved in it. And fatal accident is the one that causes death in at least one of the involved.

In Brazil, on average 34 thousand people die each year and other 400 thousand are injured or disabled as a result of traffic accidents (DENATRAN and Ministry of Cities, 2005). In 2004, the country recorded 127,470 deaths due to external factors, of which about 27.5% were caused by road accidents (Ministry of Health, 2006). According to Mantovani (2004), in the 1990s, Brazil had 3.3% of the total number of fleet vehicles worldwide, accounting for 5.5% of all fatal accidents in the world.

2.1 Accidents Index

In the literature, there are several types of index to determine accidents; each of them is used according to local convenience and availability of existing data. The most commonly used are: gross amount of accidents, gross amount of deaths, deaths per million inhabitants, deaths per 100 million passenger-km; deaths per million passengers (ERF, 2008); deaths per vehicle-mile (NHTSA, 2008), and deaths per 100 million vehicle-miles (NHTSA, 2006).

In this study, we used the indicators "accidents per million passengers" and "deaths per 100 million passengers". These indexes were chosen considering the following reasons: they adequately represent the concept of accident exposure once they take in account passengers bystanders; they have a simplified formula and showed superior performance on index related to population since many road users do not live in the places where they pass through.

2.2 Methodology for Evaluation of Severity Points

The first step of every program to improve road safety is the identification of locations prone to accidents. Considering that accidents are hazardous events, it is expected that they will be distributed randomly over time and space. But when specific points with a concentration of accidents over time are identified, it is possible to say that these points are possible candidates for locations prone to accidents.

In Brazil there are published two books whose aim is to standardize the identification of locations prone to accidents (DENATRAN, 1987, Ministry of Transport, 2002). Both publications suggest the use of a numerical method to set locations prone to accidents based on accident rates of an amount of locations.

The identification methods of locations prone to accidents can be divided into three types: numerical, probabilistic and based on analysis of traffic conflict methods. Each of the three methods has some advantages and disadvantages that should be taken into account.

This work uses a numerical method for the identification of locations prone to accidents. This method is the most optimized and identify the critical sites through the comparison of the absolute number or the accident rate at a location with previously established values. Places with values of accidents over this value are considered as locations prone to accidents. Both the absolute number of accidents and the accident rate can be based on the weighted amount of accidents using the Weighted Severity Unit, WSU (DENATRAN, 1987, Fitzpatrick et all, 2000).

The National Traffic Department (DENATRAN, 1983) established the Weighted Severity Unit (WSU) that is the results obtained from the sum of accident occurrences with the weight assigned to the respective severity. Thus, the amount of accidents determination, in WSU, is obtained from the following formula:

$$WSU = A + p \times B + q \times C \tag{1}$$

Where:
A: Accidents involving damage; B: Accidents with injuries; C: Accident deaths;
p: 5 (parameter DENATRAN), q: 13 (parameter DENATRAN).

3 CURRENT STATUS OF UNIVIAS

Table 1 shows the rate of accidents and deaths per passenger passersby the roads of Univias System compared to Federal Highways in Rio Grande do Sul and the highways of european countries. To calculate the number of passengers passersby, it was considered an average occupancy of 2.7 passengers per vehicle, value obtained in a search origin-destination.

3.1 Profile of the Accidents

All accidents on the road net managed by Univias System are recorded in a software called SSU ("Service System Univias") used in its Control Center Operations. This software was developed internally by staff of the company, with web technology (allowing remote access), high capacity of data store (SQL database). All the information relating to accidents such as recordings of calls, photos, vehicles involved, description of the accident, victims, road conditions, weather conditions, etc. are stored in SSU System. To enable the creation of reports, it was also developed a dynamic web-based spreadsheet that accesses this database, allowing all types of crossing information.

Table 1. Comparative Data of Accident and Death Index– 2006

Ranking	Country	Accid./10^6 pass.	Ranking	Country	Death/10^8 pass.
1	Denmark	10	1	Sweden	45
2	Luxemburg	11	2	Netherlands	48
3	Finland	11	3	United Kingdom	48
4	France	11	4	Malta	49
5	România	13	5	Finland	53
6	Netherlands	16	6	Luxemburg	54
7	Greece	17	7	Denmark	56
8	Lithuania	17	8	Germany	57
9	Sweden	18	9	France	64
10	Poland	21	10	Italy	74
11	Estônia	21	11	Belgium	96
12	Ireland	24	12	Austria	100
13	Bulgária	26	13	Slovenia	113
14	Latvia	27	14	Spain	117
15	United Kingdom	28	15	Ireland	130
16	Spain	28	16	Portugal	131
17	Slovakia	29	17	Czech Republic	146
18	Czech Republic	30	18	Cyprus	167
19	Italy	31	19	Federal Highways of the Rio Grande do Sul	172
20	Germany	37	20	Greece	174
21	**Univias**	**39**	21	Estonia	175
22	Malta	39	22	**Univias**	**189**
23	Hungary	43	23	Lithuania	191
24	Belgium	44	24	Slovakia	215
25	Federal Highways of the Rio Grande do Sul	47	25	Poland	235
26	Portugal	48	26	Latvia	256
27	Slovenia	50	27	Hungary	271
28	Cyprus	50	28	Bulgaria	328
29	Áustria	55	29	Romania	398

Figure 1 shows accidents by the time of the day during 2007 and 2008 on roads managed by Univias. Afternoon and early evening represent the periods when there is the greatest number of accidents; the period from 6 to 7 p.m. is the occurrence peak time (8.33%).

Regarding to the months of the year, the number of accidents is almost constant. The months of December and January have a slightly higher percentage than those of the remaining months, 9.8% and 9.0% respectively (see Figure 2). This fact occurs because the traffic in these two months is slightly higher than the traffic of other months due to holidays at the end of year (Christmas and New Year Eve) and the beginning of summer holidays.

Knowing the types of accidents in the net road makes possible to highlight the lack of security more frequently, guiding the global actions for accident reductions (see Figure 3). The types of accidents that occur more are "run-off-the roads" (26.7%), closely related to the driver sleep and use of drugs (alcohol, drugs). Lateral collisions account for 21.4% of the total and are related to passages and crossings in urban areas. Back collisions represent the third largest share of the accidents (15.5%) and are linked to sudden braking, drivers' inattention and improper distance from the vehicle in front.

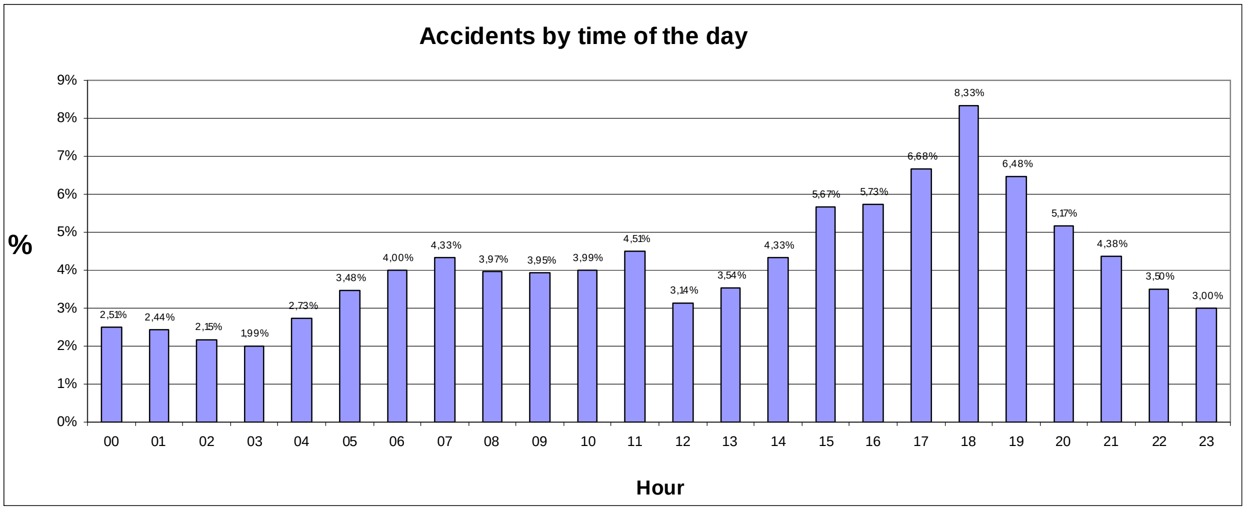

Figure 1. Accidents by Time of the Day (2007-2008)

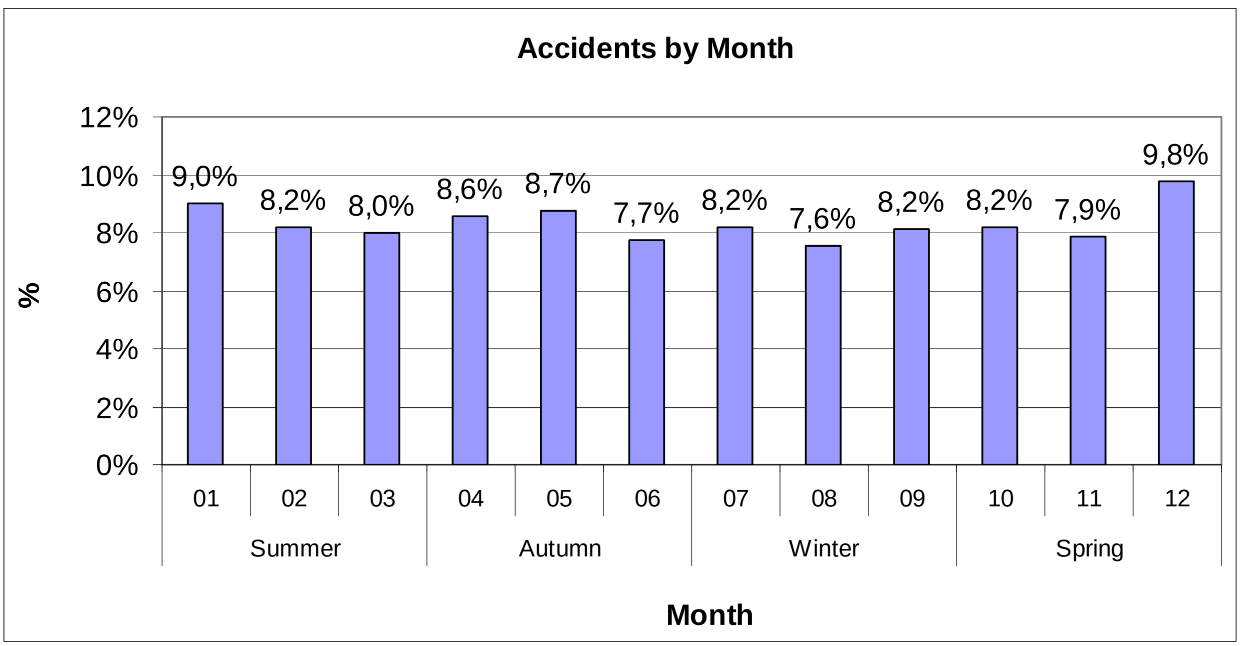

Figure 2. Accidents by Month (2007-2008)

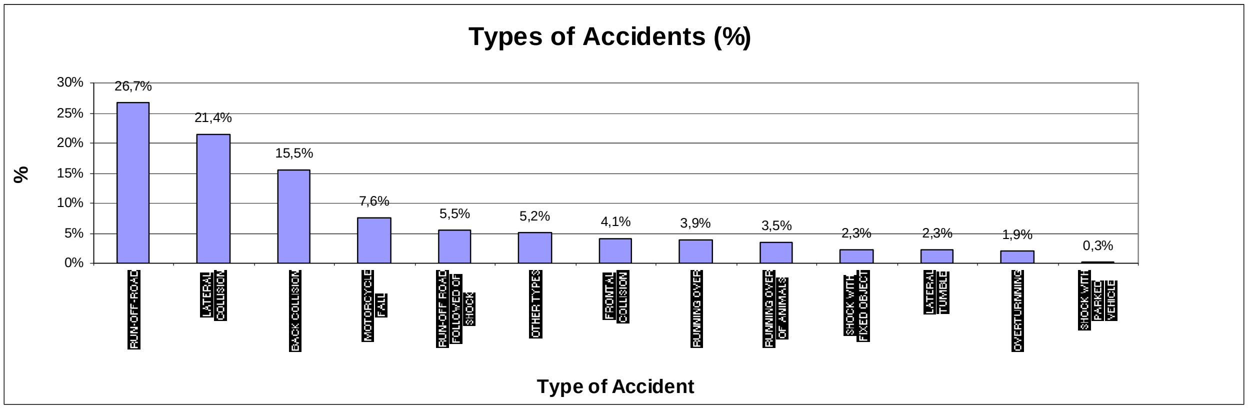

Figure 3. Types of Accidents (2007-2008)

The most severe type of accident is the frontal collision, representing 39.1% of deaths and 17.1% of serious injuries in Univias road system (see Figure 4). Running over crashes also have high levels of severity, representing 16.5% of deaths and 13% of serious injuries, followed by lateral collisions that make up 11.7% of deaths and 29.5% of serious injuries reported. Figure 4 shows all types of accidents with the respective level of severity in relation to wounded and deaths.

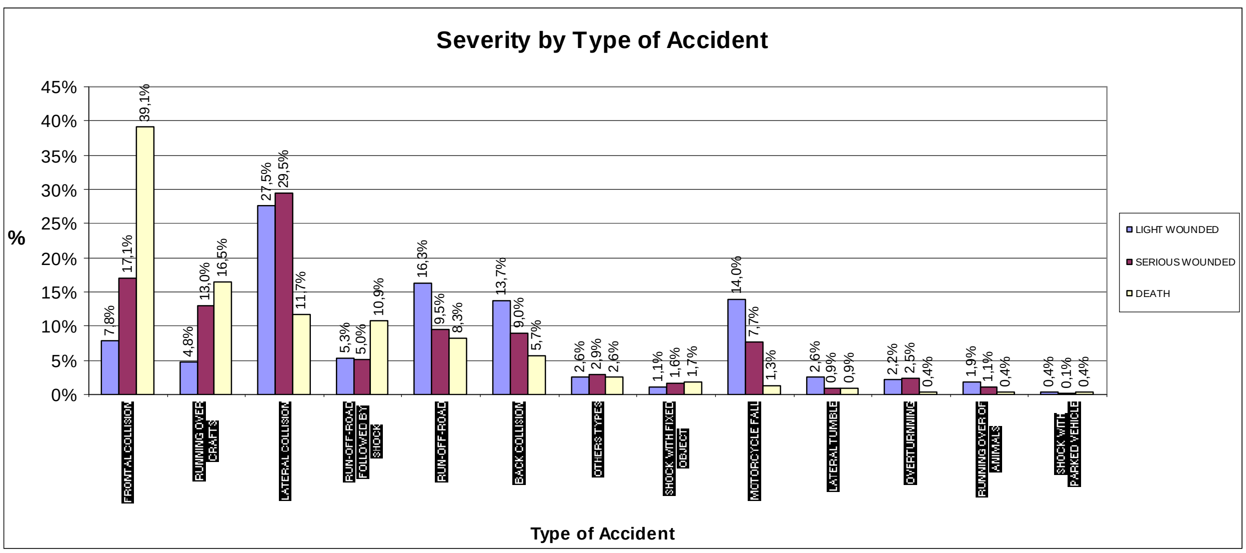

Figure 4. Severity of Accidents (2007-2008)

Regarding the gender of those involved in accidents, 81% are men and 19% women (see Figure 5). The accident most representative age group are young people between 21 to 30 years (30.1% of those involved), followed by adults between 31 and 40 years (21.9% of those involved) and adults between 41 and 50 years (18.3% of those involved).

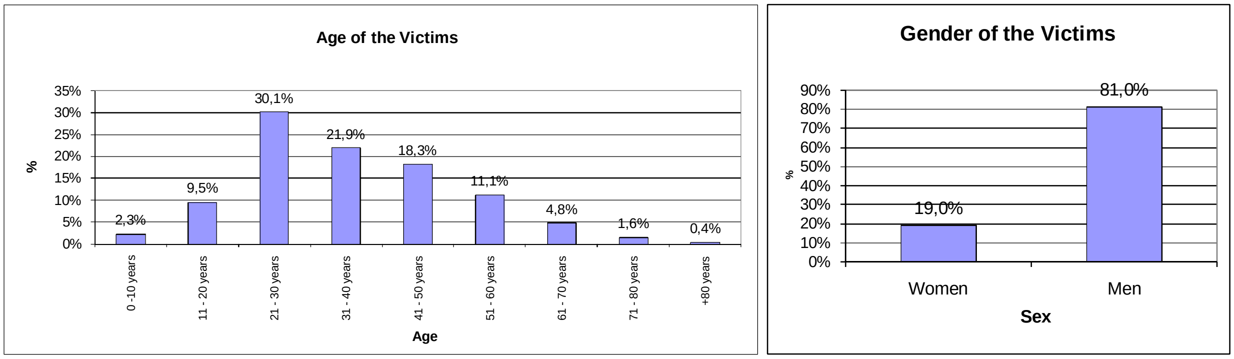

Figure 5. Age and Gender of the People Involved (2007-2008)

Figure 6 presents all types of vehicles and their involvement percentage in traffic accidents on the Univias road system. Cars represent 49.1% of the vehicles involved in accidents, followed by motorcycles (14.7%), simple trucks (14%), pick-ups and vans (10.3%) and articulated trucks (8%).

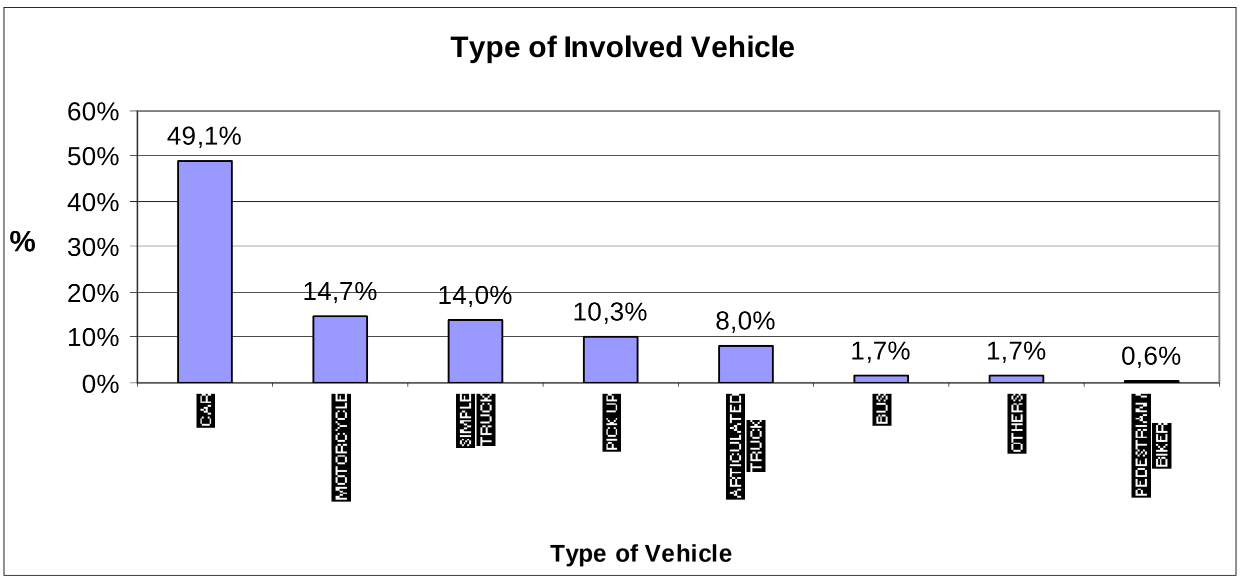

Figure 6. Vehicles involved in Accidents (2007-2008).

4 DETERMINATION OF THE SEVERITY DEGREE

Table 2 presents the 19 segments of Univias Road system with the greatest severity according to Weighted Severity Unit.

Table 2. Segments of Univias Road System with the Greatest Severity

Pole	Segment	RS / BR	Km	WSU Factor
Lajeado	Lajeado – Roca Sales	RS/130	72	300
Lajeado	Lajeado – Soledade	BR/386	343	264
Metropolitano	Gravataí – Osório	RS/030	55	208
Lajeado	Lajeado – Roca Sales	RS/130	78	176
Caxias do Sul	Caxias do Sul – Nova Milano	RS/122	59	166
Caxias do Sul	Caxias do Sul – Nova Milano	RS/122	66	160
Lajeado	Lajeado – Roca Sales	RS/130	75	160
Caxias do Sul	Caxias do Sul – Nova Milano	RS/122	61	143
Lajeado	Lajeado – Roca Sales	RS/130	73	142
Caxias do Sul	Caxias do Sul – Nova Milano	RS/122	65	140
Metropolitano	Gravataí – Osório	RS/030	51	139
Lajeado	Lajeado – Soledade	BR/386	342	137
Caxias do Sul	Caxias do Sul – Nova Milano	RS/122	63	131
Caxias do Sul	Caxias do Sul – Nova Milano	RS/122	62	126
Lajeado	Lajeado – Soledade	BR/386	341	124
Caxias do Sul	Caxias do Sul – Nova Milano	RS/122	70	124
Metropolitano	Gravataí – Osório	RS/030	52	122
Lajeado	Estrela – Tabaí	BR/386	366	116
Caxias do Sul	Caxias do Sul – Nova Milano	RS/122	80	114

The 19 km of segments with greatest severity represent 1.8% of the total of Univias System highways. However, these segments make up 10.1% of all accidents and 10.8% of all deaths in the system.

5 TREATMENT OF SEVERITY SEGMENTS

After defining the main segments of accident severity in Univias net road, it is necessary to define the engineering measures to be undertaken at these segments. For this, 10 accident reports were collected in each kilometer in order to understand the causes of the accidents.

After this, it was possible to link engineering appropriate actions to enhance road safety in each of the points. Moreover, it was calculated a preview of investment to be spent. As the availability of resources was limited, the actions have been prioritized in segments where the investment is lower, as in some points the solution involves large sums, such as the construction of new bridges and intersections.

Thus, certain engineering actions were defined for 10 of the 19 set segments. In the sequence, two actions performed in the 51 km and 55 km of Highway RS 030 are described as well as the technical procedure used and the results obtained in road safety.

5.1) 51 km of RS 030 (Urban Crossing of Santo Antonio da Patrulha City)

In the 51 km of 030 RS State Highway, there were the following issues: the passing traffic had top speed higher than urban traffic; absence of signaling; conversions left had high risk of front and lateral collisions, and; junctions were conflicting.

Thus, the road project of the location was rebuilt (see Figure 7), taking the following measures: implementation of the roundabout, provision of precast elements for ordering the return movement; allocation of vertical and horizontal signaling reduction speed (allowing safe passage of pedestrians); placement of semi-soft defenses to protect against collisions poles. Figure 8 shows images taken before and after the implementation of measures of traffic engineering; it brings more safety to he roads and the measures has increased the urban landscape of communities along the tracks, greatly improving their quality of life.

5.2) 55 km of RS 030 (Succession of curves after Santo Antonio da Patrulha)

The 55 km of RS 030 state highway presented the following problems: sinuous planimetry and wavy longitudinal topography; two horizontal curves preceded by tangents which induced high speeds causing run-off-road and accidents; the road was paved but with shoulder on gravel; the pedestrian passing was difficult; the markings were faded; the warning signs were old and with low reflectivity, and there was absence or disability of delineators on curves, contributing to the run-off-road.

The technical measures adopted were the following (see Figure 9): maintenance of the markings (check visibility distances up in overtaking), and implantation of warning signs with larger sizes, placement of new regulatory boards (gradual reduction of speed of 80 km/h to 60 km/h), use of new delineators on curves at the time and pace determined by the rules; repair of pavements using new studs in a closer cadence and studs on the axle of the road to improve the conditions of the shoulder, measure that allow the traffic of pedestrians, cyclists and coachmen. Figure 10 shows pictures of before and after the implementation of engineering measures and the improvements in visualization of the track layout, as well as the paving of its shoulder.

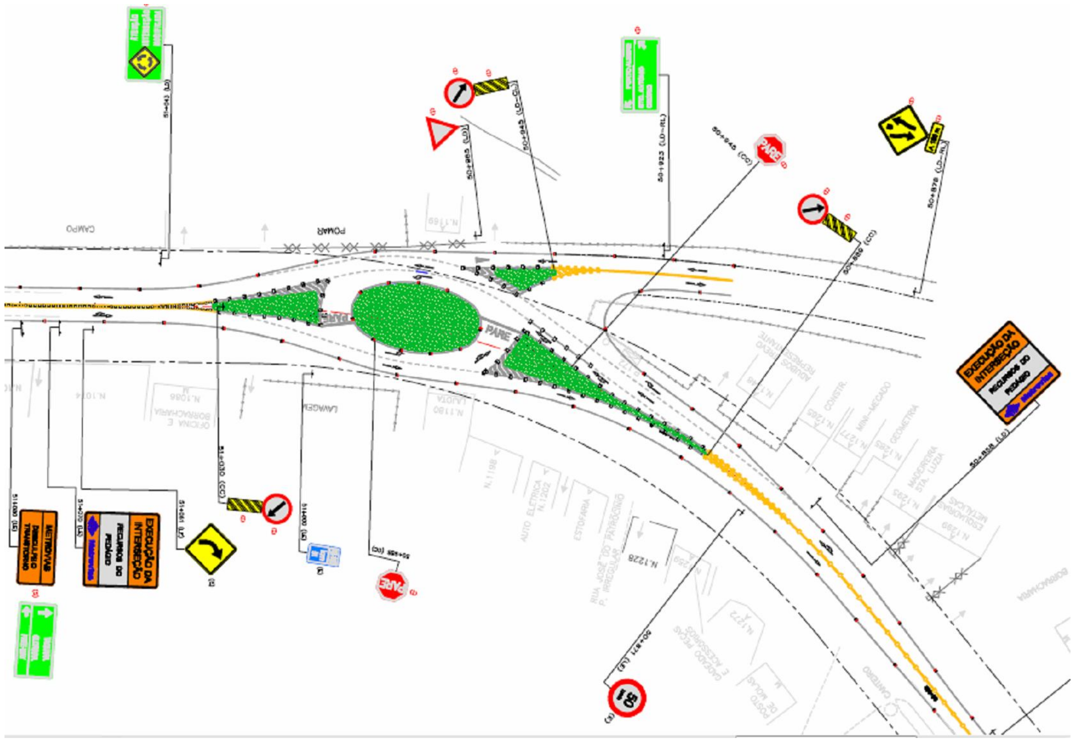

Figure 7. Improvement Project of 51 km of RS 030

BEFORE **AFTER**

Figure 8. Image Before and After the Engineering Measures at 51 km of RS 030

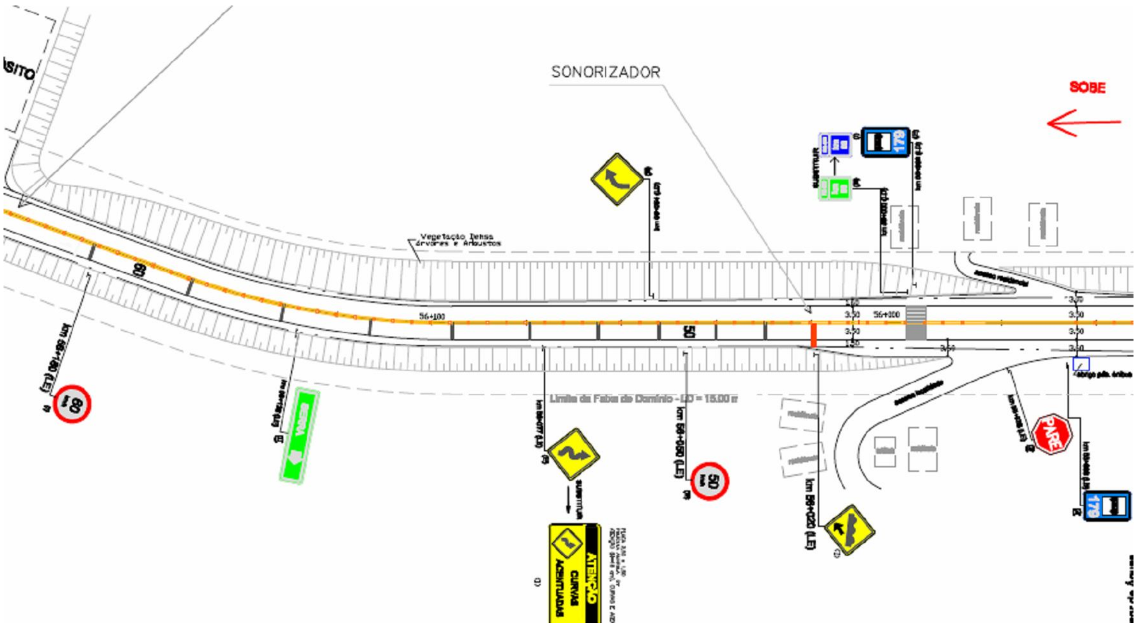

Figura 9. Improvement Project of 55 km of RS 030

BEFORE **AFTER**

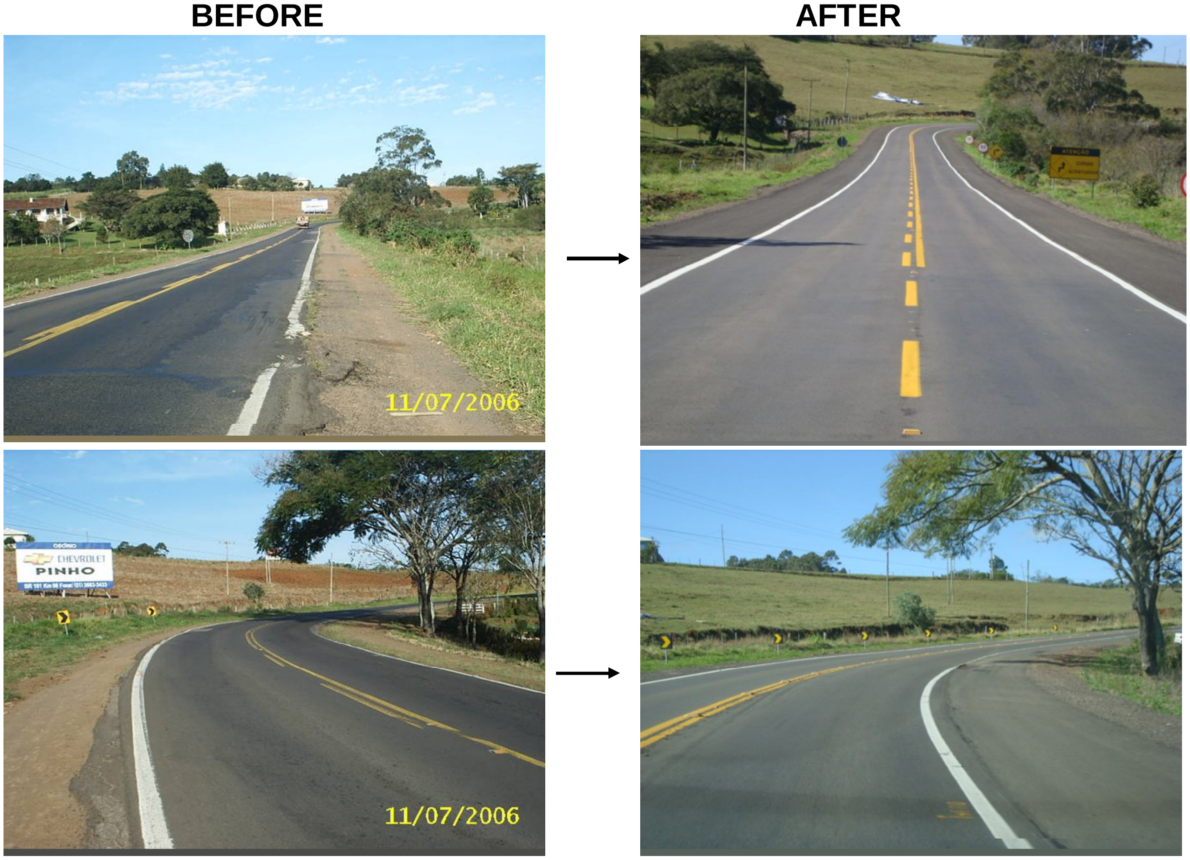

Figure 10. Image Before and After the Engineering Measures at 55 km of RS 030 km

5.3) Efficiency of the Deployed Measures

Table 3 presents the result obtained with the engineering actions performed at the two critical segments. It is possible to see that 51 km of the RS 030 was the worst eleventh kilometer of road safety in 1050 km of Univias highway system between the years 2005 and 2007, and the sixty-ninth in 2008, falling 58 positions.

The 55 km of RS 030 was the third worst point in relation to the degree of severity between 2005 and 2007 and became the thirty-second in 2008, dropping 29 positions. These findings confirm the credibility of the methodology, which helps greatly in reducing accidents.

Table 3. Results of Engineering Actions (degree of severity positions)

PLACE / YEAR	km 51, RS 030	km 55, RS 030
(BEFORE INTERVENTION) 2005 – 2007	11	3
(AFTER INTERVENTION) 2008	69	32
RANKING IMPROVEMENT	58 POSITIONS	29 POSITIONS

6 FINAL CONCLUSIONS

Through this research it was possible to learn about some concepts which contribute greatly to the improvement of safety standards for road traffic:

- indicators of road accidents (accidents and deaths) should be as simple and comprehensive as possible in order to enable comparison of performance between similar location (benchmarking). Only through this way is possible to place the local performance in a larger context of reference;
- the increase in road safety should always start by improving the locations most prone to accidents, optimizing the expenditure of resources;
- databases of accidents must have high reliability to enable the correct decision;
- most of the observed road safety problems are in the implementation of urban areas, where exposure and traffic conflicts are far superior;
- the engineering actions reduce accidents and casualties, and really improve local urban landscape, contributing greatly to increase the quality of life of its inhabitants;
- knowing of the effectiveness of each measurement technique is very important in order to maximize investments.

Through the engineering actions in the 10-segments of accident severity of Univias System seeks to target a reduction of 3% of accidents and 5% of deaths for the year 2009. The performance of each of these projects will be evaluated, confirming the effectiveness and the potential replication of these measures in other parts of accident risk in order to make the highway net as homogeneous and safer as possible.

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