BENEFIT-COST ANALYSIS OF ROUNDABOUTS IN A BRAZILIAN CITY REGARDING TO THE NUMBER AND SEVERITY OF TRAFFIC ACCIDENTS – A CASE STUDY

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ABSTRACT

This paper has the objective to analyze the benefit-cost of building roundabouts as a traffic safety infrastructure measure in Jaú city, Brazil. The chosen places have priority over other intersections because they have data available to analyze the before-after situation. Jaú city has the database with information from 2000 until 2007, as well as the dates of construction's implementation. It was made a research on the accident database of the Jaú Secretary of Transport. After this research, the cost-benefit analysis was calculated using a methodology described by Hauer (1997). The percentage of reduction in the number of accidents found in this study is in accordance which is founded in the literature, around 50% of reduction in accidents and severity (Várhely, 1996). In contradiction, other studies founded that the introduction of roundabouts reduces the severity of accidents, but increase the number of property damage accidents until 73% (Elvik and Vaa, 2004). In this study of case was found that the number of property damage accidents and severity of accidents were reduced with roundabouts. However, some disclaimers must be made with these results: it was used the naive before-after studies approach, so the percentages of reduction could be related to other factors not only to roundabouts, the vehicle flow was not considered, and as the sites was chosen due the high rates of conflicts which could have bring bias to the sample.

Keywords: roundabout, traffic safety, benefit- cost

1. INTRODUCTION

The road accidents are a serious problem in the contemporary world. WHO (2004) estimated that in 2002 occurred 1,180,000 deaths because road accidents (average of 3242 deaths per day) and around 20 to 50 millions of injured people, whom many of them with physical and mental incapacity or severe psychology sequel, which prevent normal life.

This scenario will be more tragic in the future if adequate polices would not took in practice, because the forecast is that this number will be raise reaching the milestone of 2 million of death in the year of 2020. This estimative consider an increase of 80% of death in not developed countries and a reduction of 30% in developed countries (this countries are undertaken efficient actions to reduce deaths and accidents in traffic).

The road accidents were 11th cause of deaths in the world in 2002 (around 2.1% of total). In the group of people between 5 and 40 years old, was the 2nd cause of deaths. In the year of 2020, the forecast is that road accidents will be the 6th cause, with 3.4% of total of deaths.

However, as the victims (dead and injured) in traffic are more frequent among young people, the most suitable healthy indicator of impacts of road accidents to society is DALY (Disability-Adjust Life Year): a measure that combine the number of years lost due to premature death and the number of years lived with the disability (weighted accordingly to the type of disability). With this indicator, in 1990, the road accidents were classified in the 9th position, being responsible for approximately 2.6% of total sum of all Daly's indicators. In 2020, the forecast is that road accidents will be in 3th position, behind only by heath disease and depression, being 5.15% of total sum of all Daly's indicators. Considering only the countries with medium and low developing, the road accidents will occupy in 2020 the 2nd position, behind only by heath disease.

1.1. BRAZILIAN SCENARIO

In Brazil, according to OEI (2007), MS (2006) and ABRAMET (2007), the follows annual numbers of road accidents for the year of 2005 were: 1 million of accidents, 385 thousands accidents with victims (82% in urban areas, and 18% in rural areas), 36 thousands deaths, 515 thousands injured (with 100 thousands with permanent disability), 208 accidents with victims per 100 thousand inhabitants, 91 accidents with victims per 10 thousand vehicles, 279 victims per 100 thousand inhabitants, 122 victims per 10 thousand vehicles, 19 deaths per 100 thousand inhabitants and 85 deaths per 10 thousand vehicles.

The comparison of index of mortality in traffic in Brazil with developed countries shows the seriousness of the road accidents in the Country. The relation between the number of deaths and vehicle fleet is, in Brazil, more than 10 times superior than Switzerland, Sweden and Japan: more than 8 times superior than Germany and Great Britain; 5 times superior than France, Canada; and 4 times superior United States.

This dramatic situation tend to worse furthermore, considering that the number of deaths in traffic turn to raise since 2001, after experiencing a decline in the years 1998, 1999 and 2000, due to the implementation of the new Brazilian Traffic Law (Law nº 9.503, published in 23/09/1997).

The deaths rates associated to different causes of mortality confirm the seriousness of road accidents in Brazil. Considering the top ten causes of deaths in the year of 2004, the road accidents are in 7th position, with a rate of 19.6 deaths per 100 thousands inhabitants. The other aspect extremely negative of road accidents is the impact that they have over the economy. By WHO (2004), the monetary cost of injured and deaths in traffic around the world in 2002 was estimated in 518 billions of dollars. In this estimative, were considering the follows percentages in the GDP for the cost of road accidents: 1% in countries with low developing; 1.5% in countries with medium developing and 2% in developing countries.

In this total, are included the following costs: hospital, treatment and rehabilitation of the victims, material lost (vehicles, goods, road furniture, etc.); removing crashed vehicles, rescue of victims, clean and repair of damages caused on the road environment, lost of labor days, pensions and early retirements, police and litigation costs, etc.

Based on the studies of IPEA (2003), about road accidents in urban areas, and IPEA (2006), about road accidents in rural areas, the annual cost of road accidents in Brazil is estimated to be around 21 billions of dollars, which correspond to 1.24% of Brazilian GDP in 2007, approximately. This value, 1.24%, is situated between 1.0 and 1.5% - which are the values adopted by WHO (2004) in the estimative of total cost of accidents in countries with low and medium developing, respectively. More important than the economic costs of road accidents, are, however, the human and social costs: the physical and psychological suffering of victims, and psychological suffering of relatives and people related to the victims, diseases of psychological nature that attack victims and close relatives (depression, fear, etc.), lost of quality of life of victims and their families, divorce of couples, separation of dear relatives due hospital treatment and rehabilitation, etc.

1.2. TRAFFIC ACCIDENT COSTS

Namely, traffic accident costs can be divided in three main parts: economic cost; human and social cost; and environmental cost. They will be summarized below.

Economic cost

In Brazil, two recent studies have been conduct by the Institute of statistics and economy (IPEA) of the costs of road accidents: IPEA (2003) is a research about the accidents in the city and IPEA (2006) is about accidents on highways. The average costs by type of accident obtained in the studies are indicated on the Table 1. They were updated to December 2007 by an inflation indicator well known in Brazil. Also on the Table 1 there is an indication of the annual cost of accidents on the cities and on the highways, for Brazil.

Table 1– Costs of traffic accidents (values are in Brazilian reais updated to December 2007).

Description	Highways	Cities	Country
Property damage only	18,075.00	4,125.00	-
Accidents with injury victim (R$)	92,341.00	22,077.00	-
Fatal accidents (R$)	449,018.00	182,262.00	-
All accidents (R$)	63,198.00	11,104.00	-
Total annual (billions R$/Year)	23.61	6.7	30.31

Human and social costs

More important than the economic cost of accidents is the human and social cost: physical and psychological suffering of the victims, psychological suffering of the family members and related ones, after crash psychological diseases strikes victims and related people with fear, depression; quality of life loss for to all directly or indirectly involved, couples break-up, long term hospital treatment and rehabilitation, etc.

Environmental cost

Accidents involving vehicles that transport dangerous products, in many cases, spills the load of goods provoke big environmental damage into the soil, water, forests, animals, and even on the climate. One thing is certain: these impacts are very hard to measure, however, there is no doubt that these accidents cause huge harm to the environment and to the society in general.

1.3. TARGETS TO REDUCE THE ACCIDENTS AND DEATHS ON TRAFFIC

Traffic can be considered as an open system constituted by human being, vehicles and environment, which interact adequately with each other in most cases. When this interaction does not occur in an appropriate manner, by fault of one or more associated factors related to these three elements, an accident may happen.

A systemic view about the traffic accidents was represented in the well known Haddon matrix form. Connected to the actions associated to each one of the three elements that composes the transit system aiming to avoid accidents (pre-crash period), mitigate the consequences of moment the accident happens (crash period) and mitigate the effects after it occurs (after-crash period).

In fact, there are four macro-actions used with the objective to reduce accidents and death on traffic:

- Reduction of the risk exposure

- Reduction of the accident occurrence
- Reduction of the accident severity
- Improvement of the victim's care

2. METHODOLOGY DESCRIPTION

The methodology used in this work was based on the bibliographic revision studied about road safety measures and the evaluation studies on their effects. It was created a methodology to choose primarily the locals where the roundabouts were built. The chosen places have priority over other intersections because they used to have high rate of road conflicts and also because there was some data available to analyze the before-after situation at that specific locations. Jaú has the database with information from 2000 until 2007, as well as the dates of construction's implementation, that were considered the limit point to the before-after analysis.

Even though, it is necessary to choose a time frame that contains information for the analysis of all places which have suffered infrastructures' changes. The use of tools that help to visualize the locations is essential to traffic safety works. This happens because all the constructions related to traffic have to be analyzed including their surroundings and their impact. Knowing this, interest's points of Jaú were located on a digital map. Precisely, all the roundabouts built after 1999 were added to a Geographic Information System – GIS for a better visualization and spatial data analysis, numbering then from 1 to 15 by the criteria of implementation data. After this point, it was initialized the accident database research on the database of the Transport Secretary of Jaú and the Jaú Department of Transit. The State of São Paulo Military police feed this database by the composition of documents known as "*Boletins de Ocorrências*" (official reports about accidents) that are the form in which all traffic agent or police describes the accident.

The topographic and the geometric project adopted in each roundabout was raise to better understand their geometry before and after, and also how this could affect the local traffic. This kind of analysis made possible to evaluate the roundabout's performance in the accident rate reduction in Jaú, making it feasible to compare to other locations.

After this geometric review, the cost-benefit analysis was calculated using a methodology of Naïve Before-After studies described by Hauer (1997).

The most correct actions would be to consider other variables involved with the relation between the absolute numbers of analyzed accidents; however, since there were not enough data, it was used pure number along with a comparative mean of the period before and after the construction of the roundabouts.

Based on this data, it was possible to simply analyze the accident variations related to the growth or the shrink on the number of accidents at each roundabout by subtracting the average of accidents before and after. This data associated to the costs of Brazilian accidents (IPEA, 2003) and the cost of construction of the traffic calming device, allowed us to come up with a benefit-cost analysis.

2.1. Naive Before – After Studies

The estimation of the effect of a treatment on safety always entails a prediction of what safety would have been in the after period had the treatment not been implemented, and the juxtaposition of this prediction to an estimate of what safety in the after period actually was. Accordingly with Hauer(1997) in its simplest form, an observational Before-After study consist of comparing the count of the "before" period accidents for an entity to its count of "after" period accidents. The basic logic of a naive before-after study is that the count of "before" period accidents is used to predict what would have been the expected count of "after" period accidents had the treatment not been implemented. This way of predicting reflects naive and usually unrealistic belief that the passage of time was not associated with changes that affected the safety of the entity under scrutiny. In spite of its obvious flaw, the Naive-Before study will be used here, because of the lack of data this is the only study that can be made with the available data. The statistical analysis performed here was base on the methodology presented in Hauer (1997) and is summarized below:

Let

π be what the expected number of target accidents of a specific entity in an "after" period would have been had it not been treated; π is what has to be predicted and

λ be the expected number of target accidents of the entity in the "after" period; λ is what has to be estimated.

The effect of the treatment on safety is judged by comparing λ and π. In compare the two we used:

$\delta=\pi-\lambda$ the reduction in the "after" period of the expected number of target accidents (by kind or severity), or

$\theta=\lambda/\pi$ the ratio of what safety was with the treatment to what it would have been without the treatment – the "index of effectiveness".

When $\theta<1$, the treatment is effective; when $\theta>1$ it is harmful to safety.

So, the logical essence of an observational Before-After study is the comparison of a prediction ($\hat{\pi}$) of would have been the expected number of target accidents of an entity in the "after" period, had a treatment not been implemented, with an estimate of ($\hat{\lambda}$) of what the expected number of target accidents of the entity was with the treatment in place. General expressions for doing so were given in Hauer (1997) and the entire process has been structured into four basic steps, are shown in the next session.

Statistical Analysis of the naive Before-After Study

Some treatment has been implemented on entities numbered 1, 2,..., j,..., n. During the "before" periods the accident counts were K(1), K(2),...K(n) and during the "after" periods the accident counts were L(1), L(2),...,L(n). The duration of the "before" and "after" periods may differ from entity to entity. Thus, the ratio of durations will be:

$$r_d(j) = \frac{\text{Duration of after period for entity } j}{\text{Duration of before period for entity } j}$$

Because expected values are never known, but can be estimated from observed data, the Greek letters with caret will be used meaning "estimate of" the parameter which it refers. In Table 2 are the four steps summarized.

Table 2 – The summary of four steps computations

STEP 1	STEP 2
$\hat{\lambda}$ =Σ L(j)	VÂR{$\hat{\lambda}$}= Σ L(j)
$\hat{\pi}$ = Σ r_d(j)K(j)	VÂR{$\hat{\pi}$}= Σ r_d^2(j)K(j)
STEP 3	STEP 4
δ=π – λ	VAR{$\hat{\delta}$}= VAR{$\hat{\pi}$}+ VAR{$\hat{\lambda}$}
θ*= (λ/π)/[1+VAR{$\hat{\pi}$}/ π^2]	VAR{$\hat{\theta}$}≈ θ^2[(VAR{$\hat{\lambda}$}/λ^2)+(VAR{$\hat{\pi}$}/π^2)]/[1+VAR{$\hat{\pi}$}/π^2] ^{2}

3. CASE STUDY: JAÚ-BRAZIL

Jaú is a city of approximately 130.000 inhabitants located on the State of São Paulo, Brazil. It is considered an average size town with big city problems, once its population is mainly urban. Like Jaú, there are lots of towns in the country side. In Table 3 are listed a summary of Jaú data.

Table 3 – Summary data about accidents, population, fleet and index of accidents by fleet

Year	Number of Accidents			Fleet	Population	Total number of accidents	Index of accident per fleet			
	Fatal Victims	Non fatal victims	Proper Damage Only				I_{acc} total	I_{acc} fatal	I_{acc} victims	I_{acc} PDO
1997	10	713	1427	39.508	105.966	2150	54,42	2,53	18,05	36,12
1998	10	625	1263	39.193	107.968	1898	48,43	2,55	15,95	32,23
1999	7	701	1315	40.769	109.965	2023	49,62	1,72	17,19	32,25
2000	11	569	1257	43.177	112.104	1837	42,55	2,55	13,18	29,11
2001	9	470	1235	45.811	113.952	1714	37,41	1,96	10,26	26,96
2002	5	516	1225	48.596	115.889	1746	35,93	1,03	10,62	25,21
2003	10	622	1216	51.639	117.645	1848	35,79	1,94	12,05	23,55
2004	9	709	1331	54.733	121.333	2049	37,44	1,64	12,95	24,32
2005	11	744	1355	54.727	123.374	2110	38,56	2,01	13,59	24,76
2006	6	655	1379	58.698	125.399	2040	34,75	1,02	11,16	23,49
2007	6	743	1437	63.199	125.469	2186	34,59	0,95	11,76	22,74

(*) Iacc_total, Iacc_victims e Iacc_PDO given in accidents per 1,000 vehicles, Iacc_fatal given in deaths per 10,000 vehicles.

3.1. Adopted actions by the Jaú municipality

According to Elvik and Vaa (2004), a common problem in accident and injury prevention work is lack of motivation. Common reasons why many people do not want to get involved in accident and injury prevention are that they do not regard accident as a problem or they do not believe it is worth doing anything to prevent accidents.

These authors assume that local community safety programs have been found to reduce the number of accidents in these communities significantly. However, not all local community safety programs are successful. To succeed, a community needs good local accident statistics, a capability to identify the most important local accidents problems and ways of creating a strong motivation for improving safety. These programs usually have some characteristics:

1. The systematic recording of accidents in a local community over a given period of time;
2. On the basis of accident records, the dominant accident problems in the local community are identified;
3. A steering group for accident prevention in the local community is set up, with participation from all parties which are presumably able to contribute to preventing accidents, including the municipality, schools, and the police;
4. The safety program is implemented. During the hole implementation period, changes in the number of accidents and injuries are monitored closely and information on new developments is given to all those participating in the program.

Worried about the traffic safety issue, Jaú municipality adopted a safety program since 2000, and understanding the transit as an interdisciplinary issue and focused low cost road safety effective solutions, invested basically on the macro-areas of education, engineering and enforcement, adopted along with the transit and public transportation integrated management technique.

3.2. The study of roundabouts usage to accident reduction

According to Elvik and Vaa (2004), in the chapter about roundabouts says that at road junctions heavy traffic waiting times for traffic required to give away be long. This may tempt road users to enter the junction with small margins. Frequent crossing and turning maneuvers can create dangerous situations and make the traffic situation complex. Around 40% of all injury accidents reported to the police occurs at intersections."

For them, converting intersections to roundabouts can improve safety and traffic flow. Roundabouts can contribute to increasing road safety in the following ways; by theoretically reducing the number of conflict points between the traffic streams passing through an intersection from 32 to 20 at crossroads and 9 to 8 at T-junctions.

Road users entering a roundabout are require to give way to road users already in the roundabout, no matter which road they are coming from, and thus are forced to observe traffic at the roundabout more carefully all traffic comes from one direction. Road users therefore do not have to observe traffic form several directions at the same time in order to find a gap to enter the roundabout.

Roundabouts with offside priority eliminate left-turn in front of oncoming traffic roundabout are built so that road users cannot drive a straight path through the junction but must drive round a traffic island located in the middle of the junction. The roundabout with preference to circling traffic presents, for the safety point of view, the following positive aspects: the passage happens with low speed because the change of trajectory and need to stop or yield to inside traffic; decision making to enter is done observing just one side, where the visibility to driver is better; the number of conflict points at roundabouts is smaller, and in some cases, eliminate the need for conversion to the left and crossing the opposite flow (maneuver potentially dangerous).

According to Várhelyi (1996), experiences of rebuilding a large number of intersections on arterial roads as roundabouts in England showed that the number of accidents decreased by 30-40%. As examples, he mention Simon in Switzerland, who also concluded that small roundabouts increase safety, and Van Minnen, in the Netherlands, who reported that new roundabouts reduced the total number of accidents by 50% and the number of casualties.

This way, 56 roundabouts were built from 2001 to 2007, as shown on the illustration below.

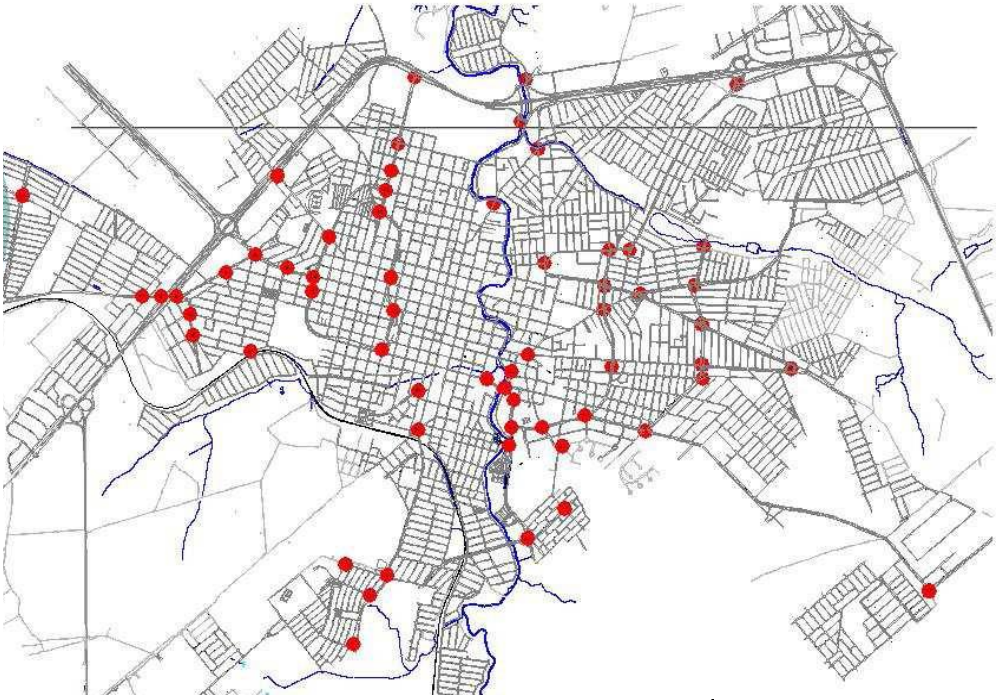

Figure1: Roundabouts built in Jaú-SP BRAZIL

From these 56, it was randomly selected 15 to analyze the accidents before and after the implementation, the locations of these 15 intersections are shown on the Figure 2.

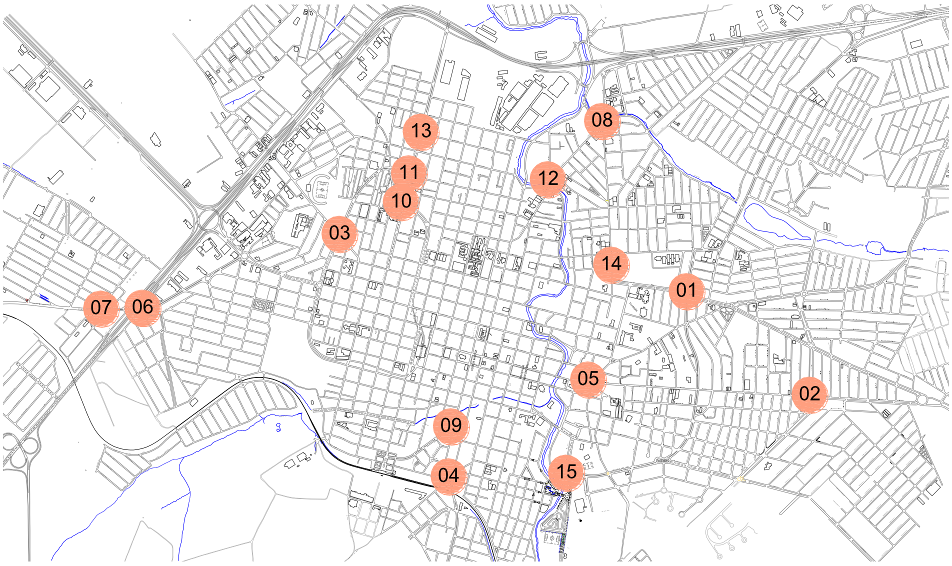

Figure 2 – Map with the location of the 15 studied roundabout

On the next table there is a list of addresses for the roundabouts used in this project to analyze the benefit-cost of the implementation of this kind of traffic calming infra-structure.

Table 2 - Addresses for the roundabouts analyzed and dates of implementation

Roundabouts changed		
J	**Date**	**Address**
01	09/2001	Av. Isaltino do Amaral Carvalho x Av. João Ferraz Neto
02	04/2002	Rua Rui Barbosa x Av. Nenê Galvão
03	06/2002	Av. Caetano Perlatti x Av. Zezinho Magalhães
04	05/2003	Av. Décio Pacheco de Almeida Prado x Rua Dr. Amaral Carvalho x Alameda Cel. Miranda Prado
05	06/2003	Rua Rui Barbosa x Rua Major Alfredo S. O. Romão x Rua D. Silveira x Rua Tenente Navarro
06	08/2003	Av. Dr. Luciano P. de Almeida Prado Neto x Av. Antonio H. G. Pelegrina x Av. Fernando de Lúcio x Rua Miro Campana
07	08/2003	Av. Dr. Luciano P. de Almeida Prado Neto x Rua Augusto Caseiro x Rua José Blassioli
08	09/2003	Av. do Café x Av. Joaquim F. de Camargo x Av. Cmte João Ribeiro de Barros
09	05/2004	Rua Major Ascânio x Av. Brasil x Travessa Pereira Lima
10	07/2004	Av. Frederico Ozanan x Av. das Nações x Rua Jesuíno dos Santos
11	07/2004	Av. Frederico Ozanan x Av. Zezinho Magalhães x Rua Alfredo Leitão
12	02/2005	Rua Pereira de Toledo x Rua Pef. Mário Ferraz Magalhães x Av. Cmte João Ribeiro de Barros
13	04/2005	Av. Frederico Ozanan x Rua Sampaio Bueno / Av. Frederico Ozanan x Francisco Sampaio
14	04/2006	Av. do Café x Rua Irmã M. Gabriela x Av. Gustavo Chiozzi
15	12/2006	Av. Isaltino do Amaral Carvalho x Av. Dr. Quinzinho

The intersection number 13 was taken out of analysis because it was formed by two intersections, and the data are aggregate for these two intersections so it was impossible disaggregated the information about accident count for each one. In Figure 3 and 4 are shown the drafts of before and after implementation of roundabouts in those 14 remain intersections.

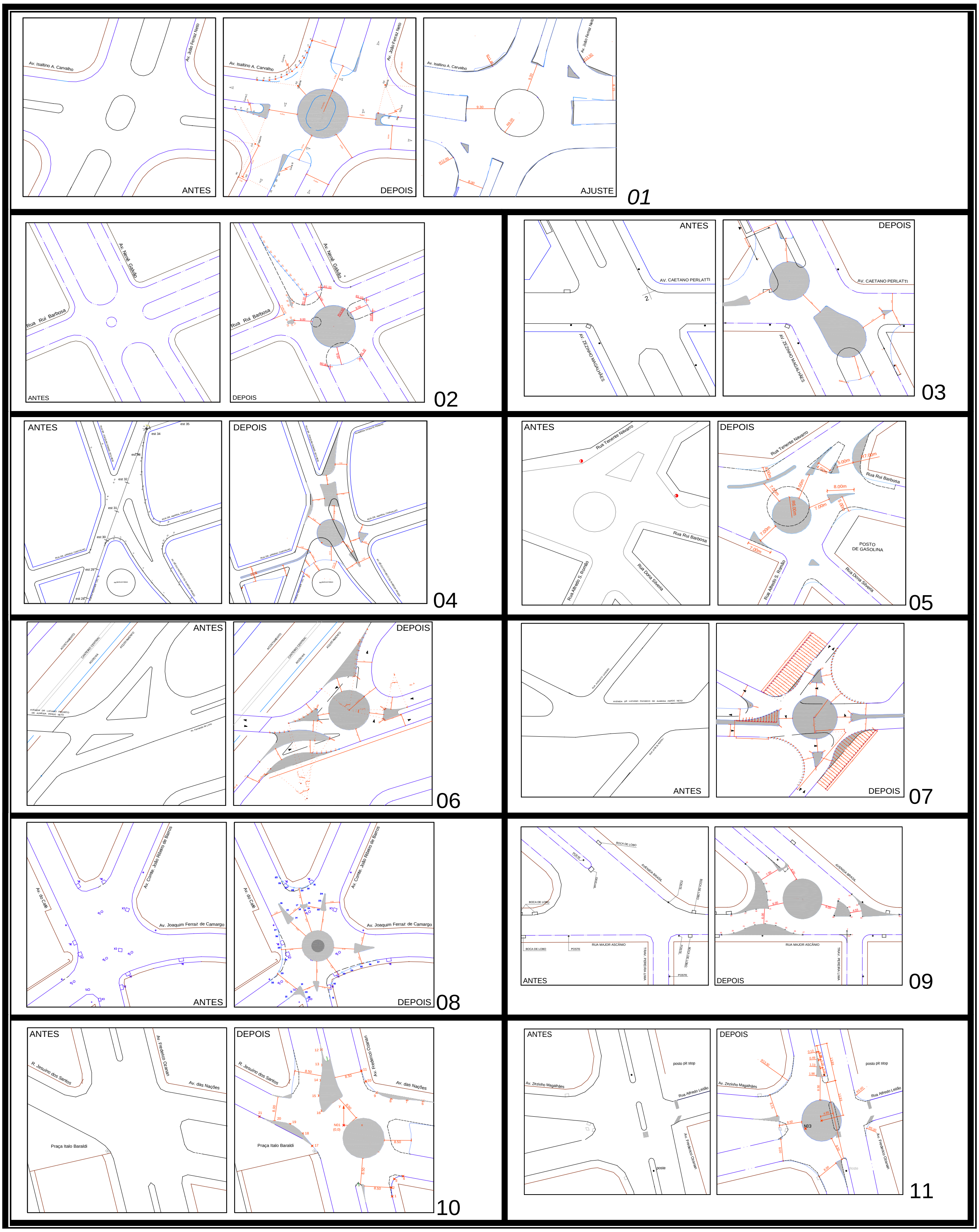

Figure 3 – Drafts of before and after implementation of roundabout at the intersections 1 to 11.

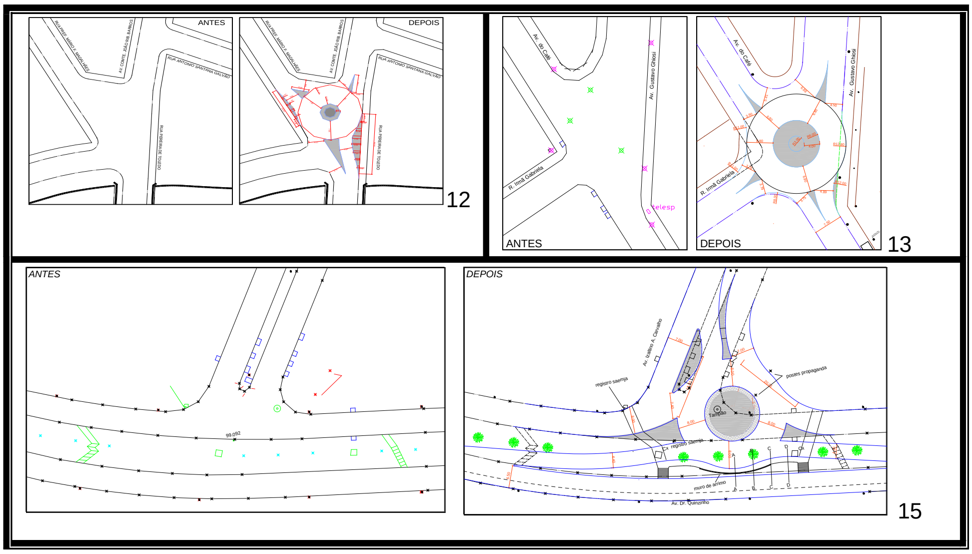

Figure 4 – Drafts of before and after implementation of roundabout at the intersections 12, 14 and 15.

3.3. Data and computations

The data and computation for those 14 intersections are shown in Table 2 for accidents with property damage only. In Table 3 are the end results of computation for those 14 intersections for accidents property damage only. In Table 4 are the data and computation for those 14 intersections for accidents with victims and in Table 5 are the respective end results. The computations follows the methodology describe in Hauer (1997).

Tabela 2 – Data and computations for accidents with property damage only

intersection number	Years Before	Years After	Acc. Before	Acc. After			
J			K(j)	L(j)	rd(j)	rd(j).K(j)	$rd^2(j).K(j)$
1	2	8	33	65	4.00	132.00	528.00
2	3	5	12	9	1.67	20.00	33.33
3	3	5	19	8	1.67	31.67	52.78
4	4	4	4	0	1.00	4.00	4.00
5	4	4	27	18	1.00	27.00	27.00
6	4	4	1	4	1.00	1.00	1.00
7	4	4	3	1	1.00	3.00	3.00
8	4	4	8	13	1.00	8.00	8.00
9	5	3	3	2	0.60	1.80	1.08
10	5	3	10	9	0.60	6.00	3.60
11	5	3	19	5	0.60	11.40	6.84
12	6	2	4	0	0.33	1.33	0.44
14	7	1	13	1	0.14	1.86	0.27
15	6	2	46	11	0.33	15.33	5.11
Sums				146		264.39	674.45

Table 3 - Results for accidents with property damage only

λ=	146.00	σ{λ}=	12.08
π=	264.39	σ{π}=	25.97
δ=	118.39	σ{δ}=	28.64
θ=	0.55	σ{θ}=	0.07

Tabela 4 – Data and computations for accidents count with victims

intersection number	Years Before	Years After	Acc. Before	Acc. After			
J			K(j)	L(j)	rd(j)	rd(j).K(j)	$rd^2(j).K(j)$
1	2	8	15	26	4.00	60.00	240.00
2	3	5	5	6	1.67	8.33	13.89
3	3	5	5	1	1.67	8.33	13.89
4	4	4	2	0	1.00	2.00	2.00
5	4	4	4	5	1.00	4.00	4.00
6	4	4	0	3	1.00	0.00	0.00
7	4	4	3	1	1.00	3.00	3.00
8	4	4	2	5	1.00	2.00	2.00
9	5	3	3	2	0.60	1.80	1.08
10	5	3	5	4	0.60	3.00	1.80
11	5	3	10	2	0.60	6.00	3.60
12	6	2	4	0	0.33	1.33	0.44
14	7	1	2	0	0.14	0.29	0.04
15	6	2	19	6	0.33	6.33	2.11
Sums			79	61		106.42	287.85

Table 5 - Results for accidents with property damage only

λ=	61.00	σ{λ}=	7.81
π=	106.42	σ{π}=	16.97
δ=	45.42	σ{δ}=	18.68
θ=	0.56	σ{θ}=	0.11

4. INTERPRETING THE RESULTS

The intersections analysed had a reduction of 118.39 ± 28.64 in the total number of accidents or 45% ± 7% of reduction in the total number of accidents. Also had a reduction of 45.42 ± 18.68 in the number of accidents with victims or 44% ± 11% of reduction in the number of accidents with victims.

Thus, the noted reduction in safety reflects not only the effect of implementation of roundabout in these 14 intersections but also the effects of factors such as traffic, weather, vehicle fleet, driver behaviour, inclinations to report accidents and so on. It is not known what part of the change can be attributed to the implementation of roundabouts and what part is due to the various other influences. And also the noted change in safety may be in part due to the spontaneous regression-to-the mean and not due to implementation of roundabout.

Inasmuch as it is the only method at hand, it will be used to computation the cost benefit analysis, but we need to have in mind the disclaimers state above.

5. BENEFIT-COST ANALYSIS

The benefit-cost analysis was based on available and possible data, such as building costs, average of accidents before and after its implementation, and the cost of accidents for the Brazilian case develop by IPEA (2003). In this case, neither the population nor the fleet was used to analyze the Benefit cost value.

It was use the total cost of built the roundabouts as the cost. The benefit cost was calculated by the estimative of reduction of accidents in the naive approach for the intersections and periods in analysis, using the results obtained in section 3.

Table 6-Accident costs of IPEA/2003 update to June of 2008 for cities.

Type of accident	Cost (R$/accident)
Property Damage Only	4,275.00
With non fatal victims	22,882.00
With fatal victims	188,902.00
All types of accidents	11,509.00

The costs of building these 14 roundabouts actualized to June of 2008 were R$ 348,000.00[1]. The total number of accidents reduction in the best scenery is 118.89 + 28.64 = 148.53 accidents without victims and 45.42 + 18.68 = 64.20 accidents with victims, which makes monetary beneficial of R$ 2,095,230.74 for the best estimates. For worst scenery we have an reduction of 118.89 -28.64 = 90.25 accidents without victims and 45.42 -18.68= 26.74 accidents with victims, which makes a monetary beneficial of R$ 995,565.12 for the worst scenery. For the median scenery we have a monetary beneficial of R$ 1,545,397.93. Those numbers are summarized on Table 7.

Table 7- Benefit –cost ratios estimatives in different sceneries

Scenery	Benefit R$	Cost R$	B/C
Best	2,095,230.74	348,000.00	6.02
Worst	995,565.00	348,000.00	2.86
Median	1,545,397.00	348,000.00	4.44

[1] Brazilian Reais

6. FINAL CONSIDERATIONS

Although the benefit-cost ratio are high for any of those sceneries we must have in mind that was used the naive Before-After studies and the changes encounter here are not only due the implementation of roundabouts. However, Brazil has an increasing in the motorization rate in the last years, in special in motorcycle fleet. Some studies point an increasing in the number of accidents, in great extent with fatal and injured victims with this kind of transportation mode (MS, 2007). Jaú also had an increasing in the percentage of motorcycles in the fleet, and almost the half of deaths was motorcyclists in 2008. As in this study the changes in vehicles flows are not take into account, the figures could be even better. Another consideration that must be made is the fact that the intersections chosen to be change in roundabouts had high number of conflicts, and the results could have been high due this fact, in other words, could have brought some bias to the sample, and an improved methodology must be applied in future work, using for example, a comparison group.

But these roughly analysis shows even in the case of Brazil were the cost of accidents are relatively low in comparison with developed countries, the roundabouts could have a benefit-cost ratio.

We would like to highlight also that the cost of constructions of the roundabouts were low because the design and construction was made with the employees of the Secretary of the Transport at that time. It shows also that roundabouts can be a low cost traffic engineering measure to reduce accidents in developing countries, were the work force is cheap in comparison with developed countries, with advantage of low cost of maintenance if compare with traffic lights. Inasmuch as Brazil has high rates of drivers running red traffic lights, roundabout have one more advantage: as is well-known the roundabout is self regulated and helps to reduce speeds and reduce the severity of accidents.

Therefore the percentage of reduction in the number of accidents found in this study is in accordance which is founded in the literature, around 50% of reduction in accidents and severity (Várhely, 1996). In contradiction, other studies founded that the introduction of roundabouts reduces the severity of accidents, but increase the number of property damage accidents until 73% (Elvik and Vaa, 2004). In this study of case was found that the number of property damage accidents and severity of accidents were reduced with roundabouts.

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