A TALE OF TWO CITIES – SOME EMPIRICAL EVIDENCES OF HOW THE URBAN AND TRANSPORTATION PLANNING INFLUENCES ACCIDENTS AT INTERSECTIONS

Barbara Stolte Bezerra
University of the State of São Paulo – Faculty of Engineering of Bauru – barbarabezerra@feb.unesp.br
Eng. Luiz Edmundo C. Coube Av., 14-01, Bauru, São Paulo - Brazil

Karla Cristina Rodrigues Silva
University of São Paulo - School of Engineering of São Carlos –karlacrs@usp.br
Trabalhador São-carlense Av., 400, São Carlos, São Paulo - Brazil

Jorge Tiago Bastos
University of São Paulo - School of Engineering of São Carlos – jtbastos@usp.br
Trabalhador São-carlense Av., 400, São Carlos, São Paulo - Brazil

Antonio Clóvis Pinto Ferraz
University of São Paulo - School of Engineering of São Carlos – coca@sc.usp.br
Trabalhador São-carlense Av., 400, São Carlos, São Paulo - Brazil

ABSTRACT
The aim of this paper is to make an analysis of traffic accidents occurrence at intersections regarding the urban and transport planning. To accomplish this objective, a case study was used comparing two cities, Lund, Sweden and São Carlos, Brazil. The cities have some similarities: they are moderate city with high tech industrial sites and universities. The main divergences are the urban form and the transport system. The comparison of Lund and São Carlos highlights the high mean of accidents, variance and systematic variation found at intersection in the second city. This large amount of systematic variation in São Carlos indicates that accidents are not occurring only by chance, but due the urbanization form and transportation planning. Congestion, degradation of environment, road accidents and security are endemic in developing countries cities. These problems are not only a question of funding projects to improve the situation, but the weaker policy, institutional context, and the lack of empowerment.

Keywords: Intersection; São Carlos; Lund; Accidents; Prediction; Urban planning

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1. INTRODUCTION

Nearly 0.5 million people die and up to 15 million people are injured in urban road accidents in developing countries each year, at a direct economic cost of between 1 and 2 percent of GDP in many countries. A majority of victims are poor, pedestrians and bicyclists. Fears for personal safety and security significantly deter the use of non-motorized transport. Thus lead of no livable cities in developing countries. Thus, it leads a negative impact on the quality of life in developing countries cities.

The World Bank have developed a series of papers that emphasized the integrity of economic, social, and environmental dimensions of a sustainable transport policy; that the urban development strategy is fundamental to livability of cities; and that is necessary an urban transport strategy review to overcome the urban transport problems in developing countries (World Bank, 1996, 2000, 2002)

Road urban congestion damages the city economy, increases environmental pollution, and harms the road-based public transport by slowing the service and torn the cities less livable. Urban development and transportation must concentrate on the movement of people rather than the movement of motor vehicles, focusing in non-motorized transport.

These questions are not only related to the developing countries, yet is related to urban and transportation planning towards the car dependency. One study shows that in Stockholm the pedestrian and bicyclist are safer than in San Francisco, but drivers face similar risks across the two cities (McAndrews, 2011). This is explain by the Swedish safety planning Vision Zero which focus on reducing exposure to hazards through traffic calming measures, the physical separation of traffic modes and the physical separation of travel and activities, that have great effect on pedestrians and bicycles safety.

The urban planning is the process of creating and developing programs that seek to improve or revitalize certain aspects (such as quality of life of the population) within a given urban area (cities or towns) or planning a new urban area in a given region, aiming to provide residents the best possible quality of life. To do so, without an authentic urban planning, it becomes difficult to organize transit. It is clear that any change in traffic, for example, has significant impacts on many other aspects of citizens' routine.

One of these aspects is the traffic accident, especially at intersections. With this in mind, the objective of this paper is to analyze some empirical evidences of how urban and transportation planning influences accidents at intersections in two different cities, one in Brazil (São Carlos) and another in Sweden (Lund). These particular cities were chosen due the authors have lived in these cities and the interest of analyzing the aspects that make cities to have differences in traffic safety level at intersections. Despite the differences of urban and transportation planning the cities have similarities, as the high Human Development Index, and both are moderate cities that have major influence of universities and high tech industries.

The relevance of this study is to show how the difference of transportation and urban planning creates difference in accident rates. Thus, with empirical evidences, it is intended to demonstrate that accidents occurrence are not by chance, but due the way that cities are being developed. The way that the cities are building and running creates their "DNA" for traffic accidents.

2. METHODOLOGY

Initial data collection was performed to identify urban form and transportation system indicators: density of population, extension of cycle paths, parking for bicycles, density of intersections, urban area, transit system, integration (fares and spatial), motorization rate, road extension and modal distribution.

Then, information regarding road accidents was obtained from the accidents database of each city, for three sequential years. It is known that in urban areas the majority of accidents happen at intersections than on road segments between intersections. The process started with identifying all intersections in Lund and dividing them into three main groups: Non-signalized, Signalized and Roundabouts. The objective is to make an estimative of the normal number of accidents for each type of intersection.

To find the expected number of accidents at each group of intersections it is necessary to have both the predicted (normal) and recorded number of accidents.

The predicted number of accidents (P) can be estimated by using a safety performance function. This function relates the normal number of accidents to a set of explanatory variables. The safety performance function that is most widely used is

$$P = \alpha \cdot Q^{\beta} \cdot e^{\Sigma y_i x_i} \tag{1}$$

Where:

α is a scaling constant,
Q is a measure of traffic volume with the exponent β,
e is the base of natural logarithms (e = 2.71828) raised to a sum of the product of coefficients *yi* and values of the variables xi (risk factors).

The safety performance function is a function of traffic volume Q. The effect of traffic volume is modeled in terms of elasticity. The elasticity shows how the predicted number of accidents changed with different values of the exponent β. The predicted number of accidents is proportional to the traffic volume if β is equals 1. If the value of β is less than 1, the number of accidents increases by a smaller percentage than traffic volume. If β is grater than 1, the number of accidents increases by a greater percentage than traffic volume.

The above mentioned equation (1) also shows the effects of various risk factors that influence the probability of accidents. It is presented by the base of natural logarithm raised to a sum of the product of coefficients y_i and values of the variables (risk factors) x_i. The choice of variables to be included in a safety performance function will often be dependent of data availability. In traffic engineering analysis, variables pertaining to highway design and traffic control would normally be included. For instance, the number of lanes, lane width, number of intersections per kilometer of road, speed limit, etc.

Finding the estimated variance of the safety performance function, it is possible to visualize the systematic variation explained by the function and the systematic variation that can not be explained by the function (residual term).

In this case study, it was not the aim to find the predicted number of accidents by using the safety performance function. The safety performance function could have been used if all necessary data for every type of intersection was available. Since the data is not available, the predicted number of accidents for each group of intersections is assumed to be equal to the mean value of the number of accidents for each group (the mean value for non-signalized intersections, signalized intersections and roundabouts). In other words, a simplification was used.

Generally, the number of accidents at a given intersection follows the Poisson distribution, where the variance is equals to the mean, hence the size of random variance in the count of accidents equals to the expected number of accidents. So the distribution of accidents should be analyzed with respect to the mean number of accidents and variance. The aim is to determine the amount of systematic variation in the number of accidents.

The total variation in the count of accidents at a given intersections, can be decomposed into random variation and systematic variation:

$$Var(x) = Var_{random}(x) + Var_s(x) \qquad (2)$$

Where:

Var(x) is total variance
$Var_{random}(x)$ is random variance
$Var_s(x)$ is systematic variance

Thus, if there is little systematic variation there is small chance to find out hazardous locations. On the other hand, if the there is perceptive difference between the mean and the variance, probably the systematic variance is significant.

One way to find if there is systematic variation in the number of accidents is using the over-dispersion parameter that is the ratio between the mean and the variance:

$$\alpha = \frac{\lambda}{Var(x)} \qquad (3)$$

Where:

λ is the overall mean
x is the number of accidents in each intersection.
Var(x) is the variance of x

By comparing mean and variance of the actual distribution it is possible to find whether there is a systematic variation or not. By finding α using formula (3) and checking if α is less than 1, there is a possibility of systematic variation.

Equation (4) is used to verify how much the systematic variation contributes:

$$S = \frac{(Var(x) - \lambda)}{\lambda} \tag{4}$$

If there is systematic variation it is necessary to take some measures to achieve better traffic safety.

In summary it was used the mean, variance, the over dispersion parameter α and the percentage of intersections with systematic variation to identify the level of safety at intersections in the two cities.

3. BACKGROUND

The description of each city is presented below.

3.1 São Carlos

The city of São Carlos has an estimative of almost 180,000 inhabitants and a car fleet around 65,000 in 2005. With an urban area of 67.25 km^2; population density in the urban area of 2.684 inhabitants/km²; density of intersections of 21.98 intersection/km²; cycle lane extension of 3.5 km; Human Development Index of 0.841; no public transportation integration (spatial integration consists in one terminal with maximum capacity for one more line and started to operate in 2005 (with no fare integration and no subsidy of the fare), modal distribution of 51,3% by private cars and motorcycles, 42% by foot, 6.7% by bus, and cyclists are insignificant. A map of São Carlos is shown in Figure 1.

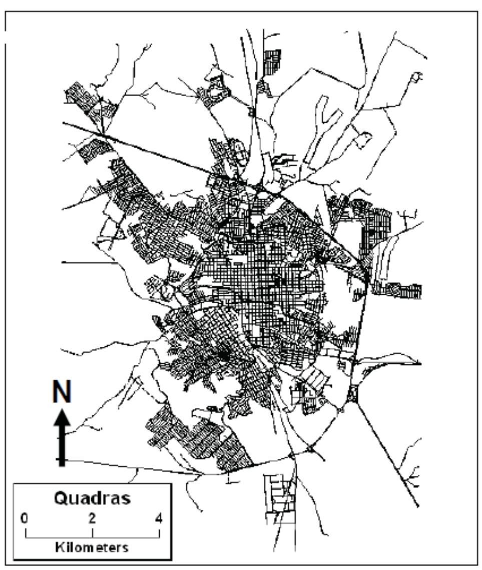

Figure 1 – Map of the city of São Carlos.

3.2 Lund

Lund is a moderate city with around 76,180 inhabitants in the urban area and a car fleet estimative of 23,178 in 2005 (lund.se, 2005). With a urban area estimative of 56 km^2; population density in the urban area of 1.360 inhabitants/km²; density of intersections of 13.16 intersection/km²; cycle lane extension of 160km; Human Development Index of 0.91; a well-developed, coordinated and frequent local and regional bus system with spatial and fare integration, modal distribution of 27% by private cars and motorcycles, 46 % by bicycles, 20% by foot, 7% by bus/train. A map of Lund is shown in Figure 2.

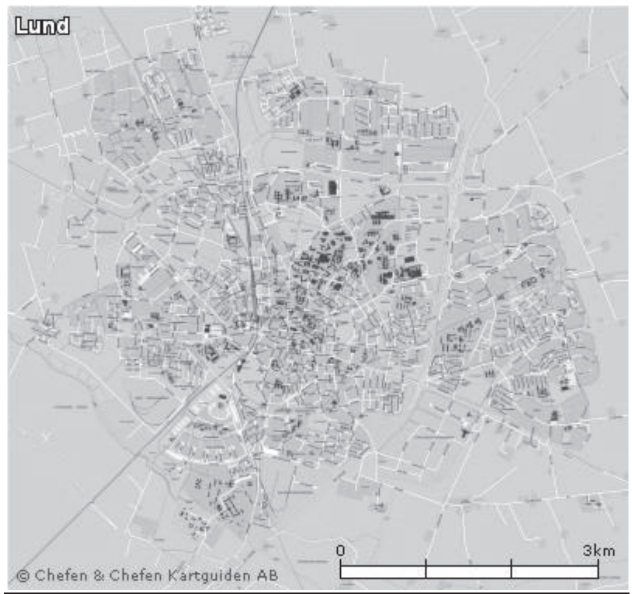

Figure 2 – Map of the city of Lund (Kartguiden.com, 2005).

3.3 Accidents

Using Swedish Traffic Data Acquisition (STRADA) it was possible to obtain information about accidents which had occurred in all intersections between 2003 and 2005 in the city of Lund. It was used only a 3 year period to be sure that no significant changes occurred in those intersections. The searching for accidents in STRADA was narrowed to intersections and roundabouts, using reports from the police and hospitals. With all this information a database was created for all intersections, which are under the control of the municipality, with the correspondent number of accidents recorded. The proceedings are similar for the city of São Carlos, using the municipality data base of accidents for the period between 2004 and 2006.

Thus, for all three groups of intersections were founded: the recorded, the predicted (mean value for each group) and the systematic variation. The outcomes for the three groups are shown below.

3.3.1 Non-signalized intersections

Table 1 contains the results for the mean, variance, α, and proportion of variance attributable to systematic variation, S. In Figures 3 and 4 are presented the Poisson distribution and the recorded number of accidents for non-signalized intersections for Lund and São Carlos, respectively.

Table 1 – Results for non-signalized intersections

Parameters	LUND	SÃO CARLOS
Mean (predicted number of accidents, P)	0.14	1.461
Variance	0.21	11.14
Over-dispersion parameter, α	0.65	0.131
Proportion of variance, S	0.53	6.623

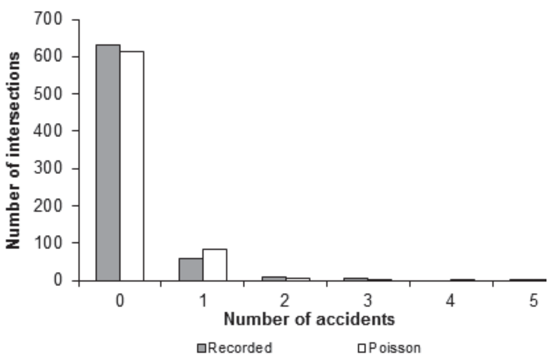

Figure 3- Poisson distribution for the non-signalized intersections Lund.

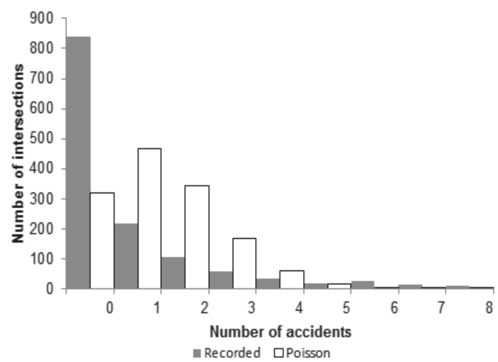

Figure 4- Poisson distribution for the non-signalized intersections São Carlos.

3.3.2 Signalized intersections

Table 2 contains the results for the mean, variance, α, and proportion of variance attributable to systematic variation, S. In Figures 5 and 6 are shown the Poisson distribution and the recorded number of accidents for signalized intersections for Lund and São Carlos, respectively.

Table 2 - Results for signalized intersections

Parameter	LUND	SÃO CARLOS
Mean (predicted number of accidents, P)	2.22	15.78
Variance	3.00	94.72
Over-dispersion parameter, α	0.74	0.167
Proportion of variance, S	0.35	5.00

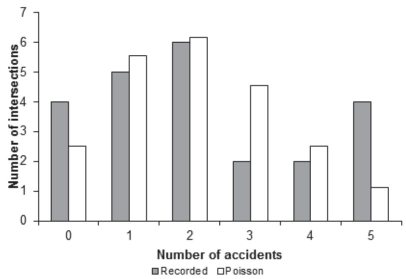

Figure 5- Poisson distribution for the signalized intersections Lund.

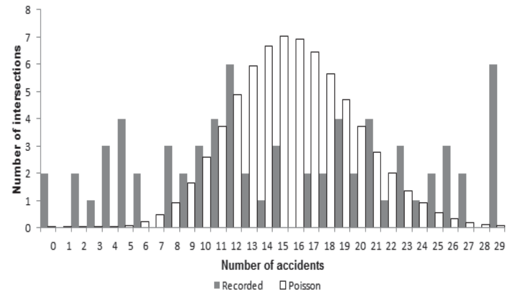

Figure 6- Poisson distribution for the signalized intersections Lund.

3.3.1 Roundabouts

Table 3 contains the results for the mean, variance, α, and proportion of variance attributable to systematic variation, S. In Figures 7 and 8 are shown the Poisson distribution and the recorded number of accidents for roundabouts for Lund and São Carlos, respectively.

Table 3 - Results for roundabouts

Parameters	**LUND**	**SÃO CARLOS**
Mean (predicted number of accidents, P)	2.30	1.64
Variance	3.12	8.41
Over-dispersion parameter, α	0.74	0.19
Proportion of variance, S	0.36	4.13

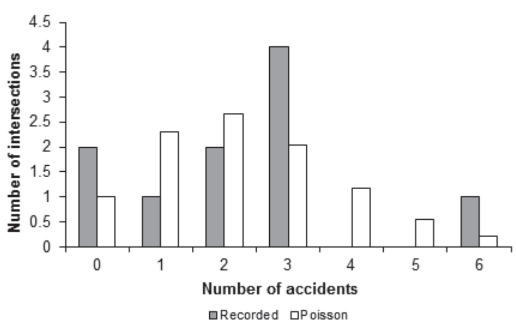

Figure 7 – Poisson distribution for roundabouts Lund.

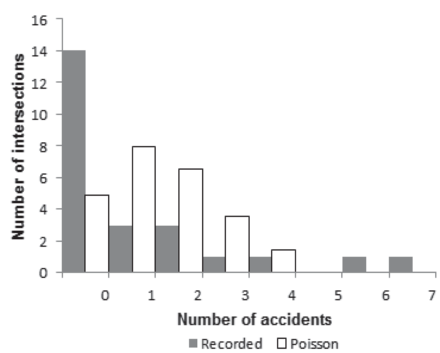

Figure 8 – Poisson distribution for roundabouts São Carlos.

In Table 4 the results are summarized

Table 4 – Summarized results

Indicator	Lund	São Carlos
Urban area km^2	56	67.25
Intersection per km^2	13.16	21.98
Car fleet	23,178	65,000
Population per km^2	1,360	2,684
Cycle lane extension km	160	3.5
Modal split %		
Car/bicycle/pedestrian/bus	27/46/20/7	51/0/42/7
HDI	0.91	0.841
Public Transport Integration	yes	No
Mean of Acc at non-signalized intersections /α/ S/var	0.14/0.65/0.53/0.21	1.46/0.13/6.62/11.14
Mean of Acc at signalized intersections /α/ S/var	2.22/0.74/0.35/3	15.78/0.17/5.0/94.72
Mean of Acc at roundabout /α/ S/ var	2.30/0.74/0.36/3.12	1.64/0.19/4.13/8.14

4. DISCUSSION

Systematic variation was found for every three types of intersections in each city. In Lund, for all types of intersections the over-dispersion parameter, α, was lower than 1 and the proportion of variance, S, was among 30 to 50 %; and the variance was among 0.21 to 3.12. In São Carlos, for all types of intersections the over-dispersion parameter, α, was lower than 0.2 and the proportion of variance, S, was among 662 to 413%; and the variance was among 8.14 to 94.72.

The comparison of Lund and São Carlos highlights the significant number of accidents at second city. This large amount of systematic variation and the variance in São Carlos indicates that accidents are not occurring only by chance, but due the urbanization form and transportation planning.

It is known that in urban areas the majority of accidents happen at intersections than in middle blocks. In São Carlos, the number of accidents at signalized intersections is higher than in other types of intersection. Entertaining the causes of this high number should be better investigated. Lund has the higher mean of accidents in roundabouts, but the systematic variation in São Carlos is larger and also the variance.

The contrasting national realities regarding road safety in Brazil and Sweden also play a role on explaining the higher number of accidents at intersections in São Carlos. Brazilian fatalities per billion-kilometer rate is 55.87, while in Sweden it is 4.40 (almost 13 times lesser). Considering São Paulo State rate (35.81 deaths per billion-kilometer traveled), where São Carlos is located, the differences decrease, but continue to be significant (Bastos, 2011).

Congestion, degradation of environment, road accidents and security are endemic in developing country cities. These problems are not only a question of funding projects to improve the situation but the weaker policy, institutional context and the lack of empowerment in developing country cities (Gwilliam, 2003).

Some issues requiring attention from policy makers in developing countries are the adverse impacts of rapid growth in vehicle ownership and use; weak and fragmented urban transportation institutions; inadequate urban transport regulation and legislation; inadequate urban transport financial mechanisms and lack of an adequate urban planning.

Overcome these institutional impediments is essential for a successful urban development, sustainable transport and reduction of road accident in developing countries. Thus, this issue should be a priority to multilateral banks and aid agencies.

The strengths of this study are that it compared safety at intersections across two cities using the average number of accidents and the systematic variation revealing the risk of each kind of intersection in a different context. The study was limited to two cities, and future research should extend the analysis to include more safety indicators and cities and the development of safety performance functions for better comparison. Notwithstanding its limitations, the study's findings draw attention to the necessity to overcome institutional problems in developing countries towards a better urban and transportation planning to achieve livability of cities, specially relate to traffic safety.

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