PARAMETERS FOR EVALUATING PEDESTRIAN SAFETY PROBLEMS IN SIGNALIZED INTERSECTIONS USING THE TRAFFIC CONFLICT ANALYSIS TECHNIQUE – A STUDY IN SÃO PAULO, BRAZIL.

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ABSTRACT
This paper aims at establishing parameters to diagnose pedestrian traffic safety problems using the Traffic Conflict Analysis Technique (TCT), particularly for pedestrian crossings at urban signalized intersections. The applied methodology, based on the U.S. Federal Highway Administration (U.S. FHWA) guides for vehicular conflicts, uses data collected from 4 critical intersections with high vehicular and pedestrians volumes at the Sao Paulo's CBD. The adaptation of the technique for the observation and analysis of pedestrian-vehicle conflicts is discussed and related to previous works. The results include the pedestrian conflict count limits C (abnormally high level of counts for problem detection) and the ratio R of accidents per million of conflicts (risk index and accident forecasting ratio) among different types of urban crossing observed in the signalized intersections.

1. INTRODUCTION

This paper presents the results of a research aiming at establishing parameters for the diagnosis of pedestrian traffic safety problems in urban signalized intersections using the Traffic Conflict Analysis Technique (abbreviated as TCT), distinguishing types of conflict and types of sites and/or crossings for signalized intersections.

Due to a huge international research effort carried-out during the eighties, the initial concept of traffic conflict was scientifically stated as an event in which two road users (or a road user and another traffic element) are set in a course of collision and an evasive action (breaking, swerving or running) is observed as the way to avoid the accident (see *1* for a historic background and the results of several studies of the international "calibration" effort).

After all, several countries published guides for applying TCTs, including recommendations and criteria for its use in the diagnosis of road safety problems (e.g. *2*, *3*, *4*, *5*, *6*). One can identifies two different ways in which the diagnosis with traffic conflict data can be done.

The basic diagnosis, reported in all TCT guides, is based on the interpretation of traffic count data, relating them to traffic and site features and to the qualitative observations made in the field. The classification of traffic conflicts by type and severity acts as aids to analysis but the task of identifying a set of site or traffic problems (and of proposals for reducing the safety torts) is an expert challenge, in a very similar way to the process of diagnosis based on accident analysis (more abundant and confident data is an advantage of TCT but this feature should be weighted against the risk of missing important factors in accident causation).

There is another type of diagnosis, recommended in the U.S.FHWA guide only (see *5*), that tries to identify traffic conflicts displaying abnormal frequency (based on limits of traffic conflict counts on a standard 11 hour period of a week day) and also tries to weight the accident proneness (measured by the ratio of accidents to conflicts, or million of conflicts, counts) that measure the risk level of each conflict and can be used to forecast accident frequency. These refined diagnostic tasks take into consideration the type of conflict and the physical and traffic features of the site and are based on objective diagnostic parameters.

Nevertheless, one should note that the viability of the refined diagnostic is constrained by the availability of previously calibrated parameters on the limit level of normal counts and on accident risk ratio of conflicts, by traffic conflict type and type of site, developed in a careful and representative study of a large set of similar sites. The U.S.FHWA guide is based on data from such kind of previous studies (*7*, *8*) for some usual classes of unsignalized and signalized intersections, and there was little progress in developing new data since then.

Despite this practical constraint, it is important to stress the content of the refined diagnostic and its meaning for the safety analysis. For example, a validation study (*9*, *10*) counted the same-direction and transversal conflicts between vehicles in an unsignalized intersection with medium traffic level. The expanded count for the standard period was 239,0 same-direction and 133,5 transversal traffic conflicts. Nevertheless, based on the FHWA data, the limits for normal frequency of conflicts are 410 and 24 (for a 90% confidence level), inverting the diagnostic about the more severe safety problem at the site. Also, again based on FHWA data, the accident/conflict ratio indicates that only transversal conflicts have a significant risk of generating accidents at this kind of site and permits one to forecast a frequency of 13,6 collisions per year on weekdays with dry weather (the record was 16 accidents on the previous year, all of them being transversal collisions, as predicted). This real case study clearly shows the importance of the diagnostic parameters.

The U.S.FHWA guide provides detailed instructions for field work and for preparation of results of TCT studies for vehicle conflicts on intersections, including the required diagnostic parameters for some usual conditions. Nevertheless, the application for the observation of pedestrian-vehicle conflicts is only roughly sketched. A similar problem can be observed in TCT guides of other countries (e.g. 2, *3*, *4*). The corresponding diagnostic parameters for pedestrian-vehicle conflicts are completely missing, even in the U.S.FHWA guide.

The research on pedestrian-vehicle conflict observation is largely inconclusive and can be classified in two phases, considering their date relative to the intense work that resulted in the official guides (i.e. *2*, *3*, *4*, *5*, *6*). The antecessor studies are mainly exploratory works (e.g. *11*, *12*, *13*, *14*, *15*) and used previous tentative concepts or classifications of traffic conflicts and other related events. The successor studies are predominantly applied works (e.g. *16*, *17*, *18*, *19*, *20*) and contain little detailed advice on theoretical or operational concepts (but there are interesting hints in *16*, *18*, *20*) and no effort on developing diagnostic parameters.

In this setting, we built on our previous research (*21*, *22*) and on the guidelines for TCT applied to vehicle conflicts (mainly in *5*) and searched for the clarification of concepts and procedures and the development of diagnostic parameters for pedestrian-vehicle conflicts. In the following, we try to present a self-contained discussion of operational criteria for the observation of pedestrian-vehicle conflicts, in section 2, of the approach used for developing diagnostic parameters (including some new criteria in relation to the proposal in *5*), in section 3, and of the results we gathered on our empiric study, in section 4. The final section advances some conclusions and suggestions for further research.

2. THE IDENTIFICATION, CLASSIFICATION AND ANALYSIS OF PEDESTRIAN-VEHICLE TRAFFIC CONFLICTS

We identified five points that should be clarified for developing operational concepts of pedestrian-vehicle conflicts. Three general points are discussed, explicitly or not, in official guides (i.e. *2*, *3*, *4*, *5*, *6*) and cover: the delimitation of real conflicts (as opposed to virtual conflicts), the identification of their severity (of the conflict itself) and of their level of risk (proneness of generating accidents). Two other points are recommendations drove to application, related to the typology of conflicts and the typology of sites that should be used for vehicle-pedestrian conflict studies, and were found only in some of the guides.

2.1. Delimitation of Relevant Traffic Conflicts (or, more generally, traffic events)

Despite the clarity of the general concept, there are a lot of practical questions that appears on field observation of conflicts that have to be judged. This point is related to the severity of the traffic conflict (remember the Hydén prism of traffic events; see *2*, p.27) but also to the identification of the traffic conflict and, perhaps, some other relevant events. The grade of severity will be discussed in the next topic. The others observational hints are covered here.

All guides disregard *virtual* or *potential* conflicts (usually described as conflicts without a significant risk of generating accidents) and also preventive maneuvers (as the lowering of vehicle speed or the running of pedestrians without the presence of a conflicting vehicle).

All guides devote special attention to quasi-accidents (conflicts with emergency evasive actions) and include near misses (events with high risk of accident, given speeds and proximity, even without course of collision by chance, in which time to reaction is very small and no evasive action was taken).

All guides distinguish conflicts from other traffic events, as traffic violations or user distraction (limiting its annotation to events that happens to generate traffic conflicts due to their occurrence), that could be of interest also but should be registered separately.

A point worth noting is that the U.S. guide is the only one that has a special concern with disregarding normal maneuvers that just give the right of way to users with priority and that clearly distinguishes principal and secondary conflicts or events with multiple conflicts.

Most of these points are not carefully discussed in all official guides and we felt it to be a missing point, especially relevant for the observation of pedestrian-vehicle conflicts.

The French guide (see *3*, pp.49-53) is the only one that includes a detailed description of pedestrian-vehicle (and motorcycle) conflicts, based on both vehicle and pedestrian evasive actions and accepting a clear analogy to vehicle conflicts. The Swedish technique seems even to recommend the use of the same criteria (and values) for classifying the severity of pedestrian-vehicle conflicts. These points will be discussed in the next topic also.

The analogy can be supposed to be the hidden assumption of all official guides. Nevertheless, in the field, the observation of who makes the evasive action is a clear distinguishing point related to pedestrian-vehicle conflicts, particularly when comparing stopping (of pedestrians) and breaking (of vehicle) maneuvers. For example, Cynecki distinguished events with each type of actor doing the evasive action and decided to use only the observation on the driver maneuver for the determination of conflict severity, based on the same feeling (*12*, p.15).

Another relevant point is that events involving multiple users are much more common when dealing with pedestrians (that usually walk in groups). The U.S.FHWA criterion for vehicle conflicts distinguishes the vehicle that generate the event and the one that takes the evasive action and recommends to count as multiple conflict with the number of vehicles taking evasive action (and as a single conflict if several vehicles are generating the conflict event).

Currently, the hidden analogy assumption of the official guides should be tempered with subjective criteria with more stringent criteria when observing pedestrian-vehicle conflicts for discarding virtual conflicts (especially if the evasive action is taken by the pedestrian) and for counting conflicts involving several users (when multiple pedestrians are involved, even when they are taking the evasive action if they are acting as one same group).

2.2. Criteria for Identifying the Severity of Traffic Conflicts (and their use)

Most of the discussion on severity in official guides is also limited to vehicle conflicts. The official guides, other than the U.S.FHWA, give great attention to the identification of the conflict severity but its final importance for the objective analysis is small. For the established methods applied for vehicle conflicts, the severity is used to identify virtual conflicts (as the lower severity level is usually discarded) and as qualitative information to the diagnostic.

The Swedish TCT is an exception in which some studies related severity of conflicts to the risk of accident for vehicles and pedestrians (see *2*, and mainly *23*). The severity criterion of the Swedish TCT is based on the value of the TA variable (Time to Accident, defined as the time until the occurrence of the potential accident if the road users keep the same trajectories and speeds at the beginning of the evasive maneuver) against a critical value. Note that, in the application of the Swedish TCT, the TA is evaluated based on the subjective estimation of distance and speed by a trained observer and the classification is done at the office.

The current critical value (*23*) is derived from a vehicle braking curve (*2*, pp.117-118) and replaced the original constant value of 1,5 seconds (*2*). This criterion can be inadequate to grade conflicts in which the evasive action is not the vehicle braking. For example, in the practical application of Swedish TCT, we observed that the “official” criterion is often complemented by a subjective judgment when evaluating pedestrian-vehicle conflicts (see *22*, in which a more general criteria, based on the available reaction time for the evasive action, excluding the maneuver duration, is suggested as a replacement).

The British TCT asks for the evaluation of four variables (time to accident, intensity and complexity of evasive maneuver and proximity of conflicting vehicles), subjectively by the trained observer. The classification of the severity is then done at the office based on a summary table for converting variable combinations into a severity grade in a four level scale (*4*, p.33 e 34), just for discarding the slightest level of conflicts.

The French TCT provides a careful description of a three level scale (light, moderate and severe conflicts) and asks for the subjective classification of road events by the trained observer (*3*, item IV3.2). The classification has to be made by trained personnel during the field observation and, again, the slightest level of conflicts is discarded.

Compared to the evaluation of the severity of each conflict in other guides, the U.S.FHWA TCT is really simplistic and only asks for identifying and discarding virtual conflicts directly (also described as conflicts with ample time for the evasive action). Nevertheless, the U.S.FHWA guide is the only one that proposes a measure of level of risk involved in the overall level of conflict frequency at a site. This is the role attributed to the count limits C of normal traffic conflict level for the standard period, differentiated by type of conflict and site, and related to the usual distribution of conflict counts for standard period in similar sites. A statistical confidence level has to be defined for C (*5*, provides $C_{90\%}$ and $C_{95\%}$ values).

For pedestrian-vehicle traffic conflicts, the attention to the discussion about the grading of conflict severity decreased along time. A subjective risk measure of safety in pedestrian crossings is proposed by Zegeer *et al*/1980 (*11*, p.28), based on conflict severity derived from constant values of *TA* (moderate severity between 1,0 and 1,5 seconds, severe under and slight over the moderate range). Cynecki (*12*) also evaluates the severity of pedestrian-vehicle conflicts but used a coarse scale (events with a distance greater than 7 meters between vehicles and pedestrians in the road were taken as slight conflicts, even without evasive actions; the events with a smaller distance and evasive action are classified as moderate conflicts and the quasi-accidents are classified as severe conflicts).

In the official guides, there is little advice other than the dubious criteria of applying the same criteria for grading the severity of conflicts involving unprotected road users (as cyclists and pedestrians). Only the French TCT proposed clear recommendations based on its subjective grading procedure on a three level scale: slight (an unforeseen stop in the walkside or a simple accelerated walking), moderate (a sudden stop, jump back or running ahead when the vehicle brakes or proceed) and severe (a very rapid jump or a sudden jump when facing the vehicle body). Of course, the criterion is specific only when the pedestrian takes the evasive action.

Based on our discussion, the subjective identification of virtual conflicts based on a subjective grading as the one proposed in the French guide but taking a more stringent criteria when the pedestrian takes the evasive action seems to be enough and good for practical purposes.

2.3. Criteria for Identifying the Measure of Risk in Traffic Conflicts

The concept of level of risk (hazard or danger) is not explicitly stated in any of the official TCT guides or even in other related papers. Nevertheless, the differences in the probability of generating an accident (accident proneness) of each type of conflict (and, perhaps, level of conflict severity) in each type of site (and, perhaps, traffic condition) are widely recognized in the official guides and other works. This is the content we attribute to concept of level of risk for traffic conflicts (that we distinguish from the level of danger, a measure that should also weights the severity of the accident eventually generated in the event).

For vehicular conflicts, the ratio R of accident to conflict, or million of conflicts, displayed by the U.S.FHWA guide is a clear example that was previously discussed as a parameter for a refined diagnostic, weighting accident proneness, and for forecasting the expected frequency of accidents. The Swedish TCT also determined and differentiated accident to conflicts ratios

(*2*, item 5.4 a 5.6), taking more general classes of conflicts and sites (signalized or unsignalized intersections, straight or turning movements, high or low speed sites, vehicles or unprotected road users). The French TCT proposed a risk matrix with weights differentiated by type of conflicts in signalized or unsignalized intersections, to evaluate the accident proneness in three levels: null/small, medium and high (*3*, p.28-30), based on the subjective evaluation of experts and considering also conflicts with pedestrians and motorcycles.

Some studies evaluate the relationship between accidents and conflicts using other tools (e.g. 17, *19*, and also *24*). Nevertheless, the obvious and practical meaning of these variables as a measure of risk leaves no question about the validity of these variables other than that related to the level of detail needed to reach a useful classification of conflicts and sites. There is no opposition, also, between the risk levels defined in the French guide and the ratio of accidents to conflicts as the former is used as a clear proxy for the later.

The same judgments can be surely extended to the study of the risk involved in pedestrian-vehicle conflicts. The data available is scarce. The generic accident to conflict ratios developed by the Swedish guide (*2*, p.71; see also *23* in which ratios vary by severity level) are the main information. Table 1 has a sample of ratios that will be used for comparison with our empiric estimates, reported in the following. The risk levels attached to pedestrian-vehicle conflicts in the French guide are the other relevant but coarse data.

<Insert Table 1>

The scarcity is noticeable as the classification (or segmentation) problem has the drawback of depending on the availability of large samples, for significant statistical analysis, both with good conflict and accident data (what is even worse when dealing with pedestrian-vehicle conflicts and accidents). So, it seems unavoidable that knowledge in this subject should progress through a series of individual studies, devoted to specific samples.

2.4. Typology of Pedestrian-Vehicle Conflicts

There is no general agreement on the more convenient typology of pedestrian-vehicle conflicts, but there is a clear trend to simplified categories based on the type of movements for each user (as in the typology of vehicle conflicts). A fundamental reason behind this option is related to the desire of adopting a typology similar to that conventionally used for accidents.

Both official guides that treat this question (*3*, *5*) recommend 4 types of pedestrian-vehicle conflicts similar to vehicle conflict types that can be combined in 5 types (the U.S.FHWA separates the conflicts with straight vehicles based on their position before or after the intersection, while the French guide aggregate them but includes a category for conflicts with pedestrians and vehicles in parallel movements). The British guide does not deal with pedestrian-vehicle conflicts and the Swedish guide does not recommend a standard typology.

Former studies (e.g. *11*, *12*, *15*) distinguished several types of events based on the way the pedestrian approaches the road, the vehicle movements involved and the type of traffic violation observed (13, 12 and 12 types in *11*, *12* and *15*). More recent studies have not kept this level of detail, even treating conflicts aggregately (despite the clear evidence on the importance of searching for an adequate typology and the difficulties faced by studies that used aggregated data, particularly for relating conflicts and accidents as in *24* and *25*). For example, Clark *et al* (*18*, p.41) used 5 types but classified based on type of evasive action, that would be difficult to use in a disaggregate analysis, despite being elucidative in the study.

Our previous research (*22*) used 8 types of pedestrian-vehicle conflict, as shown in Figure 1, based on the U.S.FHWA typology but distinguishing the pedestrian direction of flow relative to the vehicle, and recording conflicts by pedestrian crossing instead of vehicle approach (2 other types would be added based on the French guide), but was unable to demonstrate the relevance of the added detail. Our study also shows the difficulty involved in using the same typology for accidents giving the lack of clear information in police accident records for recovering the exact crossing location and pedestrian/vehicle movements.

<Insert Figure 1>

As the pool of evidences is again scarce, we feel that additional study should be devoted to this question. The use of similar typologies for conflicts and accidents is a practical advantage and the need of more detailed classes is a research theme. We keep on using the 4 classes typology based on the U.S.FHWA guide. The parallel movements conflict is rarely observed and identified in intersections. Nevertheless, the annotation of details on the events, as a way for studying and developing alternative typologies, is recommended from our experience. The use of the Swedish record sheet (see *21*, *23*) or the annotation procedure recording one conflict in each sheet line (and appending relevant comments on the events) suggested by Hummer (*26*) for the U.S.TCT, both would favor this task.

2.5. Typology of Pedestrian Crossings in Signalized Intersections

The U.S.FHWA guide suggests the use of the overall intersection, instead of each approach as the unit of analysis in the study of vehicle conflicts, at least for the refined diagnostic. One can question this option for the study of vehicle conflicts and, even more, for the study of pedestrian-vehicle conflicts. Of course, using more detailed data could bring a higher coefficient of variance and then could request more hours of observation. Nevertheless, the aggregate unit can lose significant detail and would multiply the number of possible typologies for sites, perhaps reaching a prohibitively level when considering pedestrians. So, we will treat crossings individually.

With its unit of analysis for the refined diagnostic, the U.S.FHWA had suggestions of parameters for four types of intersections: high and medium flow signalized intersections and medium and low flow unsignalized intersections, all cases considered for four leg junctions of two way approaches (some other studies analyzed three leg junctions). At the technician risk, one can apply the provided parameters for intersections with peculiar features (as some one-way approaches) with added care in the analysis of results (as in the successful real case that was commented on the introduction of this paper). The other guides had no suggestion for typology of sites (the French guide differentiated signalized and unsignalized intersections in the risk matrix and the Swedish guide further segmented low and high speed unsignalized intersection when studying accident to conflicts ratios).

Official guides have no specific recommendation for the analysis of pedestrian-vehicle conflicts, at the intersection or crossing level. Among former studies, Cynecki (*12*, p.12-13) made an exploratory discussion of relevant features, taking a large number of variables. Among more recent studies, Garder (*16*, p.440) selected a typology similar to the one used by Hydén (*2*), with three classes: signalized intersections, low speed or high speed unsignalized intersections (the effect of several other variables were also studied). Studies about accidents (e.g. *27*, *28*) also show a similar pattern of classes and variables.

Because the typology of sites will be used for developing diagnostic parameters (and determine the field effort needed for collecting data), the segmentation should be at the same time revealing and parsimonious. Nevertheless, we were not able to find any conceptual discussion of the criteria for classifying sites and adopted the distinction between essential features (that change the way road users interact) and residual features (that vary the level of safety in the interaction), on the hypothesis that the first group of features must be distinguished in the classification analysis.

Admitting also that the crossing is a better unit of diagnostic, our previous research on signalized intersections with medians (*22*) segmented pedestrian crossing in two main groups: near or stop line crossings and far or open crossings. Of course, crossings of two-way approaches without median and crossings of unsignalized intersections are other similar types.

Criteria for further segmenting pedestrian crossings, even for signalized intersections with medians, are not evident. Classes of flow or speed are natural criteria (as suggested by other studies or other settings). The existence of vehicle turning movements and red-running pedestrian crossings (that can be related to the availability of gaps on the vehicle stream) also should studied. Other factors, as the existence of pedestrian signal heads, of a signalized pedestrian crossing, the use of pedestrian refuges or displaced crossing lay-outs and even the type of treatment for pedestrian in signal phases are less probable as essential candidates.

3. METHODS FOR DETERMINING AND EVALUATING DIAGNOSTIC PARAMETERS FOR PEDESTRIAN-VEHICLE CONFLICT STUDIES

The diagnostic parameters used in the refined procedure associated to the U.S.FHWA TCT were studied using observations of pedestrian-vehicle conflicts by type of crossing.

The procedure for determining the limit counts C for traffic conflicts recommended in the U.S.FHWA guide (*5*, see also *8*) can be applied without troubles, after gathering the required data, expanded for the standard period. In this method, the abnormal level of the frequency of conflicts is determined through the analysis of the distribution of daily conflict counts per standard period on similar sites of a class, for each type of conflict. Procedures for collecting conflict counts and expanding the data to a standard period are also suggested.

The procedure for determining the ratio R of accidents per conflict, or million of conflicts, is not described in the U.S.FHWA guide or related works (i.e. *5*, *7*, *8*). Nevertheless, the diagnostic parameter is a ratio of two random variables and available methods for ratio estimators are widely discussed in statistical textbooks on sampling theory. For achieving this task, traffic accident data has to be gathered and referred to the same observational units (intersections, approaches or crossings) and traffic conflict data has to be expanded to the same time frame (e.g. a year). Again, the analysis is carried-out considering similar sites of the same class, for each type of conflict or some aggregated type. Procedures for expanding conflict counts for a year are presented in the U.S.FHWA guide (when discussing the forecasting of accident frequency using conflict data) and can be used also in this task.

For completeness, both procedures are shortly described in the following topic. The evaluation of the diagnostic parameters could be based on statistical criteria. Nevertheless, the next topic also discusses a decision criterion that is more adequate for engineering work.

3.1. Statistical Methods for Determining Diagnostic Parameters for TCTs

The determination of diagnostic parameters for TCT has two peculiar features:
- basic variables have non-gaussian distributions and
- the risk measure is a ratio of random variables.

For establishing limit counts C, accepting the empirical evidence that daily conflict counts have a Gamma distribution (*29* apud *8*), their statistical parameters (s,t) can be estimated using the method of moments and limit values can be obtained using Chi-square tables and the relationship between Chi-square and Gamma random variables (see *5* and also *7*, *8*).

Given a sample of sites, the estimates of the parameters are

$$t = m_C / s_C^2 \qquad (1)$$

$$s = t.m_C \qquad (2)$$

with the average m_C and the variance s_C^2 of daily counts, expanded to the standard period.

Using the parameters of the fitted distribution, for each type of conflict, limit counts $C_{L\%}$ for any statistical confidence level $L\%$ can be determined with a Chi-square table and the statistical property that relates the critical value $X^2_{\nu,L\%}$ for $\nu = 2.s$ degrees of freedom for the Chi-square distribution to the critical value of the Gamma distribution $C_{L\%} = \frac{X^2_{\nu,L\%}}{2.t}$ (the limit counts). Then, for selected values of $L\%$, one has to calculate ν as above and interpolate for the value of $X^2_{\nu,L\%}$ in a Chi-square table. Then the limit counts $C_{L\%}$ are calculated, applying the given formula, for each confidence level, as sketched in Figure 2.

<Insert Figure 2>

There is no procedure suggested in the U.S.FHWA guide for the statistical evaluation of the estimates of the count limits or their performance in identifying unsafe sites. Nevertheless, a decision criterion for analyzing this performance and selecting the recommended segmentation and confidence level for practical applications is suggested in the next topic.

Note also that, using the previously quoted statistical properties, the Kolmogorov-Smirnoff goodness of fit measure D can be calculated and checked. Being i the index in increasing order of each count C_i, it is easy to verify that $D = \text{máx}_i \left\{ \left| \frac{i}{n} - F_{C_i} \right| \right\}$ where F_{C_i} is the cumulative probability at $X^2_{\nu,i} = 2.t.C_i$ for $\nu = 2.s$ in the Chi-square table.

All calculations can, nowadays, be carried-out with simple spreadsheet software (as Microsoft Excel, that has the functions GAMMADIST and GAMMAINV for the density/cumulative gamma distribution and its inverse cumulative probability function, using the more usual description of the Gamma distribution with parameters $a = s$ and $b = 1/t$).

For establishing the risk measure R, and its variance, the several conventional methods of developing ratio estimators can be used. The most common estimators are the ratio of means (or totals) and the mean of ratios. Both are biased estimators and Cochran (*30*, chapter 2 or 6) suggests the use of the ratio of means or totals as it delivers a smaller mean square error (where E[R]²=Bias[R]²+Var[R], with Bias[R] the expected bias of the estimator and Var[R] its variance). With the total number of accidents (t_A) and conflicts (t_C) for all the sites in the sample or the average values of accidents (m_A) and conflicts (m_C) in the sample of sites, the estimators of the ratio R and its standard deviation are:

$$\hat{R} = \frac{t_A}{t_C^E} = \frac{\sum A_i}{\sum C_i^E} = \frac{m_A}{m_C} \qquad (3)$$

$$s(\hat{R}) = \frac{1}{m_C.\sqrt{n}}.\sqrt{\frac{\sum (A_i)^2 - 2.\hat{R}.\sum (A_i.C_i^E) + \hat{R}^2.\sum (C_i^E)^2}{n-1}} \qquad (4)$$

where A_i and C_i^E are the expanded frequencies of accidents and conflicts, referred to the same period (usually a year), for each site, and *n* is size of the sample of sites (*30*, pp.30-34).

For the ratio R, the statistical quality of the estimate is measured by its standard deviation, its variance or, relatively, by its coefficient of variation (the inverse of a t statistic). Tests on the difference between ratios on two disjoint segments can be carried-out only approximately with a standard t test, as the distribution of the ratio estimators is non-normal (and unknown). For ratios on different crossing segments, with the assumption of independent samples (see *30*, pp.180-183), tests can be approximately carried-out based on the quasi-t statistic.

The practical performance of the estimator in forecasting accident frequency can also be analyzed, following the procedures recommended in the U.S.FHWA guide.

3.2. A Method for Evaluating Segmentations and Confidence Levels for Diagnostic Parameters of TCTs based on Decision Criteria

Instead of searching for statistical criteria, the performance of alternative segmentation or confidence levels can be evaluated based on the benefits and costs of implied decisions.

For TCTs, these decisions correspond to the selection of sites for treatment. The costs and benefits are related to the realization of the potential accident reduction effect for risky sites or the waste of resources devoted to safe sites, for those sites selected for treatment, and the saving of resources of avoiding spending in safe sites or the remaining social costs of accidents, for those sites not selected for treatment, given data available and parameters used in the diagnostic activity that selected sites for treatment.

An internal validation study can be carried-out applying this analysis to the sample used for the establishment of parameters. A external (or cross) validation study would conduct this exercise in another sample of sites and will evaluate the transferability of the parameters also. The evaluation can be extended to the monitoring of the treatment costs and benefits or can use average or representative measures of potential costs and benefits. In this study, we will do an internal validation with representative measures of costs and benefits. The same approach can be applied to the other settings as well, with small methodological adaptations.

Our procedure supposes that the TCT is used in selecting sites for treatment comparing average daily counts (for any number of days) to the limit counts of a given confidence level, then deciding to treat the sites with abnormal frequency of conflicts of any type. The limit counts can be developed with alternative segmentation proposals (even aggregate). The procedure also supposes that all selected sites are treated and that representative values of costs and benefits are available for the four possible cases, as depicted in Table 2. We prefer to communicate benefits and costs in US$ (generating a kind of economic weighted index) but, of course, any other (even non-monetary) agreed compensatory scale can be used.

<Insert Table 2>

With economic based weights, the overall evaluation criterion is a kind of net economic index, following usual criteria applied of Benefit/Cost Analysis. Using the hypothetical representative weights suggested in Table 2, the net economic index E can be calculated with data on the number of sites for each cell represented (NEI, NEII, NHI, NHII) and the corresponding number of accidents (AEI, AHI only on error type I and hit type I sites).

Admitting that accidents are only partially avoidable through engineering treatments, the costs of unavoidable accidents can be ignored. Nevertheless, the treatment costs must be computed on all sites selected for treatment. A restricted net economic index would evaluate benefits at treatment sites only (ignoring the remaining accidents on non-treated sites with accident records) but a better measure of net economic performance can be constructed noting that the "do nothing" scenario has a relevant negative net economic index that should be corrected.

With weights given by α_S (accident savings) and β_C (treatment costs) as in Table 2, the net economic index of avoidable costs in the "do nothing" (E0) option is

$$E0 = -\alpha_S.A = -\alpha_S.(AHI + AEI) \qquad (5)$$

and the net economic index attained with a give criterion is

$$E = -\beta_C.NHI - \beta_C.NEII - \alpha_S.AEI \qquad (6)$$

(that can be better than the “do nothing” measure even if negative).

Based on conventional Benefit/Cost Analysis, a differential measure of the net economic index against avoidable costs in the “do nothing” scenario (DE) should be used as

$$DE = E - E0 = \alpha_S.AHI - \beta_C.NHI - \beta_C.NEII \qquad (7)$$

that is the usual restricted measure of economic performance based on treated sites only (as the number of avoidable accidents on non-treated sites cancel out).

The maximum attainable net economic index of treatment options (ME) is

$$ME = \alpha_S.A - \beta_C.NA = \alpha_S.(AHI + AEI) - \beta_C.(NHI - NEI) \qquad (8)$$

and a relative measure of performance over the maximum attainable (RE) is

$$RE = \frac{DE}{ME} = \frac{\alpha_S.AHI - \beta_C.NHI - \beta_C.NEII}{\alpha_S.(AHI + AEI) - \beta_C.(NHI + NEI)} \qquad (9)$$

that is the improved measure of economic measure previously quoted (considering all observed accidents in the validation sample).

The best segmentation and confidence level for decision is the one that delivers the greater value of the performance measure, provided that its net economic index is better than the “do nothing” option. Even if not a perfect option (ME approaching 100%) or the best possible option, any criterion with E>E0 (or DE>0) is usable. The performance measures need not deliver a positive net economic index per se (as the status quo carries significant social costs) but of treatments should attain usual positive net economic return.

This evaluation approach can not be used directly to the validation of the ratio R of accidents to conflicts. Nevertheless, in this case, the conventional criterion of comparing the relative performance of accident estimates from accident counts and conflict counts is useful.

4. APPLICATION TO THE DETERMINATION OF DIAGNOSTIC PARAMETERS FOR PEDESTRIAN-VEHICLE CONFLICTS IN THE SÃO PAULO STUDY

The diagnostic parameters for pedestrian-vehicle conflicts were obtained based on the 1998 study carried-out in four critical signalized intersections of the City of São Paulo (see *22*; the intersections are identified in the corresponding column of Table 3). Two intersections are located in the old central area: Ipiranga Avenue X São João Avenue (**Ip-SJ**) and Consolação Avenue X Caio Prado Street (**Co-CP**). The other two are located in south-west of the expanded central area: Brig. Faria Lima Avenue X Teodoro Sampaio Street (**FL-TS**) and Francisco Morato Avenue X Vital Brasil Avenue (**FM-VB**).

<Insert Table 3>

Table 3 has a simplified sketch of each intersection. Pedestrian crossings were classified and nominated as done in the original study (see 22; the crossings are also identified in the corresponding column of Table 3).

Common features of all signalized intersections are:

- high vehicle and pedestrian flows, with hourly means around 1.500 vehicles and 1.000 pedestrians, painted crossings and stop lines in good conditions; the flows related to commercial activities and transit services is very important in the areas;
- carriageways have at least two lanes and are one-way (two-way roads have separated carriageways with adequate medians); there are signal groups for vehicle and pedestrians at all intersections but the FL-TS one;
- especial lanes and especial phases for turning vehicles are absent and left turn are locally forbidden and rerouted through loops on adjacent streets.

Traffic operations at the sites were registered with cameras in 2 hours of the morning, mid-day and afternoon peaks along with the counting of conflicts by field personnel (vehicles and pedestrian flows are shown in Table 3 as well). Due to fails in the recording, pedestrian flows were missed on one crossing and its data had to be discarded from the analysis.

4.1. Data on Pedestrian Accidents at the Studied Crossings

Accident data were recovered from police reports for two years (1996 and 1997) before the conflict study. It was impossible to recover some of the accident records of each intersection. Table 4 summarizes data for accidents referred to in Table 4 occurred during the standard period of workdays, the same reference period used for conflict counts, for recovered reports of a total of 29 pedestrian accidents. This data were used in all analysis, except when estimating ratios of accidents to conflicts, when the total number of accidents was adjusted to reproduce the known total, as described in the following.

<Insert Table 4>

For each accident, an accident location index (%) had to be defined due to the lack of precise data on some police reports (see the column corresponding to accidents in Table 4). Most accidents were clearly located (i.e. had a 100% location index) but 6 of 13 pedestrian accidents had a 25 to 75% accident location index split between two (usually adjacent) crossings. Pedestrian and vehicle movements were not identified in most accidents, except when there was an obvious pattern commanded by the intersection layout and crossing site.

Nevertheless, it was possible to verify that there was sites with pedestrian accidents among near crossings with through flow (as 1:Co-TA-BC, 1:FM-TP-CB e 3:Ip-E-TP) and among far crossings with turn flows (as 2:FL-TA-IP e 7:MA-TA).

The accident location index was also interpreted as the probability of occurrence of the accident in each crossing and the aggregate accident index was taken as the expected number of accident in each crossing. The validation criterion for application of the TCT took the crossings with non-null accident index as unsafe and the others as safe (i.e. it is supposed that missing accidents occurred in the same crossings).

Of course, the net economic index had to be computed with the sample of recovered accidents. With economic weights suggested in Table 2 (a 50% reduction potential for a unit direct cost of US$ 20.000,00 per accident and a treatment cost of US$ 5.000 per crossing), the actual “do nothing” or status situation can be associated to the loss of US$ 130.000 related to the potential direct cost reduction for 13 accidents (the maximum attainable net economic index is US$ 70.000 in the 12 accident sites). This is the lower threshold against which the net economic index of alternative TCT detections should be compared. Note that relative values, more than absolute ones, matter in the comparison of alternative diagnostic criteria.

4.2. Data on Pedestrian Conflicts at the Studied Crossings

Conflict counts were carried-out during two days (a Monday and a Tuesday) of march, 1998, from 07:00 to 18:30 (using 6 one hour count and half hour rest periods, separated by one and a half hour for lunch before or after mid-day in each day). Both days had good weather (dry pavement). Recorded counts were expanded to the standard period of each day, following U.S.FHWA recommendations (*5*), and the average daily counts were obtained for each crossing and subsequently used in all analyses.

Table 5 summarizes the data obtained for each crossing. One can note that sites with higher pedestrian-vehicle daily counts are not always the sites with pedestrian accidents (near crossings with through flow, as 1:Co-TA-BC, 1:FM-TP-CB e 3:Ip-E-TP, and far crossings with turn flows, as 2:FL-TA-IP e 7:MA-TA). This observation stresses the need of diagnostic parameters for selecting unsafe sites with better success.

<Insert Table 5>

Table 5 also shows the main candidate variables for segmentation: type of crossing (in column Seg.I and column Seg.II) as will discussed in the following.

4.3. Determination of Count Limits for Daily Conflicts

Limit counts were determined for several segmentations, constrained by data availability. It is easy to see that detailed segmentations are impossible with our data as the sample size in each segment quickly becomes too small and the validation analysis loses interest (as all the sites have no accident in the sample of some segments).

The main segmentation criterion for the type of crossing distinguishes TP (i.e. near or stop line crossings) and TA (far or free crossings) sites. Remembering that all the carriageways are one-way, this is a fundamental classification based on pedestrian vehicle interaction. On TP crossings, conflicts can only occur on traffic violations by pedestrians or vehicles and this possibility increases sharply when there are available gaps. Then a further segmentation was analyzed based on the level of saturation of the vehicle approach (TP-Sat or TP-NSat). On TA crossings, there are possibilities of concurrent movements of pedestrian and vehicles even without violation and conflicts can occur also in this situation. Then, a segmentation based on the pedestrian flow was used because some crossings have very high pedestrian movements (TP-Ped or TP-Ped+, taking 900 ped/h as the threshold of high flow pedestrian crossings).

We will present results for the complete sample with aggregate and disaggregate (by conflict type with 2, 4 and 8 types) analyses and also for the TA/TP segmentation as can be seen checking columns Seg.I of Table 5 with aggregate and disaggregate (by conflict type with 2 and 4 types) analyses. Both analyses are carried-out for three levels of confidence (75%, 90% and 95%). In the following, this basic terminology is maintained: aggregate/disaggregate for pooled or distinct conflict types and complete/segmented for pooled or distinct crossing types.

More refined segmentations, with TP-Sat/TP-NSat and TP-Ped/TP-Ped+ as can be seen checking columns Seg.II of Table 5, were also submitted to a preliminary a study of aggregate analysis and disaggregate analysis. Despite the small samples available in each cell, the preliminary study of more detailed data can suggest the potential gain from further segmentation (and its effect on the need of a disaggregate analysis of conflict types).

Table 6 summarizes limits counts based on the sample of crossings, taking several alternatives for segmentation of crossings and disaggregation of conflict types. Part 6a contains the basic data for the complete sample and the segmentation of crossings in two groups TA/TP, with 4 types (P/TP, P/TA, P/TD and P/TE), with 2 types (P/VA, with P/TP and T/TA, and P/VT, with P/TD and PTE) or pooling all conflicts in an aggregate type. Part 6b contains preliminary data on more detailed analysis with further segmentation (TA-Ped/TA-Ped+, TP-NSat/TP-Sat) or disaggregation (all the 8 conflict types of Figure 1).

<Insert Table 6>

Based on the limit counts, the diagnosis is carried-out for the crossings and compared to the accident records. Note that the use of the accident location index spreads accidents among crossings but acts in the opposite direction of using the diagnosis based on the sample of recovered police accident reports. Alternative analyses with rounding of the cumulative accident index of each site delivered comparable results and the analysis based on a 50/50 split of accidents with imprecise location were kept. Table 7 presents the evaluation index of each alternative segmentation and disaggregation and for each of the 3 confidence levels. The nomenclature for errors type I and II or hits type I and II are the same of Table 2.

<Insert Table 7>

The results of Table 7 used the representative weights of Table 2. We noted that the option with best performance index is changes depending on the weight values. The lower confidence level was introduced based on the observation that there is a significant gain on using them when higher accident savings are conjectured (i.e. a higher statistical criterion runs against safety). Based on our data, the use of the 75% confidence level with the TA-TP segmentation and the classification with 4 conflict types is preferred.

The use of the more detailed segmentation is promising, based on our results. The same pattern seems to be suggested by results from the more detailed disaggregation of conflict types but, in this case, better performance is limited to higher accident savings values due the selecting a large number of sites for treatment (the same can be achieved by lowering the confidence level).

The compromise between Type I and Type II hits (or errors) is clearly shown in Table 7 (the preferred alternative reaches a 41,67% hit on identifying accident sites and a 71,43% hit on identifying safe sites). One can also see that the net economic performance is worse in crossings of the TA-Ped and TP-NSat groups (suggesting where better data and segmentation would perhaps bring some additional precision in these classes).

The use of more stringent statistical criteria (as the 95% confidence level included in the U.S.FHWA guide) seems to be overly conservative on economic grounds. With representative values are at the border of economic efficiency of each treatment (an accident saving of US$ 7.500 with the treatment cost of US$ 5.000) the same pattern of results were obtained. Higher accident saving values will favor even more liberal criteria, on behalf of safety benefits.

4.4. Determination of Ratios of Accidents per Million Conflicts.

The difficulty in identifying movements of vehicles and pedestrians involved in traffic accidents commanded an aggregate analysis of the risk measure as the ratio of accidents per million conflicts. The following analysis is, then, limited to the comparison of the ratio on each crossing type (all, TA/TP, TA-Ped/TA-Ped+ and TP-NSat/TP-Sat).

The conversion of daily conflicts in the standard period to annual conflict totals is carried-out using representative factors as displayed in Table 8 (as suggested in *5* and recommended in *9*). As our results are limited to workdays and dry pavements, the ratios can also be calculated as a rough ratio RR of yearly accidents per daily conflict. Despite its simplicity, we applied this procedure previously with good empirical results and the use of the aggregate conflict counts opens the possibility for developing better procedures in the future.

<Insert Table 8>

With such conversion factors, the calculation of the annual frequency of traffic conflicts is straightforward and can be related to the annual frequency of accidents (given our two-year data samples). Nevertheless, as our sample of accidents was only able to recover data on police reports 13 of 29 occurrences, we had to eliminate this partial data bias by inflating the estimated ratio by a correcting factor (29/13=2,23, see Table 4). One should note that this correction does not account for partial report of occurrences (as usual).

Table 9 summarizes the results on the ratio of accidents per million conflicts for each of the pedestrian crossing segments used in this study. One can clearly sees that differences in the values of the ratio are relevant based on a engineering criteria but the statistical significance is reduce by the high variance of the estimates. Use of empirical conversion factors could improve the forecasting of accidents but increases the variance of estimates (*31*, chapter 8).

<Insert Table 9>

Despite the high variance, only the segmentation of TA crossings based on pedestrian flows is discarded as nor-relevant and non-significant. This conclusion can be attributed to the high level of pedestrian flow (900 ped/h) used as a threshold between classes. As our sample have a very small number of crossings with small pedestrian flows, our choice was constrained.

The difference of the ratio of the risk measure of conflicts in TA and TP crossings is suggested to be highly relevant (one order of magnitude) and also statistically significant (at least based on the quasi-t statistic). At a smaller degree, the same meaning can be attributed to the difference between the risk measures of conflicts on TP-NSat and TP-Sat crossing and clearly point to the importance of diagnostic parameters for a proper analysis. Anyway, one should note the comparable magnitude to ratios previously reported (see Table 1).

One should stress that traffic conflicts at TP crossings, and especially at TP-NSat crossings, are a very rare event and could easily be outside the scope of safety problems that can be firmly evaluated with TCT studies. Complementary methods and data should be searched for in analyzing such kind of events involving vehicle and pedestrian conflicts.

5. CONCLUSIONS

This research aimed at determining the diagnostic parameters for the analysis of pedestrian safety problems at signalized intersections based on the traffic conflict analysis technique (TCT), based on the U.S.FHWA concepts.

We discussed specific criteria for observing and analyzing pedestrian-vehicle conflicts, trying to avoid the hidden analogy supposition to vehicle conflicts, and specific problems related to the typology of conflicts and crossings. The methodology used for the determination of diagnostic parameters and a decision based criterion for tracking the practical performance of their use in applied work was proposed and applied with a sample of crossings with high vehicular and pedestrian flows of the City of São Paulo, Brazil.

The fundamental decision was the segmentation of near or stopline crossings (TP) and far or open crossings (TA). Given our sample of divided carriage-way or one-way approaches, this is clearly sound and would suggest that other classes could be relevant in a larger sample (crossings on two-way approaches and unsignalized crossings at least). More detailed segmentations were preliminarily analyzed and further study was recommended based on the data gathered, that were able to reach useful results based on an internal validation.

The results on the criteria for identifying abnormal conflict counts recommended the use of a 75% confidence level on the segmentation of TA/TP crossings and 4 conflict types (the same types used in the U.S.FHWA guide) and suggest that further benefits can be expected from more detailed parameters. Nevertheless, the study showed that the decision on the best criteria is highly sensitive to benefit and cost parameters and could limit a robust scope for detailing.

The results on the measure of risk (accident proneness) of different conflict types or of crossing types were constrained by the impossibility of a precise identification of vehicle and pedestrian movements involved in accidents. Only the aggregate analysis of accidents and conflicts at each crossing type was possible and, even so, suggested a relevant and significant difference between the ratio of accidents per million conflicts in TA and TP crossings. This result can be traced back to the fact that this segmentation also segregates P/TP pedestrian movements (the more rare and risky movement) from other conflict types.

Despite the need of improvements, the results seem to be preliminarily applicable.

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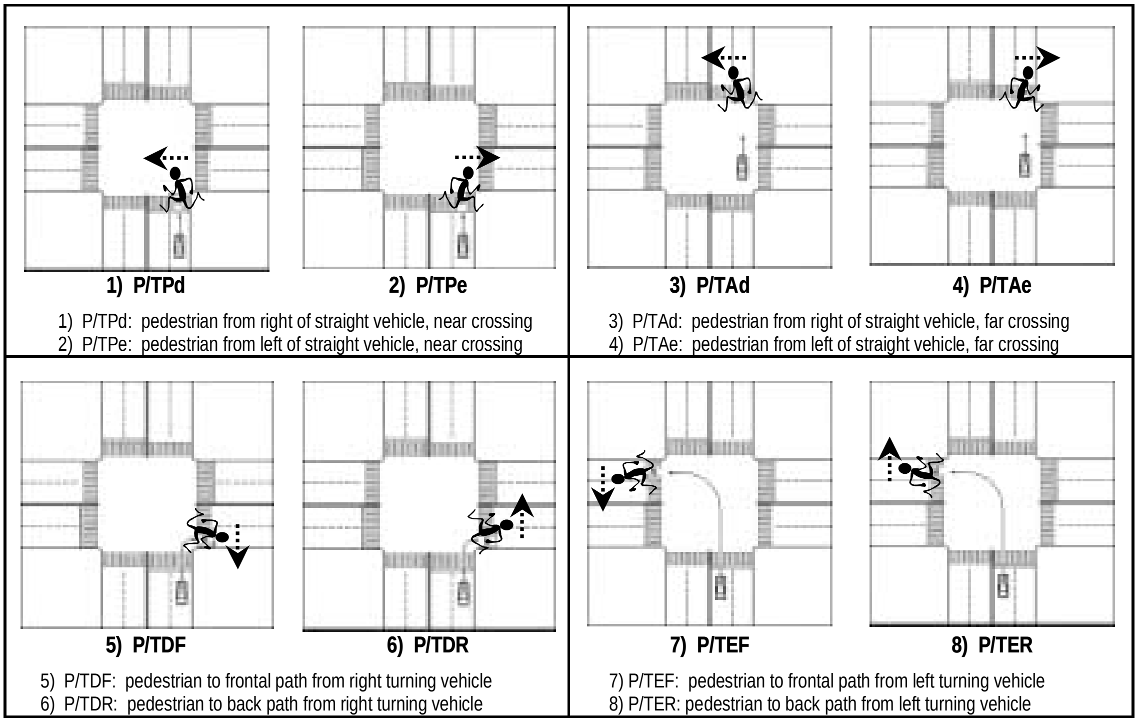


Figure 1 – Pedestrian-Vehicle Conflict Types in Intersection Crossings

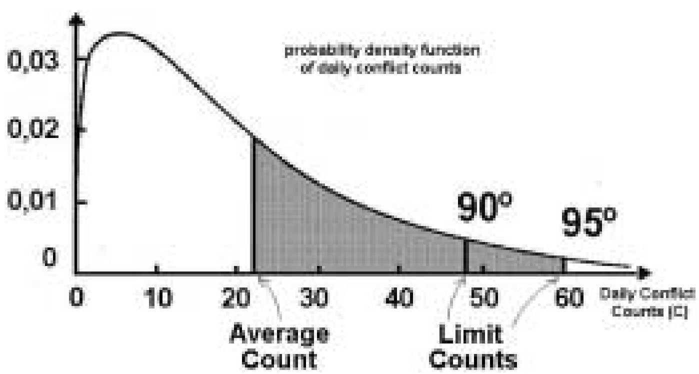


Figure 2 – Gamma Distribution and the Limit Counts for 90º and 95º quantiles

Table 1 – Ratio of Accidents per Million Conflicts from Swedish Studies.

	Sweden/98 – All Severe	Bolivia/94 – Low Severity	Bolivia/94 – High Severity
Car-Car “parallel”	28	10	60
Car-Car “right-angle”	119	40	200
Car-Unprotected Road User	339	200	700

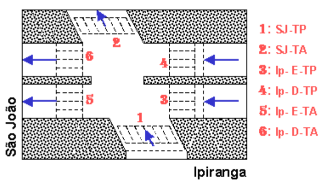
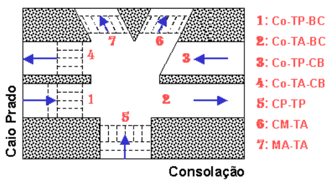
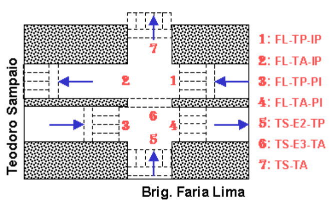
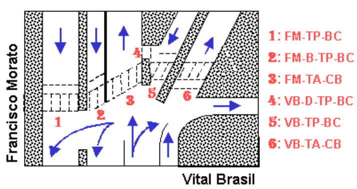
Sources: from 21, 22, 23 (transformed to Accidents per Million Conflicts)

Table 2 – Approach for the Validation with Economic-based Weights and Representative Values.

Size of the Validation Sample (N)	Sites with record of Accidents (NB)	Sites without record of Accidents (NN)
Normal sites (NS) with conflict counts under Count Limits.	**Error Type I** NEI (Neglected Risk) Costs of Avoidable Accidents	**HIT Type II** NEII (Saving of Resources) None (or benefit of alternative use)
Abnormal sites (NA) with conflict counts over Count Limits	**HIT Type I** NHI (Detected Risk) Benefit of Safety Improvement	**Error Type II** NHII (Wasting of Resources) Cost of Intervention

- Type I Error — Neglected risk: not selecting a site that has accident records in the sample information. The economic weight is related to the costs of avoidable accidents (e.g. 50% US$ 20.000/acc for direct costs of accidents).
- Type II Error — Wasting of resources: spending money for treating a site without accident record in the sample information. The economic weight is related to the cost of usual treatments (e.g. US$ 5.000/crossing for small intervention).
- Type I HIT — Detected risk: selecting a site that has accident records in the sample information. The economic weight is related to the reduction of accidents less treatment cost (e.g. 50% of US$ 20.000/acc less US$ 5.000/crossing)
- Type II HIT — Saving of Resources: avoid spending money for sites without accident records in the sample information. The economic weight is null (or the average benefit of alternative uses of resources in other areas can be used)

Table 3 – Basic Data on the Intersections and Crossings of the 1988 Study.

Intersection	Crossing	Hourly Vehicles	Hourly Pedestrians	96/97 Accident Location Index (%)	Intersection Sketches and Sites of Crossings
Ip-SJ	1: Sj-TP	1.021,20	2.073,60		
	2: SJ-TA	1.299,20	1.932,20	**1-100% (AC)**	
	3: Ip-E-TP	1.165,20	1.287,20	**1-60% e 100%(AC)**	
	4: Ip-D-TP	2.197,40	1.287,20	**1-40% (AC)**	
	5: Ip-E-TA	1.475,40	1.287,20		
	6: Ip-D-TA	1.609,20	1.287,20		
CO-CP	**1: Co-TP-BC**	4.146,80	1.007,60	**1-100% (AC)**	
	2: Co-TA-BC	4.146,80	-		
	3:Co-TP-CB	4.463,40	-		
	4: Co-TA-CB	3931,60	1.088,00		
	5: CP-TP	978,00	654,80		
	6: CM-TA	488,80	747,40		
	7: MA-TA	1.166,80	682,20	**2-100% (AC)**	
FL-TS	**1: FL-TP-IP**	1.312,40	756,80	**2-60% (AC)**	
	2: FL-TA-IP	1.347,40	902,40	**2-40% (AC)**	
	3: FL-TP-PI	1.096,60	902,40	**1-67% (AC)**	
	4: FL-TA-PI	1.096,60	756,80	**1-33% (AC)**	
	5: TS-E2-TP	1.343,80	556,40		
	6: TS-E3-TA	1.343,80	55,60		
	7: TS-TA	1.290,80	849,60		
FM-VB	**1: FM-TP-BC**	1.700,00	1.215,60	**1-75%, 1-60% e 1-100% (AC)**	
	2: FM-B-TP-BC	375,60	1.415,10*	**1-25% e 1-40% (AC)**	
	3: FM-TA-CB	1.334,10	1.142,88		
	4:VB-D-TP-BC	*	*		
	5:VB-TP-BC	867,50	1.186,32		
	6: VB-TA-CB	706,12	1.142,88	**1-100% (AC)**	
Vol. Médio horário		**1.557,17**	**1.044,26**		

Note: Cells with – have a very small number of pedestrians (were not counted). Cells with * had missing data due to equipmenf fail. Pedestrian flow on the 2- FM-B-TP-BC crossing is approximated based on flow of adjacent crossings (60% of 1-FM-TP-BC + 60% of 3-FM-TA-CB).

Table 4 – Summary of Pedestrian Accidents and Recovered Police Reports in the Intersections

Intersection	Pedestrian Accidents – 1996/1997						
	Year	Total Ped.Acc.	Work Days	Week Ends	Recovered in each year	Total in Std.P./WDy	Recovered Std.P./WDy
Ip-SJ	96	8	7	1	3	5	1
	97	7	4	3	5	3	2
Co-CP	96	5	2	3	3	3	1
	97	7	7	0	4	3	2
FM-VB	96	8	7	1	3	5	1
	97	9	7	2	3	4	3
FL-TS	96	7	4	3	4	3	2
	97	3	3	0	1	3	1
	Total	54	41	13	26	29	13

Source: Accident Records-Police of the State of São Paulo (PM)

Table 5 – Summary of average daily conflicts (for the standard 11 hours period), São Paulo Study.

				Basic Disaggregate Standard Period Conflict Count Data								**Agreggate**
Inter.	**Crossing**	**Seg.I**	**Seg.II**	P/TPD	P/TPE	P/TAD	P/TAE	P/TDF	P/TDR	P/TEF	P/TER	P/TOT
CO-CP	2: Co-TA-BC	TA	Ped	-	-	0,0	0,0	0,0	0,0	-	-	0,0
CP-CM	6: CM-TA	TA	Ped	-	-	1,0	1,0	7,5	9,8	-	-	19,3
CP-MA	7: MA-TA	TA	Ped	-	-	5,0	3,9	5,6	9,8	-	-	24,3
FL-TS	4: FL-TA-PI	TA	Ped	-	-	3,7	3,7	-	-	-	-	7,4
FL-TS	6: TS-E3-TA	TA	Ped	-	-	1,0	1,0	-	-	-	-	2,0
FL-TS	7: TS-TA	TA	Ped	-	-	37,9	19,2	36,6	16,6	-	-	110,3
CO-CP	4: Co-TA-CB	TA	Ped+	-	-	0,0	1,0	-	-	12,9	17,7	31,6
Ip-SJ	2: SJ-TA	TA	Ped+	-	-	7,5	9,0	32,4	31,6	-	-	80,5
Ip-SJ	5: Ip-E-TA	TA	Ped+	-	-	9,2	9,6	-	-	20,2	9,8	48,8
Ip-SJ	6: Ip-D-TA	TA	Ped+	-	-	1,2	8,0	-	-	12,9	10,5	32,6
FL-TS	2: FL-TA-IP	TA	Ped+	-	-	2,7	6,1	-	-	62,4	62,6	133,8
FM-VB	3: FM-TA-CB	TA	Ped+	-	-	6,3	5,9	-	-	-	-	12,2
FM-VB	6: VB-TA-CB	TA	Ped+	-	-	-	-	7,9	16,5	-	-	24,4
CO-CP	3:Co-TP-CB	TP	NSat	1,0	0,0	-	-	-	-	-	-	1,0
FM-VB	4:VB-D-TP-BC	TP	NSat	0,8	1,7	-	-	-	-	-	-	2,5
Ip-SJ	1: Sj-TP	TP	NSat	6,1	12,9	-	-	-	-	-	-	19,0
Ip-SJ	3: Ip-E-TP	TP	NSat	9,9	2,7	-	-	-	-	-	-	12,6
Ip-SJ	4: Ip-D-TP	TP	NSat	8,5	2,2	-	-	-	-	-	-	10,7
FL-TS	1: FL-TP-IP	TP	NSat	1,0	6,2	-	-	-	-	-	-	7,2
FL-TS	3: FL-TP-PI	TP	NSat	9,3	0,7	-	-	-	-	-	-	10,0
FL-TS	5: TS-E2-TP	TP	NSat	5,5	11,2	-	-	-	-	-	-	16,7
FM-VB	2: FM-B-TP-BC	TP	NSat	0,0	0,8	-	-	-	-	-	-	0,8
CO-CP	1: Co-TP-BC	TP	Sat	0,0	0,7	-	-	-	-	-	-	0,7
CO-CP	5: CP-TP	TP	Sat	0,0	0,0	-	-	-	-	-	-	0,0
FM-VB	1: FM-TP-BC	TP	Sat	1,8	9,2	-	-	-	-	-	-	11,0
FM-VB	5:VB-TP-BC	TP	Sat	0,8	2,4	-	-	-	-	-	-	3,2

Note: Cells with – can not have conflicts of the related type. Zero counts are explicitly indicates as 0,0 (no count during the surveyed and standard periods).

Table 6 – Results on Abnormal Count Limits for Pedestrian-Vehicle Conflicts, São Paulo Study.

a. Basic Normal Conflict Count Limits based on the Sample.

Segmentation	All-Aggreg	All-2Types		TA/TP-Agg	TA/TP-2 Types		TA/TP-4Types			
Confl.Type	Aggregate	P/VA	P/VT	Aggregate	P/VA	P/VT	P/TP	P/TA	P/TD	P/TE
Cros.Type	All	All		TA	TA		All-TA			
mean	23.95	9.57	20.39	40.55	11.99	20.39		11.99	29.05	52.25
75.00%	31.6	13.1	28.3	56.2	16.3	28.3		16.3	39.9	72.3
90.00%	65.0	24.2	46.9	95.2	31.1	46.9		31.1	61.5	116.1
95.00%	92.4	33.0	61.0	125.0	43.0	61.0		43.0	77.3	148.8
Cros.Type				TP	TP		All-TP			
mean				7.34	7.34		7.34			
75.00%				10.1	10.1		10.1			
90.00%				15.9	15.9		15.9			
95.00%				20.2	20.2		20.2			

b. Results for Further Segmentation Disaggregation of Normal Conflict Count Limits

Segmentation	Ped/+/N/Sa	Ped/+/N/Sat-2 Types		TA/TP-8Types							
Confl.Type	Aggregate	P/VA	P/VT	P/TPD	P/TPE	P/TAD	P/TAE	P/TDF	P/TDR	P/TEF	P/TER
Cros.Type	TA-Ped	TA-Ped		All-TA							
mean	27.22	12.90	21.48			6.29	5.70	15.00	14.05	27.10	25.15
75.00%	34.8	15.6	29.8			7.7	7.9	20.8	19.1	37.3	34.9
90.00%	76.1	37.3	50.6			18.0	12.8	35.0	28.1	58.5	58.0
95.00%	110.9	56.3	66.5			27.0	16.4	45.8	34.6	74.1	75.5
Cros.Type	TA-Ped+	TA-Ped+									
mean	51.99	11.08	19.77								
75.00%	71.1	14.5	27.4								
90.00%	107.9	19.6	46.8								
95.00%	134.8	23.1	61.6								
Cros.Type	TP-NSat	TP-NSat		All-TP							
mean	8.94	9.94		3.44	3.90						
75.00%	12.1	13.2		4.8	5.4						
90.00%	17.8	18.4		8.4	9.6						
95.00%	21.9	22.1		11.1	12.9						
Cros.Type	TP-Sat	TP-Sat									
mean	3.73	3.73									
75.00%	5.0	5.0									
90.00%	9.9	9.9									
95.00%	13.9	13.9									

Table 7 – Comparative Performance of Alternative Criteria for Abnormal Conflict Level Detection

Confidence Level		All-Aggregat	TA/TP-Aggr	Ped/+/N/Sat-	All-2Types	TA/TP-2 Typ	Ped/+/N/Sat-	TA/TP-4Typ	Ped/+/N/Sat-	TA/TP-8Typ	Ped/+/N/Sat-
75.00%	NoErr1	10	7	8	11	8	10	7	9	5	6
	NoHit1	2	5	4	1	4	2	5	3	7	6
	%Hit1	16.67%	41.67%	33.33%	8.33%	33.33%	16.67%	41.67%	25.00%	58.33%	50.00%
	NoErr2	3	3	3	4	4	4	4	4	5	5
	NoHit2	11	11	11	10	10	10	10	10	9	9
	%Hit2	78.57%	78.57%	78.57%	71.43%	71.43%	71.43%	71.43%	71.43%	64.29%	64.29%
	AccE1	11	7	7.5	12	8	10	7	9	5.5	6.5
	AccH1	2	6	5.5	1	5	3	6	4	7.5	6.5
	DE	-5	20	20	-15	10	0	15	5	15	10
	TA-Ped	-5	-5	-5	-5	-5	-5	-5	-5	15	10
	TA-Ped+	0	10	10	0	0	0	5	5	0	0
	TP-NSat	0	0	0	-10	0	-10	0	-10	5	0
	TP-Sat	0	15	15	0	15	15	15	15	15	15
	RE	-7.14%	28.57%	28.57%	-21.43%	14.29%	0.00%	21.43%	7.14%	21.43%	14.29%
90.00%	NoErr1	10	11	10	11	11	10	10	10	7	10
	NoHit1	2	1	2	1	1	2	2	2	5	2
	%Hit1	16.67%	8.33%	16.67%	8.33%	8.33%	16.67%	16.67%	16.67%	41.67%	16.67%
	NoErr2	1	3	2	1	3	2	3	2	3	3
	NoHit2	13	11	12	13	11	12	11	12	11	11
	%Hit2	92.86%	78.57%	85.71%	92.86%	78.57%	85.71%	78.57%	85.71%	78.57%	78.57%
	AccE1	11	12	10	12	12	10	11	10	8.5	10
	AccH1	2	1	3	1	1	3	2	3	4.5	3
	DE	5	-10	10	0	-10	10	-5	10	5	5
	TA-Ped	-5	-5	-5	-5	-5	-5	-5	-5	5	5
	TA-Ped+	10	5	5	5	5	5	10	5	10	5
	TP-NSat	0	-10	-5	0	-10	-5	-10	-5	0	-10
	TP-Sat	0	0	15	0	0	15	0	15	0	15
	RE	7.14%	-14.29%	14.29%	0.00%	-14.29%	14.29%	-7.14%	14.29%	7.14%	7.14%
95.00%	NoErr1	11	11	12	11	11	11	12	12	12	12
	NoHit1	1	1	0	1	1	1	0	0	0	0
	%Hit1	8.33%	8.33%	0.00%	8.33%	8.33%	8.33%	0.00%	0.00%	0.00%	0.00%
	NoErr2	1	0	0	1	1	1	1	1	2	1
	NoHit2	13	14	14	13	13	13	13	13	12	13
	%Hit2	92.86%	100.00%	100.00%	92.86%	92.86%	92.86%	92.86%	92.86%	85.71%	92.86%
	AccE1	12	12	13	12	12	12	13	13	13	13
	AccH1	1	1	0	1	1	1	0	0	0	0
	DE	0	5	0	0	0	0	-5	-5	-10	-5
	TA-Ped	-5	0	0	-5	-5	-5	-5	-5	-5	-5
	TA-Ped+	5	5	0	5	5	5	0	0	0	0
	TP-NSat	0	0	0	0	0	0	0	0	-5	0
	TP-Sat	0	0	0	0	0	0	0	0	0	0
	RE	0.00%	7.14%	0.00%	0.00%	0.00%	0.00%	-7.14%	-7.14%	-14.29%	-7.14%

Table 8 – Representative Factors for Converting Standard Period Conflict Counts to Annual Counts.

	dry pavement		wet pavement	
	Std/Day	Days/Year	Std/Day	Days/Year
Work Days	70%	4/7 of 365	70%	1/7 of 365
Week Ends	70%	3/14 of 365	70%	1/14 of 365

Table 9 – Results on the Ratio of Pedestrians Accidents to Million Conflicts, São Paulo Study.

	SampSite	SampAcc	R (Ac/MC)	R StdDev	Quasi-t	R CoefVar	Adj.Ratio	RR (A/Ch)
Aggregate-All	26	13	35.04	12.75	2.75	36.38%	78.16	0.2562
Aggregate-TA	13	5.5	17.51	8.00	2.19	45.70%	39.05	0.1280
Aggregate-TP	13	7.5	131.92	51.03	2.59	38.68%	294.29	0.9646
diff:TA/TP			-114.4182	51.6536	-2.2151			
Aggregate-TA-Ped	6	2.5	25.69	26.97	0.95	104.98%	57.31	0.1878
Aggregate-TA-Ped+	7	3	13.83	6.99	1.98	50.54%	30.86	0.1011
diff:TA-Ped/TA-Ped+			11.8560	27.8599	0.4256			
Aggregate-TP-NSat	9	4.5	93.81	43.88	2.14	46.77%	209.26	0.6859
Aggregate-TP-Sat	4	3	337.87	142.41	2.37	42.15%	753.71	2.4703
diff:TP-NSat/TP-Sat			-244.0631	149.0179	-1.6378			