EVALUATING ROAD SAFETY AUDIT PROCEDURES: SOME QUESTIONS AND A NEW METHOD OF STUDY

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Submitted for presentation at the 86th Annual Meeting of the Transportation Research Board
(January 21-27, 2007) and for publication in the Transportation Research Record journal
July 2006

Word count: 9146 words + 7 figures/tables

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Key words: road safety audits, signalized intersection safety, road safety in developing countries

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Lili L. Bornsztein, and Hugo Pietrantonio

Abstract: The paper discusses current views on the application of road safety audits (RSA) as a tool for the improvement of road safety and evaluates some features that can influence their effectiveness on the field. Starting from a review of published references on RSA in different countries, the work identified a set of questions and undertook a case study of the impact of alternative RSA procedures on its final effectiveness measured both as agreement to a safety expert checklist and to an accident-based study. Main features analyzed in the case study included the type of observer used for data collection on the field (a senior safety engineer, a senior design engineer, a junior safety engineer, a junior design engineer), and the type of checklist used as guide to work in the field (a generic set of questions, a detailed set of questions, a detailed set of questions with observation hints). Based on an exploratory study in one intersection, the performance of applications of RSA is compared using weighted indexes of concordance and disagreement and the ratings on detection or omission of observations gathered in the accident diagnostic of safety problems on the site. The main conclusions of the case study can be summarized as clear support to team work practices for field observation (as no single observer approached the full set of diagnostic features gathered in the accident-based study), support to employing less experienced personnel for field observation (at least if using detailed checklists with instructions without dispensing supervision) and sign to the need for priority setting procedures/criteria (as the large number of features included several non-critical problems or even misleading points). The conclusions are useful in selecting alternative RSA procedural guidelines in agencies responsible for promoting or enforcing RSA and in professional teams carrying-out RSAs. Several features deserving further study are also identified.

1. INTRODUCTION

The use of Road Safety Audits (RSA) as a tool for improving traffic safety has received increasing attention in the USA and in Brazil (at least since the middle of the 90's) as a result of its development and dissemination from the UK to Australia, New Zealand (and also the Europe and Canada). Examples of recommendations that are widely disseminated and recognized in several of the leading countries can be seen in references *1* to *4*. No similar documents are available in the USA or in Brazil, but several institutions lead the support to RSA in these countries, as the US.ITE (*5*) and INST in Brazil (*6*).

There is a favorable position among the general public, politicians and technicians supporting RSA application as a preventive measure that tries to avoid accidents through a (hopefully low cost and effective) revision process and that can also save money of future (more expensive) road changes. As it is usual when reviewing subjects covered by favorable views, general agreement on the merit and purposely defense of the positions do the bad job of hiding some points that vary among different concepts and practices. It is important to disentangle features that are judged to be essential from other features that are a matter of detail and should be tailored to the needs and means of each application.

A quick ride around variations in concepts and practices for RSA application is interesting as it stresses some overlooked questions and clarifies the need of more detailed methods for study of RSA application. Despite the widespread acceptance of the general idea, one can observe some variation in concepts and procedures during the recent evolution of the RSA technique in the 80's and the 90's that are not stressed or at least noted by scholars or practitioners and that can compromise the effectiveness of its application.

In the following sections, the paper tries to carried-out these two tasks. First, it discusses the main features that vary among different concepts and practices for RSA (in sections 2 and 3). Then, it presents a method of study about the comparative effectiveness of alternative procedures for field work and reports the results of its use in the application of RSA procedures in two signalized intersections (in section 4 and 5). The final section summarizes the main conclusions that can be delivered by the research on the effectiveness of alternative RSA procedures and on the validity of the method of study.

From the outset, one should note that both, the method and the results in this paper, are limited to the application of RSA for existing sites and should be extended before being usable in the study of the application of RSA in the design phase of road projects (its main scope). Other general questions (e.g. on where and when use RSAs) are also outside the realm of this work and its method (that is more useful in the study of procedural alternatives for RSA work and its tasks). Nevertheless, the problems encountered in the evaluation of RSA procedures are also relevant for a wider scope that deals with the evaluation of other surrogate measures of safety (as traffic conflicts, conflict opportunities and exposure measures).

2. ALTERNATIVE VIEWS AND CONCEPTS OF ROAD SAFETY AUDITS

Talking about the concept, the very idea of an audit on road safety can be surely traced back to the *independent* (third party) evaluation of safety by a *qualified* expert. Departing from audits on other areas as accounting and management, the *ex-ante* (preventive) feature is stressed in RSA (instead of the *ex-post* checking). The application of RSAs to the design stages of projects seems to have no parallel in the other areas. The meaning of audit is peculiar in RSA and some other areas as Environmental Impact Studies (similar in their preventive concerns) and distinctive from its general use in accounting and management in general. The *exclusive* focus on traffic safety is the specific point on RSA, a feature that is also universally acknowledged in RSA definitions, as a mean for warranting attention to its specific concern (road safety).

After this basic agreement, we identified seven features on which the final concept varies:

- the kind of essential qualification of experts (specially on accident investigation);
- the coverage of RSA application (wideness of the field for preventive action);
- the role of systematic checking (and the importance of checklists);

- the requirement for formal reporting (from auditors and from designers);
- the focus on human factors and/or all users (from pedestrians with disabilities to truck drivers);
- the focus on special road conditions (as day/night, road works, adverse weather);
- the role of multidisciplinary or multi-role teams (and their composition).

Some of the variations can be said to be inheritance of old questions (traces of the evolution in the concept of RSA) but others are actual and relevant questions that merits careful consideration and study. Sometimes it is difficult to distinguish historical questions that evolved during the maturing of the concept and the technique, and that were “solved” or “settled” in some sense, from current questions that should be discussed (and here there is some room for personal judgment, of course).

For example, in the original sources of the RSA concept, the main requirement for an independent and qualified auditor was expertise on accident investigation. This feature was stressed as a mean to bring the specific knowledge gathered in the analysis of traffic accidents to the design process, based on the judgment that design guidelines were insufficient to fully warrant traffic safety (because they stressed other goals or because they overlooked some details that matter for safety).

This view was clearly stated in the historical review of Bullpit (*7*) when the author says that the basis of RSA are the principle “prevention is better than cure” and the use on accumulated knowledge in accident investigation and prevention (*7*, pp.211). The same point is highlighted in the first version of the U.K.IHT Guidelines for Road Safety Audits (*1*, pp.9). Nevertheless, one must also note the withdrawal of this highlight in the second edition of the U.K.IHT Guidelines, where one can find a strong emphasis on the need of improved and updated knowledge by experts (*8*, pp.20).

Of course, RSA knowledge can be a source for the development of road design guidelines and the confidence on the accident investigation and prevention expert has to be conditional. Despite recognizing the importance of the specific knowledge gathered in accident investigation, one can expect that its content should be progressively subjected to scientific investigation and integrated in evolution of design guidelines sooner or later. One must also recognizes that the knowledge of accident investigation experts is subject to emphasis and changes (and that there are good and bad experts). Changes in concept can be the result of changes in the specific or historic settings but can also sign changes in departing points for the technique or its practice that can perhaps compromise its final efficiency and effectiveness.

The evaluation of current design guidelines and of RSA criteria should be an empirical question as should be the evaluation of actual experts competence. So, the adoption of one or other view on the concept would be a matter of faith unless one can evaluate the practical effectiveness of each option.

Another example: international diffusion of RSA procedures in the mid 90’s brought an overstressed attention to checklists as a tool for applying RSA (and also for communicating its principles and criteria on practical grounds, of course). Some authors mentioned its use as an essential feature of RSA (e.g. *9*).

Objectively, the development of checklists had to be carried-out by every RSA team and we have a lot of examples of real implementations. Today, one can find checklists with variations in content and organization, type of questions and also their coverage, form and mode of application, but all these features following personal taste more than application tests. The development of checklists, despite requiring considerable work, did not track well-defined and certified paths. So, one can not expect that its use would surely contribute to warrant good results *per se*. A critical assessment of their content against each other or against conventional knowledge gathers really disappointing results. The analysis carried-out by Bornsztein (*10*, chapters 3 and 4), for signalized intersections, identifies several questions set on excessively generic terms, failing to encode the available safety knowledge.

For example, the analysis of road surface on Canadian checklists (*4*) asks for checking skid resistance along curves, intersection approaches and steep grades (where we know it is critical) but questions on pavement defects and depression areas in general (see *4*, pages A-20 or B-12). Despite being one of the best checklists available, one can find similar deficiencies in several subjects covered by safety analysts (see *15*, *16*). Another example: the adequate treatment of pedestrians in traffic signals should avoid usual operation traps (vehicle flows starting/stopping at different stages, exposition to permitted left turns,) and avoid intended/unintended violations (because of excessive delay to pedestrians, of large gaps on priority vehicular flows, especially at high speed or large distance crossings) that are unnoticed in the Canadian checklists (see 4, pages A-16, 26 or B-10, 11, 16, 17). In other areas, even the accumulated knowledge of safety analysts is really vague (as on the effect of signs in accidents, when they are critical).

Of course, checklists serve more than one function (from a formalizing tool that favors an objective and fair evaluation to an *aide-memoire* guide for field work) but its main use is instrumental and should be judged by its effectiveness in contributing to the RSA goal (i.e. prevent accidents). So their adequacy must be investigated on empiric grounds in the task of tort identification.

Some other features can, perhaps, be taken as simple matters of concept and practice. For example, formalization of reports (by the auditor and by the designer) has a clear role and function: warranting explicit consideration to all and every question identified as potentially dangerous and prone to cause accidents. There is no informal RSA (an informal procedure would constitute another practice). Yet, for other questions, the answer can depend on the nature or scale of work (for example the composition of the RSA team and the procedures to be followed on the field). So, one must search for concepts and practices that have to be tailored to different types of work.

Among the identified features, coverage and scope have shown a clear path of evolution. For example, the possibility of applying RSA procedures to existing roads (not only to projects), to maintenance work (as emphasized by the U.K.IHT), to construction planning and execution (as emphasized by the U.S.FHWA), to operating procedures (as emphasized in Brazil) was recognized in a progressive trend unfolding several fields in which the technique is potentially effective (because they identified areas that bear some burden on road safety and accidents).

Another example of evolution is related to the special focus on the needs of all users (as emphasized by Austroads) and on the requirements of all road conditions (as emphasized by the U.S.FHWA), just reminding features that are usual in the causation of road accidents and supposedly are topics with important shortcomings in the current design guidelines (that then identify an area of special concern for RSA application today). Nevertheless, critical concerns can vary as better guidelines are developed or as new areas of concern appear (maybe due to changes in urban patterns or automation tools, for example).

For every defender or contender of RSA, the precise view on the concept and its essential features should be clearly stated. Our working understanding is the following one:

- the essential qualification of the expert is good knowledge about accident causation and correction (not only road design), acquired through experience or at least specific training for the subject;
- the preventive action of RSA covers all stages and activities that bear a relevant effect on road safety (ie RSA applies to different stages of design and construction, to pre-opening and initial operation, to existing roads and operational procedures, and so on);
- systematic checking (and the use of checklist) in RSA procedures is a mean (not an essential feature) for achieving a complete evaluation of features, establishing valid and fair criteria, minimizing subjectivity in results and avoiding conflicts with design experts;
- formal reporting is a need for warranting real attention to all safety concerns through the documentation of statements and for delimiting responsibilities of designers (the final decision makers) and auditors (in their advisory role);
- the focus on all users and conditions is a technical requirement for RSA, due to their importance in the realm of road safety and the lack of consistent consideration in current design guidelines;
- the need for multidisciplinary or multi-role team or any other procedural RSA feature is a practical matter that should justify itself in each RSA type (a multidisciplinary background is a conventional requirement for a traffic safety engineer or expert).

Before leaving these conceptual remarks, another comment should be directed to the role of checklists. Our view is that, despite its overstressed importance as support for good RSA, checklists should be better tailored to each subject as they are the current tools for consolidation of the RSA knowledge base. Their content should receive greater attention than usual and be submitted to systematic and critical evaluation. The lack of studies and methods for justifying the content of proposed checklists as well as the vagueness (more than openness) of most of the questions can, nevertheless, undermine this knowledge role. The wide variation in the form of presentation (mostly in the level of detail) is also a matter of study (in our study, we related it to the kind of professional used in the work of extensive observation in the field).

The point made above can be summarized in stressing that most questions should be the subject of careful empirical studies, maintaining a clear concern in warranting or preserving the potential effectiveness and efficiency of the RSA application practice, instead of taken as a matter of faith or preference.

3. ALTERNATIVE PRACTICES FOR ROAD SAFETY AUDITS

Talking about practice, two conventional sets of questions should be recognized: practice on the use of RSA (when and where) and practice on the process of RSA (who and how). Also, there are more detailed (and disregarded) questions about another set of questions: the procedures applied on RSA work.

From the RSA guidelines, one can infer a clear trade-off on setting a rigorous procedure against keeping it a simple and straight task that can be applied at large (with small burden on project costs and schedules). In the first set of questions (on the use of RSA) are the requirements that elevate it to more than a recommended technique, as a fully mandatory procedure for the overall set of projects of a class (as for trunk road schemes in the UK) or for a sampling rate of the undertaken projects (perhaps depending on their scale or nature, as done at Australia and New Zealand for small scale projects or works). This is not of main interest here despite recognizing that the kind of requirement or motivation for undertaking RSAs could be a factor in determining its final effectiveness.

We concentrated the investigation on the second and third set of questions, questions that are viewed as interlinked ones, and identified six main features on which the practice varies:

- the degree of formalization in the process and the allocation of roles (for auditors and others);
- the composition of the RSA team (if more than the expert is involved in it);
- the identification of tasks and their allocation among team members;
- the procedure in field work (observation team, number of visits, periods/tasks of work);
- the type of supporting tools used for RSAs (as measuring or registering devices);
- the type of checklists used for RSAs in special (and its relation to qualification of team members).

Some of these questions are really unnoticed by current guidelines, despite its apparent importance for the potential effectiveness of RSA application. Some of them may have effects that depend on the particular use of RSA as they can set the context for small or large scale applications. This dependence could be complex and was a strong motivation for this research.

For example, despite being optional instead of mandatory, the most well known applications of RSA in Brazil are large scale ones. The first application dealt with 1507 signalized intersections in the city of São Paulo, that were converted to real time control after 1994 (*11*). Nowadays, applications of RSA moved to overall networks of highways under concession, also voluntarily applied by some of the new infrastructure operators in the State of São Paulo (following current trends of privatization of road administration based on toll collection financing schemes), covering some hundreds of kilometers, all in once (*12*). There is also a trend to mandatory requirement of RSA for these infrastructure operators (at least for the private ones) that will favor large scale applications even more.

This practice weakens the requirements for formalization (because the application of RSA were motivated by the contractors) but enforces the interest on efficient processes (combining expert role in judgment matters with clerical roles in field observation) and quality assurance in RSA (including training, checklists, supervision, rechecking and so on). This concern with the multi-role composition of teams is markedly different from the emphasis on multidisciplinary composition stressed by U.S.FHWA case studies by emphasizing the combination of functions (not competences on complementary subjects).

Furthermore, the adoption of a mandatory requirement for RSA in a country with “soft” legal commitment to tort liability, as Brazil, means a danger of a “bureaucratic” action (i.e. safe on paper, but not on road). The legal apparatus is not the weak point in Brazil, as codes are very similar to European ones, but the lack of commitment to tort liability comes from a fragile institutional framework that undermines the application of law. Calling for consideration of RSA questions should be rooted on greater efficiency and effectiveness than on the conventional institutional framework of a developed country.

Anyway, the importance of the practical questions on RSA application raised above (in any context) seems to be obvious and the main goal of this discussion is to stress the need of informed evaluation for the several components of practical RSA procedures. Without being exhaustive, one can suggest that at least the following essential points should be addressed:

- the degree of dependence on a safety expert, that could be a constraint for application of RSA at large if it is not possible to warrant an efficient work routine, combining clerical personnel (or junior professionals at least) and expert supervision but without compromising effectiveness;
- the composition of teams, with evaluation of the comparative performance of personnel with different qualifications in alternative tasks as:
  . field observation,
  . specialized evaluations,
  . rating of risk or danger;
- the type of supporting tools used, as guide to work (especially, the type of checklist), studying the importance of tailoring them to each work routine for preserving the efficiency of the RSA process in large scale applications (including RSA preparation, e.g. training tasks);
- the degree of integration and enforcement of RSA activities and the commitment to tort liability in agencies or regions, that should be relevant for the design of RSA process, taking into account:
  . mandatory or recommended RSA application,
  . level of rigor in the calling for attention of questions;
- the organization of the RSA work, including field and office activities and the commonly stressed relationship between auditors and designers or their specific requirements and responsibilities, dealing with:
  . degree of interaction in the RSA team,
  . procedures for analysis and prioritization,
  . interaction between RSA team and decision teams.

An example can illustrate our point: much of the effectiveness of RSA, as usually carried-out, rests on the qualification and diligence of the auditor (the safety expert) and on the calling for legal responsibility of agencies and designers. In the USA, at least, there is a clear concern on increasing the exposition to tort liability as a result of wide RSA application and this is translated in a recommendation that auditor should point to unsafe features and leave the selection of corrective action to designers. In Brazil, there should be a greater concern on improving the supporting tools for RSA work and clearly setting the requirements for effective RSA activities, as a mean for promoting RSAs with real effectiveness instead of a “bureaucratic” action. Both concerns are relevant but can be valued differently in each context.

Now, our point must be put clearly: the efficiency and effectiveness of RSA must be studied carefully. All effort should be directed to selecting appropriate methods of organization and work that can warrant good results with compatible costs (money and time). Also, recalling what was said at the beginning of this section, rigorous procedures should be kept at a minimum to avoid compromising RSA viability itself.

4. A NEW METHOD FOR EVALUATING THE EFFECTIVENESS OF ROAD SAFETY AUDITS

The previous discussion set forth some questions and the motivation for better evaluation of RSA concepts and their procedures. It remains to deliver a methodological approach that can surpass most of the difficulties one would face in RSA evaluation studies.

The study of RSA application has a lot of specific problems that come from its own features (and that should be added to the usual difficulties of traffic safety studies and the analysis traffic accident data).

Most of effectiveness data on RSA application are based on studies that aimed at evaluating the cost/benefit ratio attained by specific audit trials. For example, based on studies carried-out in Scotland and New Zealand, cost/benefit ratios of 1:15 and 1:20 are usually quoted in several references (as *8*, pp.10, *9*, pp.413-4, *4*, pp.6-2). These studies are not clearly presented or discussed in the references. A recent study do a better job (see *17*) but one can grasp that these methods are not prone to the analysis of safety audit procedure alternatives in detail.

Then, a more detailed method of study is needed for evaluating the kind of questions set previously. Nevertheless, difficulties are pervasive.

As a preventive action that aims at avoiding traffic accidents, the application of a RSA procedure destroys by itself some evidence needed for certifying its worth (the accidents that would be caused by the "potential" defects on the original situations or proposals). This difficulty is especially relevant for evaluating RSA applied to the design stages or applied as preventive action for existing sites, giving the current evolution of techniques that can be applied in predicting what the accidents would be otherwise. One can believe that RSA advices were important and justified but one can not demonstrate its effect (as a before and after studies does it in the evaluation of road safety interventions).

Of course, one can try to verify the comparative performance of audited projects against control projects but, in a field in which the effect of random and exogenous factors are so important (as traffic safety), the exercise could be subjected to weaknesses that will shed relevant doubts on results (or at least weakens its statistical significance). This with/without method is a much needed approach for evaluating RSA application, through the comparison on the safety performance of audited or non-audited projects, but is probably insufficient for elucidating all the set of questions previously discussed.

The need (and cost) of subsequent corrections is also a clue on the effectiveness of RSA application to projects that has yet to be explored. The responsibility to keeping the road safe should be less burdensome in audited projects (or in the years after auditing roads). Data on these features could be easier to recover but they will leave aside the evaluation of final safety or would have to compensate for different levels of attained safety in projects or works. Then, ideally both should be studied together.

All these approaches (i.e. the monitoring of accidents after changes, the comparison of accidents against control sites and the follow on of corrections after changes) are mandatory (as it is strong evidence of the effects of RSA on the road) but are coarse for the intended use.

Another line of work can be directed to the use of RSA results. The demonstration that RSA recommendations were accepted and implemented by agencies and/or designers can be taken as an indirect sign of their value. This is surely so but is not able to clearly make its point about the final performance of RSA on improving safety on a strong base.

This paper set out an alternative approach for studying RSA application that is weaker than certifying its final effect based on accident and cost records but that could be potentially richer for evaluating the effects of detailed procedures and tools used on the field. Complementary methods are, naturally, desirable. The proposed method aims at doing a scientific evaluation of the promises of RSA applications that could affirm their potential.

This new method has two wheels: an evaluation of intermediate results and an evaluation of final results. These components can be taken almost independently. Both analyses are carried-out in the context of simulated RSA applications and they can not evaluate features that appear on real applications only (as those questions related to commitment).

The analysis of intermediate results can be used to evaluate the application of RSA in all stages but the analysis of final results can not evaluate the design of all new projects or even the design of corrective action without further adaptation (as it partially depends on previous accident records). The intermediate evaluation asks for the comparison of each alternative procedure and some standard way of doing a RSA. The evaluation is intermediate in the sense that it compares observations gathered with alternative RSA procedures against the agreed standard and not the quality of the results by themselves.

Here, the fundamental hypothesis of evaluation is simple: similar results favor the more cost effective procedure or can permit the selection based on the elicited cost/quality trade-off.

The final evaluation task judged the effectiveness of RSA application by comparing the diagnostic of safety problems based on RSA for real sites against equivalent results based on traditional accident studies (instead of trying to verify the real effect on accident and cost records). The fundamental hypothesis is now that the validity of the RSA application can be demonstrated by showing that it can reach similar conclusions about the safety problems of the studied sites to those that would be gathered from detailed accident data. So, it will decide corrections that would also be similar to the ones decided by accident studies (usually with reduced costs for the traffic agency and for the road users). At least, this comparison can demonstrate that RSA can reach similar results to accident analysis even if accident data are unavailable (even more if accident data are available).

Our study also felt the need to complement these "objective" evaluations with a "subjective" rating (based on technical judgment) on the correctness and importance of further torts identified by RSA (but not related to the available sample of accident records). Similar approaches were used by other studies. For example, the evaluation of a Road Safety Risk Index (*13*) also felt the need of using an evaluation (partially subjective) of the proneness to accident and its consequences to weight observations and called for an objective comparison with accident occurrences, building an accident-based measure for validation of the proposed index and procedure. In Australia and New Zealand, this point was developed further and incorporated in a software system (the Road Safety Risk Manager) that can be used in setting priorities to recommendations emanated from RSAs (*18*).

These results can be analyzed with simple cross-tabulation methods and subjective evaluation or can apply conventional statistical modeling methods and inference criteria. Both methods will be exemplified in the following case study and can assess a wider range of questions on RSA procedures than other methods. Statistical modeling is preferable for evaluating the effect of the procedures controlling for several confounding factors that can affect the results of application work, despite the recognized lack of robustness of techniques based on correlational data (as regression analysis).

Of course, the proposed study approach is not free of criticisms. The case study will demonstrate several shortcomings that one can find in the application and the analysis of results as well. The final section will also stress some general points on methodological strengths and weaknesses of the approach.

5. CASE STUDY OF ALTERNATIVE ROAD SAFETY AUDITS PROCEDURES ON SIGNALIZED INTERSECTIONS IN THE CITY OF SÃO PAULO/SP, BRAZIL.

The city of São Paulo has some 10 million inhabitants and heads a metropolitan region with almost 18 million inhabitants. So it has a very trafficked road network. The congestion level is noticeable for any visitor of the city. The freeway network is comparatively small (around 40 km of freeways that almost circulate the main consolidated area of the city) and the overall road network is heavily dependent on the arterial corridors. Signalized intersections with vehicular and pedestrian peak hourly flows reaching the tens of thousand are usual around the city. The sites selected for study are examples of these usual intersections, located in the consolidated part of the city (the fringe area has smaller junctions).

The case study selected four observer types and developed three types of checklists for field work. These are the main features of RSA evaluated in this research. All observations were carried-out as simulated RSAs following common required routines that can be summarized as a first visit at the afternoon peak, extended up to the subsequent (night) off-peak period, a second visit at the morning peak, extended up to the subsequent inter-peak period, and subsequent visits on special periods as selected by the observer (nevertheless, real routines varied a lot around this requested one).

The different observers were classified as Safety Engineering Expert (**Exp**, with experience in accident investigation and knowledge of RSA application), Senior Traffic Engineer (**Des**, with experience in road and signal design), a Road Safety Engineer (**SAn**, with more than 5 years experience in accident analysis) and a Junior Traffic Engineer (**Jun**, with basic professional training in traffic engineering, covering design and safety). Checklists were developed, after reviewing several sources (*1*, *2*, *3*, *4*, *6*, *8*), keeping in mind these types of observers. A Generic Checklist (**G**) was developed for the Safety Expert (**Exp**). A Detailed Checklist (**D**) was developed for the Design Engineer (**Des**) and the Safety Analyst (**SAn**). A Detailed Checklist with Instructions (**I**) was developed for the Junior Engineer (**Jun**).

TABLE 1. General Features of Generic and Detailed Checklists.

Topic	Item	No.Generic Questions	No.Detailed Questions
1. CHOICE OF TYPE AND GENERAL LAYOUT OF INTERSECTION			
1.1. INTERSECTION LOCATION	A. LOCATION IN THE ROAD NETWORK		
	a. consistency (road and surroundings)	1	7
	b. functional hierarchy	1	3
	c. speed in the intersection	2	11
	B. LOCATION IN THE URBAN TISSUE	2	9
	C. LOCATION OF PEDESTRIAN PATHS	1	5
1.2. TRAFFIC CONTROL TYPE	A. SELECTION OF SIGNAL CONTROL	1	5
1.3. INTERSECTION LAYOUT	A. GENERAL GUIDELINES OF LAYOUT		
	a. restrictions to movements	2	6
	b. geometric constraints	1	5
	c. layout comprehension	1	5
	d. attention to pedestrians	1	8
	B. OTHER GEOMETRIC DESIGN ELEMENTS		
	a. general design	3	12
	b. physical features of pedestrian crossings	1	7
1.4. VISIBILITY IN THE INTERSECTION	A. VISIBILITY FOR STOPPING IN APPROACHES TO THE INTERSECTION	1	6
	B. CONSPICUITY OF INTERSECTION	1	2
	C. VISIBILITY OF PEDESTRIAN PATHS	1	5
2. INTERSECTION PAVEMENT	A. PAVEMENT FRICTION	1	4
	B. PAVEMENT DISTRESSES	1	8
	C. PAVEMENT DRAINAGE	1	5
3. INTERSECTION LIGHTINING	A. VISIBILITY OF THE INTERSECTION AT NIGHT	1	10
	B. CONTRIBUTION OF LIGHTING TO VISIBILITY OF SIGNS	1	9
4. SIGNING	A. ROAD MARKINGS	1	9
	B. VERTICAL SIGNS	1	9
	C. PEDESTRIAN CROSSINGS	1	3
5. TRAFFIC SIGNALS			
5.1. VISIBILITY IN SIGNALS	A. VISIBILITY AT DISTANCE		
	a. stop distance visibility	1	5
	b. conspicuity of signal heads	1	7
	c. positioning and comprehension of signal heads	1	3
	d. obstructions and interferences	1	5
	B. COUNFOUNDING AT DISTANCE		
	a. signal heads of conflicting movements	1	3
	b. signal heads of adjacent stop lines in the field sight of drivers	1	2
	C. VISIBILITY AT THE STOP LINE		
	a. field of vision at the stop line	2	6
	b. signal heads of conflicting movements	1	3
	c. intervisibility between conflicting movements	1	6
5.2. SIGNAL TIMING	A. TIMING OF PHASES	1	9
	B. PHASING PLAN	2	11
	C. TIMING OF INTERGREENS	1	4
	D. TIMING FOR PEDESTRIANS	1	9
No.QUESTIONS		43	226

The research team was composed by the RSA supervisor, who carried-out all the research tasks involved in the submission and collection of RSA checklists, and an independent AAD engineer, who collected accident records for both intersections and did all the research tasks involved in the accident analysis. The basic applications are named **ExpG**, **DesD**, **SAnD**, **JunI**, combining both features, an observer type and a checklist type. Some crossed applications were also carried-out for comparison with the same observer (applied with increasing detail) and a Detailed Checklist of the Safety Expert (**ExpD**) was always gathered, as it is the standard of most comparisons. Table 1 presents the general structure of G and D checklists (I checklists are similar in structure to D checklists with added observation instructions).

The practical work applied the proposed RSAs at four signalized intersections but, because of the high number of hours required for application of the field work and for comparison of observations in checklists, the application of the analysis procedure were tried in two intersections. Furthermore, given the lack of confidence on traffic accident records (especially on the exact location of accident occurrences on the intersection), full data where adequate on one intersection only and it results are reported here.

Note that the number of hours required for field word and comparison of observations is largely due to the number of questions involved in our checklist (43 to 226 per RSA, as shown in Table 1). From a methodological point of view, the method can be better applied to a smaller number of questions whose status is surely known (from a clearly deficient and dangerous feature to a clearly deficient but almost safe feature or a clearly sufficient but critical design), delivering a more controlled application. Reducing the time required for data acquisition and processing would permit large scale studies. Nevertheless, as the final effectiveness analysis depends on accident data, this would be a constraint to any application.

A. Data Gathering and Processing

The **Co-CP** intersection, shown in Figure 1, is at the border of the old CBD (well inside the consolidated area) and links some major arterials to the old CBD and to a major arterial ring road through the Consolação (**Co**) road. Pedestrian flows are heavy and mainly related to local land uses and to a major university campus located after the intersection, in the Maria Antonia (**MA**) street (the other street, Cesário Mota, **CM**, is a minor street with predominance of local traffic). Crossing roads are one way from the Caio Prado (**CP**) street to the Maria Antonia (**MA**) and Cesário Mota (**CM**) streets. Left turn movements are forbidden in the two-way road (**Co**) as usual in São Paulo. The Consolação (**Co**) radial arterial carries a heavier traffic in the inbound direction during all the day due to the connection function to the arterial ring road. Nevertheless, the Consolação (**Co**) road also has heavy flow on the outbound direction especially during the afternoon peak. The Caio Prado (**CP**) road has one-way operation and combines the access function to the radial arterial with the function of carrying vehicular flows crossing the arterial (including left turn and return flows to the outbound direction).

The intersection is operated under real time control of the central area (São Paulo has five real time control areas which sum up around 1500 signals of a total around 5000 signals in its urban area and these control areas cover most of the arterial network). Traffic signal plans for the intersection are also shown in Figure 1. The **Co-CP** intersection signal operates with three stages just to handle pedestrians in the crossing of the outbound direction (after intersection) in the **Co** road (phase 1 in Figure 1). The cycle times are around 120s in the peaks (pedestrian delays are high for some movements, mainly in phase 1) and the two-way road receives the major share of green. Pedestrian signal heads are used on all painted pedestrian crossings and the number of pedestrians outside these crossings is small. Nevertheless, the number of pedestrian crossing against their red display is significant (mainly for pedestrians of phase 1 movements, crossing in other stages, due to the great delay and some available gaps).

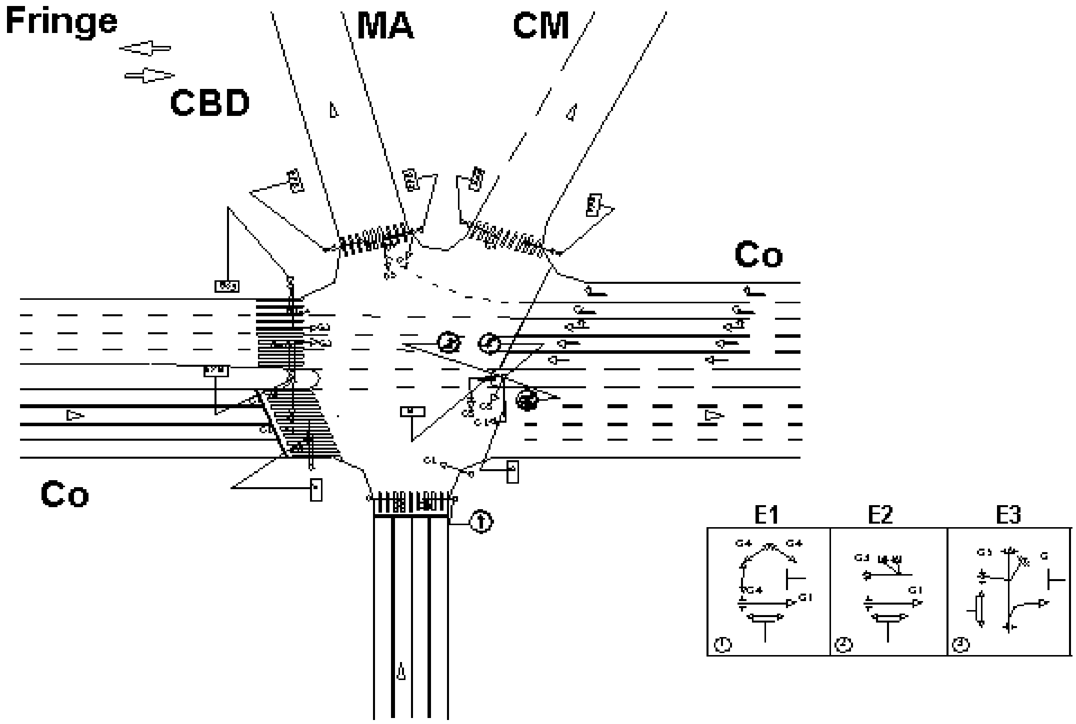
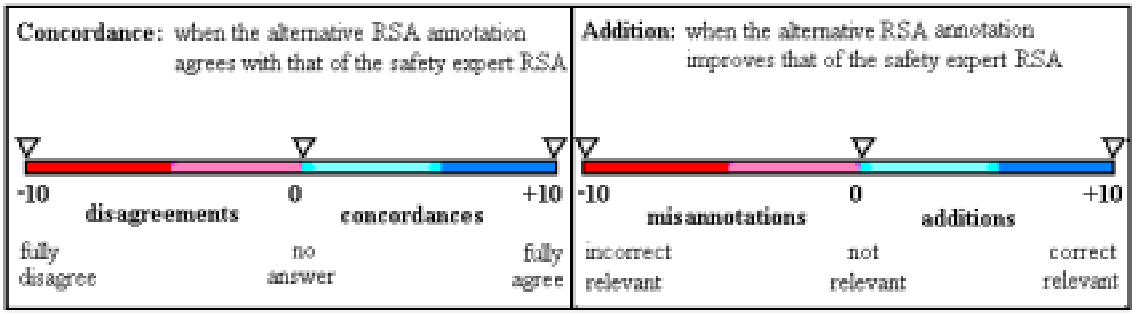


FIGURE 1. Study Intersections: Consolação x Caio Prado (Co-CP)

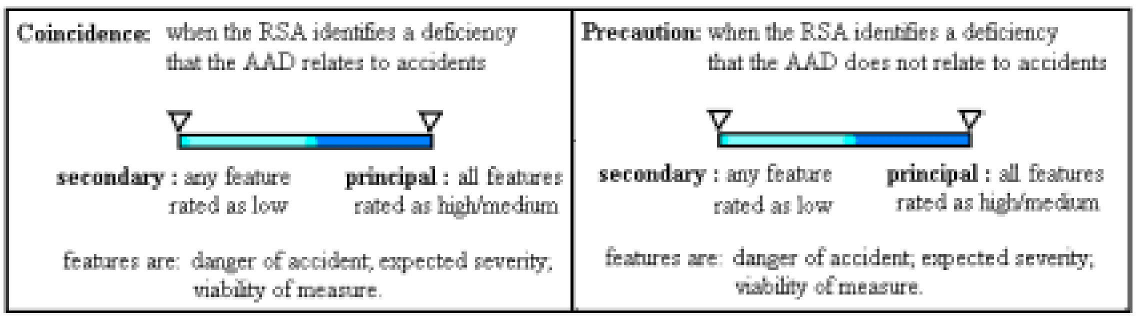
Our data sample consists of results from different RSA procedures, for each separate question or each subject area. A representative sample of accident records was recovered for pedestrian accidents and vehicular injury accidents in both intersections. For PDO accidents, the fraction and number of accident records recovered was smaller and this set of data was disregarded in the rest of analysis. The accident analysis engineer carried-out his field observation routines in both intersections as usually done in accident investigations, without having access to data gathered by the RSA observers (the RSA observers also had no access to accident data). Accident records were processed and a list of problems that were related to the recovered sample of accident records was prepared for the intersection. The quality of accident data for the **Co-CP** intersection for two years (1996, 1997) was felt to be much better because the accidents could be located precisely in the intersection (as streets change their name before and after crossing the main road and pedestrian movements are limited to one side of the main road). Nevertheless, the precision of the accident analysis diagnostic was felt to be a critical point of the proposed method of study (as it is the mean for evaluating the final effectiveness of alternative RSA procedures).

The comparisons were carried-out by the RSA supervisor and submitted to the AAD engineer for discussion only during the research tasks involved in the comparison of results. General criteria of comparison are represented in Figure 2. After RSA observation and data processing, a preliminary comparison of results was subjected to all field observers and their comments were used to correct the initial AAD after a careful discussion between observers and researchers.

For each quotation of the different RSA checklists collected at the field, a comparison of agreement was done, taking the Detailed Checklist of the Safety Expert (**ExpD**) as a standard. Quotations in common questions were rated for agreement or disagreement. Additions were also rated for value. Figure 2a graphically sketch the criteria used for the comparison of RSAs. Omissions were not rated as it was felt that their importance would appear in the subsequent comparison. One should note that several agreements/disagreements and additions/omissions were partial (i.e. there could be a partial agreement and a simultaneous addition in the comparison for the same item). In the comparison to the accident analysis diagnostic (AAD), the RSA quotations were classified as coincidences (if supported by the AAD results) or precautions (if not) and rated for relevance. Figure 2b graphically sketch the criteria used for the comparison with AAD.



a. comparison between road safety audits (RSAs) quotations



b. comparison of road safety audits (RSAs) and accident analysis diagnostic (AAD) quotations.

FIGURE 2. Criteria for Comparing Alternative RSAs and for Comparing RSAs and AAD Results.

The rating for value used general criteria studied for prioritizing deficiencies (see *13*, *14*, *18*), taking into consideration the predicted danger of accident occurrence (considering frequency of risk and proneness to accident), the expected accident severity (in the event of a probable accident) and also the viability of correction (with measures usually applied at São Paulo) into high, medium and low degrees for each feature. Any feature rated as low was taken as a sign for a less relevant quotation or deficiency and this observation was used to qualify quotations as main (relevant) or secondary (less relevant) factors.

Of course, there is some degree of subjectivity in the comparison and rating of several quotations. Most of all, the comparison was shown to be really burdensome as there is a need to reach a revised reporting of answers to compensate for errors in the place of quotation (keeping the content of the answer itself as the real point). The complexity of the checklists and of the intersections increased the difficulty in filling the forms. Overall, it was felt that the results were robust to the degree of subjectivity.

In the comparison to the AAD, the aggregate analysis was supplemented by a finer analysis, classifying questions by type based on three subject matters (functional design, geometric design, signs and signals), Other segmentations were considered (for example based on the existence of observational clues in checklists for identification or judgment, among other features) but were not analyzed.

B. Presentation and Analysis of Results

The following results are exploratory and intend to discuss the kind of conclusions that can be based on the qualitative analysis of the comparisons or on the statistical analysis of their data. Table 2 presents the general results of the comparison between RSAs and the comparison of each RSA with AAD for the main study in the **Co-CP** intersection. Table 3 presents the results on the average success of each observer in detecting features listed on the AAD items (called coincidences) or on a superset of non-AAD items (called precautions), with data on each of the four observers on three subject areas (Functional Design, Geometric Design and Design of Signs and Signals), that gave us a sample of 12 measurements.

A qualitative analysis of the results on the comparative performance of alternative RSA procedures can be summarized as:

- the degree of concordance achieved was high in all cases; only one average score for agreements was smaller than 9,00 (for the Safety Analyst, mainly for additions of less relevant quotations);
- the Safety Expert use of the Generic checklist was comparable to the Detailed one (given the general agreement of observations) but the number of relevant additions was also noticeable;
- the number of omissions was high for less qualified personnel (that directly applied the detailed checklist); all of the observers had difficulties in answering questions about lighting and drainage;
- the number of disagreements was also high for less qualified personnel (the Safety Analyst disagreed in 23,5% of the common quotations with the Safety Expert; nevertheless, the average score for disagreements of 6,60 reveals that some are relevant but most are less important);
- the small number of misannotations and the average score for misannotations also show a pattern (occurred only for the Junior Professional);
- the number of additions also increased for the less qualified personnel but the average score for additions and the proportion of relevant additions decreased (the Senior Designer had the smaller number of additions).

A qualitative analysis of the results on the final performance obtained by comparison of the RSAs to the AAD (and accidents), can be summarized as:

- the Safety Analyst and also the Junior Professional had the large number of detections and precautions (they also were the observers with higher number of quotations among all);
- no single observer was able to reach a high level of detection; nevertheless, combining all the observations, the "team" was able to detect 20 of 32 deficiencies (with 15 of 24 main detections).

TABLE 2. Results on the Comparison of RSAs and the Comparison of RSAs and AAD.

Comparison between RSAs	**ExpDxExpG**	**DesDxExpD**	**SAnDxExpD**	**JunIxExpD**
Number of strong agreements	218	189	143	162
Number of weak agreements	1	5	10	2
Average score for agreement	9,91	9,39	8,80	9,40
Number of disagreements	0	25	47	30
Average score for disagreement	0,00	-8,10	-6,60	-8,10
Number of relevant additions	11	10	21	10
Number of secondary additions	6	6	50	38
Average score for additions	4,50	4,90	3,70	3,60
Number of misannotations	0	0	0	4
Average score for misannotations	0,00	0,00	0,00	-10,0
Number of common omissions	-	7	7	7
Total number of omissions (7 in ExpD)	-	7	24	32
Comparison of RSAs and DAA	**ExpDxAAD**	**DesDxAAD**	**SAnDxAAD**	**JunIxAAD**
Principal Coincidences (of 24):	4	3	8	8
Principal Precautions:	2	1	7	6
Secondary Coincidences (of 8):	1	0	3	3
Secondary Precautions:	9	9	17	9

Notes:
[1]- Analysis of quotations on Road Safety Audits (RSA) and features of Accident Analysis Diagnostic (AAD);
[2]- Observers classified as Safety Experts (**Exp**), Design Engineer (**Des**), Safety Analyst (**SAn**) and Junior Engineer (**Jun**) and checklists classified as Generic (**G**), Detailed (**D**) and Detailed with Instructions (**I**).

TABLE 3. Average Observer Performance by Subject Area as %Hit in Identifying Features of the Global Diagnostic

		Observed	RSA Expert (**Exp**)		Senior Designer (**Des**)		Safety Analyst (**SAn**)		Junior Engineer (**Jun**)	
		No.Cases	No.Hits	%Cases	No.Hits	%Cases	No.Hits	%Cases	No.Hits	%Cases
Principal Accident Factors	Functional Design	12	2	16.67%	1	8.33%	7	58.33%	4	33.33%
	Geometric Design	4	0	0.00%	1	25.00%	0	0.00%	2	50.00%
	Signs and Signals	8	2	25.00%	1	12.50%	1	12.50%	2	25.00%
	All Subjects	24	4	16.67%	3	12.50%	8	33.33%	8	33.33%
All Accident Factors	Functional Design	18	3	16.67%	1	5.56%	9	50.00%	7	38.89%
	Geometric Design	4	0	0.00%	1	25.00%	0	0.00%	2	50.00%
	Signs and Signals	10	2	20.00%	1	10.00%	2	20.00%	2	20.00%
	All Subjects	32	5	15.63%	3	9.38%	11	34.38%	11	34.38%
Principal Preventive Factors	Functional Design	9	2	22.22%	1	11.11%	4	44.44%	4	44.44%
	Geometric Design	3	0	0.00%	0	0.00%	1	33.33%	1	33.33%
	Signs and Signals	2	0	0.00%	0	0.00%	2	100.00%	0	0.00%
	All Subjects	14	2	14.29%	1	7.14%	7	50.00%	5	35.71%
All Preventive Factors	Functional Design	22	8	36.36%	4	18.18%	12	54.55%	8	36.36%
	Geometric Design	7	0	0.00%	1	14.29%	3	42.86%	3	42.86%
	Signs and Signals	18	0	0.00%	5	27.78%	9	50.00%	4	22.22%
	All Subjects	47	8	17.02%	10	21.28%	24	51.06%	15	31.91%
Both Main Factors	All Subjects	38	6	15.79%	4	10.53%	15	39.47%	13	34.21%
All Factors	All Subjects	79	13	16.46%	13	16.46%	35	44.30%	26	32.91%

For analyzing these results, it was felt important to keep in mind some peculiarities of each observer. For the main study on the **Co-CP** intersection, all observers had good previous knowledge about the site (as it is a well known intersection in the city) but the Senior Designer and the Safety Analyst had worked previously on the design of the current signal scheme in the past (the Safety Analyst moved from this traffic management area some 5 years ago and the Senior Design remains in charge in this area). The Junior Professional also had some knowledge about the current design and its problems from previous studies. This fact could explain, at least in part, the large number of additions of the Safety Analyst and also the small number of additions of the Senior Designer (who knows and weights most of the constraints to action). Also the performance of the Junior Professional could benefit from his previous knowledge.

The statistical analysis of the data on the relative performance of each observer against a set of explanatory variables was evaluated using logistic regression. Dependent variables were the relative performance of observers on each of three types of subject areas (functional design, geometric design and design of signs and signals), measured by the percentage of detections achieved on the features identified by the accident analysis diagnostic (called coincidences) and on the superset of features that were not related to the accident analysis diagnostic but that were judged relevant as preventive actions based on our technical investigation at the site (called precautions). Types of subject area were introduced as a mean to permit more robust aggregate analysis based on the average rating in a group of questions. Analyses could be carried-out using types of questions (for example, general or specific questions, questions with or without the identification of settings where the deficiency is critical, and so on) or other aggregate groups. Of course, it is possible to carried-out a disaggregate analysis as well.

Estimation of logistic regression models is widely discussed in the literature on analysis of discrete data or choice modeling and is made possible by the used of several statistical packages. Our illustrative results were based on the analysis of average detection percentage in each subject area using the nonlinear regression model option (NLSQ) of LIMDEP version 7 (see *19*, chapter 19). This is done because the NLSQ procedure permits better control of model specification and seems to be more robust numerically. Separate analyses were carried-out for main coincidences, total coincidences, main precautions and total precautions, adding explanatory variables for features of observers: their technical training, their professional experience and by their previous knowledge of the site and their participation on the design of the current project operating at the site for each subject area, represented as scores based on a relative scale, as shown on Table 4.

TABLE 4. Further Data for the Evaluation of Observer Performance Features

Observer	Subject	Technical Training (**T**)	Professional Experience (**E**)	Knowledge Of Site (**K**)	Participation In Project (**P**)
RSA Expert	Functional Design	3	3	2	0
	Geometric Design	3	3	1	0
	Signs and Signals	3	2	2	0
Senior Designer	Functional Design	3	2	3	2
	Geometric Design	3	2	2	2
	Signs and Signals	3	3	3	3
Safety Analyst	Functional Design	3	2	1	1
	Geometric Design	2	2	1	1
	Signs and Signals	3	3	2	1
Junior Engineer	Functional Design	1	0	3	0
	Geometric Design	1	0	3	0
	Signs and Signals	2	0	2	0

Note: Scores were based on the following qualitative scale
Formal Training: 0=no special training, 1=quick courses, 2=specialized training, 3=expert;
Professional Experience: 0=small experience; 1=1-2 years; 2=2-5 years; 3=more than 5 years
Previous Knowledge: 0=no knowledge; 1=site info; 2= accident info; 3=diagnostic info;
Participation in the Project: 0=no participation; 1=shared information; 2=partial tasks; 3=project leader.

Several specifications were tried, searching for a meaning-full and robust set of models. The individual effects of training and experience were hard to distinguish as the variables were naturally correlated. We tried combinations of training and experience scores as we did with site knowledge and current design scores. Combinations by averages and maximum scores were rationalized as complementarity or substitutability of attributes. We also tried generic intercepts or sets of observer specific dummies or subject area specific dummies. The more meaning-full and robust models used the maximum of training and experience scores, individual scores for previous knowledge and current design and also included a set of observer specific dummies in the model. The results on model coefficients are presented in Table 5. As can be seen, model estimation shows that:

- the inclusion of observer features always increase the adjusted explained variance ratio (even if marginally as in the case of main coincidences);
- the Akaike information criteria delivers opposite results (an improvement is indicated only for main precautions);
- the coefficients of observer specific dummies, in general, are statistically significant in the estimation of the simplest model (the dummy-only specification) but their values are not robust to the inclusion of observer attributes in the more complex model;
- the coefficients of observer attributes variables, in general, are not statistically significant in the estimation of the more complex model but the parameters values, in general, are consistent
    . all signs are as expected except for the coefficient of training and experience in the explanation of detection of all precautions;
    . in all other cases, trained and experienced observers were more effective and the use of junior professional is justified based on cost considerations only;.
    . in all cases, participation in the design of the project operating on the site were correlated with less effective performance (so there is a commitment effect);
    . in all cases, previous knowledge of the site were correlated with more effective performance;
- observer specific dummies remains different and relevant in value even in the more complex model, and remain the more statistically significant coefficients, even in the more complex model (signing for the presence of important omitted variables).

Such kind of model can be useful for predicting the performance of some standard observer of each type (for example, a observer without previous knowledge or participation on the design) or measuring the effect of changing some variable (for example, the requirement of training or experience for observers). The sensitivity is more relevant for coincidences than precautions (increasing the detection, around 20%, by 7% for main coincidences and 5% for all coincidences). For sure, the estimated models would be unsound for use in developing guidelines, giving the data problems we had and our limited sample. Nevertheless, it is interesting to note that such results are reasonable even in an illustrative application and to emphasize the usefulness of the method of analysis.

TABLE 5. Results on the Logistic Regression for Selected %Hit Models (LIMDEP output with NLSQ procedure).

	Accident Factors-Main Coincidences								
Model	Dummies only		dExp	dDes	dSAn	dJun			
AdjR2	32.06%	Coeff.	-1.82455	-1.71298	-1.17412	-0.570545			
AIC	-0.295	t-ratio	-2.52666	-2.56728	-2.45202	-1.52412			
Model	D&Ob.attributes		dExp	dDes	dSAn	dJun	MaxTE	SKnow	ProjP
AdjR2	34.17%	Coeff.	-3.0216	-2.28376	-1.84587	-1.4823	0.310598	0.183978	-0.38196
AIC	0.173	t-ratio	-1.11798	-0.519037	-0.680754	-0.705371	0.45234	0.321319	-0.243038
	sensitivity to training or experience					at 20%	7.24%	at 50%	11.31%
	Accident Factors-All Coincidences								
Model	Dummies only		dExp	dDes	dSAn	dJun			
AdjR2	39.52%	Coeff.	-1.97155	-1.85587	-1.18958	-0.562527			
AIC	-0.511	t-ratio	-2.72814	-2.79849	-2.74474	-1.67762			
Model	D&Ob.attributes		dExp	dDes	dSAn	dJun	MaxTE	SKnow	ProjP
AdjR2	44.58%	Coeff.	-3.29174	-2.66948	-1.8678	-2.10597	0.193672	0.486311	-0.522563
AIC	-0.098	t-ratio	-1.31521	-5.96E-01	-7.04E-01	-1.08747	0.310301	0.912817	-3.18E-01
	sensitivity to training or experience					at 20%	4.96%	at 50%	7.76%
	Preventive Factors-Main Precautions								
Model	Dummies only		dExp	dDes	dSAn	dJun			
AdjR2	62.41%	Coeff.	-2.52573	-3.2581	0.374693	-1.04982			
AIC	0.112	t-ratio	-1.63671	-1.09787	0.854678	-1.90484			
Model	D&Ob.attributes		dExp	dDes	dSAn	dJun	MaxTE	SKnow	ProjP
AdjR2	97.12%	Coeff.	-31.8606	-6.55861	3.92506	-43.4787	0.470002	14.1856	-19.7438
AIC	-1.959	t-ratio	-0.000352	-1.07E-07	1.28E-07	-0.00032	0.16522	0.000313	-6.45E-07
	sensitivity to training or experience					at 20%	2.64%	at 50%	4.13%
	Preventive Factors-All Precautions								
Model	Dummies only		dExp	dDes	dSAn	dJun			
AdjR2	67.27%	Coeff.	-1.5384	-1.38119	-0.034636	-0.671579			
AIC	-1.233	t-ratio	-4.14289	-4.10214	-0.160192	-2.78144			
Model	D&Ob.attributes		dExp	dDes	dSAn	dJun	MaxTE	SKnow	ProjP
AdjR2	79.88%	Coeff.	-2.27385	-3.88083	-1.12265	-2.12014	-0.043931	0.563382	0.455656
AIC	-1.220	t-ratio	-2.19421	-2.26368	-1.13405	-2.5613	-0.155113	2.24287	0.848456
	sensitivity to training or experience					at 20%	-2.48%	at 50%	-3.88%

Note: MaxTE=maximum of training and experience scores; SKnow=previous knowledge about the intersection; ProjP=participation in design projects on the intersection.

Some conclusions can be grasped from these studies, mainly the adequacy of using less experienced professionals for field observation (with appropriate checklists) and the importance of teamwork on field tasks. The importance of expert supervision on evaluating quotations seems also clearly supported. The sufficiency of the Safety Expert for the final effectiveness of the RSA is not supported (despite the large experience of the observers of this type that collaborated in the research). Nevertheless, the role of the expert supervision on prioritizing quotations and achieving a better final evaluation should be stressed.

Overall, this research seems to show that the proposed method of study is a valuable alternative. It is important to note that the same approach can also be used to analyzing several finer questions about procedures or tools. For example, our study shown that checklists vary a lot in the way they put questions to the RSA observer and the proposed method can be used to evaluate the comparative success of tort detection in alternative forms. Also, our exercise have shown that several observations were hard to fill at the sites (specially those related to lighting and drainage) and the effectiveness of engineering measures as supporting data for further analysis can be used as a help and be evaluated in the same way. These more detailed analysis were not carried-out in this research but seems to be worth of investigation.

6. CONCLUSIONS.

This paper discussed Road Safety Audits (RSA) as a safety improvement technique with the aim at identifying alternative conceptual or practical features that can bear on the effectiveness of the procedure and proposed a new method of study that can be used to evaluate detailed procedures. Several features of RSAs were identified and a case study was designed for evaluating three main points: the degree of dependence on a safety expert, the comparative performance of personnel with different qualification for field observation and the adequacy of different types of checklists. Four types of observers and three types of checklists were used for the field study.

After reviewing some methodological questions about the evaluation of RSA applications, the new method proposed two analyses: a comparative analysis of quotations gathered with alternative RSA procedures against a standard (view as an intermediate evaluation task) and a comparative analysis of the RSA results against an accident analysis diagnostic (view as a final evaluation task). After applying the alternative RSA procedures in four intersections, the study was tried in two intersections and finally applied to one of them, due to the large volume of data processing and handling tasks (a feature that can be attributed to the large number of questions of the RSA) and the need of a precise accident data for the comparative diagnostic (that is needed for the final evaluation task). The intermediate analysis rated quotations as agreements or disagreements with the standard application (a safety expert with a detailed checklist). The final analysis rated the quotations as coincidences with the accident analysis diagnosis or as further precautions. Each quotation was also rated as main or secondary based on the predicted danger of accident occurrence (considering frequency of risk and proneness to accident), the expected accident severity (in the event of a probable accident) and also the viability of correction (with measures usually applied at São Paulo).

The dependence on accident data is major problem, at least for developing countries as Brazil, and the use of alternative standards for comparisons (as a super-RSA, based on all evidences) is worth of study. The time required for data collection and analysis can be reduced by using a smaller set of well defined questions in a simulated RSA (what can potentially deliver also more confident results).

Despite the need of subjective rating of quotations, it was felt that the method produced useful results on the global performance of each RSA procedure that support the use of less experienced personnel for field observation (as they can reach a good agreement with expert observations, using detailed checklists) but with recourse to team work (combining professionals with different degrees of qualification and background experience) and to the supervision of a qualified expert (as there was found a clear trend for less relevant quotations and even some misleading observations by less experienced professionals). So the proposed method is thought to be a valuable option for further study, being capable of finer analysis (comparing types of questions, for example) and additional investigations (analyzing observation routines or use of other data or measurements, for example).

Last but not least, one should stress the need of complementary methods of study that can be applied to grasp the value of RSA on real applications based on a direct evaluation of its real final effects on the safety improvement and/or reduction of future corrections. Otherwise, one can note that the same kind of method can be applied to other safety evaluation procedure based on surrogate measures.

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ACKNOWLEDGEMENTS

We would like to thank to the Traffic Engineering Company of the City of São Paulo for providing data and support for most of the work, to the professionals who collaborate as observers in the field study, to FAPESP (the Foundation for Research Aid of the State of São Paulo) that funded the project that supplied the accident data, and also especially to Denise Lima Lopes and Veridiana Armond Vasconcelos who help us in the data processing tasks.