IMPLEMENTING ROAD SAFETY AUDITS IN BRAZIL

JOSÉ LUIZ FUZARO RODRIGUES
HIGHWAY DEPARTMENT OF SÃO PAULO, BRAZIL
jlfuzaro@uol.com.br

BARBARA STOLTE BEZERRA
UNIVERSITY OF SÃO PAULO, DEPARTMENT OF TRANSPORT EESC
barbarabezerra@hotmail.com

1. Introduction

Road Safety Audit (RSA) is a proactive approach to improving transportation safety. Road Safety practices tend to reflect local regulation, and behavior, as one of the objectives of detailed technical regulations and guidelines is to ensure road safety through good practices on road design, maintenance and traffic control. Various aspects of accident reduction programs, in Brazil nowadays, are based upon the development of remedial measures at sites or locations with a high frequency of accidents. A new approach is necessary to focus on accident prevention, with a proactive approach to improve road safety before accident records and to ensure that the road system is safe. This approach involves besides others components the use of road safety audit. Road safety audit in Brazil is not yet considered as a part of an inherent process to achieve safety.

Developed countries found out that investments in road safety can save lives and money. That experience should impact developing countries to adjust their procedures and investments, to pay more attention on road safety, and raise the awareness of the government, society and traffic and road engineers. Our country can not stand the high numbers accidents, injuries, death and property damages. Is a higher price to pay for this negligence: lives, money and health care time.

RSA practices in Brazil are still incipient, with just a few audits performed. These guidelines intends to be a small step in this direction, making road safety audit more feasible and well known throughout Brazil, providing some tools and procedures to achieve that.

2. What is a Road Safety Audit?

A road safety audit is a formal safety performance examination of an existing or future road or intersection by an independent audit team. Road safety audits can be used in any phase of project development from planning and preliminary engineering, design and construction. RSAs can also be used on any sized project from minor intersection and roadway retrofits to mega-projects.

The Danish definition of road safety audit is systematic and independent assessment of the safety aspects of road projects. Its purpose is to make new and reconstructed roads as safe as possible - before construction is started and before accidents occur.
AUSTROADS (1994) define a road safety audit as a formal examination of a future road or traffic project, an existing road or any project which interacts with road users, in which an independent, qualified team reports on the project's accident potential and safety performance.

3. The need of a Road Safety Audit

One of the main objectives nowadays in traffic safety is to reduce the number of accidents and the number of casualties. The application of safety principles when implementing, improving or maintaining roads contribute to accident prevention.

Road Safety Audit is an excellent tool to identify potential safety problems to the road users and to assure that safety measures to eliminate or reduce the problems are fully considered.

Road users should travel on a consistently safe product where adverse highway factor contributing to accidents is very low, and the RSA is a procedure that aids to achieve that.

“The earlier a road is audited within the design and development process the better”. Austroads. (1994).

4. Benefits

It is well known that the number of accidents and fatalities are very high in Brazil with a great loss of lives, high number of injuries, and a huge amount of properties damages.

Introducing Road Safety Audit procedures, with systematic application into various stages of highway projects, can ensure that they will operate as safely as practicable, meaning that safety will be considered throughout the whole project.

Expected benefits are:

- Minimize the risk and probability of accidents; Minimize the severity of accidents occurred; Minimize the risk on adjacent roads, avoiding to create accidents in the network; Increase the awareness of highway safety and safe design principles by all involved in the design and construction; Produce a positive effect in reviewing existing Standards and Regulations; Reduce the long term cost of a project, reducing the need of expensive reconstruction of unsafe design; Ensure that all users are considered regarding safe designs; Provide feedback to highway designers that can be applied to other projects.

In the longer term, Safety Audits encourage good design. They give safety a higher profile in the design process and act as a conduit for informing engineers of current safety understanding. The recommendations of safety auditors are not based on checking individual design elements against standards, but on considering how the scheme as a whole may affect overall safety, or deciding what to do when standards conflict.
5. Stages of a RSA

Road Safety Audit can be conducted on at one or more of the following stages of a specific project.

1. Feasibility Design

At this stage road safety audit can verify and influence fundamental issues such as route choice, design standards, continuity with existing adjacent roads, intersection type, layout, and number.

The selection of an inappropriate concept or design at this stage may be almost impossible to change later on. A poor choice of design criteria or concept can have an adverse impact on the overall safety of the project.

2. Preliminary Design

Typically the road safety audit at this stage will include vertical and horizontal alignments, intersections layouts and sight lines. Inconsistent or unexpected features can become hazardous to road users breaking driver’s expectancy, leading to errors.

3. Detail Design

On completion of detailed design, or during design, the road safety audit will verify the details of the project, including detailed intersection design, signs, signals, markings, roadside objects and barriers, drainage, lighting, fences, etc.

This is the last chance to change the design before construction, avoiding last-minute changes and reducing unnecessary repair costs.

4. Pre-opening to traffic

Immediately prior the opening, the audit involves a detailed inspection of the new scheme, its approaches and connections. The audit team drives, or when appropriate ride and walk the new route, to ensure that safety needs for all users are provided.

It is essential a night-time inspection to ensure that safety is also achieved during hours of darkness to guarantee that a proper visibility, delineation, signing and lighting is provided, and also if any confusion or misunderstanding of the layout is present.

5. Existing Roads

A after opening audit can be undertaken to check how the road is actually being used, if any deficiency of the project concept or implementation details is present. The RSA should identify safety deficiencies of design, layout and road furniture.

Also the RSA can be applied to existing road or network to identify features that are hazardous and may lead to future accidents or increase the accident consequences or allows additional injury. Sometimes the RSA at this stage is also known as safety review or safety monitoring.
6. How to conduct a RSA

A RSA is a systematic process that can be tailored according to specific organizational culture and safety issues. Generally, an audit comprises the following steps:

- Select the road safety audit team; Provide relevant data and documentation; Hold kickoff meeting; Assess data and documents; Inspect site; Discuss audit safety issues with the designer or internal client; Write RSA report; Hold completion meeting; Respond to report; Implement agreed-on changes; Share lessons learned.

Above all, RSA looks at a highway project for the sole purpose of identifying safety issues.

7. Safety Principles

1. Principles of Road Safety

Road safety is a result of the complicated interaction that occurs between many elements, and the literal applications of norms and rules certainly do not always lead to the safest possible design. This is particularly the case where the rules (also) take into account conditions other than safety.

Road users and their behavior are a contributory cause in by far the greater part of all road accidents. Road users represents a broad cross-section of the public and there are limits to what the road users, can cope with when converting information – from the layout of the road, signs and road markings, other road users and conditions in general – into action. As is the with anyone else, road users overestimate their own abilities and misunderstand each other’s intentions when the situation becomes too complex, unclear or unusual and there is too little time in which to think and react. It is therefore a vital task of the designers and road safety auditors to design our road installations according to human criteria and not to demand too many actions per unit time.

Road users must perceive and process information, make decisions and react, all within a limited time. Safe road environments:

- Warn road user of all conditions that do not conform to the norm or are in any way unusual; Inform road users of the conditions they will encounter; Guide road users through unusual sections, conflict points or areas; Forgive road users’ errors and inappropriate behavior.

Considerations should be given to the special needs of the different groups of road users, e.g., the need for facilities for pedestrians and cyclists, especially in urban areas.

2. Geometric Design

The geometric design elements that have special influence on road safety can be roughly divided into:

- Access control; Cross-section; Horizontal and vertical Alignment (and their mutual interaction); Design of junctions.

Road user’s correct use of road installations is normally conditional on the presence of markings. All markings and road equipment must therefore be included as an integral
part of the geometric design project. This also ensures that the geometry is designed so that it is possible to apply clear, easily understood markings.

Access control
Access in this context refers to the entry to a roadway of traffic from other roads, including intersections, business driveways, private driveways, and medians crossovers. FHWA (1982) describes that access control as “the most important single factor ever developed for accident reduction”. Controlling access on existing roads through the use of frontage roads can be an effective safety device, or grade-separated interchanges. In most roads, it is not possible or meaningful eliminate access points, but the effects of access can be moderate by reducing the conflict at access points into treatments which reduce the number of accesses - eliminating median openings, providing frontage roads, and providing access via frontage roads rather than the main roadway), and separate through vehicles from vehicles using the access – turning lanes, acceleration and deceleration lanes.

Cross section elements
The road cross section includes the carriageway or roadway, shoulders, kerbs, drainage features, and cut and fills batters. Studies have been conducted to study the correlation with cross section elements and accident types, but the findings were not clear. But, there a general consensus about some aspects those are relevant and were describe below.

Lane widths of 3.4 – 3.7 have been shown to have the lowest accident rate on rural roads. Lane widths of less than 3 m have been shown to contribute to multi-vehicle accidents. There is some evidence that accident rates reduce as shoulder width increases up to about 3 m.

Sight distance
A driver needs to be able to see the roadway ahead in order to guide and control the vehicle. This forward sight distance on a roadway (as distinct from sight distance at intersections) should be not less than the distance required stopping, referred to as stopping, and referred to as stopping sight distance. So, there is a need for the road designer to ensure that the driver can travel safely at the speed appropriate to the road, marking allowance for forward sight distance. Poor sight distance is associated with accidents. Sight distance is particularly important for trucks, since in general they have poor braking performance and this must be compensated, in part, by greater sight distance. Improving sight distance on horizontal curves is very like to be cost-effective if it involves relatively low-cost treatments like clearing of vegetation or other minor obstructions, and if there are significant truck volumes present.

Horizontal and vertical alignment
Vertical curves and gradients also affect safety, but the designer should principally be aware of the need for integration of the horizontal and vertical alignment details, and consistency of design standard along a length of road.

Accidents are more likely to occur on highway curves than on straight sections of road. Some studies determined that curve radius was the main factor affecting safety curves, but shoulder width, and the length of the curve were also important, in general they describe that curve radii greater than 500 m did not produce safety problems, but curves sharper than this are associated with high increases in risk of accidents.

Horizontal and vertical alignments should not be considered either independently of each other, or of the design standards applicable to the rest of the road in question.
Consistency along the road is critical important, the effect of geometric design feature depends upon its context.

In treating existing roads, a special concern is need to isolated or unexpected sub-standard features, including sharp curves and steep grades, and other road features such as intersections. The worst situation occurs when two or more such features occur simultaneously or in close proximity to each other. However, consistency in design standard along a length of road is more important than the standard of an individual element, since driver expectations is determine behavior.

Horizontal curves should utilize plan transitions to connect the straight with the circular arc, particularly on roads with a high proportion of articulated trucks. Provision of the correct amount of super elevation also contributes to safety.

3. Road Surface Characteristics

Pavement surface should present some characteristics as to provide safety and comfort to road users. When not well designed, constructed or maintained road surface can rapidly deteriorate, reducing safety, comfort and therefore increasing accidents and travel time and costs.

Rehabilitation and resurfacing projects, especially on stretches of road deteriorated to the point of presenting potholes, have shown an odd result of increasing the number of accidents, mainly due to the increase in the overall speed, and therefore intriguing authorities that are using this measures as a safety measure, to reduce accidents.

Wet pavement represents around 20 - 30 per cent of accidents. Most of these involve skidding, and up to 70 per cent can potentially be improved by providing better skid resistance. Various methods are available to improve the skid resistance of road surfaces, including the application of high-friction overlay, or cutting grooves into the pavement. From a road safety engineering viewpoint, the need is to target to resurfacing works at sites with a history of accidents which are potentially improve to treatment by pavement resurfacing.

Transportation Research Board (1987a) has noted that the potential effect of resurfacing on safety is a result of two factors working in opposite directions. First, resurfacing lead to increase average speeds. Second, resurfacing often increases pavement skid resistance, which reduces stopping distance and improves vehicle controllability when the pavement surface is wet.

4. Pavement markings, vertical signs, and delineation

Road signs and markings are important to regulate the use of a road, warn of dangerous situations and guide road users to destiny in a uniform and safe way.

Especially at night and under adverse weather conditions road signs and markings play an important role is safety and they must be retroreflective or illuminated.

The signing system should provide a safe environment to road users therefore:

- Guiding drivers with directions for route finding; Controlling the use of the road with mandatory signs; Warning the drivers of any substandard or unusual features with warning signs, to aid road users to identify the situation ahead and anticipate hazards; Providing consistency within the road signing system, with similar situation receiving the same treatment; Providing night-time visibility as well as day-time visibility; Inform of services rendered to users and emergencies; The functions of Vertical Signs are to guide, warn, regulate, and educate road users.
This can be achieved by the use of:

- Regulatory signs give notice of traffic laws and regulations that applies to the road or to specific location, conveying obligations, prohibitions and restrictions; Warning signs are used to indicate in advance hazards or potentially hazardous locations and have a great benefit to safety by providing an alert to the situation ahead and assisting the road users on how to proceed in face of the situation; Guide signs show destinations, directions, distances, services and points of interest to road users.

The use of horizontal signs, markings and delineators can assist to reduce be number and severity of accidents by keeping the vehicles in the traveled way.

From the safety point of view, during daytime the horizontal signs must have a good color and present a proper contrast with the pavement assuring a good daytime visibility, and during nighttime and under adverse weather conditions the horizontal signs must remain visible by proper retroreflectivity.

The sign system should consider the visual needs of road users, especially an ageing population providing a proper visibility and legibility of signs. All signs must be legible to those for whom it is intended and understood in time to allow a proper response and a safe manoeuvre.

Uniformity of shape, colour, legend and dimension as well as an adequate size of lettering and symbols are important to guarantee legibility and understanding.

5. Intersections

Intersections are the most critical element of road network from a safety viewpoint. Because different road users (vehicles, pedestrians, cyclists) are required to use the same space. Around one half of reported urban accidents and one-third of reported rural accidents are at intersections.

The main design principles for intersections are:

- Minimise the number of conflict points and hence the opportunities for accidents; both t-intersections and roundabouts have fewer conflict points than a cross-section, which is one of the main reasons for their superior safety performance; Give precedence to major movements through alignment, delineation, and traffic control; Separate conflicts in space or time; Control the angle of conflict; crossing streams of traffic should intersect at a right angle or close to it while merging streams should intersect at small angles to ensure low relative speed; Define and minimise conflict areas; Define vehicles paths; Ensure adequate sight distances; Control approach speeds using alignment, lane width, traffic control or speed limits; Provide for all vehicular and non-vehicular traffic likely to use the intersection, including where necessary special provisions for heavy vehicles, public transport vehicles, and pedestrians and other vulnerable road users; Simplify the driving task; Minimise road user delay.

One of the challenging aspect in designing solutions at hazardous locations is to achieve the safety objectives for user groups, while at same time achieve a balance between other objectives related to traffic, such as road capacity and delay, and the environment (noise, aesthetics). In particular, pedestrians have special needs that should be considered when investigating safety problems and developing countermeasures.

Different configurations (cross intersection, t-intersections, multi-leg intersection, roundabouts), different forms of control (no signalized, signalized), and different road functions (primary, arterial, secondary arterial, collector, etc.) all influence the safety
performance. It is common to combine safety, environmental, and capacity considerations to develop guidelines as to which type of intersection is appropriate to particular situations.

6. Restraint Devices
Restraint devices like guardrails, concrete barriers, crash cushions are protective devices to minimise severity of collisions. They are used primarily to prevent collisions with opposite traffic and also to prevent collisions with fixed objects and roadside obstacles and to avoid dangerous areas. Barriers are used also as safety devices to control improper access and returns and to control and segregate the movement of pedestrians and cyclists.

Barrier warrants are based on the premise that a traffic barrier should be installed only if it reduces the severity of potential crashes. They provide safety by containing and redirecting vehicles, minimising the severity of impact for vehicle occupants while maintaining vehicle's stability. To work properly a traffic barrier should be well designed, installed and maintained.

The design should consider an adequate length of need to prevent vehicles from hitting the obstacle from behind the barrier, consider a lateral distance from the obstacle to accommodate barrier's deflection characteristics like the dynamic deflection and working space, consider the design height, and have a proper terminal and transitions.

The use of crash cushions is warranted when there is no other safe treatment feasible. During preliminary design stages the need of crash cushions and the space requirements to shield non-removable fixed objects should be considered. The site conditions may dictate the type of crash cushion needed. Crash cushions and barrier end treatment are not intended to reduce the frequency of crashes but to lessen their severity.

A crashworthy end treatment is considered essential if a barrier terminates within the designed clear zone or is located in an area where it is likely to be hit by an errant vehicle. The terrain between the travelled way and the terminal and the approach in front of any terminal should be essential flat so that impact vehicle will be relatively stable at the moment of contact.

Crash cushions or impact attenuators are protective devices that prevent errant vehicles from impacting fixed objects. Crash cushions are ideally suited for use at locations where fixed objects cannot be removed, relocated, or made breakaway, and cannot be adequately shielded by a longitudinal barrier.

7. Provision For Vulnerable Users
Pedestrians are vulnerable when placed in a situation of potential conflict with a motor vehicle, with the very young, the elderly and people with disabilities or under the influence of alcohol being of particular concern. There are a range of traffic engineering treatments which, when installed appropriately, are likely be effective in reducing pedestrians accidents.

Suggested guidelines:
- Check the design in three dimensions; Ensure that the scheme takes account of the likely range of vehicle speeds; Ensure that islands are large enough to cater for pedestrians, as well as, for the necessary street furniture; Check that pedestrian routes are continuous; Avoid mixing different types of pedestrian control in close proximity; Minimize pedestrian crossing distances; Where pedestrians are to be
deterred from crossing, ensure that fencing is adequate; Provide refuges where possible on heavily trafficked roads to enable pedestrians to cross the road in stages; Ensure that pedestrians underpass are wide, straight, and open; Ensure that pedestrian lighting is adequate having regard to needs and standards; Footpaths should be smooth, skid resistant, and kept clear from overhanging foliage; Ensure pedestrian walk times at, signals are adequate for elderly pedestrians; Provide audio-tactile devices where possible; Ensure that ramps (dropped kerbs, kerb cuts) are flush the invert; Manage parking to maximize sight distances at pedestrian crossings; Ensure that street furniture does not obstruct the vision of and by pedestrians, especially children; Ensure that crossings can be identified and negotiated by visually impaired pedestrians, and; Where possible, ensure that islands, refuges, etc. are wide enough to accommodate a wheelchair.

8. Traffic control during construction

Work zones are by nature potentially dangerous location and need special care to maintain safety. The work activity presents an abnormal and often disruptive situation to drivers. The purpose of traffic control during construction is to protect drivers, vulnerable road users, and workers from work zone hazards, and the work being carried.

The traffic controls in work zones are to:
- Warn drivers and pedestrians of hazards; Advise drivers of the proper travel path and speed through the area; Delineate areas where traffic should not operate; Segregate and protect road users and the work force.

The traffic control in work zones should guarantee uniform and consistent information to drivers and road users to enhance a proper response from them.

The work activity and traffic control must be co-ordinated to provide safe and smooth movement of traffic and pedestrians, while the work activity progress as safety and efficiently as possible. They require close and regular monitoring of the implementation, maintenance and closure.

To enhance safety in work zone some principles should be followed:
- Make traffic safety an integral an high priority element of every project: The geometric should be as nearly as possible to normal situation; Avoid inhibiting traffic as much as possible: Use reduced speed only where it is absolutely necessary; avoid abrupt and frequent changes in geometric; provide for safe operations of work vehicles and machinery; minimize work time to reduce exposure; Guide drivers in a clear and positive way: Remove conflicting pavement markings; provide adequate warning, channelization and delineation to convey positive guidance; Perform routine inspection of traffic control devices: The responsibility for the traffic control in work zones should be assigned to trained personnel only; make modifications in traffic control or working conditions when necessary; traffic control devices should be removed immediately when they are no longer needed; Give constant attention to roadside safety: Construction equipment, materials and debris should be stored in a way to minimize the opportunity for errant vehicles impacts; use lightweight, breakaway devices which will yield on impacts; provide uniform, conspicuous, and positive control devices; traffic control devices must maintained.

No road should be opened to traffic without adequate signing. Therefore temporary pavement marking should be installed before nightfall.
9. Illumination

The introduction of adequate street and road lighting can help reduce night-time accidents and is an established accident prevention measure in urban areas. It is particularly important where there are high proportions of pedestrians, cyclists and other poorly lit road users including animals. Lighting has benefits other than accident prevention and can often be justified as a general amenity with an associated improvement in personal security.

Lighting should provide a uniformly lit road surface against which vehicles, pedestrians or other objects are seen in silhouette. The design of the lighting system should relate to the road surface reflection characteristics in order to provide the optimum quality and quantity of illumination.

Generally there is a need to improve street lighting especially where there are high pedestrian flows. The most important aspects to consider are:

- Evenness of illumination is important, requiring good design and maintenance; Lamp posts should not be placed in positions where they will be a danger to a vehicle leaving the road. If this is not possible, then they should be designed to collapse on impact or be protected by crash barriers; Lighting is most important at key locations such as at sub-standard design sections, at sites where the layout may be unclear, at intersections, and where pedestrians cross.

10. Drainage

Drainage ditches are an essential part of any road which is not on an embankment and must be incorporated into most highways. These are designed to accommodate the expected rainfall but can often be hazardous to vehicles that run off the road. Adequate attention must therefore be given to the safety considerations of drainage facilities when designing and upgrading highways.

Drainage ditches collect and disperse the water from the roadway pavement and the run off from the uphill side of the carriageway. Careful design and location of such ditches can reduce the potential hazard of such structures.

The development of drainage ditches which can cope with expected rainfall levels and yet do not create unsafe conditions for the traffic is not an easy task and inevitably a compromise is required.

8. Checklists

Checklists are a useful tool for conducting a RSA, and are not a rigid instrument. Instead, it should be a flexible guideline and reminder of things to look for, steering the team to a comprehensive evaluation of the project. Checklists:

- Are formulated to guide the process; Can be modified to fit the stage of the audit and the project; Should be considered an aid, not the final product; Should be considered a tool, not a rigid requirement

Checklists are only tools

A checklist is one tool available to the audit team; just as the project data and documentation are tools. Checking off all items on a checklist does not mean that the audit has been fully completed.

After reviewing a project’s data and documentation, tailor a checklist to the specific audit.

An example of Checklist is suggested, extracted from Austroads, as a start point and should be modified to fit specific needs and fit the stage of the audit and the project.
9. Liability and Legal Considerations

The Brazilian Federal law no 9.503 that set up the new transit code, established that agencies taking part of the National System of Traffic have objective liability (into the scope of their own ability). This liability includes the damages caused to citizens by actions, neglect or mistakes in the execution and maintenance of programs, projects and services, which ensure the exercise of the right of safety traffic.

Some fear that RSAs can be used against a state in a lawsuit – that they create evidence of safety defect that can enable a plaintiff to prevail in a court of law. In reality, the opposite might be true. RSAs could become a powerful defense. A RSA written report could show that communication concerning a safety issue occur prior to accident. In the opinions of some, this would amount to admitting that a problem exists and that the state is knowledgeable of it and fear that it would hurt the state in the event of the lawsuit. They would rather ignore a safety defect or discuss it without creating a written reported. However, a court probably would favor a state that can show it is a proactive in identifying and correcting a safety defects by conducting RSA, and have little sympathy for a state that ignores safety issues and pretends safety defects do not exist.

10. Keys to Successful Implementation

Worldwide experience found the following keys to successfully implementing RSAs:

- RSAs are dependent on top-down support; Cooperation among organizational units within the agency is essential; Keep the audit team small – 4 to 5 members – and balanced among expertise. Include a team member who can provide a maintenance perspective; Train team members to conduct audits; Designate a safety coordinator to provide overall project management; Empower team members to “think outside the box”; Conduct audits early in a project, when revisions are easier and less expensive to make; Not every project lends itself to an audit; Develop an audit schedule and establish a set period of performance; Focus on what is doable, do not waste time on what is not possible or feasible; Avoid using the word “recommendation”; Documentation and publish the costs and benefits of RSAs conducted.

The experiences globally show that top management support is vital. Management must be willing to provide the resources needed to accomplish program objectives.
11. References

Austroads (2002). Road Safety Audits, AU.
Conaset (2003). Guia para Realizar una Auditoria de Seguridad Vial, Chile.