Road safety audit effectiveness at urban junctions

O. Giuffre, A. Di Francisca and A. Granà
Department of Road Infrastructure Engineering, University of Palermo, Italy

Abstract

In accordance with the Road Safety National Plan recently adopted in Italy and the initiatives subsequently undertaken by the National Infrastructure and Transport Department, this paper contains proposals for implementing an urban road safety audit in Italy. Our research will aim at evaluating the possible effects of such a practice.

Our more specific aim is to determine the real or potential risk on roads by examining road infrastructure and observing road user behaviour in the absence of accident data. Four urban junctions, situated on one of the main thoroughfares of urban traffic in Palermo, were studied and a comparison was made between the data obtained by observing road user behaviour and that, which would have been supplied by expensive accident data analysis.

1 Premise

Following the revision of the Highway Code, which came into effect in 1993, the competent authority (the LLPP Ministry, currently the Ministry of Infrastructure and Transport) has encouraged a considerable amount of pre-regulatory studies. Such activity has recently generated numerous technical documents of two types: regulatory regarding planning, construction and road control and programmatic concerning traffic safety.

In implementing a system of preventive safety control, the National Plan for Road Safety, whose lines of enquiry have recently been approved by the National Parliament, identified a preferential measure in making traffic mobility safer. Starting from this perspective, the relevant Minister issued special guidelines to analyze safety, thereby inspiring well-known international procedures such as the Road Safety Audit [1].
Preparing these guidelines was a university work-group, including experts from various Italian universities (the Department of Engineering Transport from the Federico II University in Naples, the Department of Civil Engineering at the University of Florence and the Department of Road Infrastructure Engineering at the University of Palermo). More specifically, the work group undertook pilot studies on projects and roads with traffic in rural and urban areas.

2 Study objectives

This paper refers to the results of a study that was specifically drawn up in order to evaluate the potential efficacy of the Road Safety Audit procedure, in accordance with the 'Guidelines' introduced into Italy. A more general objective was to identify objective and/or potential risks that were related to road use only by examining the infrastructure and its uses (regarding, in particular, road user behavior), also in the absence of information regarding accidents.

From a methodological point of view, the study proceeded by means of accurate urban case studies, each one subject to a double safety test:
- on the one hand, via the road safety audit procedure without information about previous accidents;
- on the other, and independently of the results of the preceding analysis, through a traditional diagnostic study on safety based on the disaggregate analysis of accidents which have already occurred.

The efficacy of the road safety procedure was evaluated by comparing it with the results obtained after the disaggregated study of accidents.

3 Case study

Cases subject to safety analysis concerned four intersections (Fig. 1) on one of the principal arteries of the urban road network in Palermo (Viale Lazio), classified by the Road Regulations as a main street and characterized by:
- intense transversal mobility, also outside the intersections;
- heterogeneous traffic with a considerable number of pedestrians;
- multiple access to shops and residences which open directly onto the road;
- the presence of lanes reserved for public transport, running in an opposite direction to the main traffic flow.

From a functional point of view, the road artery in question constitutes one of the penetrating axes in the urban texture, arranged in an almost orthogonal direction to longitudinally axes running in a north-sound direction. This artery expands by a little more than one kilometer to the ring-road (Viale Regione Siciliana) until Viale della Libertà, the latter which has historically represented a fundamental axis of the urban network in a north-south direction.

The intersections on this route, nearly all with traffic lights, are on average slightly less than 200 m from each other, being ascribable to traditional junction frameworks.
The results of applying the audit procedure.

4.1 Methodological approach
In accordance with the principles inspired by the Road Safety Audit [2] [3] [4] [5] [6], the examination of the safety conditions of the cases in our analysis was carried out by a special work group. They proceeded according to what had already been envisaged by the aforementioned 'Road Safety Audit Guidelines' [1].

The various logical phases into which the work group's analysis was divided can be summarized thus:
- surveys in various weather and traffic conditions;
- highlighting existing generalised and specific safety problems;
- the drawing up of a list of important problems in situ;
- integrating this list with more information taken from photographic material and video extracts, and a verbal comparison amongst members of the work group;
- editing the final report, in which both general and specific safety problems were highlighted from particular sites. For every problem encountered, suitable corrective action was proposed by way of a recommendation aimed at improving (or eliminating) the risk situations encountered.

4.2 Identified safety problems
The problems highlighted and recommendations proposed by the work group in final audit report have been documented in a format which is typical for this type of document in a previous paper. [7].

Briefly, the problems encountered can be described in general terms (referring to risk situations which are common to the intersections under examination) and in specific terms for each intersection. Regarding a description of the latter, we will refer, for reasons of brevity, to the most critical intersection.

4.2.1 General problems
The observed road axis presents numerous situations in which road users are particularly exposed to risk. In nearly all cases, these situations are attributable to:

a. the needs of vulnerable road users:
- pedestrian crossings which are too long compared to the road surface of the crossing;
- parked cars on the roadsides block the visibility of pedestrians waiting to cross and, reciprocally, pedestrians are unable to see vehicles using the intersection;

b. the organization of intersections, particularly regarding:
- inadequate lane channeling due to a deterioration in horizontal road signs;
- cars waiting near the crossing which make it dangerous for other cars to turn;
- defects in interpreting road signs, in particular regarding the inadequate communicative features of these signs;

c. the necessity for maintenance:
- deterioration, to the point of unevenness, of the road surface and pavement;
- the presence of objects on the roadside which prevent pedestrians from crossing and which increase the seriousness of consequences when an accident occurs.

4.2.2 Specific problems

Of the case studies examined, field observations of road user behavior particularly highlighted the critical conditions of the intersection between Viale Lazio and Via E. Restivo. Indeed, the functioning of this intersection (Figs. 1d-2) is significantly influenced by the presence of another intersection nearby.

Both the crossings are controlled by traffic lights with staggered frequencies of a few seconds and they can, therefore, be considered as one intersection. Moreover, it is necessary to highlight the presence of a wide stretch on the right of the carriageway in Via E. Restivo (immediately after the intersection with Via B. Verona). Here the carriageway divides into four lanes, of which one is for public transport (going in the opposite direction), two are located on the axis with Via E. Restivo and the fourth is on the right, separated from the previous ones by a pedestrian isle.

The circulation of vehicles which use the first three lanes is regulated by traffic lights located in Viale Lazio. Vehicles entering Viale Lazio coming from the inner lane are regulated by the sign 'give way'.

Surveys carried out during the safety audit highlighted potentially dangerous situations where traffic enters Viale Lazio and near the wide stretch between the two intersections with traffic lights:
- to avoid the traffic lights at the crossing with Viale Lazio, vehicles coming from Via E. Restivo and Via B. Verona prefer to use the side road beyond the pedestrian isle to enter Viale Lazio; when the traffic lights are green for vehicles coming from Viale Lazio, a situation of potential conflict (which could be particularly treacherous) is created immediately after the main intersection, that is, Viale Lazio with Via Sciuti. This is due to i) the surprise effect of the approaching flow of vehicles immediately after the intersection controlled by traffic lights; ii) and the behaviour of road users entering Viale Lazio via the right filter lane, irrespective of the 'give way' sign. This conflict situation was highlighted in field observations by frequent emergency manoeuvres (swerving brusquely, braking) to which the vehicles traveling along Viale Lazio are subjected.
- Visibility limitations at the pedestrian crossing on the wide stretch in Via Restivo (in front of the crossing with Via B. Verona) reduce the visibility of vehicles turning, thereby creating particularly risky conditions for pedestrians.

Other potential situations of risk include:
- pedestrian crossings without traffic lights for pedestrians;
- the presence of a private access road (not indicated) immediately after the crossing of Viale Lazio with Via Sciuti. The entering and, more importantly, the exit of vehicles could constitute a serious danger for vehicles traveling along the preferential lane in Via G. Sciuti as well as for pedestrians on the pavement;
The Sustainable City II

- the presence of parked cars hinders users' visibility who, coming from Via B. Verona, enter the intersection;
- the poor condition of horizontal road signs makes it difficult for car drivers to effectively read the road signs, thereby compromising any understanding of their function;
- the lack of vertical road signs at the intersection worsens these readability defects.

5 Accident analysis

Turning to the Municipal Police archives, accidents occurring within the last five years at the intersections in this study were examined:
- there were 55 accidents at the Lazio/Liberta/Di Giorgi intersection;
- there were 60 accidents at the Lazio-Sicilia intersection;
- there were 24 accidents at the Lazio-Campania-Piemonte intersection;
- and there were 42 accidents at the Lazio-Restivo-Scuti intersection.

A detailed analysis was carried out with the help of collision diagrams [8][9][10] and the information required to identify and typify the accidents was expressed with an alpha-numerical code and reproduced in a multi-field table (7 for intersections with traffic lights; 6 for intersections without traffic lights).

Included in Table 1 are classes of information (an example of the collision diagrams is reproduced in Fig.2 regarding the single intersection of Lazio-E. Restivo):

Table 1: Accident Coding

<table>
<thead>
<tr>
<th>FIELD 1</th>
<th>Accident type/road user category</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIELD 2/3</td>
<td>Time and date</td>
</tr>
<tr>
<td>FIELD 4</td>
<td>Condition of pavement/presence of road works</td>
</tr>
<tr>
<td>FIELD 5</td>
<td>Weather conditions</td>
</tr>
<tr>
<td>FIELD 6</td>
<td>Functioning of traffic lights</td>
</tr>
<tr>
<td>FIELD 7</td>
<td>Seriousness of the consequences</td>
</tr>
</tbody>
</table>

5.1 Identifying critical accidents

5.1.1 The Lazio-Liberta-Di Giorgio Intersection (Fig 1a)

More than half of the observed accidents (29 out of 55) concern preferential lanes. Of these, approximately half involve users on two-wheels who, unauthorized, travel in preferential lanes and whose presence is unexpected by road users effecting a turning manoeuvre. Contrarily, the other half of observed accidents is caused by road users who, whilst going through green traffic lights, do not give way to vehicles who are permitted to travel in the preferential lane in Via Libertà.

The cause of these latter accidents is directly attributable to the poor visibility in the preferential lane in Via Libertà for road users traveling on Via Di Giorgio going towards Viale Lazio as visibility is effectively compromised by the wall of
a building which occupies the block (a school). There are no recurring reasons for the remaining 26 accidents. Finally, an examination of the conflict diagram reveals an elevated percentage of incidents which causes accidents (71%).

5.1.2 The Lazio – Sicilia Intersection (Fig. 1b)
The majority of accidents (36 out of 60) is caused by road users coming from Via Sicilia who do not then obey the 'stop' sign. Such behaviour, as highlighted by field analysis, can be attributed to a defect in visibility due:
- to the poor readability of the vertical 'stop' sign on Via Sicilia which is in turn partially obstructed by the presence of vegetation near the intersection;
- to parked cars near the crossing.

The number of accidents caused by road users who, whilst crossing the intersection omit to give way to authorized vehicles travelling in the preferential lane, is also substantial. The number of accidents resulting in bodily injuries is particularly high (63.2%).

5.1.3 The Lazio–Campania–Piemonte Intersection (Fig. 1c)
Compared to other sites that were examined, this intersection recorded a lower number of accidents (24 in the 5-year survey). The predominant type of accident is attributable to crossing the road, and in nearly all cases involved bodily injuries.

As derived from written evidence, the fact that such accidents take place (one for every two incidents) - when the traffic lights are not functioning (at night or if out of order) - is important. Furthermore, disaggregated accident analysis demonstrates the presence of a type of accident related to the busiest confluences on Viale Lazio (lateral collisions between vehicles which turn simultaneously) and a not inconsiderable number of accidents with fixed obstacles (e.g., the base of the traffic lights), the driver having lost control of the vehicle.

5.1.4 Lazio–Restivo–Sciuti Intersection (Fig. 2)
The most dangerous manoeuvre, notwithstanding the presence of traffic lights, is crossing the road; indeed, 26 out of a total of 41 accidents can be traced back to this site.

These accidents very often cause bodily injuries (26 incidents of which 21 are accidents).

The seriousness of the consequences of the accidents is attributable both to the angle of impact between the vehicles involved (about 90%) and the high speed of the vehicles.

Of the possible causes that determine such a high number of accidents, the following can be highlighted:
- the close sequence of traffic lights and the phasing of cycle times (the slow timing of the first traffic lights for users travelling in Via E. Restivo);
- when the traffic lights are switched off, the poor readability of vertical signs (the 'stop' sign) in Viale Lazio, attributable to the presence of trees on the
Figure 2: Collision diagram for Lazio-Sciuti-Restivo Intersection.
Figure 3: Criteria for comparing the results of safety analysis (rs/a/d)
pavement and the inconsistency of the sign with respect to those at the two preceding intersections, going in the direction of the traffic.

Other accidents do not show particular anomalies regarding infrastructure, nor, for that matter, were they located at precise points in the intersection.

6 Comparative criterion of results

The logical path followed in validating the road safety audit procedure with the meaning specified (cfr paragraph 2) is shown in Fig. 3. An application of the case studies examined necessitated the preliminary homogenisation of the output of the two approaches used: road safety audit (rsa)/disaggregated accident analysis (daa).

With this aim, two levels can be said to be operating:

- the first level was directed towards establishing common comparative terms between the two methods of analysis. It seemed more appropriate to refer to accident-causing factors (defects), in that they may be related to the intersection geometry, local anomalies in the layout of the intersection, environmental interference or other circumstances found in the analysis, such as aggravating factors of risk conditions (cfr. Table 2);
- the second level aimed at working out the typology of critical accidents (similar accident type which is repeated in the same place), provided by disaggregated accident analysis, possible causes of accidents (possible defects), in accordance with the coding which was established for comparison. Consequently, a corresponding table was constructed (cfr. Table 3):

Table 2. Coding of identified defects.

<table>
<thead>
<tr>
<th>A</th>
<th>CROSSING GEOMETRY</th>
<th>B</th>
<th>LOCAL ANOMALIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Speed not compatible with layout</td>
<td>B1</td>
<td>Visibility obstructions</td>
</tr>
<tr>
<td>A2</td>
<td>Extended pedestrian crossing</td>
<td>B2</td>
<td>Irregular road surface</td>
</tr>
<tr>
<td>A3</td>
<td>Confluence and diverging manoeuvres at broad angles</td>
<td>B3</td>
<td>Incorrect locating of vertical road signs</td>
</tr>
<tr>
<td>A4</td>
<td>Inadequate canalization and delineation in preferential lanes</td>
<td>B4</td>
<td>Absence of physical protection at the crossing then vehicles pile up</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C</th>
<th>ENVIRONMENTAL INTERFERENCE</th>
<th>D</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Poor safety clearances</td>
<td>D1</td>
<td>Condition of the pavement</td>
</tr>
<tr>
<td>C2</td>
<td>Presence of private access roads</td>
<td>D2</td>
<td>Unfavorable weather conditions</td>
</tr>
<tr>
<td>C3</td>
<td>Particular features of pedestrian routes (obstacles on the pavement, shops, private access roads)</td>
<td>D3</td>
<td>Unfavorable lighting</td>
</tr>
<tr>
<td>C4</td>
<td>Invasion of preferential lanes by unauthorized vehicles</td>
<td>D4</td>
<td>Error-inducing context</td>
</tr>
</tbody>
</table>
Table 3. Corresponding table for accident type and possible defect

<table>
<thead>
<tr>
<th>Type of accident</th>
<th>Manoeuvre/trajectory</th>
<th>Possible defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolated accident</td>
<td>Inappropriate driving style for road conditions</td>
<td>A1 A2 A3 A4</td>
</tr>
<tr>
<td>Accident with pedestrian</td>
<td>Crossing an unprotected area, invasion of the road, turning at a pedestrian crossing</td>
<td>A1 A2 A3 A4</td>
</tr>
<tr>
<td>Lateral collision</td>
<td>Crossing, entering from the right, turning left</td>
<td>A1 A2 A3 A4</td>
</tr>
<tr>
<td>Change of direction</td>
<td>Diversion</td>
<td>A1 A2 A3 A4</td>
</tr>
<tr>
<td>Crash</td>
<td>Tailback</td>
<td>A1 A2 A3 A4</td>
</tr>
</tbody>
</table>

7 Discussion of results

Table 4 shows the result of comparing the safety analysis results (rsa and daa) with the four cases examined:
- the grey shading highlights cases of absolute agreement;
- the + sign denotes a defect highlighted by the road safety audit procedure which is not highlighted by the disaggregated accident analysis (the opposite situation is indicated by the '-' sign).

Table 4. The efficacy of the Road Safety Audit Procedure in relationship to disaggregated accident analysis

<table>
<thead>
<tr>
<th>JUNCTIONS</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The result obtained suggests various considerations about the efficacy of the road safety audit procedure, particularly regarding the urban environment.
1. It is worth noting how the results obtained via field observations offer a quality of information which is totally comparable with the results obtained by disaggregated accident analysis. This latter information, developed in the cases studied with the help of collision diagrams, can be used to document the seriousness of the causes of the accident (and related hierarchy), which the audit procedure permits us to conclude by only employing the experience of the analysis team.
2. The comparison employed highlights again that accident analysis can lead us to underestimate risk. Observing road user behaviour allows us to identify situations of potential danger, where accidents do not occur, few accidents take place or, finally, if the accidents are of a non-serious nature. On the contrary and based on events which have bodily or material consequences, disaggregated accident analysis only partially demonstrates the possible causes of the accident (defects) and if, and by how much, accidents of a certain gravity have taken place. This is much more evident in the urban sphere, where speed limitations particularly reduce the seriousness of the consequences of accidents (as shown in paragraph 4.2).

Furthermore, the above allows us to confirm that accident analysis on its own is not able to highlight all the possible combinations of risk factors. The causes of accidents can be deduced by comparing and integrating the results of analyzing road situations (infrastructure data, a reduction in road traffic, the road environment and margins) and accident analysis. In this case, agreement between possible defects, obtainable by accident analysis and the observed situation (existing defects), allows us to deduce the reasons for accident and the tendency for corrective and efficacious action [11].

Such a method of analysis can, however, prove to be difficult when it is necessary to observe itineraries or parts of networks of a certain size. In this case, it is without doubt expedient to first of all conduct a generalised examination which highlights more critical situations, which merit further study. Due to the rapidity and economy of actions which are to be undertaken, the road safety audit procedure allows us to mediate between the demands of completing a safety study (with reliable results) and the resources which can be realistically activated to this end.

References

[1] Circ. Min. LL.PP. n°3699 del 08/06/01 – “Linee guida per le analisi di sicurezza delle strade”.
