Improving Consistency of RSAR for a Collector Rural Road

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SYNOPSIS

The Road Safety Audit Review (RSAR) process has been applied to a particular type of collector rural road in the neighbourhoods of a medium town in Italy with the aim of providing a useful guide for practising engineers by developing a less subjective procedure and by improving consistency of the safety issues identified by RSAR.

The process has been applied by following the proposal of guidelines on Road Safety Audit published by the Italian Ministry of Public Works; the document proposes a series of general checklists, containing questions to be answered for an aid to look for potential safety problems of the road.

It is well known that RSA of existing roads can be useful but they require large amounts of money to correct any deficiencies. How can a Road Authority justify spending such large amounts on locations that may have no crash history if there are black spots with an established crash history to be remedied?

Based on this consideration, an attempt has been made of developing a procedure aimed at better identifying real hazardous situations by integrating results of the RSAR with those of accident data analysis; this procedure can be a useful task for Road Authorities in order to identify a prioritization criterion of locations that need works to be remedied.

The RSAR has been applied to a collector rural road with a few principal intersections and many secondary intersections or approaches; this road serves small communities and it links traffic generators of intra-county importance with the nearby county town, so the traffic flow is composed of habitual users.

As potential safety problems of roads are different depending on their functional classification, geometrical characteristics and environmental features, some questions contained in the checklists have been specialised or integrated in order to take into account problems related to the particular road context. The implementation of the RSAR to the aforementioned existing road has allowed identifying many safety issues.

On the same road, an accident-monitoring program has been started; it consists of collecting and managing accident data by using a software tool with a Geographic Information System. Accidents have been classified by using the “Accident Scenarios” method, which has demonstrated to be a useful procedure in order to identify accident causes related to infrastructure problems. The analysis of crashes has showed that the most of them are located at intersections and that they are mainly caused by wrong manoeuvres of turning, crossing or approaching to intersections.

In order to improve consistency of RSAR applied to this particular type of collector rural road, some weighing factors to be assigned to questions contained in the checklists have been defined by comparing the safety issues identified by the RSAR with those identified by using accident data analysis. This comparison has allowed finding agreements and discrepancies between issues assessed by using the two procedures; moreover, by means of the same comparison, the most hazardous situations can be identified reliably.

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INTRODUCTION

The proposal of guidelines published by the Italian Ministry of Public Works defines some lines of action for the institution of a safety monitoring system on road network [Ministero LL.PP. Ispettorato Generale per la Circolazione e la Sicurezza Stradale (2001, 25 Gennaio)]; the aim of this system is to analyse the state and evolution of safety on Italian road network and to identify risk factors as related to mobility features.
The document recognises the RSAR as a useful process to improve road safety of existing roads and it proposes a series of general check lists containing questions to be answered that are just a way to help auditors to remind some of the most common potential safety problems that they can face on the road.
It is well known that RSAR process is knowledge based and we should not pretend that checklists can provide us with a “score”. In most practical cases, checklists alone are insufficient to conduct a RSAR since there are always unique site conditions that cannot be captured on a checklist yet that are very important for safety. Otherwise, checklists could be a good mean for increasing the sensibility of road engineers in identifying risk factors and their evolution in a specific road context. For this aim, it is necessary to dispose of useful criteria that can steer the safety analysis on particular types of roads by assigning a major importance to specific aspects, which can influence road accidents directly, or indirectly [Wilson E.M. (2000, July)]. For this purpose, check lists must be specialized, being very difficult to identify real safety problems of roads by using the same checklists for all type of roads.

On our and of other people opinion, RSA of existing roads can be useful but in some practical cases potential safety issues identified by RSAR are not real safety hazardous situations and they require large amounts of money to correct any deficiencies. How can a Road Authority justify spending such large amounts on locations that may have no crash history if there are black spots with an established crash history to be remedied?

Based on these considerations, in this work an attempt has been made of refining the checklists provided by the aforementioned guidelines in order to be able to better identify real safety issues of a particular type of collector rural road. It is important to underline that the aim of this study is to provide a useful guide for practising engineers by developing a less subjective procedure and by improving consistency of the safety issues identified by RSAR. There is a need of identifying some prioritization criteria for the selection of locations to be remedied when there aren’t enough funds to correct any deficiencies identified by RSAR.

Even if crash investigations can become mistaken for RSAR, and vice versa, within this work the results of RSAR have been compared with those of accident data analysis in order to verify the correspondence between potential safety issues and real hazardous situations. Being the comparison made for a particular type of collector rural road, the obtained results are true only for this type of road but the procedure could be extended to whichever type of road to obtain the same kind of results.

Within this study, checklists reported in the aforementioned guidelines have been modified suitably in order to better outline potential infrastructure deficiencies of the analysed collector rural road; at the same time, an analysis of accident dynamic, by using the method of accident scenarios, which are closely related to infrastructure problems, has been carried out.
Starting from the scenarios defined in the report [Losa M. Ristori C., 2004], we have tried to identify critical accidents, namely those that occur more often in the same place. The correspondence between critical accidents and potential deficiencies allows identifying the real risk factors, which influence the crash probability in the specific context analysed.
Based on such correspondence the questions have been raised, which are able to identify infrastructure deficiencies having higher influence on accident occurrences.

INFRASTRUCTURE FEATURES

The study has been carried out on a collector rural road in the neighbourhood of a small town in Italy (Fig. 1). The road passes through a land with different social and economic features, which influence the road

functions. It links three county towns and, within these urban centres, the road has features like in an urban context; in fact, these built-up areas are arisen behind this infrastructure promoting social and economic activities.
Moreover, the road passes through some commercial and industrial areas while the remaining sections are within agricultural contexts.
The road is principally build-up on short embankments; for sections of significant length, there are high trunk trees on the edge of the carriageway.
The alignment is composed of tangents and circular curves without transition curves.
Generally, circular curves have wide radius (for 68% of curves the radius is > 200 m) with the exception of a few curves with small radius. Three of them have radius r < 50m and three have 50m < r < 100m; in these cases, the presence of obstacles on the edge of the road-platform reduces the sight distance below the minimum stopping sight distance.

Along the road, we find a lot of secondary intersections or approaches and a few primary intersections.
The road has a single carriageway with one lane for each direction; with the exception for only one intersection, generally there are not specialised lanes for left turning.
The width of carriageway changes depending on territorial context passed trough; it is smaller in urban contexts and wider in rural contexts even if dimensions of lanes and shoulders are not in agreement with those reported in the New Policy on Geometric Design of Roads published by the Italian Ministry of Infrastructures and Transportation.

APPLICATION OF THE ROAD SAFETY AUDIT REVIEW

The increase of accident number on the described road can be caused by many factors, between them the most important are a poor infrastructure maintenance and both a rise and a change of traffic travelling on a road which is so old that hasn't been designed at all.

The RSAR process can be inserted easily in a global management program of road safety [Owers S.R. Wilson E.M. (2000) and (2001)] and it is useful both to identify road safety deficiencies and to program periodic works for road maintenance [ITE Technical Council Committee (1995); Jordan P. (1999)]. Therefore, it could be considered as an integration of the ordinary accident analysis methods because the two procedures together allow to visualize the "black spots" generated by functional or infrastructural deficiencies and to highlight issues that can cause crashes.

In order to conduct the RSAR, the Auditor group has been composed of three people so that during the audit one can drive, one can look for potential safety issues and one can take some picture of the deficiencies or make a film.
In the first stage of the analysis ("Preliminary analysis"), the auditor group prepared the following documentation:

- the map of the road (Fig. 1);
- the check lists containing possible safety issues to look for (Appendices);
- the map with the "black spots"; this last document has been useful for helping auditors to pay more attention in these areas (Fig. 2).

Checklists have been specialized for this particular type of collector rural road in order to help auditors in identifying potential safety deficiencies [Morgan R. (1999)].

Questions contained in the checklists deal with these subjects:

1) roadside features	[Checklist n. 1]
2) geometry	[Checklist n. 2]
3) intersections	[Checklist n. 3]
4) road surface – pavement markings, signing, delineation and lighting	[Checklist n. 4]
5) special road users (pedestrians and cyclists)	[Checklist n. 5]
6) safety barriers	
7) road surface pavement condition	[Checklist n. 7]
8) parking	
9) speed limit	

The Auditors have driven more times through the test section at the posted speed limit or at safe operating speed, looking at the travel way and to the right (one direction at time).

During the application of the RSAR for this collector rural road, Auditors have found the following major problems, listed for group of locations:

- *at intersections and on approaching branches*: road alignment allows high operating speeds, sight distance is poor, marking of specialized lane for left turning is lacking or poor, sight restrictions of the intersections and of the approaches;
- *at intersections with traffic lights*: lack of protected left turning, people do not comply with the signal of the traffic light so this type of intersection seems to be not well suitable for this type of collector rural road.
- *on road sections*: stopping sight distance and overtaking sight distance are poor, pavement is rough and texture is poor, operating speeds are higher than design speeds, inadequate width of the carriageway, presence of obstacles without safety barriers properly working.
- *at urban centres*: drivers do not perceive to limit speed in urban context, lack of road crossing and special pedestrian and/or cyclist route, poor visibility of road crossing, bus stops on the road and vehicles parked on the road, special route without protection.

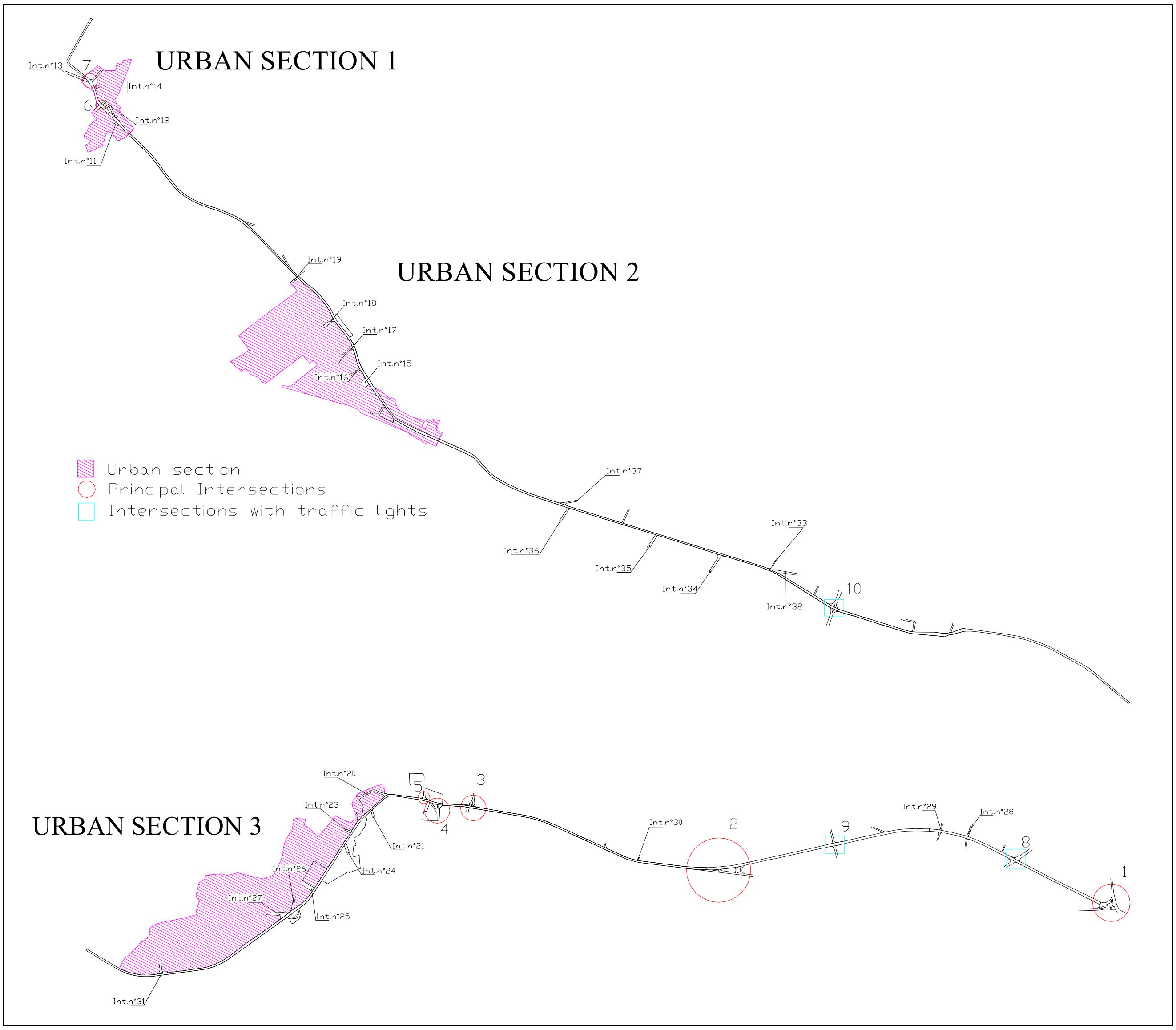

Figure 1: Map of the road

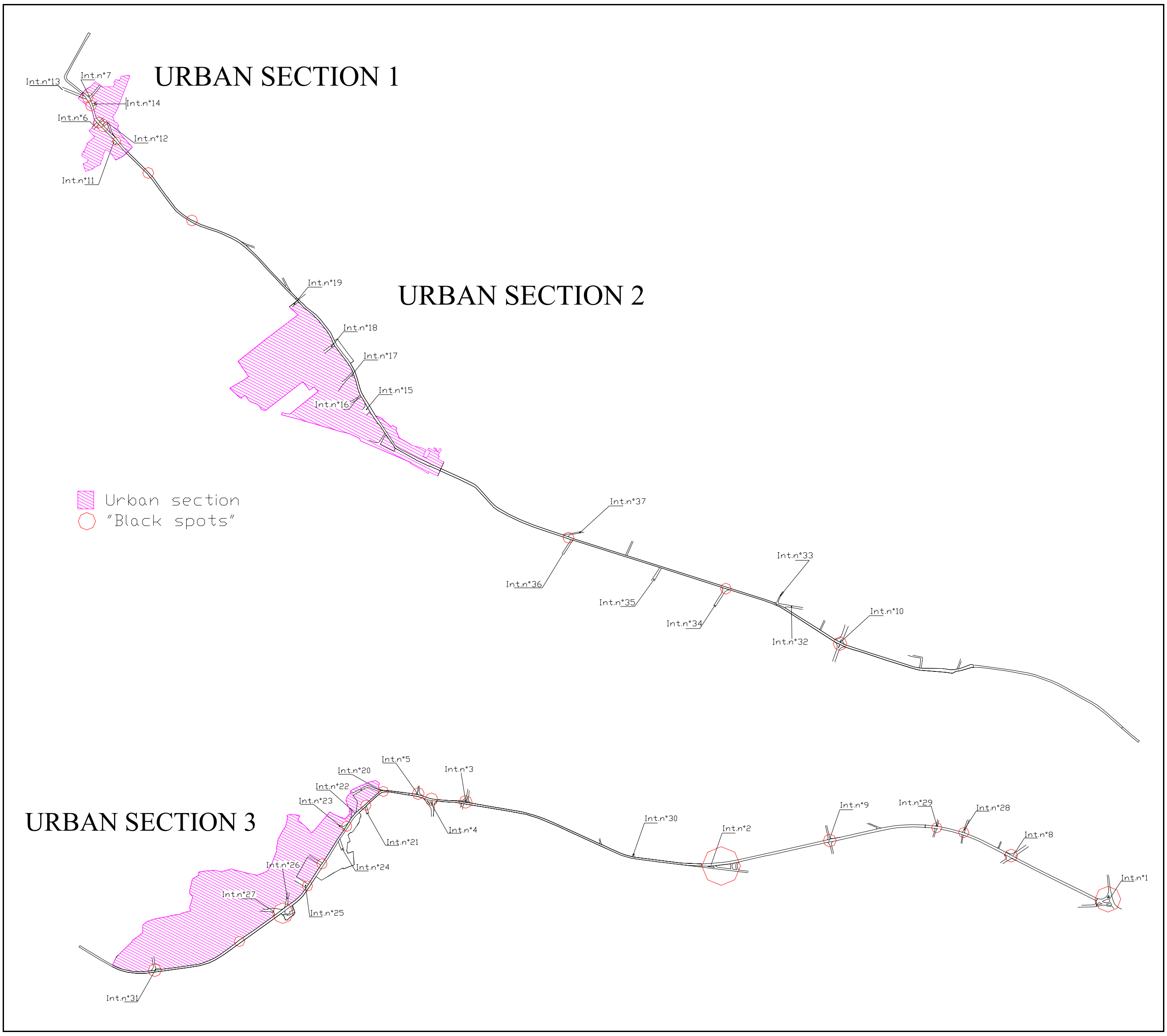

Figure 2: Map of "black spots"

ACCIDENT ANALYSIS

Road accidents have been collected for a period of five years from 1998 to 2002, by reading directly the Police reports; we consider all kinds of accidents: with wounded, with dead and with material damages only.
Accident data have been listed following both the Italian Statistical Institute "ISTAT" model and other international experiences [Brenac T. Fleury D. (2001); Golob T. Recker W.W. (2004); Tira M. (1999)]; data index card considers the following objects:

- the Police organ which has done the survey
- accident day and hour
- description of collision location and road function
- the weather and road surface- pavement condition
- the kind of involved vehicles and their damage
- people implicated in collision
- crash dynamic sequences
- type of collision

All accidents have been classified with the method of the "Accident prototypical scenario" [Brenac T. Fleury D. (2001)]; this is an analysis tool which has been used since the late 1980s in French road safety research, but it has been diffused only in the 1990s and it is very useful to study and to classify accidents.

A prototypical scenario is a prototype of the accident process corresponding to a series of accidents that are similar in terms of the chain of facts and causal relationships throughout the various accident stages [Brenac T. (1997)]; it is an aid to understand the crash dynamic sequences and the causes of the collision.

Each “Accident scenario” is composed of four stages:
- General condition and driving situation: this part describes the situation before the “discontinuity”;
- Accident situation (discontinuity): it describes the situation or the manoeuvre which determines the discontinuity in the vehicle movement and creates a dangerous circumstance;
- Emergency situation: in this stage the involved people could avoid the collision if they have done a particular manoeuvre;
- Impact situation: it describes the collision

In a previous analysis [Losa M. Ristori C. 2004] of the collected accident data, the Authors divided the 310 accidents found on the road in nine categories and fifty different scenarios:

1) isolated vehicle (nine scenarios)
2) overtaking (four scenarios)
3) changing lane (five scenarios)
4) at intersections (twelve scenarios)
5) at intersections with traffic lights (four scenarios)
6) rear end collision (five scenarios)
7) parking (five scenarios)
8) involving pedestrians (five scenarios)
9) other causes

Accident data have been stored in an ad hoc defined database and crash locations have been reported on the map by using a GIS tool, which allows to visualize the information contained in the database, with particular regard to the classification and location of accidents.

The analysis of crashes has showed that most of them are located at intersections and they are mainly caused by wrong manoeuvres of turning, crossing or approaching to the intersection; this fact highlights that the types of collisions are essentially frontal, lateral or rear end.

PROCEDURE FOR RANKING DEFICIENCIES

In order to identify the most serious safety deficiencies of this collector rural road, safety issues identified by the RSAR have been compared with those identified by using accident data analysis. By means of this comparison, we can select questions reported in the checklists that refer to aspects that are more important in identifying hazardous problems of road as they can determine dangerous crashes [Koorey G. Carpenter M. Appleton I. (2003)].
For this purpose, in order to distinguish between road sections with different features we have analyzed separately principal intersections, intersections with traffic lights, urban sections and finally sections not included in the ones primarily mentioned.

For each examined group of intersections or road sections an ad hoc defined Relative Gravity Index (RGI) has been evaluated for all accident scenarios as a function of the number of accidents.
In this evaluation, by taking into account accident costs reported in [Girdano R. Bastano I. (2001)], where unitary cost of accidents with dead is equal to about 10 times the unitary cost of accidents with seriously wounded, the number of accidents with dead is multiplied by a factor equal to 10.

The Relative Gravity Index RGI_{iK} of the i-th accident scenario, calculated for the group K of intersections or road sections of the same type (principal intersections, intersections with traffic lights, urban sections and sections not included in these ones), is calculated by the following expression:

$$RGI_{i,K} = \frac{\sum_{j \in K} (N_{w_{ij}} + 10 N_{d_{ij}})}{\sum_{i=1}^{n} \sum_{j \in K} (N_{w_{ij}} + 10 N_{d_{ij}})} \qquad (1)$$

where:
n is the total number of scenarios

$N_{d_{ij}}$ and $N_{w_{ij}}$ are respectively the number of accidents with dead and wounded, included in the i-th scenario, which are localized in the j-th element of the group K.

The results of these computations are reported for each scenario described in [Losa, M., Ristori, C., 2004] in the following tables from 1 to 4, grouped for type of intersections or road sections.
The total number of accidents registered in the group is reported in the first column of the table. In the other columns, beside the code of the accident scenario, there are the number of accidents with dead or wounded N_{dw}, the values of $RGI_{i,K}$ and the deficiencies identified by the RSAR that can concur to cause the accident described in the examined scenario. Based on these data, we can identify easily the critical accidents, namely those occurring more often in the same location.

Table 1: Comparison accident data analysis/RSAR for principal intersections

N	Scenario	N_{dw}	RGI_i	Results of RSAR
82	4_02/ 4_03	19	0,23	poor perception of intersection/ poor visibility on entering
	4_09	8	0,10	lack of special lane to turn left/poor visibility of vehicles when turning left
	1_08	3	0,04	poor perception of intersection/ lack of lighting
	6_05	2	0,02	poor visibility on entering
	6_01	2	0,02	lack of special lane to turn left
	2_01	1	0,01	lack of special lane to turn left
	4_06	1	0,01	high traffic volume for the type of the road

Table 2: Comparison accident data analysis/RSAR for intersections with traffic lights

N	Scenario	N_{dw}	RGI_i	Results of RSAR
19	5_02/5_04	4	0,21	drivers do not comply with the traffic lights/ planimetric features that allow to drive at high speed also close to intersections
	5_01/5_03	4	0,21	Poor safety conditions for left turn only
	4_09	3	0,16	Poor safety conditions for left turn only
	4_02/4_03	3	0,16	drivers do not comply with the traffic lights/ planimetric features that allow to drive at high speed also close to intersections

Table 3: Comparison accident data analysis/RSAR for urban contexts

N	Scenario	N_{d+w}	RGI_i	Results of RSAR
122	4_02	17	0,14	poor visibility on entering
	8_01	1†+4	0,12	wrong location of road crossing
	4_09	1†+2	0,10	poor visibility of vehicles close to intersections when turning left
	3_03	1†	0,08	lack of special pedestrians or cycle routes to separate the different traffic components
	1_01	8	0,07	curve with small radius
	6_01	6	0.05	high traffic volume for the type of road in urban context
	6_02	5	0,04	lack of traffic calming device close to intersection
	4_09	3	0,03	high traffic volume for the type of the road in urban context
	1_04	3	0,03	curve with small radius / poor friction data
	2_01	2	0,02	high traffic volume for the type of road in urban context
	4_01/4_05	2	0,02	poor visibility on entering
	8_05	2	0,02	lack of adequate road crossing
	6_02	1	0,01	poor visibility of vehicles in the queue
	8_03	1	0,01	lack of special pedestrians or cycle routes to separate the different traffic components
	6_04	1	0,01	lack of traffic calming device close to intersection
	6_03	1	0,01	lack of traffic calming device close to intersection
	4_10	1	0,01	poor visibility on entering
	2_03	1	0,01	high traffic volume for the type of the road in urban context
	3_02	1	0,01	lack of an appropriate place for the bus stop

† Accidents with dead

Table 4: Comparison accident data analysis/RSAR for other sections

N	Scenario*	N_{d+w}	RGI_i	Note
86	4_02	1[†]+5	0,17	poor visibility on entering
	1_01	6	0,07	poor friction data/ curve with small radius
	6_04	5	0,06	alignment allowing people to drive at high speed also close to intersections/ lack of traffic calming device close to intersection
	6_02	5	0,06	lack of traffic calming device close to intersection or approach
	6_01	4	0,05	curve with poor stopping sight distance/ heavy traffic for the type of road
	2_01	4	0,05	lack of traffic calming device close to approach
	8_03	3	0,04	lack of special pedestrians or cycle routes to separate the different traffic components
	4_09	2	0,02	high traffic volume for the type of road
	4_01	1	0,01	poor visibility on entering
	4_05	1	0,01	poor visibility on entering
	8_01	1	0,01	poor visibility of the road crossing
	2_03	1	0,01	curve with poor stopping sight distance

[†] Accidents with dead

For each infrastructural problem identified by the RSAR, on intersections or road sections, an attempt has been made of searching for accident scenarios describing crashes may be caused by that particular deficiency. The Relative Gravity Index of the deficiency RGI_{dK}, identified in the group K of intersections or road sections, is calculated by the following relationship:

$$RGI_{d,K} = \sum_{i=1}^{m} RGI_{i,K} \qquad (2)$$

being *m* the number of accident scenarios that may be related to the examined deficiency.

(For example, in principal intersections, the deficiency consisting of a poor perception of the same intersection by drivers travelling on the approaching branchs can cause accidents with the following scenarios: 4_02/ 4_03/ 1_08; so the $RGI_{d,K} = RGI_{4\_02,K} + RGI_{4\_03,K} + RGI_{1\_08,K}$.)

The greater values of $RGI_{d,K}$ identify the most dangerous infrastructural problems which can be causes of risky collision; by comparing problems found by accidents data analysis with those assessed by the RSAR it has been possible to check if the potential factor of risk would have a direct or indirect influence on accident situations.
For this purpose, deficiencies identified by the RSAR for this road have been ranked in three levels of importance.

High $RGI_{d,K} \geq 0.21$
Medium $0.05 \leq RGI_{d,K} < 0.21$
Low $RGI_{d,K} < 0.05$

The threshold values of $RGI_{d,K}$ have been determined by means of statistical considerations. By considering that the values of $RGI_{d,K}$ are normally distributed, we have defined as high and low levels the values of $RGI_{d,K}$ contained in the two tails of the distribution with a likelihood of 25%; by this way, we consider as medium level the values of $RGI_{d,K}$ with a 50% of confidence. Therefore, the threshold values $RGI_{d,min}$ and $RGI_{d,max}$ of the confidence interval for the medium level are calculated by the following expression:

$$(RGI_{d,\min}, RGI_{d,\max}) = \overline{RGI}_{d,K} \pm 0.6745\sigma(RGI_{d,K}) \qquad (3)$$

where:

$\overline{RGI}_{d,K}$ is the mean of the $RGD_{d,K}$ values for the examined deficiencies in the road;
$\sigma(RGI_{d,K})$ is the square root of variance.

This comparison has allowed us to get the infrastructural deficiencies of primary importance into perspective, so as to identify the specific questions related to those issues during the RSAR.

In the following Table n. 5 we can see the results of the comparison; here we can read the high and medium importance problems found on the analysed road sections and the relative "accident scenarios" [Losa M. Ristori C. (2004)] assessed in the same sections (the letter D beside the accident scenario indicates the presence of dead). This classification of deficiencies can be assumed as a prioritization criterion to identify locations where works are needed to improve road safety conditions.

Table 5: List of high and medium importance problems found on the road

Principal Intersections		
Description	Accident scenarios	$RGI_{d,K}$
High importance problems		
Poor perception of intersection	4_02/ 4_03/ 1_08	0.27
Poor visibility on entering	4_02/ 4_03/ 6_05	0.25
Medium importance problems		
Lack of special lane to turn left	4_09/ 6_01/ 2_01	0.13
Poor visibility of vehicles from the opposite direction when turning left from the main road	4_09	0.10
Intersections with traffic lights		
Description	Accident scenarios	RGI_d
High importance problems		
inadequate type of intersection for this road as drivers don't comply with traffic lights	5_02/5_04/4_02/4_03	0.37
planimetric features which help people to drive at high speed also close to intersection	5_02/5_04/4_02/4_03	0.37
Poor safety conditions for left turn	5_01/ 5_03/ 4_09	0.37
Urban context		
Description	Accident scenarios	RGI_d
Medium importance problems		
poor visibility on entering	4_02/4-01/4_05/4_10	0.17
wrong location of road crossing	8_01M	0.12
high traffic volume for the type of the road in urban context	4_09/2_01/2_03/6_01	0.11
curve with small radius/poor friction data	1_01/1_04	0.10
poor visibility of the vehicles close to the intersection for planoaltimetric problems	4_09M	0.10
lack of special pedestrians or cycle routes to separate the different traffic components	8_03/ 3_03M	0.09
lack of traffic calming devices close to intersection	6_02/ 6_03/ 6_04	0.06
Along the road		
Description	Accident scenarios	RGI_d
Medium importance problems		
poor visibility on entering	4_02/ 4_01/ 4_05	0.19
lack of traffic calming devices close to intersection or approach/ planimetric features allowing people to drive at high speed also close to intersections	6_04/ 6_02/2_01	0.17
curve with poor stopping sight distance/high traffic volume for the type of road	6_01/ 4_09/ 2_03	0.08
curve with small radius/ poor friction data	1_01	0.07

DISCUSSION ON PRINCIPAL RESULTS OF THE ANALYSIS

By using this procedure of comparison, it has been possible to show that infrastructure problems, corresponding to higher gravity index, are primarily concentrated at intersections and they refer to problems that are strictly related to sight distance. In fact we have found that in these specific road sections there is a high risk of accidents when traffic flows coming from different directions can not see each other perfectly: for example when a vehicle is entering the main road or it is turning from the main road. For this reason, the presence of obstacles on the edge of the road, like buildings or trees or something else, which can obstruct the correct view of the vehicles coming and/or the perception of the intersection (i.e. planoaltimetric singularities), must be considered as problems to give a closer consideration [Figure 3-4].

Principal Intersections
By way of improving safety at principal intersections, the most important problem is to assure a good perception of the intersection and a good visibility of vehicles close to the intersection in order to execute safe entering manoeuvres. It is necessary that special lanes for left turning should be adequately located and designed, to help drivers to turn left from the main road and at the same time to improve perception conditions when they are waiting for turning. From what has been previously mentioned it is obvious that principal intersections need an adequate lighting during the night; the lack of this can cause a poor perception of the intersection itself generating a potential risk factor in nighttimes.

Intersections with Traffic Lights
As far as intersections with traffic lights is regarding, the comparison has revealed their unsuitability for this type of road as drivers, when they arrive at the traffic lights, do not usually comply with the red light indicating "to stop"; this is principally caused by high speeds that drivers maintain close to these road sections. Even if it would be better to reduce the number of this kind of intersections in this type of collector rural roads (as they can generate potential factors of collision), when they are used it is needed to insert a specialised phase for left turning. By this way, we can avoid interferences between drivers who are waiting to turn left and traffic flow going straight ahead at high speed, in the opposite and/or in the same direction.

Figure3: Intersection N. 3

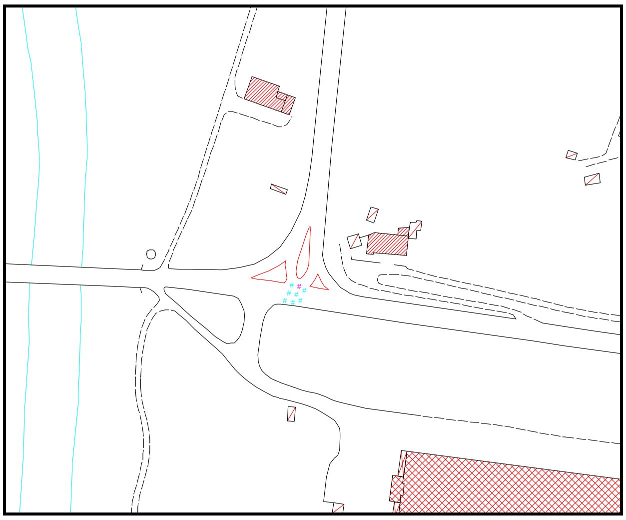

Figure 4: Location of accidents with wounded in intersection N. 3

Minor Intersections
The same kinds of interferences found at principal and with traffic lights intersections also exist at minor intersections. Those, which can be considered real factors of risk, are interferences between drivers who want to turn from the main road and those who go straight ahead at high speed in the same direction and do not realize that the vehicle is at a standstill waiting to make the manoeuvre from the main road. A way to reduce rear end type of collisions it may be the introduction of traffic calming devices on sections approaching to these intersections, so as to compel drivers to moderate their speeds and at the same time to improve the perception of vehicles approaching the intersections.

Urban Context
In urban contexts, besides the above mentioned problems related to intersections and to entering manoeuvres from the approaches, agreements between the two procedures used have underlined that dangerous factors can be found when there are too many interferences between the different traffic components (pedestrians, cyclists, vehicles). These risky interferences can be caused by the lack of adequate pedestrian and cycle routes or by the lack and bad location of road crossings; these issues are increased by the presence of high traffic volumes crossing this context [Figure 5-6].

Other Road Sections
As far as the alignment is regarding, issues, which are a potential factor of risk, have been identified in curves with small radius or with poor stopping sight distance; each of them becomes a more risky factor when pavements have poor friction [Figure 6-7] and traffic volumes are important.

Based on the performed comparisons and on the agreements between the issues assessed by using the two procedures, some useful considerations can be drawn. We can implement RSAR for this particular type of collector rural road with the aid of check lists specialised for this use by assigning a weighing factor equal to three to those questions which are able to identify the infrastructure problems of high importance. To questions, which help to put in evidence issues with medium importance, we can assign a weighing factor equal to two while to all other questions, we can assign a weight equal to one.
These weights are not universally valid; they can only help the Auditors to steer the RSAR but Auditors must take in mind that each problem described in the checklists can have high importance in a particular context. Auditors can verify this circumstance by comparing RSAR deficiencies with results of accident data analysis.

Figure 5: Urban context N. 3

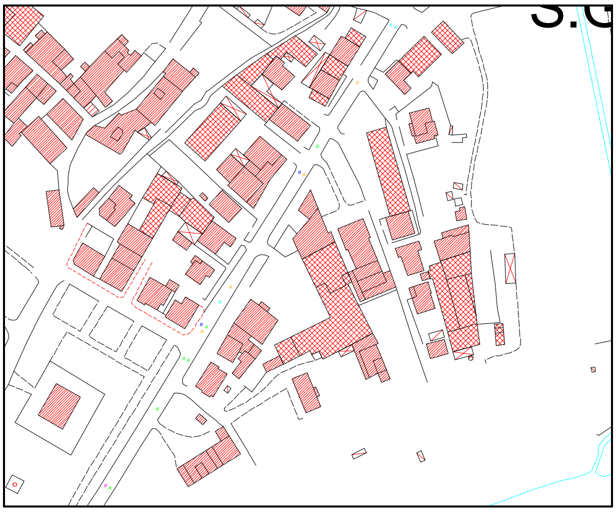

Figure 6: Location of accidents with wounded and dead in road section of the urban context N. 3

Figure 6: Curve with small radius along the road

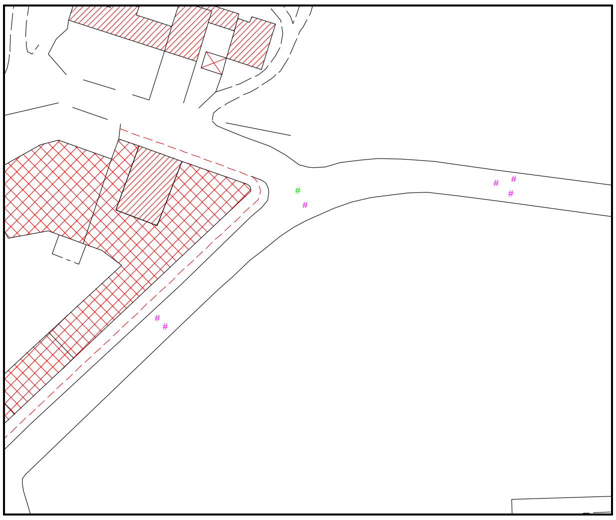

Figure 7: Location of accidents with wounded

CONCLUSIONS

The introduction of the RSAR in the Italian engineering culture, for verifying the state of road safety and for planning maintenance works, reveals itself to be of primary importance. In fact, it supplies a quick and an efficacious tool of analysis, which does not need sophisticated audit to assess the infrastructure problems that can be potential factors of risk.

It's known that RSAR process is knowledge based and we should not pretend that checklists can provide us with a "score". Nevertheless, for a useful application of the RSAR, to highlight the real causes of accident events, it can be helpful to prepare a detailed list of questions, which will be able to steer the engineers executing this kind of analysis. These questions must also be able to give prominence to higher gravity infrastructure defects for the particular type of road examined; for this reason, each question of the checklists could have an adequate weighing factor to be determined based on accident data analysis.

After individuating real infrastructure problems, an accident data analysis is essential to plan the priority of maintenance works useful to improve road safety conditions. By this way, we can concentrate actions on those locations where crashes are particularly dangerous.

During this research, by following the guide lines of the Italian Ministry of Public Works [Ministero LL.PP. (2001)], we have tried to draw up a sequence of questions helpful for the application of the RSAR on a particular type of collector rural road.
By means of a comparison between infrastructure issues found on this road by a RSAR and the accident scenarios assessed in the same sections, it has been possible to identify the questions of checklists referring to problems to which it would be better to put more care during the RSAR. In this way, we can identify the road factors that can have a direct or indirect influence on the occurrence of accidents, namely those with higher risk for the road safety.

In a collector rural road with the aforementioned features, the infrastructure issues that can be causes of accident events, concern mainly with the interferences can be generated between the traffic flows. Consequently, they would be located principally at the intersections, where sight of approaching vehicles can be obstructed by obstacles on the edge of the road or by planoaltimetric singularities.
With regard to the different traffic components, which are present in the urban context, it would be necessary to separate them adequately by using suitable pedestrian and cycle routes; in such a way as to concentrate interferences between vehicles, pedestrians and cyclists only in definite sites which should be appropriately signposted and visible from every direction.

Along the road, infrastructure factors which have an higher influence on the occurrence of accidents are mostly related to friction problems, therefore on geometric elements like curves with small radius and also with surface defects, which can cause the vehicle skidding. Geometric features (ordinary in the collector rural roads) which help drivers to keep high speeds increase these problems.
These conclusions are not exhaustive of the problem. By applying the same procedure to other collector rural roads, new problems with higher relevance can be found and new conclusions can be drawn depending on road features. In order to prove the efficacy of this method, it would be interesting to plan the application of this procedure on other collector rural roads.

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APPENDICES

Check list n°1

Check list n°1 Road side features	**Weighing Factor**
Traffic	
1) Adequate road section 1.1) to traffic volume	2
1.2) to heavy vehicles	1
Lay-by	
2) Enough lay-bays	1
3) Adequate distance between lay-bays	1
4) Correctly located lay-bays	1
5) Maintained lay-bays	1
Weather	
6) Presence of fog 6.1) condition of signals	N.A.
7) Presence of strong wind 7.1) condition of signals	N.A.
8) Presence of snow and/or ice 8.1) condition of signals	N.A.
9) Risk of slippery road with wet surface 9.1) condition of signals	2
10) Risk of flooding 10.1) signals	1
Territorial context	
11) Presence of devices which indicate drivers to reduce speed in	
the trasition from rural (suburban) section to urban section	1
12) High traffic flow through the urban section	2
13) Lack of attention caused by advertising posters	1
Approaches	
14) Location	1
15) Visibility for drivers on the main road	3
16) Visibility on entering	3
17) Dangerous interferences for safety of movement (queue with poor perception)	1
Night dazzling	
18) Traffic flow in the opposite direction	1
19) Other traffic flows	1
20) Lighting of the adjacent roads	1
21) Signs	1

Check list n°2

Check list n°2 Geometry	**Weighing Factor**
Horizontal alignment	
1) Safety condition 1.1) on the tangent	1
1.2) on the curves	2
2) Condition of perception	1
3) Planimetric features which allow to drive at high speed also close to intersections	3
Vertical alignment	
4) Safety conditions 4.1) on grade with high slope	N.A.
4.2) on vertical curves	1
Combination of horizontal and vertical alignment	
5) Visibility (reappearance distance)	2
6) Perception (optical – loss of the road – restriction)	2
Sight	
7) Passing sight distance	1
8) Stopping sight distance (operating speeds)	3
9) Perception distance of singularities in the road (narrowings, intersections ect…)	3
10) Sight obstructed by objects which are on the edge of the carriageway	
10.1) trees, parapets, safety barriers, fences	3
10.2) buildings	3
10.3) road signs, advertising posters	3
10.4) parked vehicles, rubbish bins	3
Transversal section	
11) Narrowings of carriageway	1
12) Space for paved lay-by	1
13) Space for marginal elements	1
14) Changing of section close structures	1
Drainage	
15) Adequate works for a correct drainage	1
Side slopes	
16) Fall of materials	N.A.
17) Protuberant rock slope	N.A.

Check list n°3

Check list n°3 Intersections	**Weighing Factor**
- with stop	
- with traffic lights	
- round-about	
Intersection adequacy	
1) Adequate type of intersection 1.1) for the traffic	1
1.2) for speeds of vehicles	3
2) Presence of traffic calming devices close to the intersections	2
Site	
3) Location	1
4) Visibility of queues	1
5) Perception from all directions	3
Visibility	
6) Intersection visibility from all directions	3
7) Intersection visibility during the night	3
8) Poor visibility because of the presence of obstacles	
8.1) trees, parapets, fences, safety barriers	3
8.2) buildings	3
8.3) road signs, advertising posters	3
8.4) parked vehicles, rubbish bins	3
9) Visibility of vehicles close to the intersections	3
Comprehension	
10) Comprehension from all directions	1
Auxiliary/ Canalization/ Speed-change lanes	
11) Auxiliary or Canalization lanes 11.1) Location	2
11.2) Geometry	2
12) Entering lanes 12.1) Location	1
12.2) Geometry	1
13) Leaving lanes 13.1) Location	1
13.2) Geometry	1
14) Suitability for buses	1
Manoeuvres	
15) Comprehension of all manoeuvres by everybody	1
Islands	
16) Island location and delineation	1
Marking (check list n°4)	
Signing (check list n°4)	
Lighting (check list n°4)	
Railroad Crossing	
17) Railroad crossing signs	N.A.
Round-About	N.A.
18) Suitability of deflection angles at the entrance for traffic	
19) Suitability of the flarings at the entrance sections	
20) Suitability of the central island	
21) The transversal slope of section is adequate	
22) Circulation 22.1) for pedestrians	
22.2) for cyclists	

Check List n°4

Check List n°4 road surface – pavement markings, signing, delineation and lighting	**Weighing Factor**
Pavement Markings	
1) Adequate pavement markings	1
2) Maintenance	1
3) Consistent with vehicle movements	1
4) Visibility 4.1) during the day	1
4.2) during the night	1
4.3) with bad weather	1
5) Old pavement markings that affect the safety of the roadway	1
6) Can they indicate the correct movement in particular situations	1
Signings	
7) Location	1
8) Visibility of the signings 8.1) during the day	1
8.2) during the night	1
9) Informations of the signings	1
10) Maintenance	1
Speed Limits	
11) Location	1
12) Efficacy of speed limits	1
13) Are they consistent with the road section	1
Delineation	
14) Delineation 14.1) of the margin	1
14.2) of the centre line	1
15) Maintenance	1
16) Are they adequate to sign the presence of dangerous curves	1
17) Signing of the traffic islands	1
18) Reflecting signing on the safety barriers and on delination posts	1
19) Visibility during the night	1
Traffic light	
20) Visibility 20.1) when there are parked vehicles	1
20.2) during sunrise	1
20.3) during sunset	1
21) Perception by everybody	1
22) Warning signs when they are not visible	1
23) Security for left turn only	3
24) Device for handicapped people	1
25) Protection for pedestrian routes	1
26) Device to call the green light	1
27) Visibility of waiting pedestrians	1
28) Respect of traffic lights	3
Lighting	
29) Visibility of the road during the night	1
30) Lighting 30.1) intersections	3
30.2) road crossing	3
31) Transition through sites with different lighting	1
32) Lighting in tunnels	N.A.

Check List n°5

Check List n°5 Special road users	**Weighing Factor**
Pedestrians road crossings	
1) Location	2
2) Visibility at the road crossings 2.1) of pedestrains who are waiting (e.g. children)	
by drivers	1
2.2) of traffic flow by pedestrians	1
2.3) during the night	1
3) Coordination between pedestrian routes and road crossings	2
4) Adequate for 4.1) road width	1
4.2) traffic flow speed	1
5) Compatibility of the road crossings with speed limits	1
6) Presence of devices to moderate the speed of vehicles close to the road crossings	1
7) Space near the road crossings for waiting pedestrians	1
8) Location of road crossings to discourage pedestrians to cross in other places	1
9) Canalization devices to direct pedestrians on road crossings	1
10) Presence of devices for handicapped people	1
11) Presence of road crossings near the bus stops	1
Pedestrians route	
12) Presence of sidewalks when there is significant pedestrian flow	2
13) Width of sidewalks	2
14) Presence of obstacles	1
15) Practicability by all types of pedestrians (also handicapped people)	1
16) Continuity of pedestrian routes	2
Cyclists routes	
17) Presence of adequate cyclist routes	2
18) Visibility of cyclist routes by drivers	1
19) Cyclist routes signing	1
20) Cyclist routes width	1
21) Cyclist routes continuity	1
22) Grade of risk in the intersections	1
23) Paving of cyclist routes	1
Motorcyclists	
24) Presence of dangerous elements for motorcyclists	1
25) Suitability of paving	1

Check List n°7

Check List n°7 Pavement	**Weighing Factor**
Texture	
1) Suitability	1
Friction	
2) Friction condition 2.1) in the curve	2
2.2) in the grade with high slope	1
2.3) near the intersection	1
2.4) near road crossings	1
Surface drainage	
3) Risk of accumulation of water for defects of pavement surface	1
4) Risk of superficial streaming	1
State of road surface	
5) Presence of defects 5.1) ruts	1
5.2) superficial deficiencies	1
5.3) loose gravel or fine from road surface	1
5.4) holes	1
6) Presence of singolarity (manholes, junctions ect…) in curves and in	
decelaration sections	1
7) Paving of layby	1
8) Stability of margins	1