SAFETY EVALUATION PROCESS FOR TWO-LANE RURAL HIGHWAYS

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ABSTRACT

In the contest of the EU program " Road Safety in EU: the 1997-2001 program", the "IASP" project, proposed by the Province of Catania with the scientific support of the Department of Civil and Environmental Engineering of University of Catania, was approved and co-funded by European Commission (DG TREN).

A methodological approach for the safety evaluation of two-lane rural highway segments that uses both analytical procedures referring to road safety inspection processes and alignment design consistency models is presented. Road safety inspections (RSI) are recognized as an effective tool for identifying safety issues. However, due to the subjective nature of the process, they may give rise to disagreements which limit their effectiveness. A RSI procedure aimed at improving the effectiveness and the reliability of the methodology was defined. Many studies show that safety evaluations based on the analysis of alignment design consistency can be effective in identifying hazardous road locations. The proposed approach makes use of theoretical-experimental models for the evaluation of alignment design consistency.

A safety index (SI) that quantitatively measures the relative safety performance of a road segment is calculated from the procedure. The SI is formulated by combining three components of risk: the exposure of road users to road hazards, the probability of a vehicle being involved in an accident and the resulting consequences should an accident occur.

Validation of the procedure was carried out on a sample of roads by a comparison of the risk rank obtained using the SI and accident history. The SI was assessed in 30 segments chosen from a sample of two-lane rural highways in Italy and the actual accident situation was obtained with the EB procedure. Spearman's rank-correlation was used to determine the level of agreement between the rankings obtained using the two techniques. The results from the Spearman's rank-correlation analysis validate the SI, indicating that the ranking from the SI scores and the EB estimates agree at the 99.9% level of significance with a correlation coefficient equal to 0.8.

Keywords: road safety inspections, design consistency, safety index, ranking criteria

1. INTRODUCTION

An essential part of any road safety improvement program is the network screening, that is the identification of sites where the greatest cost-effectiveness of the safety measures is expected. Several alternative ranking criteria are used in screening (Hauer et al., 2004). The more recently proposed procedures are based on the empirical Bayes (EB) technique (Hauer et al., 2002), which aims to smooth out the random fluctuation in accident data by specifying the safety of a site as an estimate of its long-term mean. While accident data analysis is essential, it is well recognized that accident data suffer from a number of shortcomings (PIARC, 2004) and that there are clues to hazardousness other than accident occurrence (Hauer, 1996).

As a result of these considerations, it appears that the network screening can be better performed if a joint use is made of all the important clues and not only of the accident history. In the framework of the research project “Identification of Hazard Locations and Ranking of Measures to Improve Safety on Local Rural Roads” (Italian acronym IASP), funded by the European Commission (DG TREN) and the Province of Catania (Italy), a methodological approach for the safety evaluation of two-lane rural highways which uses both analytical procedures referring to alignment design consistency models and the safety inspection process was defined (Cafiso et al., 2004, 2005, 2006a, 2006b, 2006c, 2007).

Many studies show that safety evaluations based on the analysis of alignment design consistency can be effective in identifying hazardous road locations (Lamm et al., 1999, 2002). The IASP procedure makes use of theoretical-experimental models for the evaluation of alignment design consistency. However, the resulting analyses, even if effective in addressing alignment inconsistencies, do not highlight all the potential accident contributory factors. Hence, the methodology integrates the results of the models with those deriving from the safety issues evaluation made during the Safety Inspection process.

Road Safety Inspections (RSI) are aimed at identifying potential hazards, which are assessed by measuring risk in relation to those road features that may lead to future accidents, so that remedial treatments may be implemented before accidents happen. Safety inspections are recognized as an effective tool and are becoming an accepted practice in many agencies around the world. Recent researches performed in British Columbia (De Leur and Sayed, 2002) and in Italy (Montella, 2005, 2007; Cafiso, La Cava and Montella, 2007) have shown that road safety impact assessment based on RSIs can be effective. A systematic and replicable safety inspection process was defined.

From the procedure, a quantitative safety index (SI) is assessed, based on the data obtained from the RSI combined with information from theoretical-experimental models. The SI has two main applications. High-risk segments, where safety measures that can reduce accident frequency and/or severity already exist, can be identified and ranked. Specific safety issues, that give more contribution to unsafety, are pointed out in order to give indications regarding more appropriate mass-action programs.

2. THE SAFETY INSPECTION METHODOLOGY

Various countries adopted safety inspection procedures which are defined in guidelines, but they do not fully satisfy the scope of the project. In order to effectively use safety inspections as part of a quantitative road safety impact assessment, the procedure must satisfy the following objectives: 1) it must be operative; 2) it must be replicable; 3) it must rank safety problems; 4) rankings must be reliable. Defined procedure is widely described in the IASP Safety Inspection Manual (Cafiso et al., 2006a) while below only main aspects are concisely reported.

2.1 Actors Involved in the Process

Actors involved in the process are the inspection team and the client.

The team must comprise three or more people because: 1) the road inspections, due to operative reasons, require at least three inspectors; 2) diverse backgrounds and different approaches of distinct people create cross-fertilization of ideas and are beneficial in problems identification and analysis. Main requisites of the safety inspection team are independence and qualification.

The client is the road agency. Before the inspection starts, the client selects the roads to be inspected and the team. After the inspection, the client decides upon implementation of safety measures recommended by the team. An innovative aspect of the procedure is the active participation of the client in the inspection phase. The client participates as an observer to the site inspections and to the preliminary in office discussion about general safety problems.

2.2 Road Inspections and Problems Identification

More site inspections are required: preliminary inspections, in daytime, aimed at understanding the general road safety conditions and the relationships of the road segments with surrounding land use, terrain and road network; general inspections, in daytime, aimed at examining the general safety concerns along the road segments; detailed inspections, in daytime, aimed at examining in detail safety concerns of specific sites; night time inspections, aimed at analyzing the road perception without natural lighting.

In the preliminary inspections, each road is ran in both directions at normal speed, that is the prevailing traffic speed. During the inspection a video recording is performed and inspectors' comments are recorded in the same video-tape. Driver calls traveled distance and refers about corrective maneuvers and driving perception of the road. Inspectors on front seat and back seat make safety comments.

In the general inspections, the road is ran in both directions at very low speed (about 30 km/h): video recording is performed, the driver calls traveled distance any 100 m, inspectors in front and back seats compile the checklists. IASP checklists are very synthetic, since they relate only to the main safety features which usually are present along two-lane rural highways. Features which concern horizontal and vertical alignment are not considered since alignment evaluation is performed as a separate quantitative procedure. The following safety issues are assessed: accesses, cross section, delineation, markings, pavement, roadside, sight distance and signs. In order to improve safety issues evaluation, each item is divided in more detailed concerns (see Table 1 and Table 2). Checklists are filled in both directions. Front seat and back seat inspectors, which have different views of the road, compile different checklists filling the boxes with a step of 200 m (24 s at 30 km/h). In order to simplify the inspectors' task, any checklist is split in two parts: part A has to be compiled on site, part B can be compiled both on site and during the video examination performed in the office. Safety issues are ranked as: high level problem, low level problem and no problem. If an high level problem occurs, the inspector fills the gray box, if a low level problem occurs, the inspector fills the blank box. Since a good friction evaluation requires instrumented measures, the friction problems are ranked with only two levels of judgment: problem and no problem. In order to improve reliability and repeatability of the process, criteria for identifying and ranking safety issues have been defined.

Table 1 Checklist for general inspection: module for front seat inspector

	0.2	0.4	0.6	0.8	1.0
PART A					
Roadside					
Embankments					
Bridges					
Dangerous terminals and transitions					
Trees, utility poles and rigid obstacles					
Ditches					
Sight distance					
Inadequate sight distance on horizontal curve					
Inadequate sight distance on vertical curve					
PART B					
Accesses					
Dangeroussness of accesses					
Presence of accesses					

Table 2 Checklist for general inspection: module for back seat inspector

	0.2	0.4	0.6	0.8	1.0
PART A					
Cross section					
Lane width					
Shoulder width					
Pavement					
Friction					
Unevenness					
Delineation					
Chevrons					
Guideposts and barrier reflectors					
PART B					
Signs					
Warning signs, regulation signs					
Markings					
Edge lines					
Center line					

After the preliminary inspection, in the office, the team analyzes videos and (if it wasn't done on site) compiles part B of the checklists. By brainstorming among the team members, checklist results are examined and the final version of the checklists is edited. Safety issues are classified as general problems if they are present along a substantial portion of the road. General problems require mass action safety programs. The IASP Manual (Cafiso et al., 2006a) suggests for each general problem the recommendation typologies. The checklists results, the safety comments recorded during the preliminary inspection and the manual suggestions are a valid support to formulate recommendations for general safety problems. Recommendations indicate the type of measures, without specifying detailed technical issues. As final result of the meeting, a preliminary report describing general problems and recommendations is written.

In the site detailed inspections, the road is ran in both direction at low speed, stopping the car in sites which show the greatest safety problems or specific features which require investigation deepening. During the driving through photos related to general problems are taken. In selected sites, the team performs the inspections by walking and observing both the road features and the road users' behavior. Photos of identified problems and videos of dangerous behaviors are helpful both in the problem analysis and in the report writing. Road users' behavior analysis is one of the main tasks in the investigation. If critical traffic conditions occur, traffic counts (in the rush hour) and speed measurements can be acquired.

In night time inspections, each road is ran at normal speed in both directions. of the Road's videos and inspectors' comments are recorded. The day after the inspection, a meeting in the office is carried out. Videos are examined and identified problems are annotated in the report.

2.3 Final Report

For each road, a specific inspection report is written. The report is written in "problem/recommendation" format, where the problem is described in terms of safety issues and accident risk to a road user, and the recommendations are engineering solutions to the reported problem. After discussion among the inspectors, the final report is edited and signed. The report describes the analysis procedure and contains the study results, which are detailed and explained.

2.4 Reliability of the Procedure

In order to test the reliability of the methodology, the agreement of the results of the general safety issues ranks produced by different groups of inspectors for the road segments has been addressed. Specifically, with the aim of checking the consistency of the risk assignment between different inspectors, the statistic kappa has been used.

The kappa coefficient (k) provides a measure of agreement among a set of inspectors, who have rated a set of N objects using a nominal scale with M different category judgments, correcting for expected chance agreement:

$$k = \frac{P - P_e}{1 - P_e} \qquad \text{(Eq. 1)}$$

where:
P = proportion of times that the inspectors agree (0.00 ÷ 1.00);
P_e = proportion of times that agreement by chance is expected (0.00 ÷ 1.00).

If there is total agreement k is equal to 1. If there is no agreement other than that which would be expected by chance k is equal to 0. A negative kappa value indicates disagreement between inspectors.

Moreover, it is possible to test whether the level of agreement is statistically significant. When N is large (> 30), the sampling distribution of kappa is approximately Normal. Therefore, under a test hypothesis of no agreement beyond chance, the level of significance α of the agreement can be determined evaluating the probability of $k/\sqrt{var(k)}$ for a standard Normal distribution. An α of 10% can be used as level of significance.

The checklists were compiled with respect to three different two-lane rural highways with a total length of 40 km (200 segments). Each group was composed by two inspectors: one in front seat and the other one in back seat. Results reported in table 3 show that there is a significant level of agreement for the majority of the safety issues.

Table 3 K statistics and level of agreement between two inspectors with a nominal scale of three judgments

Safety issues / Calculated values	P	P_e	k	Var(k)	Significance Level (%)	Significance (α= 10%)
Roadside						
Embankments	0.753	0.721	0.117	0.0177	18.8	**No**
Bridges	1.000	1.000	-	-	-	Not significant data
Dangerous terminals and transitions	0.623	0.478	0.278	0.0063	<0.1	**Yes**
Trees, utility poles and rigid obstacles	0.324	0.368	-0.041	0.0040	74.2	**No**
Ditches	1.000	1.000	-	-	-	Not significant data
Sight distance						
Sight distance on horizontal curve	0.630	0.552	0.174	0.0062	1.3	**Yes**
Sight distance on vertical curve	0.955	0.951	-	-	-	Not significant data
Accesses						
Dangerous accesses	0.515	0.482	0.063	0.0047	17.7	**No**
Presence of accesses	0.595	0.360	0.367	0.0028	<0.1	**Yes**
Cross section						
Lane width	0.603	0.524	0.165	0.0075	2.9	**Yes**
Shoulder width	0.534	0.456	0.144	0.0057	2.9	**Yes**
Pavement						
Friction	0.905	0.909	-	-	-	Not significant data
Unevenness	0.675	0.542	0.291	0.0059	<0.1	**Yes**
Delineation						
Chevrons	0.655	0.519	0.283	0.0054	<0.1	**Yes**
Guideposts and barrier reflectors	0.890	0.895	-	-	-	Not significant data
Signs						
Warning signs, regulation signs	0.835	0.791	0.212	0.0189	6.2	**Yes**
Markings						
Edge lines	0.570	0.421	0.258	0.0036	<0.1	**Yes**
Center line	0.735	0.401	0.558	0.0034	<0.1	**Yes**

On 18 factors, 5 issues were not tested due to not significant data, 3 issues showed not significant agreement and 10 safety issues showed good agreement between different inspectors. For bridges, ditches, sight distance on vertical curves, delineation guideposts and friction the collected data were not significant for the test because the judgment expressed by both the groups assumed an almost constant value along the entire roads. Safety issues where there is not a statistically significant level of agreement are embankments, roadside obstacles and dangerousness of accesses. As far as embankments is concerned, there is indication of a slight level of agreement, since k is greater than 0 and inspectors' ranks agree in 75% of the evaluations (P = 0.753). A good evaluation of embankments dangerousness is not an easy task without stopping the car. As far as dangerousness of accesses (k > 0) and roadside obstacles is concerned, it must be remembered that they are isolated elements.

On the whole, the reliability of the procedure is satisfactory, especially if it is considered that the identification of the safety issues is a very complex task based on human evaluations and expertise not supported by instrumental measures.

3. THE SAFETY INDEX

The safety index (SI) measures the relative safety performance of a road segment. It does not take into account junctions and it refers to two-lane rural highways.

The SI is formulated by combining three components of risk: the exposure of road users to road hazards (Exposure factor), the probability of a vehicle being involved in an accident (Accident Frequency factor) and the resulting consequences should an accident occur (Accident Severity factor). General formulation of SI is as follows:

$$\text{SI} = \text{Exposure factor} \times \text{Accident Frequency factor} \times \text{Accident Severity factor} \quad \text{(Eq. 2)}$$

3.1 Exposure Factor

The Exposure factor measures the exposure of road users to road hazards, and is assessed by equation 3 as follows:

$$\text{Exposure factor} = L \times \text{AADT} \quad \text{(Eq. 3)}$$

where:

L = length of the segment under consideration (km);

AADT = average annual daily traffic [(1,000 vehicles per day)].

3.2 Accident Frequency Factor

The Accident Frequency factor depends on the safety features of the segment, which are assessed by two analysis methodologies: 1) road safety inspections; 2) design consistency evaluations and design standards check. The Accident Frequency factor is obtained by the formula:

$$\text{Accident Frequency factor} = \text{RSI AF} \times \text{GD AF} \quad \text{(Eq. 4)}$$

where:
RSI AF = Road Safety Inspection Accident Frequency factor;
GD AF = Geometric Design Accident Frequency factor.

Using scores assigned to each inspection unit (segment 200 m long) during the survey, a weighted score of each safety issue j (WS_j), ranging from 0 to 1, is computed by the formula:

$$\mathrm{WS_j} = \frac{1}{2 \times \mathrm{n} \times m_j} \times \sum_{i=1}^{m_j} \sum_{k=1}^{2 \times n} S_{ik} \qquad \text{(Eq. 5)}$$

where:
S_{ik} = score of the detailed safety issue i in the inspection unit k;
n = number of inspection units which form the section under consideration;
m_j = number of detailed issues associated with the issue j;
2 = factor to take both directions into account.

For each safety issue j the related Accident Frequency factor (AF_j) is computed by the formula:

$$AF_j = 1 + WS_j \times \Delta AF_j \times P_j \qquad \text{(Eq. 6)}$$

where:
ΔAF_j = estimated relative increase in accident risk due to the issue j;
P_j = proportion of accidents typologies affected by the issue j.

The cumulative influence of all the safety issues j is assessed by the RSI Accident Frequency factor, computed as follows:

$$\mathrm{RSI\ AF} = \prod_{\mathrm{j}=1}^{\ell} \mathrm{AF_j} \qquad \text{(Eq. 7)}$$

where:
ℓ = number of safety issues, equal to 8 in the IASP model.

Based on existing literature (Cafiso, La Cava and Montella, 2007), the relative increase in accident risk due to each issue was estimated (see Table 4).

TABLE 4 Safety effects of the issues

Safety Issue	Related Accidents	ΔAF (%)
Accesses	All	135
Cross section	Run off the road Head-on Sideswipe	15 - 100 f(AADT)
Delineation	All	30
Markings	All	20
Pavement	All	10
Roadside	Run off the road	0
Sight distance	All	50
Signs	All	20

Design consistency evaluates an overall Safety Module (Lamm et al., 1999, 2002, 2006) defining three design classes: poor, fair, good. The Safety Module is used to check the consistency of curves. With regard to the safety concerns related to long or short tangents, two design standards checks are carried out according to the criteria defined in the Italian Standards (Italian Ministry of Infrastructures and Transports, 2001): 1) maximum length of tangents (TL_{max}); 2) minimum length of tangents (TL_{min}).

The Geometric Design Accident Frequency factor (GD AF) is assessed by the formula:

$$\text{GD AF} = 1 + WS_{GD} \times \Delta AF_{GD} \times P_{GD} \qquad \text{(Eq. 8)}$$

where:

WS_{GD} = weighted score of the safety issue GD;

ΔAF_{GD} = estimated relative increase in accident risk due to the issue GD;

P_{GD} = proportion of accidents affected by the issue GD.

For a section of ν geometrical elements, WSGD is computed through a weighted mean of GDSℓ :

$$WS_{GD} = \frac{\sum_{\ell=1}^{\nu} GDS_{\ell} \times L_{\ell}}{\sum_{\ell=1}^{\nu} L_{\ell}} \qquad \text{(Eq. 9)}$$

where:

ν = number of geometrical elements that form the section under consideration;

L_{ℓ} = length of the geometrical element ℓ;

GDS_{ℓ} = Geometric Design Score of element ℓ.

Each GDS_{ℓ} (ranging from 0 to 1) was estimated (see Table 5) by analyzing the increase of the accident rate with respect to:

- poor, fair and good Design Class for the curved elements;
- check of minimum and maximum length, according Italian design standards, for tangents.

TABLE 5 Geometric design scores (GDSℓ)

Curved Elements		**Tangents**		**Related Accidents**
Good	0.2	Overall Standards Check	0.0	Run off the road
Fair	0.5	Minimum Length	0.1	Partially (50%):
Poor	1.0	Maximum length	0.1	Head-on
				Same direction and opposite direction sideswipe

The state of the art (Lamm et al., 1999) indicates an increase in accident risk on poor curved segments as compared to tangents (ΔAF_{GD}) equal to 700%.

3.3 Accident Severity Factor

Accident Severity is intended as a measure of the ratio between the number of severe accidents (injury or fatal) and the total number of accidents. Two factors were considered significant: 1) operating speed; 2) roadside hazard.

The Accident Severity factor for the segment is computed with the following formula:

$$\text{Accident Severity factor} = \left(\frac{V_{85}}{V_{base}}\right) \times \text{RSI AS}_{roadside} \qquad \text{(Eq. 10)}$$

where:

V_{85} = average 85th percentile of speed along the segment (weighted to element length);

V_{base} = base operating speed for two-lane, local, rural highways (assumed equal to the posted speed limit of 90 km/h);

RSI $AS_{roadside}$ = Roadside Safety Inspection Accident Severity factor of the segment.

Road Safety Inspection Accident Severity factor of the roadside safety issue (RSI $AS_{roadside}$) is equal to:

$$\text{RSI AS}_{roadside} = 1 + WS_{roadside} \times P_{roadside} \times \Delta AS_{roadside} \qquad \text{(Eq. 11)}$$

where:

$WS_{roadside}$ = weighted score of the roadside safety issue;

$P_{roadside}$ = proportion of accidents related to the roadside issue, equal to the proportion of run off the road accidents;

$\Delta AS_{roadside}$ = estimated relative increase in accident severity due to the issue j. This value was assumed equal to 2 considering the maximum increase in proportion of injury accidents due to roadside hazard (AASTO, 1996).

Considering that RSI $AS_{roadside}$ evaluates roadside items including embankments, bridges, dangerous barrier terminals and transitions, trees, utility poles and rigid obstacles and ditches, a weighted mean of the roadside issue ($WS_{roadside}$) is computed as follows:

$$WS_{roadside} = \frac{\sum_{k=1}^{2\times n} \max_i (Score_{ik} \times Weight_i)}{2 \times n \times 5} \qquad \text{(Eq. 12)}$$

where:

$Score_{ik}$ = score of the roadside safety items i in the inspection units k (0, 0.5 or 1);

$Weight_i$ = relative weight of the roadside safety item i (see Table 6).

TABLE 6 Relative weights of the roadside safety items

Detailed Safety Issue	Relative Weight
Embankments	3
Bridges	5
Dangerous terminals and transitions	2
Trees, utility poles and rigid obstacles	2
Ditches	1

3.4 VALIDATION OF PROCEDURE

A sample of about 100 km of two-lane, local, rural highways, located in the Province of Catania (Italy) was used in order to apply and validate the procedure. A segmentation into homogeneous sections was carried out on the basis of the geometric alignment characteristics and traffic flow volumes. Thirty homogeneous segments were obtained. From crash data collected for a five years period of accident history on the road sample, a model that predicts road segment accident frequency, using the segment length and the AADT volume as explanatory variables, was developed (Cafiso, La Cava and Montella, 2007). Generalized linear modeling techniques (GLIM) were used to fit the model, and a negative binomial distribution error structure was assumed. The crash estimates were then subjected to an empirical Bayes refinement technique (EB) to correct for regression-to-mean bias and to obtain a better estimate of the expected accident frequency. To test the procedure, comparisons were carried out between SI scores and EB safety estimates. The correlation between SI values and EB safety estimates is highly significant ($t = 9.64$, p-value < 0.001), with 77% ($R^2=0.77$) of the variation in the estimated number of accidents explained by the SI value. This means that the relationship between EB estimates and SI scores had less than 0.1% chance of occurring by accident. Comparisons between SI/L scores and EB/L safety estimates give similar results. The correlation between EB/L safety estimates and SI/L values is highly significant ($t = 9.05$, p-value < 0.001), with 75% of the variation in the estimated number of accidents per kilometer explained by the SI/L value (see Figure 1).

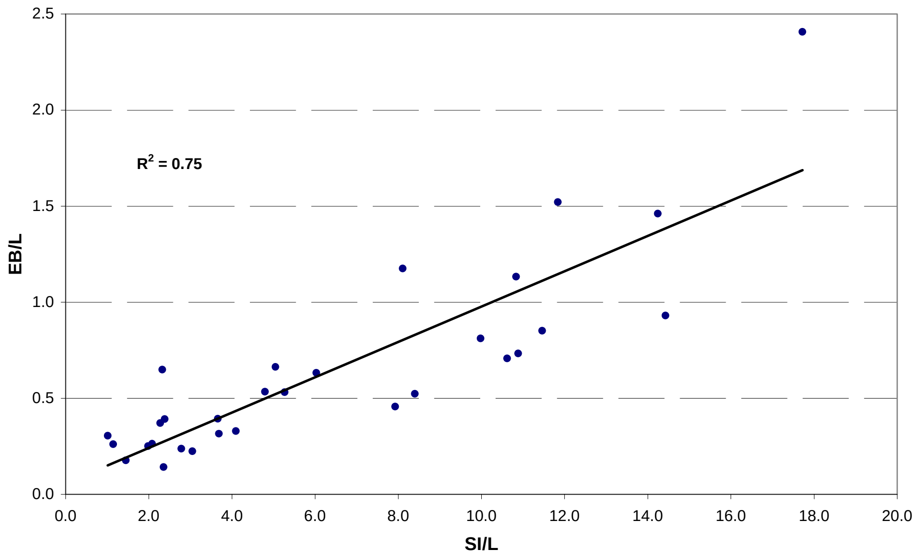

FIGURE 1 Correlation between SI/L scores and EB/L safety estimates.

Indeed, the main target of the procedure is to define management priorities with respect to road safety, to test the procedure further, a comparison was made of the rankings obtained by the SI and by the EB technique. Spearman's rank-correlation was used to determine the level of agreement between the rankings obtained using the two techniques. The results from the Spearman's rank-correlation analysis provide further validation for the SI indicating that the ranking from the SI and the EB estimate agree at the 99.9% level of significance with a correlation coefficient of 0.87. The same level of agreement is obtained if rankings from SI/L and from EB/L are compared (Cafiso, La Cava and Montella, 2007).

4. IDENTIFICATION AND RANKING OF SAFETY MEASURES

The SI has two main applications. High-risk segments, where safety measures that can reduce accident frequency and/or severity already exist, can be identified and ranked by the SI score. Specific safety issues, that give more contribution to unsafety, are pointed out by their safety index in order to give indications regarding more appropriate mass-action programs. In order to highlight safety issues effect, the safety index of each safety issue was evaluated. It was calculated assuming that all the other safety issues do not present any problem. In figure 2, as an example, the SI of the specific safety issues for the top ranked segments is reported. Geometric Design gives more contribution to unsafety in the segments 3 and 4, whereas Accesses give more contribution to unsafety in the segment 26.

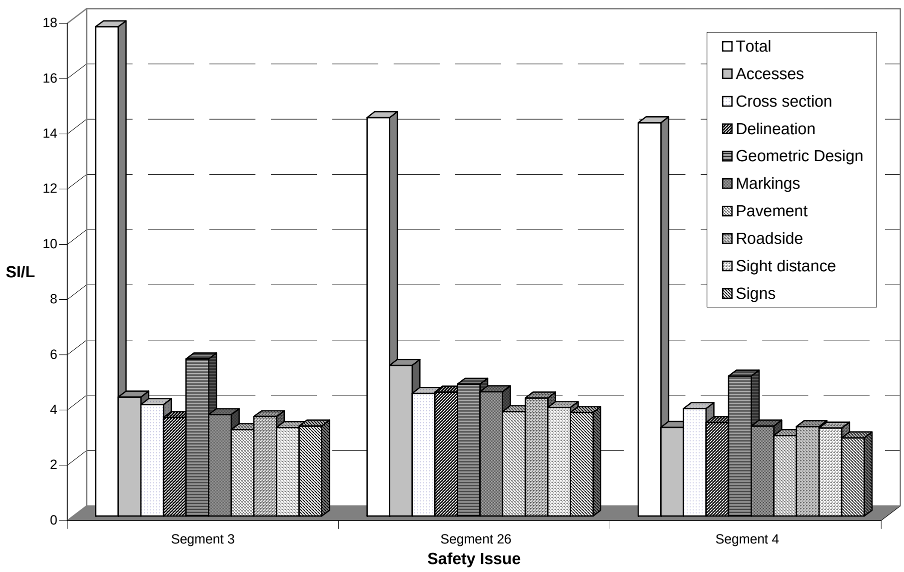

FIGURE 2 Safety Index of the safety issues.

If a specific improvement program (e.g., pavement surfacing) is planned, ranking of the sites can be performed according the SI of the related safety issue. Moreover, changes in SI due to improvement of such safety issues can be evaluated in order to define the more effective interventions priorities and mass-action programs based on available budget (see Figure 3).

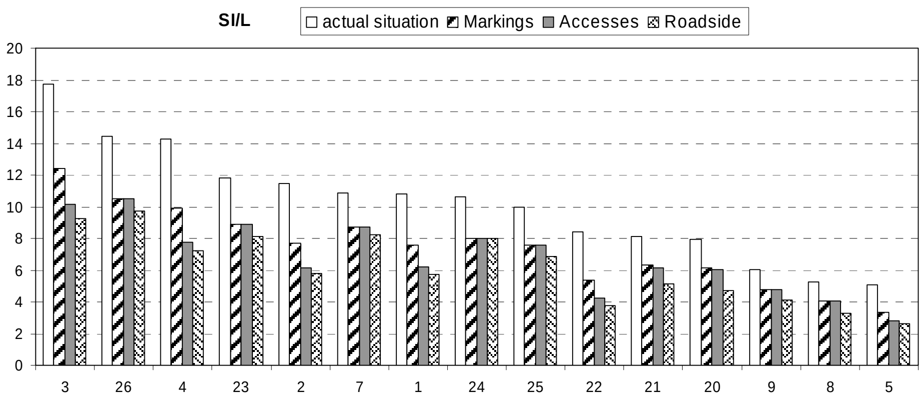

FIGURE 3 Effectiveness of improvement of safety issues.

5. CONCLUSIONS

The procedure integrates two different approaches, one based on design consistency evaluation and the other on safety inspections, and makes it possible to effectively address a wide variety of safety issues. The RSI carried out according to the defined procedures showed that there is a statistically significant level of agreement of the safety issues ranks produced by different inspectors for the majority of the safety issues. As a result, the reliability of the procedure is satisfactory, specially if it is considered that the identification of the safety issues is a very complex task based on human evaluations and expertise not supported by instrumental measures. The SI can be assessed whether accident data are available or not. If accident data are available and are of good quality, the SI can be effectively used in conjunction with accident frequency as ranking criteria. If accident data are not available or are unreliable, the SI can be used as a proxy for accident data and becomes the only ranking criteria. High-risk segments, where safety measures that can reduce accident frequency and/or severity already exist, can be identified and ranked by the SI score. Specific safety issues, that give more contribution to unsafety, are pointed out by their safety index in order to give indications regarding more appropriate mass-action programs.

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