ASSESSING ROAD SAFETY LEVELS IN A ROAD NETWORK ON THE BASIS OF UNLOCALISED ACCIDENT DATA

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ABSTRACT

In Italy, road authorities have been obliged under law to maintain sufficient levels of information regarding safety condition and quality.

Though this, safety data are not always reliable and assessing safety levels in a road network can be often very difficult due to the absence of well-localised accident data. Therefore, the management of road safety interventions becomes more and more complex and empirical.

In the light of the above-mentioned problems, the objective of this paper was to propose a method able to rank, on the basis of safety levels, the different sections of a road network in which accident data gathering has been affected by localization issues and defects.

An experimental investigation has been carried out in the road network of the Province of Reggio Calabria – Southern Italy; for each section, alignment, road conditions, accident level and where possible localizations have been examined for many years.

Statistical analyses have been performed.

When possible, accident data, traffic flows, operational speeds and general statistics have been synergistically analysed. Once set up the methodology, modelling studies have been completed through the application to the selected road sections in order to assess road safety levels and support road safety interventions.
Keywords: road network, safety, accident data

1. PROBLEM STATEMENT

As is well known, road safety issues are often managed in terms of accident indicators (such as Accident Rate), alignment descriptors (such as curves radii, curvature change rate (CCR), etc…), and other variables (V_{85}, V_{design}, etc.) concerning the functional characteristics of the road network.

Several studies [Richl et al. 2005, Polus et al. 2004, Sayed et al. 2004] have demonstrated the influence of the geometric design consistency on the safety of two-lane roads; therefore, several accident prediction models that incorporate design consistency measures have been developed.

These measures are based on the analysis of the following main descriptors:

- operating speed; this is the most used indicator of inconsistencies because when the road design violates driver expectancy, the driver usually reduces the speed of the vehicle [Poe et al. 1996, Morrall et al. 1994, Lamm et al. 1999];
- vehicle stability; a road section that doesn't provide vehicle stability can be considered as geometric design inconsistency and, sometimes, as black spot. For example, insufficient side friction at horizontal curve may cause vehicles skid out, roll-over or head-on accidents [Lamm et al. 1999];
- driver workload; it deals with the time rate at which drivers must perform the driving task that changes continuously during the trip. Two indicators related to driver workload have been proposed in literature, namely the sight distance and the visual demand [Messer 1980];
- alignment indices, that are the quantitative measures of the general character of an alignment. They reveal geometric inconsistencies when the general parameters of the alignment change significantly between two close road sections.

According to many authors, operating speeds, vehicles stability and driver workload are reliable but indirect indicators of design consistency; in fact, they measure the consequence of the inconsistency, while the geometric characteristics cause the inconsistency; so the alignment indices can provide a better measure of alignment consistency; moreover, they can contribute to individualize strategies and locations for safety improvements.

In particular, on a logical point of view, it seems that an adequate attention should be paid to the analyses of the deviations from the average values of geometric descriptors such as, for example, curve radii, CCR, tangent length, etc, and the assessment of possible correlations between the quoted deviations and accident and traffic levels.

Unfortunately, in most cases, traffic data and accident data are insufficient in terms of localization and it is not easy to link accident, traffic and geometrical features and to identify the factors that have caused the accident.

In these cases, for a reliable analysis of the safety conditions, it is possible to consider global indicators of accident and to correlate these indicators with overall alignment parameters.

In the light of above-mentioned facts, this paper deals with the management of road systems in which the localization of accident data is unsatisfactory, but, of course, a mitigation of accident statistics well-supported in logic is required.

In particular, owing to the fact that in these cases accident statistics are not properly referred to the single horizontal alignment element, this work aims to ascertain the relationships between overall alignment indices and accident rate.

The under-laying idea is to use un-localised accident data merged with localized geometric data in order to assess if an overall consideration of geometric data can explain un-localised accident data, according to the following scheme:

Accident Rate (from unlocalised data) = F(overall alignment indices).

The final goal of this study still remains to efficiently inspect the road network to meet legal obligations and responsibilities, to focus upon engineering features, to increasingly improve the linkages between safety needs and funding and to progressively apply consistency in the approach to road safety across the entire network.

In order to pursue the above recalled objectives, an experimental plan has been designed and performed.

In this stage of the study, as Figure 1 shows, the criteria for the selection of the sample of roads have been based on the location in the provincial area, on the geometrical features and on the main functions in the provincial road network.

The aim was to create a first sample of the road provincial network to reach, since this phase, explorative findings that must be optimised and validated more in detail in the successive phases of the undertaken research.

Seven roads in the Province of Reggio Calabria (Italy) have been considered:

a) SP1; which runs from Gioia-Tauro to Locri and it is about 53 km long. It was a national road, nowadays downgraded to provincial road, and links the Tyrrhenian and the Ionic side of the Province of Reggio Calabria.
   Two sections of this road have been considered: the section that runs from Gioia Tauro to Taurianova (in the following indicated as SP1(1)), and the one from Gerace to Locri, (SP1(2)).
b) SP4; which runs from Taurianova to Dinami and it is about 40 Km long. In the provincial road network, the SP4 plays an important function of accessibility to the north – west area of the Reggio Calabria Province. In the experimental plan a section of 6.5 Km long near Taurianova has been considered.
c) SP21; it is sited in the south area of the province and it is about 6.3 Km long.
d) SP22; it is sited in the south area of the province and it is about 9.5 Km long.
e) SP52; which runs from Rosarno to Mantegna, in the Tyrrhenian side of Reggio Calabria Province. It links a lot of rural communities in the north-west of the provincial area. For this road a section of 8.8 Km length, near Rosarno, has been considered.
f) SP72; it is sited in the Ionic side of the Province and it is about 10.3 Km long.

In total, approximately 90 Km of road have been considered. All the sections have two lane and carriageway width is about 9.50 – 10.00 m.

Figure 1 – Localization of the considered roads

2. EXPERIMENTS (DATA DESCRIPTION)

This section deals with the performed experiments and describes the data used for model development. In particular, traffic, geometric and accident data are analysed.

2.1 Traffic data

The traffic statistics have been collected over a period of time of 5 years. Figure 2 shows the results of a typical survey.

During the surveys also the operating speeds have been measured.

		TRAFFIC FLOW S.P.1 - DIRECTION GIOIA T.-TAURIANOVA								
Time		Vehicles	Trucks >30 q	Trucks <30 q	Trailer trucks	Articulated Trucks	Motorcycles	Bus	Agricultural vehicles	TOTAL
7,30	**7,35**	19	1	1	0	0	0	1	0	22
7,35	**7,40**	22	5	0	0	1	0	1	0	29
7,40	**7,45**	24	6	0	0	0	0	0	0	30
7,45	**7,50**	22	1	2	1	1	0	1	0	28
7,50	**7,55**	16	0	2	1	1	0	0	0	20
7,55	**8,00**	13	4	0	1	0	1	0	0	19
8,00	**8,05**	23	5	0	0	2	0	0	0	30
8,05	**8,10**	18	3	1	0	0	0	1	0	23
8,10	**8,15**	14	5	0	0	1	0	0	0	20
8,15	**8,20**	23	5	3	0	0	0	0	0	31
8,20	**8,25**	21	7	4	2	0	0	0	0	34
8,25	**8,30**	20	3	4	1	0	0	0	0	28
8,30	**8,35**	17	3	1	0	0	0	0	1	22
8,35	**8,40**	17	4	2	0	1	0	0	0	24
8,40	**8,45**	14	1	0	0	0	0	0	0	15
8,45	**8,50**	19	3	1	1	0	0	0	0	24
8,50	**8,55**	14	3	2	1	0	0	0	0	20
8,55	**9,00**	28	3	0	0	0	1	0	0	32
9,00	**9,05**	25	4	2	0	0	0	0	0	31
9,05	**9,10**	13	3	2	0	0	0	0	0	18
9,10	**9,15**	19	3	2	0	0	0	1	0	25
9,15	**9,20**	23	4	1	0	0	0	0	0	28
9,20	**9,25**	15	5	1	0	0	0	1	0	22
9,25	9,30	20	4	1	0	0	0	0	0	25
	TOTAL	459	85	32	8	7	2	6	1	**600**
	%	76,50	14,17	5,33	1,33	1,17	0,33	1,00	0,17	**100,00**

Figure 2 - Traffic survey for the road SP1

From the traffic data, recorded and referred to the peak hour, the Average Daily Traffic (ADT) and other traffic parameters have been derived.

To the aim of the present research only the total ADT has been considered and used.

Table 1 summarises the ADT related to each road. It is possible to observe considerable differences in traffic flows. In fact, the ADT ranges from 1200 up to 7700 vehicles/day.

Table 1 - Traffic data

	SP1(1)	**SP1(2)**	**SP4**	**SP21**	**SP22**	**SP52**	**SP72**
ADT (veh/day)	7700	1200	5300	2200	2500	4000	3600

2.2 Geometric data

The geometric data have been extracted from topographic plans furnished by Province of Reggio Calabria.

In many cases it has been necessary to redesign the horizontal alignment of the roads and to determine the curves and tangent parameters.

From the horizontal alignment data, the Curvature Change Rate (CCR) of each curve has been derived.

To characterise the entire alignment of roads using overall alignment parameters, several indicators such as the total length of curves and tangent and some statistics (minimum, maximum, mean and standard deviation) of curves radii, CCR and tangents length have been calculated.

Table 2 shows for each road section the quoted indicators. Also in this case it is possible to note a large range of variability of the indicators that confirms the different geometric features of the analysed roads.

Table 2 - Alignment data

	SP1(1)	**SP1(2)**	**SP4**	**SP21**	**SP22**	**SP52**	**SP72**
ROAD SECTION							
Length [m]	17598	8393	6472	6332	9527	8856	10395
CURVES							
Total length [m]	4887	2760	1941	2787	4203	3050	2951
Total length [%]	27.7	32.9	30.0	44.0	44.1	34.4	28.4
Rmin [m]	26	12	16	9	8	11	9
Rmax [m]	449	176	493	213	94	252	215
Rmean [m]	83	40	84	25	28	71	57
St.Dev (R) [m]	65	26	102	21	15	51	49
CCRmin [gon/Km]	31	120	30	425	186	57	64
CCRmax [gon/Km]	2895	6370	2548	10291	9100	3908	10617
CCRmean [gon/Km]	385	1893	554	2683	2464	815	1322
St.Dev (CCR) [gon/Km]	436	1448	566	1952	1572	737	1732
TANGENTS							
Total length [m]	12711	5633	4531	3545	5323	5806	7444
Total length [%]	72.3	67.1	70.0	56.0	55.9	65.6	71.6
Lmin [m]	21	11	83	7	8	20	17
Lmax [m]	692	1115	669	251	228	1763	1049
Lmean [m]	231	85	238	39	43	157	158
St.Dev. [m]	153	150	181	37	31	290	225

The seven roads cross hilly and mountain terrains and are, often, characterized by successive curves with short tangents (L_{min} = 7m-83m; L_{max} = 228m-1763 m); R_{min} ranges from 8 m up to 26 m, while R_{max} ranges from 94m up to 493m.

This extreme variability of the alignment data makes our database well-representative of the typical topography of the road network of the Province of Reggio di Calabria.

2.3 Accident data

Accident data were extracted from ISTAT database.

The used database records all the accidents occurred in this provincial area.

The database structure is represented in Table 3.

Table 3 - Accident data

YEAR	NAME	RECORDS NUMBER	FIELD NUMBER
1999	Prov ReggioCalabriaStrad1999	1622	160
2000	Prov ReggioCalabriaStrad2000	1332	
2001	Prov ReggioCalabriaStrad2001	1169	
2002	Prov ReggioCalabriaStrad2002	1093	
2003	Prov ReggioCalabriaStrad2003	1289	
2001	Prov ReggioCalabriaStrad2004	1123	

Each record represents an accident while the fields contain the accident information, including road name and localisation.

The information about accident localisation are given only for the main roads, while for provincial roads the accidents are not localised; therefore, for the accident occurred in the provincial roads, the information about the road name and the localisation are not available.

So, to attribute the un-localised accident to the pertinent road a filtering procedure has performed. Filtering has been carried out by means of simple e-sheet utilities (filters) on the basis of few relevant accident information such as:

a) code of town or district;
b) urban or rural
c) junction /no junction;
d) number of line;
e) one way or not;
f) pavement typology.

In this way it was possible to determine, with sufficient reliability, the accidents that were occurred in the considered road sections. Accident rates followed the determination of accident numbers.

In Table 4 are reported some accident indicators such as the number of accident injuries and deaths per year, the accident density and the number of injuries and deaths for one million of vehicles-kilometres.

It is possible to note that, in general, the number of accidents, though meaningful variations among the roads are detectable, is not elevated. This may be due to the low traffic levels.

Table 4- Accident Data

	Number of Accident per year	Accident Density [Acc/Km per year]	Injuries and Deaths per year	Injuries and Deaths per 10^6 vehic·Km
SP1 (1)	1.66	0.095	6.830	0.39
SP1 (2)	0.33	0.040	0.167	0.02
SP4	0.33	0.052	1.000	1.56
SP21	1.33	0.210	0.333	0.62
SP22	0.67	0.070	0.167	0.55
SP52	1.33	0.049	1.167	1.20
SP72	3.00	0.289	2.500	1.28

3. RESULTS AND DISCUSSION

To characterise possible correlations between geometric features of road and accident rate (AR), namely the number of accident for one million vehicles kilometres, some geometric indicators have been considered:

- the mean CCR along the horizontal alignment (CCR mean);
- the standard deviation of CCR (St.dev (CCR));
- the ratio between the standard deviation of the CCR and the alignment length (L);
- the ratio between the standard deviation of the CCR and the mean CCR.

The values of these indicators and that of the accident rate for each road are summarised in Table 5, in which a first ranking is proposed.

Figure 3 shows the correlation between the overall geometric indicators and the accident rate.

Table 5 - Accident Rate and Alignment Statistics

	CCR mean	St.dev(CCR)	Length [m]	St.dev/ L	St.dev(CCR)/CCRmean	AR
SP21	2683	1952	6332	308	0.73	0.26
SP72	1322	1732	10395	167	1.31	0.22
SP1 (2)	1893	1448	8393	172	0.76	0.09
SP22	2464	1572	9527	165	0.64	0.08
SP1 (1)	385	436	17598	25	1.13	0.03
SP4	554	566	6472	87	1.02	0.03
SP52	815	737	8856	83	0.90	0.03

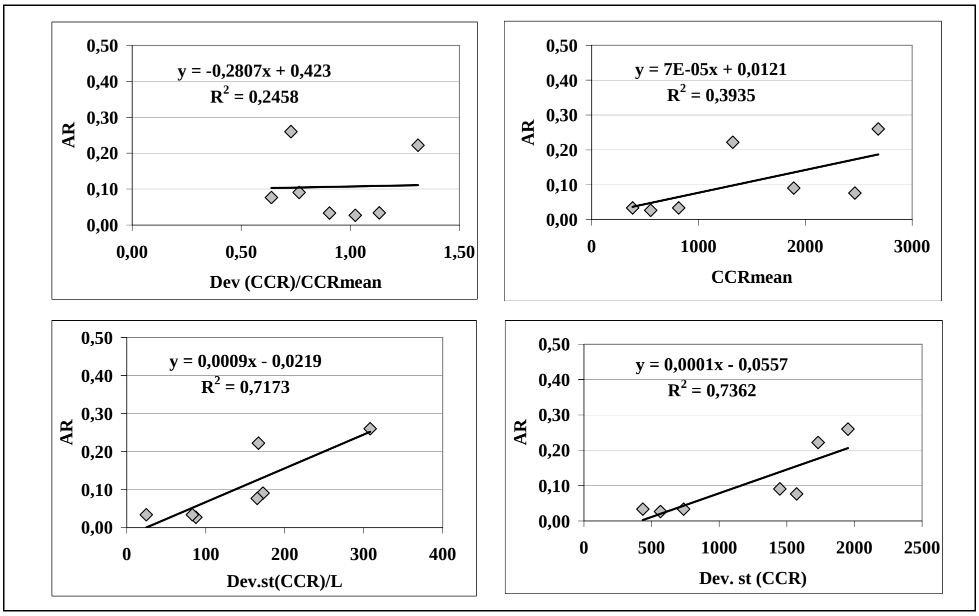

Figure 3 - Accident Rate vs Alignment statistics

Results demonstrate that, for the selected sample of road sections, the mean CCR seems not appropriate to assess safety performance of road sections while the standard deviation of CCR values is well-correlated with the accident rate. R-square values range from 0.72 up to 0.74, when the normalization to the section length is not considered.

Though more research is needed on this topic, experiments prove the representativeness of this descriptor in analysing and predicting accident issues for the considered road network.

On these bases, a ranking of the entire network can be performed and this can constitute a well-grounded key-factor in terms of road management systems.

4. CONCLUSIONS

When accident data are not reliable and/or not properly localised, the safety management of a road network can result empirical and biased.

In these cases, the aggregation of accident rates along the sections and the estimate of the standard deviation of given alignment features can be a suitable strategy to perform a first safety ranking of the road network.

In the proposed application, the formalised model has supported safety assessment in a network where data gathering has been affected by localization problems; results show that the formalised method can be used to evaluate safety levels and interventions also where accident data localisation is defective.

The standard deviation of CCR of the entire road, here introduced in order to assess the safety level of a road network, proves to be a useful descriptor.

The proposed methodology appears able to efficiently inspect the road network and to detect the highest risk sections, to meet legal obligations and responsibilities, to focus upon engineering features.

This can permit to increasingly improve the linkages between safety needs and funding and to progressively apply consistency in the approach to road safety across the entire network.

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