Research and definition of Car Accident Scenarios for Roadway Safety Managment of S.S. 372 “Telesina”

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Abstract

The present paper has been developed on traffic, car accident and geometric data surveyed on the 61 kms of the italian rural road SS (Strada Statale) 372 “Telesina”. The SS 372 starts from the motorway exit of Caianello, located on the Rome - Naples highway and ends in the town of Benevento. It has a variable cross section but in average it is about 9 m wide. The road alignment is typical of rural roads running in the hilly countryside of Campania region, southern Italy. The vertical alignment is made with several crests among upgrades but their values are lower than 3,5%; in the final part of the track heading Benevento there is just one 7% upgrade. All along the track there are many motorway exits made on different levels with small lenght acceleration and deceleration lanes.

Car accident data related to a 11 year period ranging from 1993 to 2003 have been collected and analysed from Police reports. The resulting database is made of about 180 accidents. The ANAS statistics on 3 sections of the road track have been collected too, being ANAS the Italian society deputed to the management of most part of rural roads. So, it has been possible to share the whole track in 3 parts. The ADT (Average Daily Traffic) has been supposed to be constant within each part of the road.

The preliminary general analyses done on the whole track showed not so high accident indexes. Nevertheless, the successive scenario research showed some specific matters.

First, a database of the road has been built. The database has been shared in three parts: 1) geometric data; 2) traffic data; 3) accident data. The first part has been built with the help of the existing topographic data: the whole track has been summarized with specific regard to horizontal and vertical alignment and location of motorway exits. The second part has been built on ANAS data as previously stated. The third part has been built on the police data. Accident location, traffic and road pavement conditions have been filed.

Finally, a matrix data in which the following quantities have been associated to every accident has been built: “heading (to Benevento or Caianello) of the car which caused the accident, extracted from part 3; light conditions (day or night) at the moment of the accident, extracted from part 3; road pavement conditions (wet or dry) at the moment of the accident, extracted from part 3; horizontal alignment (curve or tangent), vertical alignment (positive, negative or plan) in the area of the accident, extracted from part 1 and finally the sight distance of the point in which the car accident happened (yes or no) calculated with informations provided from parts 1 and 3. Part 2 data have been just used to share the road into three homogeneous traffic conditions. Not all components have been used to build scenarios. Finally, 96 different possible scenarios have been built. As soon as each scenario has been characterized on the temporal and spatial point of view their hazardousness has been evaluated with the accident index.

Results showed that all 3 most dangerous scenarios included the component “lack of passing sight distance”. Details showed that the first and most dangerous scenario is made with the following components: “daytime, wet, curve, lack of passing sight distance”; the second one “daytime, dry, curve, lack of passing sight distance”. So, it seems clear that the component ”lack of passing sight distance” has a prevalent influence on the hazardousness of scenarios; in order to improve safety it should be necessary to work on this component for instance by enlarging the shoulders of the road or making adequate excavation in curve.

1. INTRODUCTION

The rural road SS 372 “Telesina” has a total lenght of 61 kms and it has been built between the late 60’s and the early 70’s. It joins the highway A2 Roma - Napoli exit of Caianello with the town of Benevento. Its cross section width is variable from about 8 m to 9,5 m in the wider parts.
The horizontal alignment starts with two tangents each of them is about 10 kms long; then, the curves increase in number and the radius are included in the 180 – 3000 m range. The final part of the track is the most winding as it includes curve radius mostly lower than 200 m.
The vertical alignment is characterized by several crests both concavo and convex type and this causes lack of sight distance also in the long tangents. Generally, it is hilly type with slopes never higher than 4% except the final part heading Benevento where a 7% one is present.
All along the track there are many motorway exits made on different levels with small lenght acceleration and deceleration lanes. Also, there are gas stations located every 10 kms about. Private leveled accesses are not allowed while stop lay-by are present all along the track aproximatively every kilometer for each running versus. The buildings present on the track are mainly bridges almost all in tangent and just 1 tunnel is located close to Benevento: nevertheless its length is modest.
The trafic on the SS 372 Telesina has been evaluated through the analyses of ANAS data. ANAS S. p. A. is the italian society deputed to the managment of the most part of italian rural roads: the SS 372 is included in its database. Specifically, ANAS owns 3 survey points along the track: they are located at kms 19+050, 28+500 and 56+850. For each station, aggregated data for years 1990 and 2000 were available in ADT terms. They were available in a disaggregated way for the 2003 year. Nevertheless, 2003 data have supplied in such a way to obtain the 2003 ADT using the Geneve formula. Also, ADT of intersecting roads were supplied for years 1990 and 2000 so it has been possible to make an approximate hypothesis of trafic distribution all along the track. Finally, 3 tracks with constant ADT values have been characterized: they are showed in tab. 1.

Tab 1: SS 372 tracks with constant trafic [Supply: ANAS]

Track	Station	Start	End	ADT 90	ADT 00	ADT 03
1	19+050	0+000	20+100	na	na	13.966
2	28+500	20+100	45+350	5.920	8.442	na
3	56+850	45+350	61+000	13.021	16.878	na

Then, as traffic data relevant to every year between 1993 and 2003 were necessary, ADT values have been interpolated and increased, where necessary, with an annual growth of 3,62% for track two and 2,62% for track three. In this way, trafic data have been assigned for each year in which accident reports have been made available by competent authority. The ADT annual growth of part 1 of the track has been assumed to be 3%: it represents a value included between the growth rate of the other two tracks. The final result is showed in tab. 2.

Tab 2: ADT values for SS 372

Year	19+050	28+500	56+850
1993	10.300	6.600	14.100
1994	10.600	6.800	14.400
1995	10.900	7.100	14.800
1996	11.300	7.300	15.200
1997	11.600	7.600	15.600
1998	12.000	7.900	16.000
1999	12.300	8.100	16.400
2000	12.700	8.442	16.877
2001	13.100	8.700	17.300
2002	13.500	9.100	17.800
2003	13.966	9.400	18.200

The ACI-ISTAT yearbooks show accident data reported in tab. 3 referred to years 1995, 1997, 1998 and 1999. The ACI-ISTAT yearbook reports every year for every road where and how many accidents have happened on each rural road and highway, being ACI the Italian Automobile Club and ISTAT the National Institute of Statistics. The number of cars involved in the accidents is not available.

Tab 3: ACI-ISTAT data for years 1995, 1997, 1998 e 1999 SS 372 [Supply: ACI ISTAT]

Year	I Track [0.000-20.100]			II Track [20.100-45.350]			III Track [45.350-61.000]		
	Accidents	Injured	Dead	Accidents	Injured	Dead	Accidents	Injured	Dead
1995	2	4	3	13	35	3	7	11	0
1997	0	0	0	8	16	1	5	10	2
1998	0	0	0	12	23	3	4	10	2
1999	0	0	0	22	34	0	7	16	0
TOTAL	2	4	3	55	108	7	23	47	4

It has been determined [supply: 21] that in 1997 the average national ratio between accidents and injured was about of 2 inj. per accident and it was about 1 dead every 10 accidents. Specifically to the SS 372, the death rate of the track 2 is of 1 dead every 5,6 accidents while the injured rate is close to the national average value: this means a severity higher than average.
The values of accident indexes determined on the basis of trafic data and tab. 3 informations (evaluated later in the present paper) are not so high but we will show that for the third part only of the road the use of more complete informations like police accident reports allowed to determine high hazardousness situations.
Besides, it must not be forgotten that the cross section of the road will be adjusted to B2 type so that it will get highway characteristics. So, it is interesting to analyse SS 372 by mean of a safety management system because of the cross section change. Later, it will be possible to quantify the effectivness of the intervention on the safety point of view.
The methodology used for building the road safety management system is that of accident scenarios in rural environment. The use of this methodology involves the construction of a database shared in 4 parts: 1) road geometric data, 2) traffic data, 3) accident data, and 4) rain data. We define an "accident scenario" the set of environmental, traffic and infrastructural components in which one or more accident events happen. All components must be extracted from the database previously built.
The database construction involves the knowledge of a certain number of informations. Informations concerning environmental conditions present at the moment of accidents are partially found in the Police (or Carabinieri or other local police) reports (rain, trafic). These are useful to build part 3 of the database. Part 1 data have been deduced from ANAS topographic surveys especially made for the forthcoming enlargement works. Part 2 data have been instead extracted from the ANAS database; finally, part 4 data have been judged to have no significance in this case because of the low number of accidents reported. In fact, the number of components of scenarios to be defined based on database informations is strictly related to the accident number available.
Accident reports happened from 1993 to 2003 in the last 30 kms of the rural road SS 372 have been supplied by competent authority. In this way, 180 accident forms have been collected. These represent about 60% of total accidents happened on the SS 372 if compared with the official ACI ISTAT bullettin data.

1.1 Background

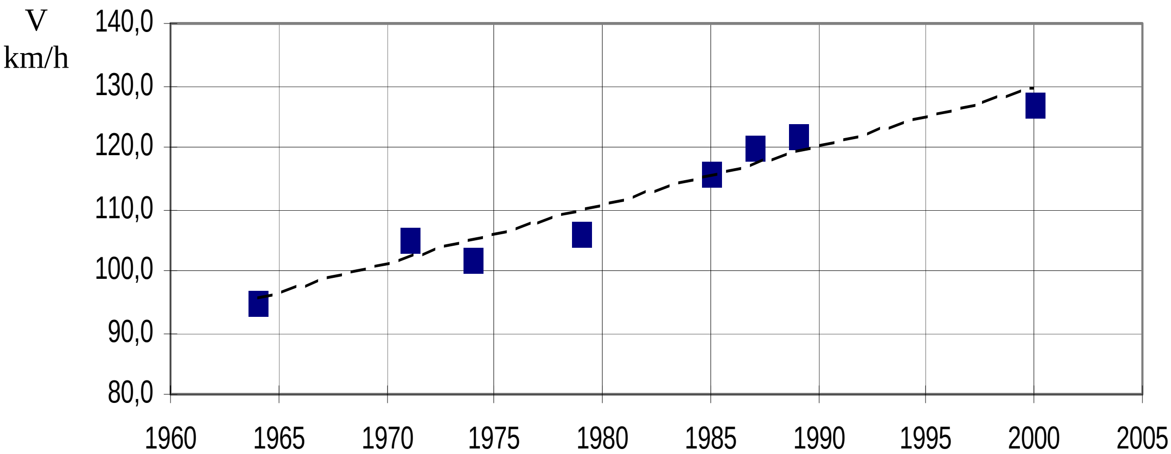
A road safety management system involves many factors. Hence, references are extensive, too many ones also after a careful selection. So, we will just cite some concerning the main parts of the system.
We can affirm that road safety studies begun in the late 50's or the early 60's. Since then, many researchers dealt with the problem of accident reduction by mean of experimental or theoretical studies. The influence of driver, vehicle and environment has been treated separately or jointly [1].
The role of risk-taking behaviour in the causation of injury has received considerable attention in the scientific literature [2] [3] [4] [5] [6] [7] [8] [9].
Many other papers study the relation between accidentality and single factors like road components, traffic components, risk exposure, environmental conditions, etc. [10] [11] [12] [13] [14] [15] [16] [17].
Others deal with all components of the system in order to define management strategies for road safety [18] [19] [20] [21].
The methodology is mostly statistics-oriented as the phenomenon is random [22] [23] [24]. Most part of studies are based on a database formed with data coming from the three components of transportation system [25] [26] [27] [28]. Results are given in form of models and usually are probabilistic [29] [30] [31] [32] [33]. One method to present results is the finding of accident scenarios hazardousness [34] [35] [36].
Finally, the other important factor involved in the road safety management is the cost-effective one. Wide references are available on this argument. We remind here works [37] [38] [39] and other 2 works concerning DSS [40] [41].

2. BEHAVIOUR MEASURES AND SCENARIO COMPONENTS

A deep analyses of driver behaviour in presence of external stimulus is necessary for managing the road

safety. We intend the driver behaviour as the set of reactions to external and internal stimulus performed with driving acts. Based on this, we intend as stimulus everything allowing a change in driving behaviour, i. e. also including the passage from a relaxed drive to a careful one. Generally, driver reactions performed with steer, brakes and throttle simply modify the direction of the speed vector. So, driver behaviour can be evaluated with the study of actual speed and its variation due to environmental stimulus. For instance, speed will be higher on the highway and will get its maximum on plain tangents, in sunny weather, daytime and low trafic conditions (desired speed).
Desired speed is affected by the continuous increase of vehicular fleet performances [Supply: 3]. Average speed measured on plain and tangent highways in daylight and sunny wheather conditions is showed in fig. 1. The draft is referred to some years of the 1964-2000 period and it shows the trend of desired speed in the 35-year period. It is possible to note that speed increases depending on the vehicular fleet performance: the increasing rate is about 1 km/h per year.

Fig. 1: trend of average desired speed in the 1964-2000 period measured on plain and tangent highways in daylight and sunny wheather conditions [Supply: 3]



Recent studies [supply: 36] developed on a part of Salerno-Reggio Calabria A3 highway allowed to evaluate the current low hazardousness of a similar behaviour. 42 scenarios obtained on the highway letting vary daylight, curve radius, upgrade value and hourly rain height have been compared: the closest scenario to the one in which drivers realize the desired speed has a very low accident index (33rd over 42).
The driver behaviour become conditioned when moving from highway driving to rural road. The behaviour can be assessed with equations (1), (2) or (3). They supply the value of 85th percentile of actual speed distribution depending on variation of curve radius and upgrade value in daytime and daylight conditions on 2 lane rural roads with low trafic volume.

$$V_{85} = 118.9 - 0.062\ CCRs \quad \text{[Supply: 9]} \qquad (1)$$

being: 118,9 km/h the unconditioned flow speed measured in tangent and; CCRs the assessment of the tortuosity track given by the sum of deviation angles existing in the observed road track shared for its lenght.

$$V_{85} = 120 - 2{,}3\,|\,i\,| - 3512/R \quad \text{[Supply: 3]} \qquad (2)$$

Being: 120 km/h the unconditioned flow speed measured in tangent;
i the upgrade value in percentage;
R the curve radium in m.

$$V_{85} = 48{,}447 - (4995{,}01/R) + 163893{,}24/R^2 + 0{,}5598 \times V_{env} \quad \text{[Supply: 17]} \qquad (3)$$

Being:
V_{env} the environmental speed given again in function of CCR i. e. of the track tortuosity as previously described.
R the curve radius.
The three formulas (1, 2 and 3) previously reported supply a speed value very close to 120 km/h. This is the maximum actual speed in 2 lane rural roads. It can also be assumed a standard deviation a bit lower than 20 km/h [supply: 3] if V_{85} is 120 km/h. This has been studied based on several speed findings. It can be noted

that these values are very far from actual speed limit of 90 km/h valid in Italy.
If compared with 2000 highway average speed of 130 km/h (see fig. 1) it is possibile to get the behavioural answer of drivers: ΔV = –30 km/h moving from a highway cross section to a simple 2 lane rural road one.
In this last case (two single lanes roadway, plain tangent, daylight, dry weather, low trafic volume and controlled accesses), direct checks on scenario hazardousness are missing; nevertheless, we are running some preliminary checks which seem to indicate that its accident index should be substantially low (see also tab. 3 for track 1).
It is possible to verify a relation between behaviour and accidentality looking at results showed in fig. 2 [Supply: 3]. They are recognized by italian rules too.
The study has been developed on the rural road SS 107 Paola – Cosenza (Calabria region, southern Italy). It clearly shows an increase of the accident rate depending on actual speed gradient between two consecutive elements of the track. The starting rate ΔV was found to be included betwen 10 and 15 km/h.

Fig. 2: Relation between accidents and speed variations along upgrades [Supply: 6]

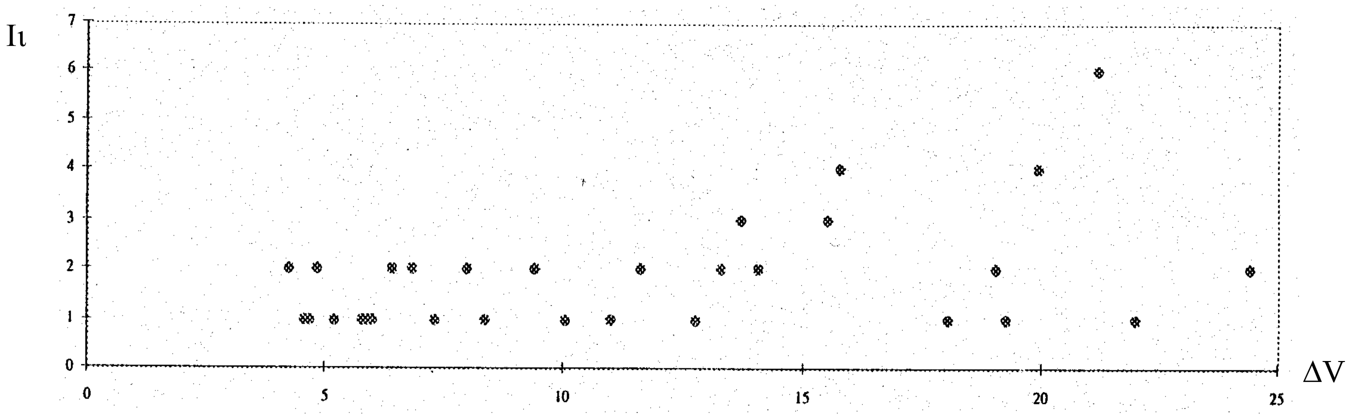
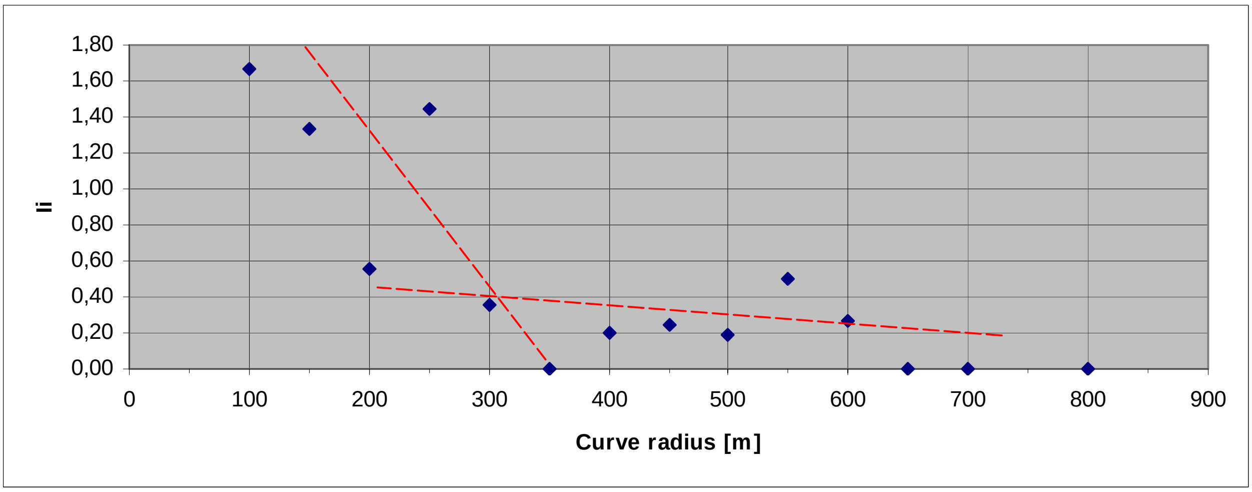
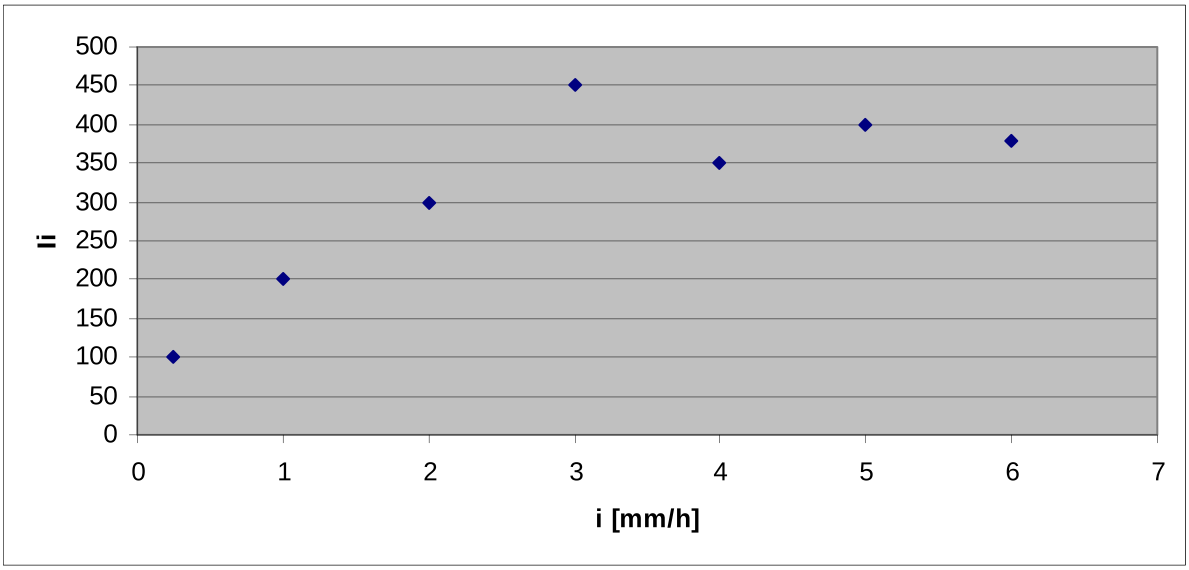


Fig. 3: Relation between accident number per curve and curve radius on the rural road SS 107 (Paola – Rende Track) [Supply: 6]



A preliminary study on accidents happened along curves of the first 24 kms of SS 107 rural road carried out results showed in fig. 3 [Supply: 6].

Fig. 4: Relation between accident index Vs rain height [Supply: 36]



The ordinates indicate the accident number shared for the curve number belonging to a specific radius class. Then, the abscissa indicates the curve radius class in which accidents have happened. Note that accidents have a small decrease with the increase of R after the value of 300 m while it has a strong increase before the 300 m value.

This, is the first sign that radius below 300 m can generate potentially higly dangerous scenarios on roads having structural characteristics similar to the SS 107 one (extraurban roads with high actual speed values). The same remark can be extended to the extraurban roads with lower actual speed (those with uncontrolled private accesses) where scenarios can become dangerous if radius are lower than 100 m.

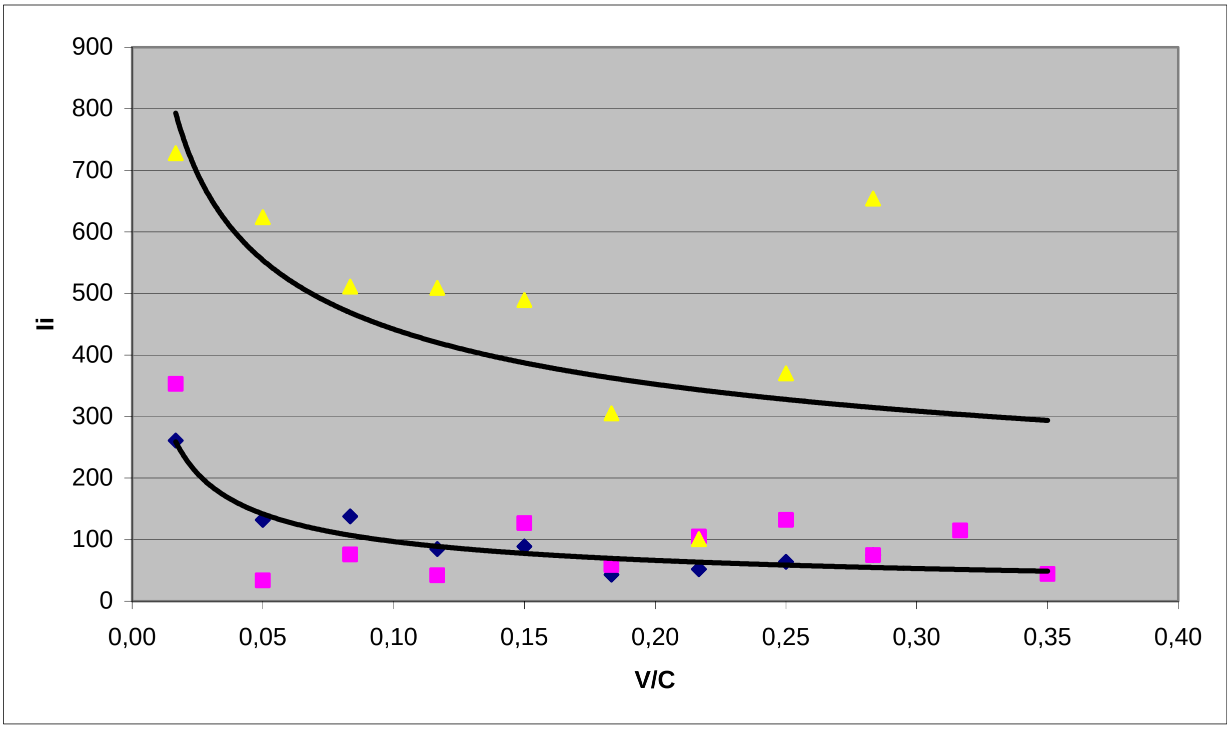
Further studies have been developed to understand how road dangerousness varies with rain height [Supply: 36]. Fig. 4 shows results obtained on a plain part of the A3 highway. The ordinates report the accident index Ii and the abscissa shows the rain height.

The trend in picture shows that accidentality increase with rain height until 3 mm/h. Then, it aproximatively remain constant.

It is possibile to keep into account of this matter with the building of scenarios with different hourly rain heights. Neverhteless, it is possible to consider only 2 approximate distinct situations; in each of them accidentality can be considered as constant varying rain height: until 1,5 mm/h and beyond this value. We intend the first case to describe the dry road situation. The building of scenarios can be simply done with the distinction of dry or wet pavement.

The last study concerning simple relations between accidentality and one single factor concerns trafic volume. This study was developed on A3 highway too [Supply: 36]. Results are showed in fig. 5 where ordinates are accident index Ii values and abscissa is the V/C value i. e. the share of hourly trafic volume and road capacity. The study was made on 2 tracks having different vertical and horizontal characteristics.

Fig. 5: Relation between accident index Vs. V/C [Supply: 36]



The two curves have the same trend: they decrease if V/C increase. This trend can be extended to the V/C values higher than those experimentally found. In fact, it is possible to suppose that accidentality increases beyond certain values of V/C, as it is possible to read elsewhere in techinical literature. Both curves diverge going towards the 0 trafic conditions. The accident index difference in the close to zero area can be intended as the hazardousness difference between the two tracks in low trafic volume conditions.
Note that comparing two different situations (in road or scenario terms) is strictly correct only if the V/C ratio is the same. Different scenarios like “day/night” or “dry/wet” would require the knowledge of the corresponding capacity value in order to be compared. As these values are not known, we will act to approximate by comparing accident indexes apart from V/C values.

3. OPERATING PROCEDURE

It is possible to prefigure several situations characterized with a different accident index if we use the experimental relations described in the previous paragraph. For instance, accidentality could be relevant for vehicles running a two-lane road in descent upgrade (>4%), radius < 300 m, rain height > 2 mm/h, low trafic volume, ΔV > 15 km/h.
The search of these situations is the base of the trafic safety study in a road network. It is necessary to have accident informations, road and network characteristics, trafic and wheather conditions in order to formulate significative scenarios.
The use of the informations is set to happen in successive phases of the study: starting from relations linking accidentality to one scenario component only (i. e. accidentality – curve radius), then mixing components by which scenarios can be characterized, finally using them in order to evaluate priorities and amount of works to be done on the road network. It is necessary that all avalaible data be collected and organized in a database so that all phases previous described be achieved. So it should be possible to extract, to modify, to combine informations to get aims previously described.
The database shape of the SS 372 has first been realized on the basis of previous works. Then, sight distance of the point where accident has happened was introduced as a scenario component. This happened because operating procedure requires the introduction of new components if preliminary analyses are not satisfactory.
In both phases the database architecture has not been changed: it has been made in the following four parts:

- The first one includes axis and cross section geometric characteristics, some infos on intersections and buildings and pavement conditions too.

- the second includes all trafic data;
- the third incudes all accident informations taken by police accident reports;
- the fourth includes all rain data.

The database includes a good amount of data. Nevertheless, not all of them are necessary and very often they are not avalaible in a useful form for the analyses. So, collected data must be selected and put in an useful way. For instance, the hour in which accident happened must be defined as “daylight” or “night” if scenarios are built adding components step by step. Otherwise, if cluster tecnique has been used now the component “daylight or night” will assume the two values 1 or 0. All data, eventually varied in the shape depending on their kind of use are collected in one matrix only: this is called the “user matrix” as it has been adapted and shaped in order to be useful to the use of database. In tab. 5 an extract of section 2 of database is showed.

Tab. 5: extract of the 2nd section of database: traffic data

Road code	Date	Progressive [km]	Heading	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11	Hour 12
372	29/01/2000	56+850	nd	546	787	986	957	956	1117	937	744	821	829	806	709
372	13/02/2000	56+850	nd	252	473	683	818	684	878	665	416	350	1486	1182	1066
372	21/02/2000	56+850	nd	1159	1391	1103	1245	1243	1159	1278	1004	953	1209	1353	985
372	08/04/2000	56+850	nd	891	1075	1278	1104	1148	1237	1188	755	826	825	998	1005
372	07/05/2000	56+850	nd	1089	1310	1172	1039	1584	1393	1598	1467	1536	1612	1761	1569
372	07/06/2000	56+850	nd	1179	1137	621	535	318	231	129	100	109	171	276	572
372	04/07/2000	56+850	nd	1251	1476	1545	1596	1700	1416	1673	1748	1590	1705	1895	1849
372	23/07/2000	56+850	nd	631	751	977	1238	1049	1075	950	639	627	838	1187	1165
372	15/092000	56+850	nd	1809	1825	1961	2105	2070	2037	2012	2071	2081	2569	2607	2357
372	12/11/2000	56+850	nd	348	577	510	642	781	737	480	743	982	900	1194	1192

The first column defines the road designation number; the second is the date of trafic survey; the third is the location of survey on the road; the fourth is the direction of trafic flow; finally, columns reporting trafic survey follow (on hour 1, 2, 3, 4 etc.).
Data showed in tab. 5 are disaggregated and they do not supply ADT value directly. So, total trafic volume must be determined with the Geneve formula. Then, ADT values will be reported in the user matrix. The following informations are also available in the user matrix:

- accident date and hour;
- accident location characterized by progressive;
- day or night light conditions; the component daylight/night has been defined on the basis of done and sunset hour for the city of Benevento (lat. 41,1 – long. 14,8); this, does not keep into account transition from one enlightmnent condition to the other;
- road pavement condition: dry or wet; as for these data we referred to police reports
- heading of the vehicle causing the accident. B means heading to Benevento, C means heading to Caianello;
- curve radius;
- upgrade value; the value is that of the veihicle causing the accident;
- Sight distance: has been evaluated as the sight distance of the point ion which the accident has happened.

The building of the user matrix for each of the three tracks meant the abandonment of the study of the first and second one. Accident data were not enough for the first track and trafic data were not reliable for the second one. So, we have just considered accidents of the third track (94 accidents over 173 totally filed in the user matrix). Tab. 6 shows an extract of the whole road user matrix. The ADT is not present ad it assumes only the value of the third track.

Tab. 6: Extract of the user matrix

date	time	Km	light	Road pav. cond.	Head.	Radius [m]	Upgr. [%]	Sight distance [m]	# cars involv.
20/10/1996	15.45	0+700	day	dry	B	∞	-0,5	264	2
05/10/1996	7.50	8+100	day	wet	B	∞	1,5	4819	2
06/10/1996	7.50	8+100	day	wet	C	∞	-1,5	2135	2
25/10/1994	7.12	12+100	day	dry	C	∞	0,3	2952	1
12/11/1993	19.00	17+100	night	wet	B	∞	-1,7	2197	3
07/08/1996	13.30	19+000	day	wet	B	∞	0	707	2
07/09/1996	13.30	19+000	day	wet	B	∞	0	707	2
12/09/1996	7.45	19+500	day	wet	B	980	0,7	445	2
07/09/1996	13.30	19+700	day	wet	B	980	0,7	361	2
21/09/1994	9.40	19+979	day	wet	C	950	-0,7	246	2
05/12/1995	13.00	21+400	day	wet	C	∞	0,2	349	1
09/02/1996	11.35	23+400	day	dry	C	1930	1,5	300	2
07/06/1999	13.00	23+600	day	dry	C	1930	1,5	246	2
21/09/1999	20.00	27+700	night	dry	C	500	0,9	105	2

Parameters in the user matrix are scenario components. Their number necessarily depends on the limited amount of available accident data. The selection of components has been done via an iterative procedure: first, environmental components (i. e. daylight or road pavement conditions) have been considered and then the others. It has been observed that the most interesting results have been obtained with the following components taken from the user matrix:

Tab. 7: scenario matrix for SS 372 “Telesina”

Scenario	D/N	W/D	C/S	Sight distance	Acc.	Vehicles involved
1	day	dry	tangent	Yes	9	23
2	day	dry	tangent	No	19	39
3	day	dry	curve	Yes	2	3
4	day	dry	curve	No	18	40
5	day	wet	tangent	Yes	6	13
6	day	wet	tangent	No	5	11
7	day	wet	curve	Yes	0	0
8	day	wet	curve	No	11	21
9	night	dry	tangent	Yes	6	14
10	night	dry	tangent	No	9	23
11	night	dry	curve	Yes	0	0
12	night	dry	curve	No	3	6
13	night	wet	tangent	Yes	1	2
14	night	wet	tangent	No	4	10
15	night	wet	curve	Yes	0	0
16	night	wet	curve	No	1	3

- Component “Enlightment”: D/N (Day/Night);
- Component “Road pavement condition”: D/W (Dry/Wet);
- Component “Tangent or curve”: if $R < 800$ m $\Rightarrow$ curve; if $R \geq 800$ m $\Rightarrow$ tangent;

- Component “Sight distance”: yes/no. The sight distance of the location of accident has been compared with the passing necessary distance. This has been evaluated with the formula Do=5,5xV being V=120 Km/h.

The choosing of 120 km/h speed has been evaluated on V_{85} (i = 0, R = ∞) values deduced by formulas reported in paragraph 2 and on the serie of pictures (shooted at 2s speed) in which the three showed in paragraph 4 are reported.
16 possible scenarios have been defined by combining the four components previously reported. Accidents happened in each of them have been considered using the third section of database. Scenarios and their related accidents happened in the third track of SS 372 “Telesina” are showed in tab. 7.

4. SCENARIO HAZARDOUSNESS

The scenario hazardousness has been evaluated using three indexes: the accident index, the frequency of accidents over total vehicles traveled, or, the frequency of vehicles involved in accidents. The lone accident number, or number of vehicles involved is not enough to establish if a given scenario is dangerous or not. It must be compared to the number of vehicles traveling along the considered road track. For instance, it is possible to have 100 vehicles involved in accidents over 10 milion vehicles running the road track within a certain time window or 1 lone accidented vehicle over 1000 vehicles running, in the same time window, the same road track. The frequency in the last case is 100 greater than the first one being accident numerosity 100 times lower.
It is necessary to use trafic data (hourly trafic data) in order to evaluate the three indexes previously described (database section # 2). This is the only way to get the true number of vehicles traveled in the scenario. For instance, let’s consider scenarios having components “night” and “wet pavement condition”: if observation period is 1 year now trafic to be considered is given by the sum of trafic volume in the night hours in which rain has happened (to be taken in the fourth section). The yearly exposure will be given by the product of yearly trafic and of scenario lenght, or, by the sum of several products if there are several trafic survey stations along the track.
If these data are missing, it is possible to have aproximate correct values by multipling total trafic volume for appropriate coefficients.
The ADT value for track 3 evaluated for year 2000 over ANAS data is 19.072 vehicles per day. This value has been manipulated in order to get other ADT values for the other years considered (from 1993 to 2003) by increasing or decreasing of 3,5% per year. The 3,5% value has been determined comparing trafic increase from 1990 to 2000 in another survey section but on the same road. ADT values have been summed 11 times (one for each year in study) getting 176.677 total vehicles.
The coefficients used for ADT are:

- 0,7 or 0,3 if scenario is “daylight” or “night”; this data has been evaluated on an average value of daily and night ADT available;
- 0,75 or 0,25 if scenario is “dry” or “wet” (dry condition or wet condition for road pavement); we made the hypothesis that 90 days over one year are rainy ones;
- lenght of tangent part (12.340 m) or curve part (3.812 m); lenghts must be multiplied for 0,63 if scenario is without sight distance in tangent and 0,79 if without sight distance in curve; if sight distance is available, values to be adopted are those complementary to 1.

Once defined the exposure, it is possible to get the accident index: number of vehicles involved/exposure; this value has been multiplied for 10^8 to be more readable. The frequency has been evaluated as number of vehicles involved/number of vehicles traveling the scenario x 10^8. Tab. 8 shows scenarios ordered with the highest accident index first.
Once defined scenarios and their hazardousness level it is possibile to characterize some interventions allowing to modify scenarios in such a way that their hazardousness could be reduced.
For instance, scenario # 8 “daylight, wet pavement, curve, without sight distance”, is the first in hazardousness order. It could be modified in scenario 7 “daylight, wet pavement, curve, with sight distance” with suitable works on the road. Scenario 7 has no accidents recorded within available data. Scenario 4 “daylight, dry pavement, curve, without sight distance” can be modified in scenario 3 “daylight, dry pavement, curve, with sight distance”. It is possible to assume an accident index reduction from 40 x 10^-8 to 11 x 10^-8.
In both cases, the component to be modified is sight distance in curve. So, interventions on axis geometry and/or cross section enlargments must be taken into account.
Another possible intervention for scenario 8 is the building of a draining pavement along curves having R<800 m. The scenario 8 would move into scenario 2 so that accident index changes from 63 to 40 due sliding reduction.

Tab. 8: Scenario matrix including accident index and frequency

Scenario	Exposure	Acc. Index x10^8	freq.x10^8
8	33.519.733	63	190
4	100.559.199	40	120
14	37.085.103	27	210
5	50.820.326	26	119
1	111.255.309	21	96
10	111.255.309	21	163
9	65.340.420	21	96
16	14.365.600	21	63
2	259.596.036	15	117
12	43.096.799	14	42
6	86.531.907	13	101
3	26.730.926	11	9
13	21.780.140	9	41
7	8.910.309	0	0
11	11.456.111	0	0
15	3.818.704	0	0

The third scenario is # 14. The relatively high accident index has been generated by the low exposure (much lower than the other 5 next) and by the just 4 accidents with 10 vehicles involved surveyed by police. These statistical data are not enough to make hypothesis on interventions to be done on the road track in order to reduce scenario hazardousness. Nevertheless, by applying just for instance the procedure described in the present paper, we note that scenario 14 “night, wet pavement, tangent, without sight distance” accident index is mostly linked to accidents happened next to roadway exits. So, it could be possible to build an enlightment equipment next to motorway exits so that scenario 14 would be moved to scenario 6 “daylight, wet pavement, tangent, without sight distance” reducing the index from 27 to 13.

Picture 1: SS 372 Telesina heading to Benevento

A good but not cost-effective solution could be to double the cross section as the lack of passing sight distance is one of the prevailing causes of SS 372 hazardousness.
An inspection on the road has been done and several pictures have been taken. Note the sequence of pics

1, 2 and 3, fired with a digital camera at 2” speed.

Picture 2: SS 372 Telesina heading to Benevento

Picture 3: SS 372 Telesina heading to Benevento

The risk taken by Fiat Punto while overtaking the car where pics were taken from is clear. The passing started at pic. 1 when the vehicle coming from the opposite direction (the red one) was not visible yet (time: 0.00 s). Luckely, the passing was completed without problems but just while the red vehicle came alongside

the Fiat Punto (time: 4.00 s). It is not possible to establish if the red vehicle had to slow down in order to let the Fiat end the passing.
Even though doubling the cross section can be considered a valid option, it is not possible yet to say if this is the best intervention to be adopted. In fact, it is necessary to quantify the intervention effectivness in term of accidentality reduction with a network analyses. Then, it will be possible to establish if this could be one of the prioritary interventions within a network management program.

5. CONCLUSION

Accident analyses happened on SS 372 based on ACI-ISTAT data supplied values that if compared with average national indexes show a not specifically alarming accidentality. Next study, based on police reports showed instead an accident concentration over some particularly dangerous scenarios. Details show that the three most dangerous ones (see tab. 8) have as a common component: the lack of passing sight distance. Their high accident rate is also due to the high presence of heavy vehicles.
Besides, the methodology described in the present paper allows to characterize possible interventions for decreasing road accident rate. This can happen if a dangerous scenario is moved into another less dangerous one by modifying its infrastructural layout.
For instance, the most dangerous scenario "daylight, wet pavement, curve, lack of sight distance" can be moved into scenario 14 "daylight, wet pavement, curve, with sight distance". The last one resulted a scenario without accidents in the context analysed. In this case, cross section enlargments or earth moving will have to be acted in order to improve sight distance. The total cost can be evaluated by the sum of intervention projects. This can be compared to the monetary advantage coming from the accident decrease. If accident decrease worths more than intervention now this can be accepted, otherwise not.
It is possible to formulate a road safety managment strategy by applying the procedure described in the present paper to a road network managed by one entity only. Data must be more extensive than those presented in this work but results could be more reliable. An attempt has already been done with the ANAS network in the Cosenza county, southern Italy.
Once characterized scenarios and put them in decreasing dangerousness order, accidentality reduction can be obtained by moving a dangerous sceanario into one following in the chart. Every moving can be characterized by a price of intervention and by a social benefit (i. e. the reduction of accident cost.). Choosing one way or the other can be done in several ways: the most useful one consists in maximize the total benefit if given a determined cost.
In this way the method described in the present paper works like a Decision Support System (DSS) for the management of a road network.

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