An Experimental Investigation On The Relationship Between Speed And Road Geometry

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SYNOPSIS

In this work we had to face the topic of intrinsic road safety experimentally by investigating two interurban roads. These roads are characterised by different types of traffic. The results of the investigation are given in the form of prediction relations with their relevant speed diagrams.
The present investigation, to be carried out in the field, intends to verify, on some sections considered as significant, the relationship and mutual incidence between the variables flow, road geometry and speed. In the processing of the results, use will also be made of specific instruments for evaluating the geometrical consistency of the road alignment in accordance with operating speed.
Our experimental investigation aimed at studying operating speeds on two different categories of roads as regards both importance and circulation. First of all we selected the road samples which belong to the A18 Messina-Catania motorway and to the SS 626 Licata-Ravanusa state highway.
The study contemplated the use of a laser beam speedometer and some digital camcorders.
In each section we considered two cross-sections at the same time, one on a tangent and one on a curve. At the same time, we also measured traffic flows which were subsequently disaggregated according to all the calculation parameters necessary to establish the level of service.
In order to have a clearer interpretation of the experimental evidence and to propose some prediction relations we analysed the rapport between V_{85} and some geometrical parameters like CCR_s, CCR, i_s and i.
Both prediction relations and their determination coefficients show that it is the simultaneous and synergic action of planimetric and altimetric elements that determines a high degree of correlation to V_{85}.
In both road samples we found that operating speed values are almost always higher than the design speed of the geometrical elements considered.
On the other hand, a general increase in operating speed involves very small speed variations in the transition from one element to the other. This leads us to think that the layouts are appreciably consistent, as can be seen from the diagrams prepared on the basis of the prediction reports V_{85}-CCR_s-i_s.
As for the motorway sections studied, this datum conflicts with what the curvature planimetric-design speed diagrams, prepared on the basis of the present Italian geometric design standard, affirm.
We think that these prediction relations could become behavioural models, on the basis of more thorough studies, referring to a specific category of road geometry characterised by a specific mobility function.
Moreover, the values of the evaluation parameters of the consistency of the road should vary – although the intervals should always be small – in relation to both the geometrical and functional characteristics of the road.

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INTRODUCTION

The fact that when planning we consider behavioural models which help us to interpret driving processes testifies to the importance of the user's role in determining the safety conditions of any road facilities.
The relationship between the user and the road environment – which is made up of the road, its surrounding areas, traffic and weather conditions – is particularly complex. Users have to decide how to drive on the basis of both their physical and mental states, using their perception, acquisition and elaboration capabilities to filter the visual information which is taken in while driving.
The quality of this information also depends on road design that can guarantee some necessary basics – such as readability, predictability and consistency – which can make a road safe. Consistency is a very important parameter when talking about the level of intrinsic safety of a road; this can be measured by means of speed parameters. When evaluating existing roads, the kinematic parameter is the operating speed that, by definition, is statistically representative of the prevailing real conditions corresponding to the free flow.
Thanks to surveys carried out on different interurban roads, which in the majority of cases have a two-lane rural roads, scholars from different countries have together gathered some prediction models of operating speed based on exclusively geometrical variables which are useful when designing to evaluate the consistency of a road layout beforehand.
On the other hand, geometric design standards in several foreign countries prescribe operating speed as the estimation kinematic parameter for dimensioning planimetric and altimetric elements. In Italy, instead, evaluation of both consistency – developed by means of a planimetric curvature-speed diagram – and dimensioning is carried out on the basis of the design speed.
This assumption can be dangerous as regards this type of road – especially when considering main and secondary interurban roads – since design speeds are often lower than operating ones, as demonstrated by a vast experimental sample. Hence, after carefully examining a number of foreign geometric design standards, we thought we had to face the topic of intrinsic road safety experimentally by investigating two interurban roads, one freeway and one highway. These roads are characterised by different types of traffic. The results of the investigation are given in the form of prediction relations with their relevant speed diagrams.

A CRITICAL ANALYSIS OF DESIGN STANDARDS AND GUIDELINES

Several studies concerning road safety recognise that there is a strong link between safety standards on any road and the capability of the latter to generate behaviours in the user which are consistent with the real potentialities offered.
Usually even a very binding element, when inserted in the right context, does not represent a risk. Dangerous conditions – that is to say conditions that herald anomalous behaviours – arise above all when the road elements do not match users' expectations.
In this view we can understand the efforts made by several countries to refine the procedures which allow us to evaluate correct road design in terms of consistency. Nevertheless, the gap between the effort made to find parameters mirroring users' behaviours and the slowness with which geometric design standards adopt these indications is still wide.
It is worth stressing that in spite of the fact that scientific research in the United States has reached important results in evaluating design consistency through the analysis of V_{85}, geometric design standards in that country still do not allow substantial changes in road design criteria.
An analysis of the geometric design standards in some countries, among which Italy, confirms the habit of using speed both as the main parameter for dimensioning the most binding elements of the road and for evaluation procedures, when contemplated; it also shows that nowadays a speed parameter capable of better interpreting users' behaviours is used more and more, thus replacing the traditional design speed.

As regards the establishing the values of some planimetric and altimetric elements of the layout, the French, English, German and Australian geometric design standards introduce operating speed (V_0), which usually matches the speed exceeded only by 15% of the users (V_{85}), so as to consider the conditioning users experience while driving and how the latter react to external circumstances. Considering the above mentioned speed involves determining it and contemplates while planning the definition of specific prediction models which allow us to calculate the operating speed on the basis of the geometrical elements of the road layout. However, although these regulations, by introducing operating speed, point out the need to define an evaluation parameter which is more appropriate than the design speed, they are nonetheless poor as regards prediction aspects and this is due to the fact that the current V_{85} formulations are not thorough yet. This obstacle could be overcome by deriving V_{85} from experimental surveys which, properly interpreted, would allow us to create reliable enough prediction relations. Moreover, it should be stressed that the current models have been developed for and applied to two-lane rural roads.
As regards dimensioning of the binding elements of the layout (**R_o** *horizontal radius*, **A** *parameter of transition curve*, **L_T** *length of tangent*, **L_c** *length of circular curve*, **D_{S1}** *stopping sight distance*, **D_{S2}** *passing sight distance*, **q** *superelevation rate*, **i** *grade*, **$R_{V,sag}$** *radius of sag vertical curve*, **$R_{V,crest}$** *radius of crest vertical curve*) some countries, among which Italy, Switzerland, Spain, Belgium, Canada and United States, have geometric design standards which contemplate the calculation of limits just on the basis of design speed, thus neglecting the well-known considerations about documented deviations between the latter and the actual speed on the road.
The following synoptic chart (Table 1) shows how design speed (V_p) and operating speed (V_o) have a part in the layout all over the world.

Table 1: Dimensioning of the elements of the road depending on speed

COUNTRY	HORIZONTAL							VERTICAL		
	R_o	A	L_T	L_c	D_{S1}	D_{S2}	q	i	$R_{V,sag}$	$R_{V,crest}$
France	V_P	-	-	-	V_o	-	V_P	-	-	V_o
Germany	V_P	V_P	V_P	V_P	V_o	V_o	V_o	V_P	V_P	V_P
England	V_o	V_o	-	-	V_o	V_o	V_o	-	V_o	V_o
Italy	V_P	V_P	V_P	V_P	V_P	V_P	V_P	-	V_P	V_P
Spain	V_P	V_P	V_P	-	V_P	V_P	V_P	V_P	V_P	V_P
United States	V_P	V_P	-	-	V_P	V_P	V_P	V_P	V_P	V_P
Switzerland	V_P	V_P	V_P	V_P	V_P	V_P	V_P	V_P	V_P	V_P
Australia	V_o	V_o	*	*	V_o	V_o	V_o	V_o	V_o	V_o
Belgium	V_P	V_P	*	*	V_P	V_P	V_P	V_P	V_P	V_P
Canada	V_P	V_P	*	*	V_P	V_P	V_P	V_P	V_P	V_P
"-" indicates an element independent of speed; "*" indicates not available information										

As regards the procedures which allow us to verify the consistency of layouts, the regulations analysed share the need to define reliable evaluation criteria: the Italian and Swiss geometric design standards introduce the concept of speed diagram. Moreover, the evaluation process is based on the assumption that the travelling speed only depends on the curvature of the elements of the horizontal alignment; a judgement on consistency is formulated on the basis of respecting limit values when it comes to changing the design speed of elements present along the road.
The Spanish geometric design standards do not contemplate any significant indications as regards consistency evaluation; by contrast, the German geometric design standards contemplate an iterative evaluation process which aims at making V_{85} as similar as possible to the design speed. Moreover, it is worth stressing the importance of attempting to find prediction models which are valid for the operating speed.
Australia too has felt the need to verify design consistency so as to see the real behaviour on the users' part and their real expectations: this is the reason why a regulation defining the environmental speed has been introduced. This speed corresponds to the speed of the 85^{th} percentile which is the speed the user keeps due to the surrounding environment and to the function of the road.
Only in France the evaluation is carried out by examining the visibility conditions on the road by means of a reiterative criterion based on the comparison between the sight distances measured on the basis of V_{85} and those offered by the designed road.
In Belgium and Canada designing takes place considering conception speeds that are similar to the design speed and there are no significant criteria to evaluate consistency.
It is worth stressing that the criteria used at the moment to evaluate the consistency of road layouts are always independent of their profiles, although the incidence of the vertical alignment is seen more and more as a determining factor in defining V_{85} [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20].

EXPERIMENTAL INVESTIGATION

V_{85} prediction models which take into account the influence road the environment has on driving can hardly be generalised due to the great variety of possible scenarios. However, once such variables as category and function of the road, main type of users and characteristics of the traffic have been identified, we can determine some relationships which are valid not just locally. As a consequence, it is opportune to widen the sample of roads studied.

Our experimental investigation aimed at studying operating speeds on two different categories of roads as regards both importance and circulation. First of all we selected the road samples which belong to the A18 Messina-Catania motorway and to the SS 626 Licata-Ravanusa state highway. We had access to practically all the design papers necessary to choose what parts to study.

Within each road layout we identified some parts according to the tangent-circular curve horizontal sequence, choosing homologous elements that have similar – or at least comparable – length and radius. In particular, the choice of the sample on the motorway was based on the criterion of having circular elements with a radius below 700 m, while as regards the state highway the radius had to be less than 600 m. This was decided because we wanted to see whether during the transition from the tangent to the circular curve, having a relatively small radius, the speed was different from what was expected.

This first group of roads gave rise to the definitive sample studied. The latter was considerably smaller – it was made up of a sequence whose physical configuration in the surrounding areas made it possible to have ideal positioning (suitable standing height and distance from the edge of the roadway) and to keep the equipment hidden from drivers, parallel to the medial cross-section of both the tangent and the circular curves.

The study contemplated the use of a laser beam speedometer connected to a PC having a specific software which elaborates signals translating them into flow and kinematic data and some digital camcorders. The PC has measurement precision higher than 99.5% and was successfully tested by measuring the speeds imposed a priori on vehicles circulating on tracks closed to ordinary traffic. Measurement by means of digital camcorders took place according to the chart below (Fig. 1); it made use of two level rods placed at a b_r (*reference base*) distance from each other on the edge of the roadway.

Fig. 1: Chart of camcorder measurement and measurement positioning

The camcorder was placed outside the roadway, at a distance *d*; its shooting angle, within which the above-mentioned level rods were placed, also intercepted the bases b_1 and b_2 which represent the calculation bases to establish the speed of the vehicles. The optical axis of the camcorder was perpendicular to the middle of the reference basis.

The trajectories of the vehicles are supposed to be centred with respect to the lane width; moreover, considering the brevity of the calculation bases, we can reasonably suppose that motion is uniform along them. After the shooting was finished, images were downloaded onto the PC whose imaging software allows us to see one frame at a time (1 frame = 1/25 sec). In this way, at each single passage, we could count the frames needed to cover one of the two calculation bases and then deduce the speed.

When the speeds of the vehicles are not perfectly centred with regard to the lane, there could be differences in the calculation bases. These differences could lead to mistakes in evaluating the speed. We avoided this risk by making sure that the distance d between the reference base and the camcorder was not too small. In

this way the differences between the assumed calculation bases and the ones resulting from possible shifting are slight and do not substantially influence the calculation of the speed.
To verify the reliability of the camcorder measurement system we carried out several preliminary surveys on existing interurban roads during which we used a laser speedometer together with the digital camcorders, which confirmed the measurements. The results of this verification are shown in the chart below (Fig. 2).
You will see that there is a substantial coincidence between real speed data, assumed on the basis of what was recorded by the speedometer, and data observed through the camcorders.

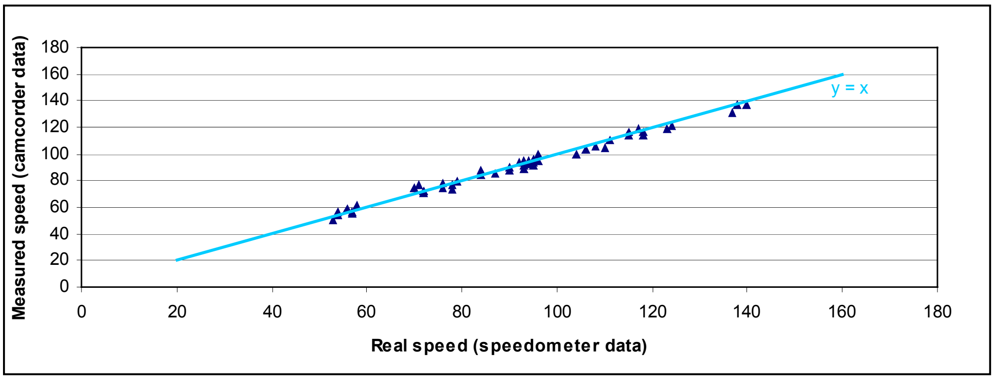

Fig. 2: Data camcorder versus data speedometer

Measurements on SS 626 dir.

State highway SS 626 dir. is in Agrigento province; considering its geometrical and functional characteristics it can be included in the C1 category (secondary interurban road): its typical cross-section is made up of two lanes that are 3,75 m wide; the shoulder is 1,5 m wide and the range design speed is 60-100 km/h.
The road has a total length of 39,223 km and from a horizontal point of view it is made up of tangent, clotoids and circular curves whose radius varies between 350 and 1.025 m. From an vertical point of view the road is flat and the maximum grade is 4,8%. Users are mostly habitual and they mainly live in the area.
First of all, we observed the flow conditions in the sample interurban road chosen so as to establish the most ideal times to carry out the survey.
The speed measurements concerning the vehicles driving on just one lane were carried out on two sections each characterised by a tangent-clotoid-circular curve sequence (Fig. 3); you will also see the measurement positions (A-speedometer and T-camcorder). In each section we considered two cross-sections at the same time, one on a tangent and one on a curve. At the same time, we also measured traffic flows which were subsequently disaggregated according to all the calculation parameters necessary to establish the level of service.

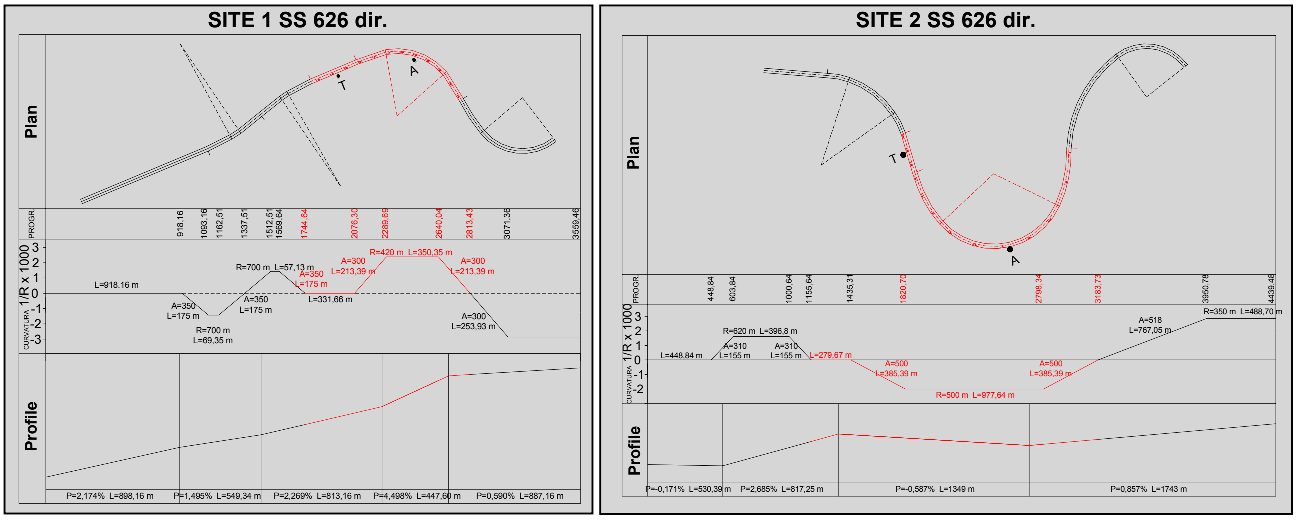

Fig. 3: Plans and profiles of sites on SS 626 dir.

The survey was carried out on weekdays in the day; the weather was fine and the road surface was dry and in perfect condition. An example of field speed data and the results regarding each site are shown in the figure 4 and table 2: you will see the days on which the measurements were carried out, the data regarding the traffic Φ_t (total flow), Φ_c (flow on the lane) and the percentage of heavy vehicles (%P). The table also includes the kinematic data (average speed Vm and operating speeds V_{50} and V_{85} which concern just light vehicles as regards the two elements in the planimetric sequence) and the level of service LOS.

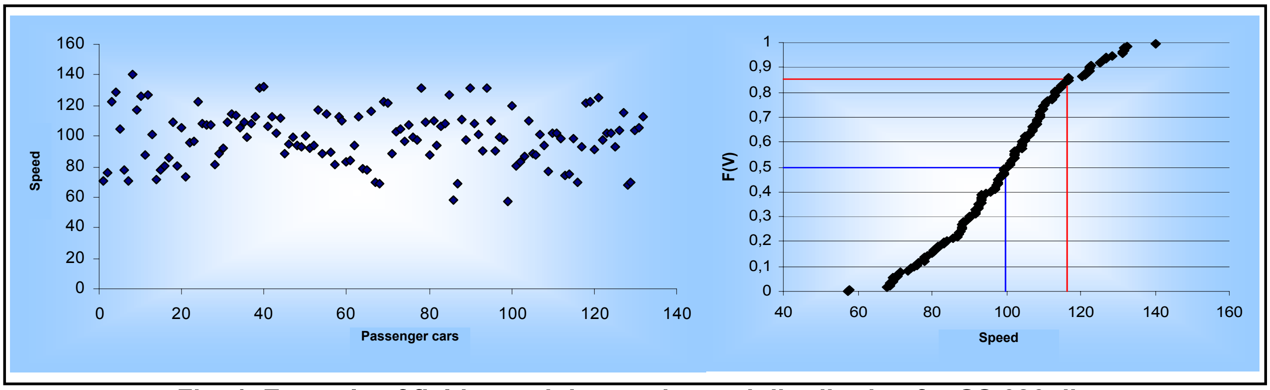

Fig. 4: Example of field speed data and speed distribution for SS 626 dir.

Table 2: Speed, traffic data and LOS (SS 626 dir.)

SITES	DAY OF MEASUREMENT	Φ_t	Φ_c	%P	LOS	TANGENT			CURVE		
						V_m	V_{50}	V_{85}	V_m	V_{50}	V_{85}
SITE 1	02/12/2003	182	106	14	B	102	103	119	100	101	117
	02/12/2003	172	95	17	B	101	100	115	94	95	113
	02/12/2003	177	93	12	B	102	101	126	97	94	121
	03/12/2003	218	143	13	B	98	99	116	92	94	110
	03/12/2003	171	72	6	A	110	106	133	100	101	119
	03/12/2003	147	54	4	A	108	107	124	98	102	112
	04/12/2003	214	132	7	B	101	102	117	97	98	114
	04/12/2003	167	93	15	B	105	104	122	98	100	116
	04/12/2003	173	80	8	A	106	108	125	102	104	120
SITE 2	16/12/2003	175	112	12	B	99	101	117	102	102	122
	16/12/2003	146	77	9	A	102	102	124	115	114	135
	16/12/2003	137	55	13	A	108	106	131	104	102	122
	17/12/2003	206	113	10	B	110	110	128	107	113	124
	17/12/2003	179	94	15	B	105	106	126	107	105	133
	17/12/2003	139	72	17	A	108	105	121	99	101	120
	18/12/2003	238	168	10	B	104	102	125	103	102	125
	18/12/2003	183	93	15	B	97	96	119	105	104	124
	18/12/2003	168	69	13	A	106	105	120	107	107	121

As regards the first site, the LOS confirms that there is always the same condition of free flow: in each element operating speeds tend to decrease when the flow within a small interval of variation increases. This confirms the hypothesis that observed speeds are determined solely on the basis of the geometrical characteristics of the roadway and the road layout.
The average speed V_m is nearly always higher than the design speed of the two elements; the speed reached or exceeded by light vehicles varies between 99 and 108 km/h on the tangent and between 94 and 104 km/h on the curve, while the operating speed varies respectively between 115 and 133 km/h and 110 and 121 km/h.
The average difference in the operating speed between the two elements of the plan sequence is about 6 km/h.
As regards the second site, there was always free flow; however, the speed is not unequivocal along the plan sequence. Instead, in most cases the value of each kinematic parameter is higher on the curve rather than on the tangent and in any case higher than design speeds.
This means that speed is also influenced by other geometrical variables which modify the expected outcome depending only on the horizontal alignment.
The average speed V_m is almost always higher than the design speed of the two elements; the speed reached or exceeded by half the light vehicles varies between 96 and 110 km/h on the tangent and between 101 and 114 km/h on the curve; on the other hand, the operating speed varies respectively between 117 and 131 km/h and between 120 and 135 km/h. The average operating speed difference between the two elements of the planimetric sequence is about 4 km/h.
The comparison between the results regarding the two sites shows that usually the operating speed is higher than the design speed and that, although both sequences have similar planimetric characteristics, operating speeds vary conversely in the transition from one to the other elements of the road.

As a consequence, we can infer that plan alone cannot determine speed trends so that in order to analyse and evaluate the influence of the layout properly we must also consider the characteristic elements of its profile.

Measurements on A18

The A18 Catania-Messina motorway connects the two biggest provinces in eastern Sicily. On the basis of its geometrical and functional characteristics, this important road can be included in Category A (interurban motorway) according to the official classification. It has two lanes which are 3,75 m wide and the shoulder on the right is 3 m wide. The median is 4 m wide and the design speed range is 90-140 km/h.
The motorway is 76,3 km long and its horizontal alignment is made up of tangent, clotoids and circular curves whose radii vary between 500 and 2.600 m. From an altimetric point of view, the motorway is flat with a maximum grade, both upgrading and downgrading, of 4%. The users are composite and vary according to the seasons due to the many tourists in the area and to the many people travelling along the road on business. Speed measurements were carried out in four sections – two heading towards Messina and two heading towards Catania. Each section was characterised by a tangent-circular curve sequence. The figure 5 shows the planimetric-altimetric scheme of each section; you will also see the measurement positions.

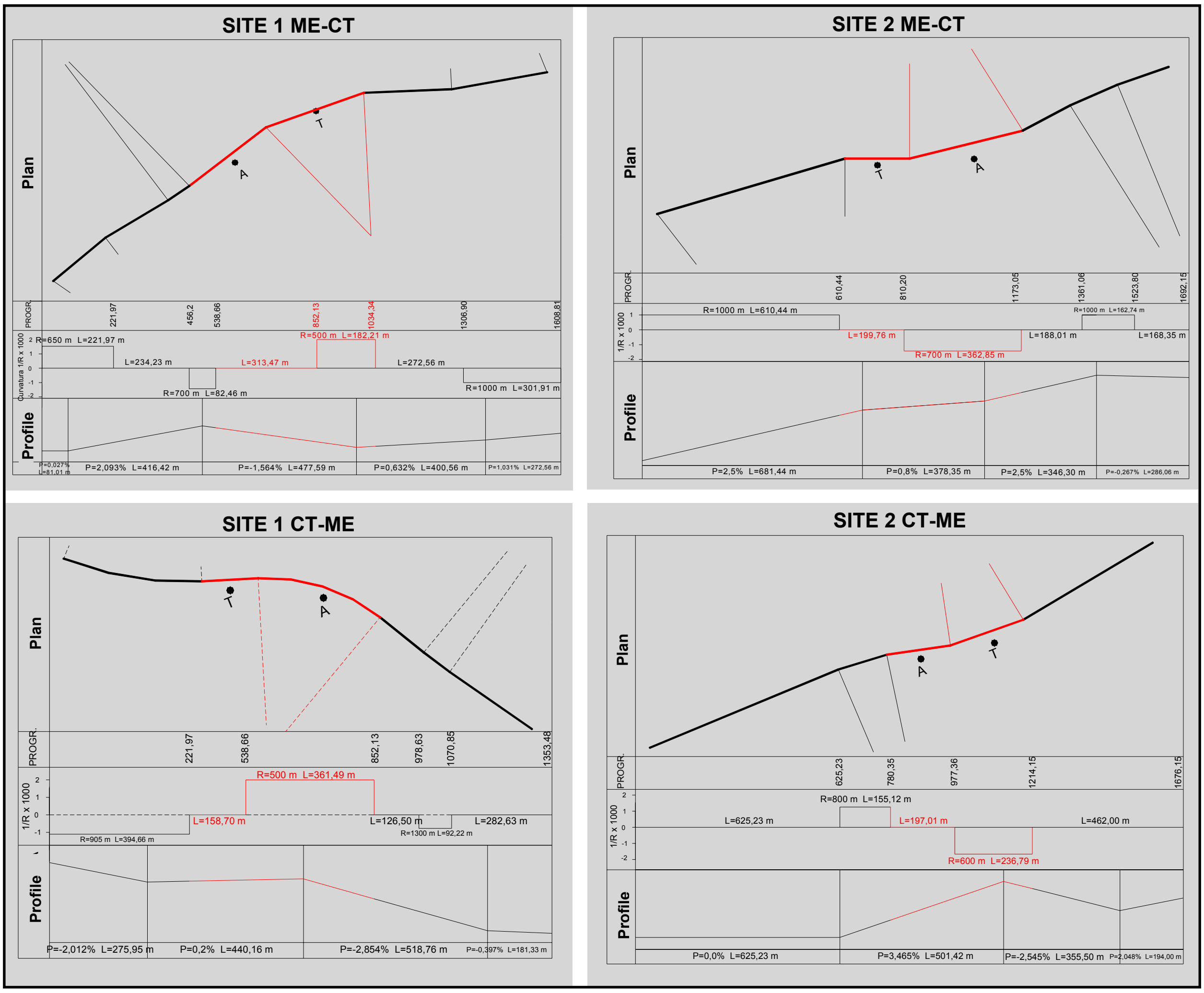

Fig. 5: Plans and profiles of sites on A18

The survey was carried out on weekdays, during the day. The weather condition was good and the road surface was in perfect condition. An example of field speed data and the results of the survey are shown in figure 6 and the table 3.

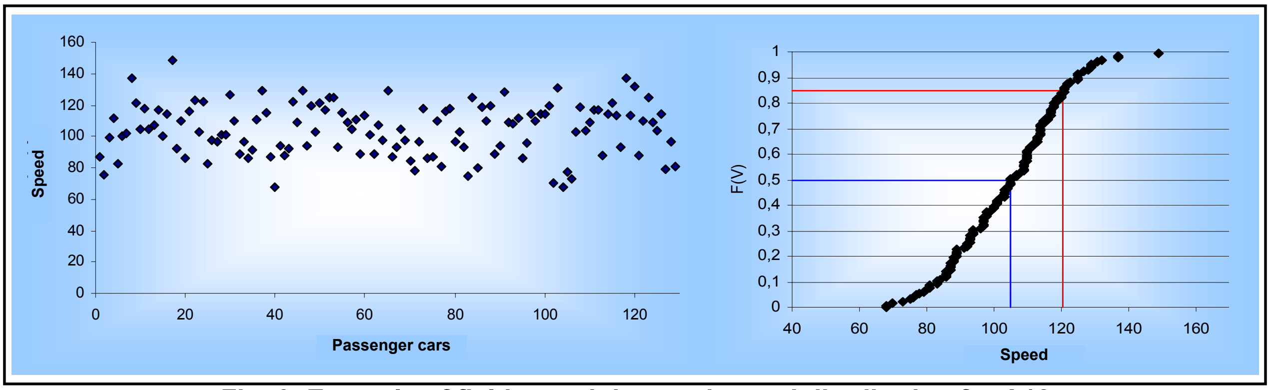

Fig. 6: Example of field speed data and speed distribution for A18

Table 3: Speed, traffic data and LOS (A18)

SITES	DAY OF MEASUREMENT	Φc	%P	LOS	TANGENT			CURVE		
					V_m	V_{50}	V_{85}	V_m	V_{50}	V_{85}
SITE 1	18/02/2004	636	19	A	117	115	133	107	106	121
	19/02/2004	548	15	A	119	119	138	107	109	121
	20/02/2004	576	19	A	123	122	147	108	112	123
SITE 2	19/02/2004	384	15	A	112	110	130	108	105	127
	20/02/2004	656	19	A	119	120	140	114	113	133
SITE 3	17/02/2004	544	22	A	116	114	135	114	113	131
	17/02/2004	540	21	A	117	118	135	116	117	134
	18/02/2004	612	14	A	113	113	132	115	115	133
SITE 4	18/02/2004	820	6	A	120	118	142	114	114	131
	19/02/2004	688	20	A	111	110	134	109	109	128
	20/02/2004	1016	16	A	115	117	133	114	115	129

After analysing the data we can see that in conditions of free flow, the average gap above 6 seconds and LOS A always measured, the variations in operating speeds have no univocal trend when traffic gets heavier on the elements of the sequences – values always vary within small intervals and this shows that the incidence of the vehicular interaction on speed processes is marginal.
V_{50} and V_m most closely resemble the design speeds of the elements considered and they were inferred from the speed diagrams for the different sections. V_{85} is always much higher. We noticed that in every sequence and during the entire period in which the survey was carried out the latter always dropped in the transition from tangent to circular curve – the average difference varied between 2 and 17 km/h, depending on the site observed.
The algebraic sign referring to such differences confirms the importance of the planimetric element of the layout, while the variability spectrum of the values shows the incidence of other geometrical factors.

RESULTS

In order to have a clearer interpretation of the experimental evidence and to propose some prediction relations we analysed the rapport between V_{85} and some geometrical parameters like CCR_s, CCR, i_s and i: in plan and profile the first and the third refer to the variation rate of curvature and average grade studied for each element [1], [2], [3], [4], [5], [6]; the second and the fourth are calculated for each section of 1000 m (highway) or 500 m (motorway) which precede the observed site.
The definition of interpretative relations for the users' behaviours was first of all based on binary rapports between operating speed and each geometrical parameter we considered in order to establish its importance. Then, on the basis of the results obtained, we established some multivariable connections, at the same time processing the planimetric and altimetric data.

Below you will see some diagrams in which speed is connected only to the planimetric characteristics of the SS 626 dir. layout . We must stress that the V_{85} average values, obtained each day for every element.

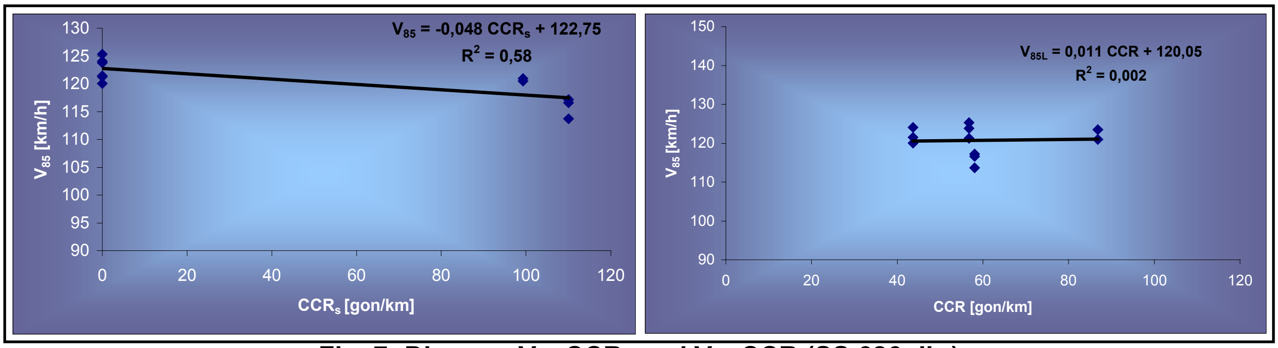

Fig. 7: Diagram V_{85}-CCR_s and V_{85}-CCR (SS 626 dir.)

These trends show a statistically satisfactory link between V_{85} and CCR_s; on the other hand, the connection between V_{85} and CCR does not seem very significant. Hence, driving behaviours seem to be mainly influenced by the planimetric characteristics of the element which the vehicle is on at that specific moment, that is to say when the measurement is being carried out. These considerations led us to choose CCR_s as the variable of the prediction model.

As regards the importance of the profile for the operating speed, you will see in figure 8 that there is a significant link between V_{85} and i_s; this further proves that the geometrical characteristics of the section being studied have a significant influence on the results.

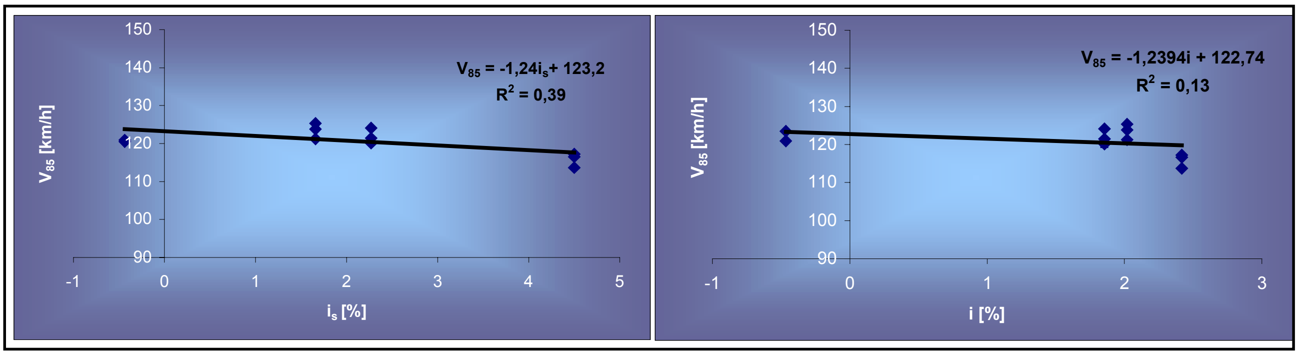

Fig. 8: Diagram V_{85}-i_c and V_{85}-i

Multivariable linear regression gave the following result (Fig. 9):

$$V_{85} = 125{,}13 - 0{,}034 \cdot CCR_s - 1{,}253 \cdot i_s$$

$$R^2 = 0{,}79$$

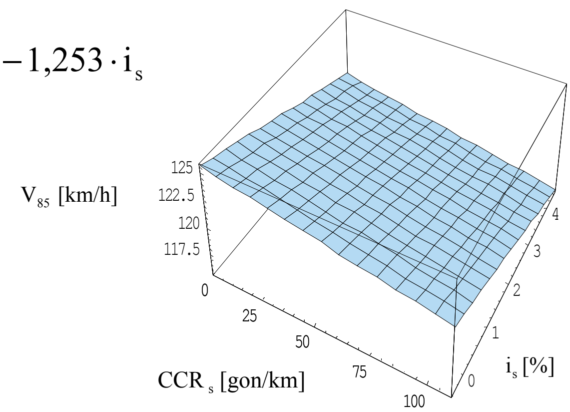

Fig. 9: Prediction relation V_{85} - CCR_s - i_s (SS 626 dir.)

The resulting V_{85} expression and its determination coefficient show that it is the simultaneous and synergic action of planimetric and altimetric elements that determines a high degree of correlation.

As already mentioned, the regulations we studied do not include significant prediction relations as regards motorways. However, on the basis of the study we carried out we tried to infer a correlation between the variables present.

For motorways we used the method described above, thus determining simple and multivariable linear relations for the representative V_{85} operating speeds whose values are averages of the operating speeds values for each element and by ruling out those speeds whose difference from this set value is over 5%.
You will see the trends resulting from our research on A18 in figures 10 and 11.

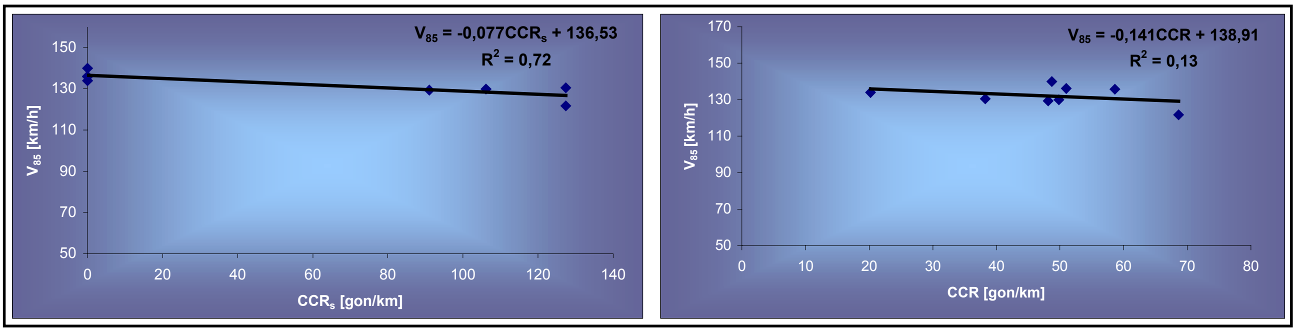

Fig. 10: Diagrams V_{85} - CCR_s and V_{85} – CCR (A18)

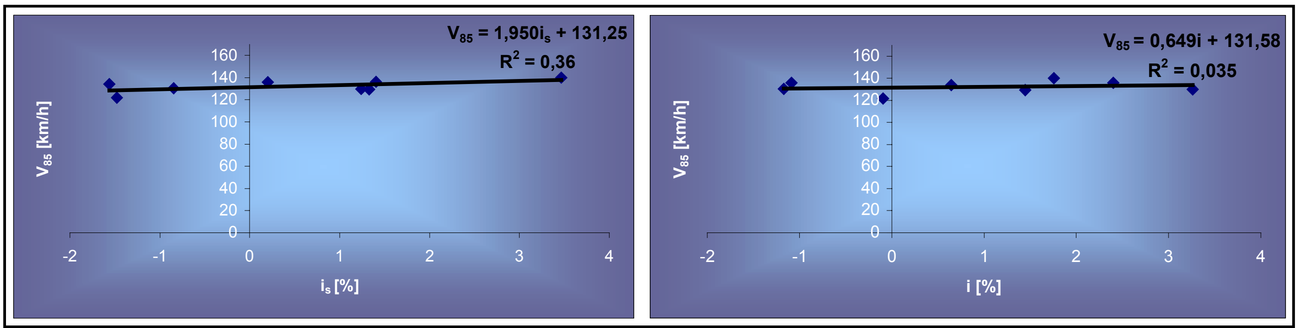

Fig. 11: Diagrams V_{85} - is and V_{85} – i (A18)

These diagrams show that the most significant influence on speed is exerted by the geometrical characteristics of the element studied rather than by the characteristics of the preceding section.
According to significant parameters multivariable linear regression showed once again satisfactory results, as you can see in the graph and expression below (Fig. 12):

$$V_{85} = 135{,}37 - 0{,}066 \cdot CCR_s + 1{,}142 \cdot i_s$$

$$R^2 = 0{,}83$$

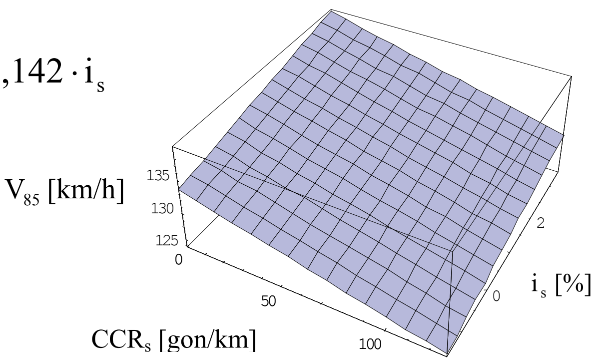

Fig. 12: Prediction relation V_{85} - CCR_s - i_s (A18)

As regards admissibility of the mathematical formulation, the positive sign referring to the grade might seem surprising. This can be explained with the fact that, in a condition of free flow, as soon as users perceive a positive variation in grade they tend to accelerate so as not to lower their degree of satisfaction while driving.

CONCLUSIONS

In both road samples we found that operating speed values are almost always higher than the design speed of the geometrical elements considered.

On the other hand, a general increase in operating speed involves very small speed variations in the transition from one element to the other. This leads us to think that the layouts are appreciably consistent, as can be seen from the diagrams prepared on the basis of the prediction reports CCR_s-i_s-V_{85} in figures 13 and 14.
As for the motorway sections studied, this datum conflicts with what the curvature planimetric-design speed diagrams prepared on the basis of the present Italian geometric design standard affirm.
In general, the processing of prediction reports, by including horizontal and vertical variables, should allow one a more reliable interpretation of the influence that road geometry has on the speed of vehicles. However, we think that these prediction reports could become behavioural models on the basis of more thorough studies referring to a specific typology of road geometry characterised by a specific mobility function.

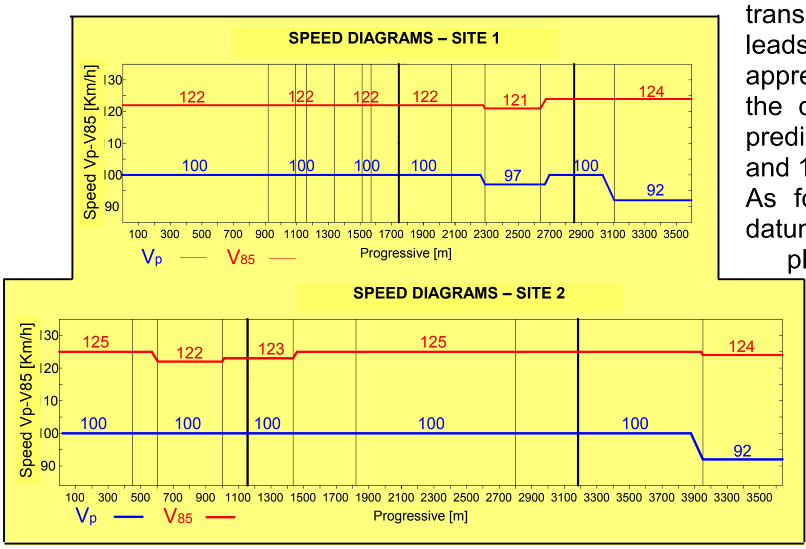

Fig. 13: Design speed diagram versus operating speed diagram (SS 626 dir.)

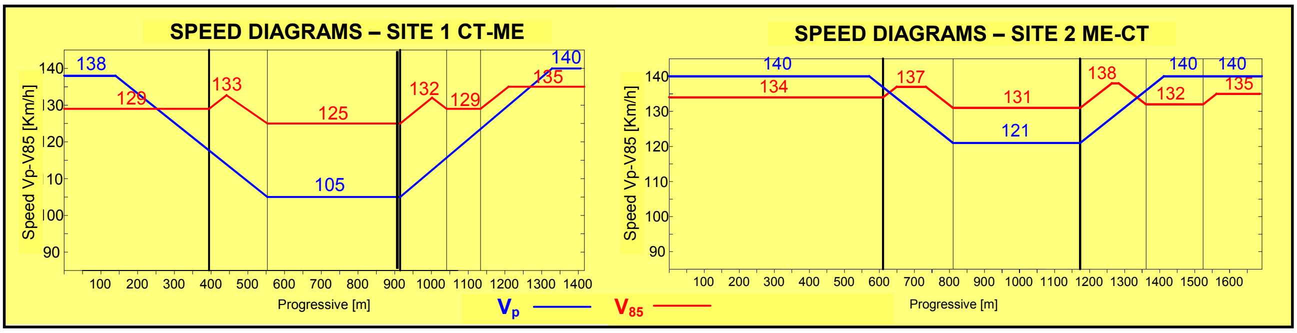

Fig. 14: Design speed diagram versus operating speed diagram for two sites of A18

The latter determines the main type of users that statistically characterise the use conditions of a road: habitual users, such as the ones studied on the highway, are characterised by high operating speeds which originate from past experience. The shorter the section, the stronger the experience is.
By contrast, the more composite the users are the more intrinsic safety of longer roads is founded on the consistency of the road layout, where the word ‘composite’ refers to both knowledge of the road and reasons for the journey.
Hence we can deduce that the values of the evaluation parameters of the consistency of the road should vary – although the intervals should always be small – in relation to both the geometrical and functional characteristics of the road.

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ACKNOWLEDGEMENTS

The authors would like to acknowledge Dr. P. Di Maida and Dr. F. Failla Mulone for their operating support during the experimental investigation.