Optimization Analysis to Detect Significant Variables in Road Safety

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Synopsis

The control of the safety conditions in the phase of design or check of a road, represents a complex problem according to numerous factors and variables indispensable to formulate an objective assessment.

In the last years, this argument has been studied very in-depth, producing new criteria and methodologies to approach the problem.

In particular, the necessity of a systemic study is emerged, where road and driver become the most important factors to improve the usual safety analysis, especially with environmental context rather articulated.

The Italian Road Standard, the DM 5.11.2001, foresees the instrument of derogation in case of difficult conditions (local, environmental, landscape, archaeological, economic). Nevertheless, there is always the obligation to prepare suitable safety checks to support the design choices and to avoid the overcoming of certain threshold values.

On this subject, a survey promoted by the Società Italiana Infrastrutture Viarie (SIIV), has highlighted that some engineers, addressed to the control of road designs, have expressed many doubts about the limits of validity of the road standard.

To exceed these problems, the paper analyses the most influent parameters inside the mathematical formulas through reliability analysis techniques. In this way has been possible to find the validity interval of the variables, having as function objective the maximization of the safety.

The application to some practical cases has demonstrated that this methodology can be easily used to design or to verify a road, reducing the subjective judgement and evaluating only the variables more influential.

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The DM of 5.11.2001 has introduced for the first time in Italy a normative reference for the geometric designing of the roads [1].
Its structure receives some guide lines based on the swiss and german standards, especially as regards some consistency concepts of the route, in the management of geometric elements, in the characterization of the speed with the introduction of the design speed diagram [2].
The most attended aspects, even because subject of critics, reflections and researches, belong to the chapter fifth and regard the planimetric and altimetric composition of the alignment. Among the news, there are:

- friction coefficients in function of the pavement surface quality;
- the reaction time in relation to the speed;
- the possible utilization of transition curves different from the clothoid;
- a new abacus to determine the cross-sectional slope in function of the radius and speed;
- some aspects for the calculation of the clothoid parameter A;
- the definition of minimal lengths for geometric elements at constant curvature;
- the introduction of the design speed diagram.

As regards the purely planning aspect, the application of the standard principles, implies some difficulties more recently signalled and highlighted.
One of the most debated subjects, concerned the items of the ministerial decree 5/11/2001, that confer to the designer the possibility to deviate from the prescriptive obligations on condition to suggest some appropriate safety analysis. It has derived the necessity to individuate which methodologies are most suitable case-by-case, quantifying, if possible, in an objective way, the removal effect from the reference values established by the rule [3].
In this clause, in order to give a help to solve these problems, it is proposed a procedure that allows to identify the most important variables that come into play in the composition of a planimetric transition curve.
The involved parameters have been assembled among them inside a series-parallel system similarly to the traditional schematizations used in the industrial field. Such a approach, has permitted an easy evaluation of the system state, even if one or more components have exceeded the pre-established thresholds. The procedure has allowed an exact and reliable quantification of the effects of such a removals.
As follows, it has been reported some critical states related to a transition curve composition, already highlighted in a previous study.
Moreover, to illustrate the procedure, some short accounts have been reported, regarding the reliability analysis of a system and the determination of important coefficients of the variables involved within.
Such a procedure has been applied in the study of a planimetric composition of a clothoid with the aim to evaluate, which are the most critical parameters for the fulfilment of the requirements determined by the rule and which are less binding.

CRITICALITIES CONNECTED TO THE COMPOSITION OF A TRANSITION CURVE

The results emerged from the study have highlighted that some prescriptions, in particular for some roads categories, are too much restrictive. In particular, we refer to the methods for the clothoid designing, that is, to observance of a minimum development of the residual arc, that together with the criterion relative to the dynamic parameter, could bring from the formal point of view, to unjustified designing solutions and also to the forcing of the design that can be incompatible with the territorial pre-existences and with the necessity of controlling of the costs [4].
The analysis realized for a local rural road has allowed to reach some results, later mentioned, and that are the base of the proposed methodologies in the present study.
Particularly, the relations between the value of the circumference arc R and the deflection angle α between two straights have been analyzed, when the parameter A of the clothoid varies.
In order to operate in the observance of the standards, to calculate the parameter A, it has been evaluated, even the further value A*, which individuates that specific clothoid arc which corresponds a residual development of the circumference equal to a run distance of 2.5 s.
Therefore, if with A_{norma} is indicated the highest value among the lowest ones required by the rule, the last value of A will have to respect the inequality $A_{norma} \leq A \leq A^*$.
Obviously, with small angles of deflection it is necessary to use very large radius R, otherwise, the too short clothoid branches developments wouldn't guarantee the other verifications on the parameter A. In fact, if

results A>A*, the clothoid would have a length that doesn't respect the lowest value of the residual arc development.

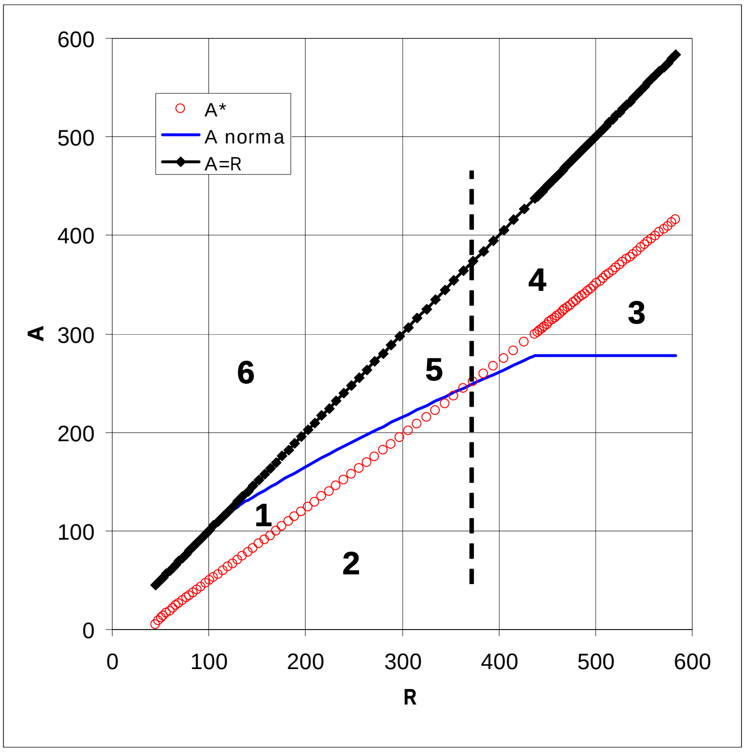

Figure 1: Relationship among A*, A_{norma} and A=R with α= 40[c] and V_{clo}= V_{cir}+ΔV(15 km/h)

A further condition of the new rule is about the calculation of the parameter A, with the so called dynamic criterion, for which is imposed the use of the highest design speed value to be deduced from the proper diagram, generally higher respect to the Vp which characterizes the run on the circumference arc.

In fact, being the Vp variable along the clothoid arc, for sufficient lengths of the same, in the point at null curvature, the Vp could even to have the interval highest value. Therefore, for local rural roads, could be in some cases necessary to determine a parameter A_{din} adopting a design speed V_{clo} of 100 km/h. Obviously, we can't deny that the effective maximum value of V_{clo} is influenced, besides its development, also by a series of parameters, which are the straight lengths , the ΔV_p between the two elements with a constant curvature, the transition distance D_T, etc.

In fact, a prescription of the standards specifies that, in order to guarantee the route homogeneity, the ΔV_p has to be quite contained (for V_{pMax}= 100 km/h, $\Delta V_p \leq$ 20 km/h) and this could be obtained, adopting radius large enough in relation to the V_{pMax} of the point at null curvature or giving to the less binding elements lower speeds of the higher interval range. As deduced from the considerations above mentioned, the application of the dynamic criterion bring to a complex design of the alignment, because the constraint ΔV_p.(even if it was adopted a variation of the design speed of only 10 km/h) could determine parameters A_{din}, that in unfavourable cases (little deflection angles and short radius), would be "self-limited" from the radius R.

The condition A=R is purely theoretic, because there is not the possibility to use excessive lengths of the clothoid that would be incompatible with the maintenance of an arc with a circumference long enough to assure a run of 2.5 s at least.

In order to have the utmost observance of the standards criteria, the solution is obtained with a very large radius and consequently, with very large Vp, unless we don't want to modify the deflection angle between the straight stretches.

From the different carried out applications, it has been observed that the admissible zone with value R reduces considerably at the decrease of the deflection angle between the straight stretches.

Values lower than 40° determine a so moderate admissible zones that make difficult the utmost observance of the standards criteria.

It has been evaluated the function of A* versus the variation of the angle α and with the same meaning of the previous case, all the possible cases to the variation of the parameters in question have been determined (Fig. 1 and 2).

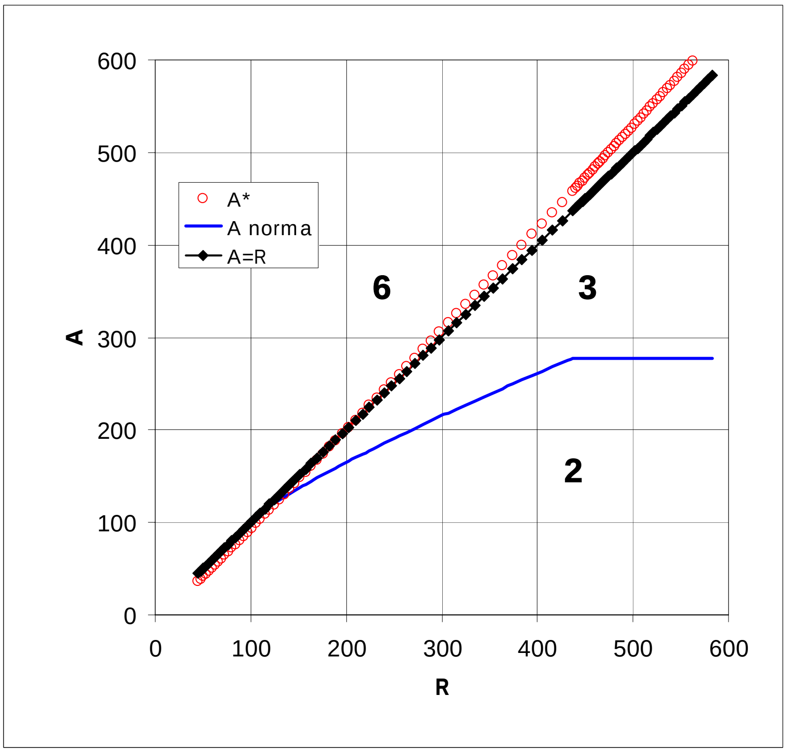

Figure 2: Relationship among A*, A_{norma} and A=R with α= 80^c and V_{clo}= V_{cir}+ΔV(15 km/h)

SYSTEMIC APPROACH AND IMPORTANCE MEASURES OF THE COMPONENTS

In relation to what has been already said, the standard formulations that allow the problem solution can be decomposed and the involved variables can be represented as a set of components connected among them. This, with the aim to measure the single variables and the entire organism reliability [5].

Referring to the notations, traditionally used in literature for the study of the systems reliability, it is indicated what follows:

x_i =functioning i^{th} unit

$\bar{x}_i$ =the i^{th} unit is not working

$P(x_i)$=the probability that the i^{th} unit is functioning

$P(\bar{x}_i)$= the probability that the i^{th} unit is not functioning

R=system reliability

P_f =system unreliability

In the case of series-connected components so that the system is reliable, all the n components must be functioning. The algorithm that values the R is the following:

$R= P(x_1) \times P(x_2/x_1) \times (Px_3/x_1 \times x_2) \times .... \times (P(x_n/x_1 \times x_2 \times x_3 \times \ldots \times x_{n-1})$

When it's possible to consider all the single faults independent, the previous expression can be simplified as follows:

$R= P(x_1) \times P(x_2) \times (Px_3) \times (P(x_n)$

Or with the formula:

$$R = \prod_{i=1}^{n} P(x_i)$$

Instead, in the case of configuration of the elements in parallel, the fault of one or more units doesn't bring necessarily to a general collapse. In other words, the reliability, in this case, is the probability that a path inside the graphic representation, is at least operative, that is:

$R=[P(x_1) + P(x_2) + (Px_3) + (P(x_n)] – [P(x_1 \times x_2) + (Px_1 \times x_3) +....+ P_{i\neq j}(x_i \times x_j)]$
$+ \ldots +(-1)^{n-1} \times P(x_1 \times x_2 \times x_3 \times \ldots \times x_n)$

In the hypothesis in which the elements can be considered independent, we obtain:

$$R = 1 - \prod_{i=1}^{n} P(\bar{x}_i)$$

For very complex systems, it's good to divide them into easier parts and so, consider them in series or parallel representations.

For example, a parallel-series configuration in which there are m paths in parallel and n series-connected units, and where it is indicated with $P(x_{ij})$, the reliability of the component J on the path i, is deduced the reliability of this last one, from the following expression:

$$P_i = \prod_{j=1}^{n} P(x_{ij}) \text{ with i=1, 2, …, m and j=1, 2, .., n}$$

The reliability is given by:

$$R = 1 - \prod_{i=1}^{m}\left[1 - \prod_{j=1}^{n} P(x_{ij})\right]$$

Instead, in a series-parallel system, in which there are n series-subsystems with m parallel units, it is obtained:

$$R = \prod_{i=1}^{n}\left[1 - \prod_{j=1}^{m}\left(1 - P(x_{ij})\right)\right]$$

IMPORTANCE OF COMPONENTS

During a design check, the problem relative to the weakness of the components identification, crucial to the global functioning, can rise. Such verification is useful not only to recognize possible weak points about of what it has been designed or built, but also to address in the best way the maintenance charges and obtaining, therefore, the maximization of the reliability with the lower charge obligation.
In the last years, owing to the risk analysis development, many procedures have been affirmed; they help to quantify such quantities, and among the most famous ones, there are those that lead back to the studies of Birnbaum, Gandini and Fussell-Vesely [6, 7]. However, it has to be said, that almost all theories base on the system reliability, in relation to the functioning or not of the single component. Therefore, the final measure is deduced from the algebraic manipulations of these quantities.
For example, in the case of n elementary units (N=1,2…n), let's suppose that the system can be only in a functioning state indicated as 0, or is out of order, indicating, then, as 1 this variable. As the system state depends only on that of its components, we indicate as $X = (X_1, X_2, …, X_n)$, the vector of uncertain variables, which represents the components state to a t instant. If $\Phi(x)$ is the uncertain variables which represents the Function Structure of the system, that is the function which represents the system functioning in relation to the components configuration, it can be confirmed that when $\Phi(x) = 0$ the system works regularly, while when $\Phi(x) = 1$ there is a fault. As $P[\Phi(x)=1] = E[\Phi(x)]$ and assuming that the X_i are independent variables, with $P[Xi=1] = q_i$, $E[\Phi(x)]$ becomes a function of the vector $q = (q_1, q_2, …, q_n)$ that expresses the state (functioning or not functioning) of the components.
If $G(q) = E[\Phi(x)]$, then G(q) is called Unreliability Function of the system and it is used for the evaluation of the importance of elements. Some details, about the theories proposed by the authors before mentioned, are reported as follows.

Importance of Birnbaum

The importance $I_B^i(t)$ of the component i in terms of reliability, is the probability that the i^{th} component is critical at the system operation at time t. The representative expression becomes:

$$I_B^i(t) = \frac{\partial G\left(q(t)\right)}{\partial q_i(t)} = G\left(1_i, q(t)\right) - G\left(0_i, q(t)\right)$$

Or:

$$I_B^i(t) \equiv \Delta G_i(t)$$

In which the meaning of the symbology is:

$G\left(1_i, q(t)\right)$ is the system unreliability when the component i is broken;

$G\left(0_i, q(t)\right)$ is the system unreliability when the component i is functioning.

According to other authors (Henley and Kumamoto) the coefficient of importance can be expressed as follow:

$$I_B^i(t) = E\left[\Phi\left(1_i, X(t)\right) - \Phi\left(0_i, X(t)\right)\right]$$

$$= 1 \times P\left[\Phi\left(1_i, X(t)\right) - \Phi\left(0_i, X(t)\right) = 1\right] + 0 \times P\left[\Phi\left(1_i, X(t)\right) - \Phi\left(0_i, X(t)\right) = 0\right]$$

which can be even written:

$$I_B^i(t) = P\left[\Phi\left(1_i, X(t)\right) - \Phi\left(0_i, X(t)\right) = 1\right]$$

Critical importance of Gandini

This measure corresponds to the conditional probability that the system is broken at time t, supposing that the critical components is broken. The quantification takes place through the following expression:

$$I^{i}_{CR}(t) = \frac{\partial G(q(t))}{\partial q_i(t)} \times \frac{q_i(t)}{G(q(t))}$$

which can be written again as follows:

$$I^{i}_{CR}(t) = \frac{\left[G(1_i, q(t)) - G(0_i, q(t))\right] \times q_i(t)}{G(q(t))}$$

Importance of Fussell-Vesely

The component measure proposed by Fussell-Vesely, suggests considerations about the probability that the system life corresponds to the Cut Set fault containing the component i. It can be expressed as follows:

$$I^{i}_{FV}(t) = \frac{G_i(q(t))}{G(q(t))}$$

where $G_i(q(t))$ is the component probability to contribute to the Cut Set fault. A Cut Set is a series of components that stops the connection between the start and end terminals of the system when they are removed from the flow-chart. The Minimal Cut Set is the set of minimal number of components that when are broken, cause the damage of the system; it is meant that, if one of these elements keeps on working, the system will do the same.

NUMERICAL EXAMPLE

The reliability analysis of a system, in a theoretic line, has never been applied to the simulation of the road design procedure, because the reduction in single components and the determination of their reliabilities is not immediate.

In spite of such approach difficulties, a functional scheme has been supposed and reported in figure 3, where the different components refer to the main variables in question and the type of connection between the one and the other, indicates also the dependence or not of the different phases among them.

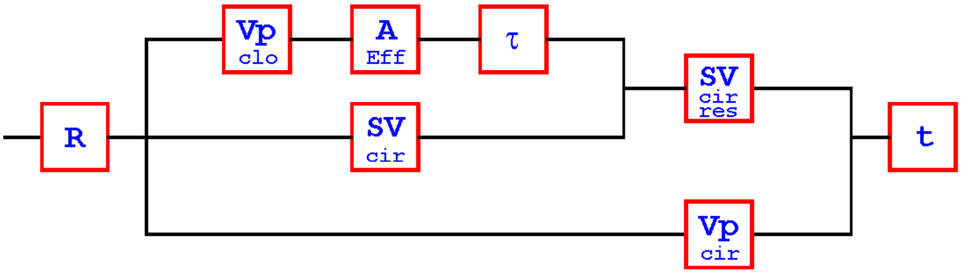

Figure 3: System Model

At this purpose, a superficial consideration could lead to consider very clear the dependence among the parameters in question. For this reason, the marginal probabilities of each component should be determined, that is, the probabilities that the element works, on condition that even the dependent ones work.

In reality, this hasn't been necessary, because the variable reliability has been calculated through the relationship between two validity intervals of the variable. The domain D1 has been placed to the numerator of this relationship, inside of which, the selected parameter assures the fulfilment of rule requirements with those conditions at the edge; the whole interval D2 will be placed to the denominator inside of which, the examined variable can potentially vary.

The result, expressed in percentage terms, gives a frequency measure, with which, that variable fulfils the rule requirements and can be used, therefore, as reliability measure.

In the specific case, the reliability of a given component compares with the contemporaneous reliability of the other elements of the system, that is, the possibility to realize the clothoid geometrically, respecting all conditions; this means that, the reliability requirement of a variable, for example the radius, assumes the contemporary suitability of the others involved in the design, such as the parameter A, the circumference development, etc. Such a situation, determines a sort of marginal probability: that is, if the probability of a determined parameter is in a "functioning" state, assumes that even the others are in the same state.

Further details will be given in the paragraph relative to the reliability calculations of the single components.

With regard to the traditional design phases, a transition curve bases on the following definitions:

- radius R between the two consecutive sides of an axis polygonal;

- circumference arc development ;
- design speed of the circular curve;
- maximum design speed of the clothoid (in the specific case, it has been assumed this value equals to that of the circumference +15km/h);
- effective parameter A, chosen among the three criteria, besides the radius higher limitation;
- angle of the clothoid end point;
- residual circumference development;
- residual circumference run-time.

Where the used symbology indicates the following quantities:

- R: circular curve radius;
- Vp_{clo}: the maximum speed in the clothoid;
- A_{eff}: the parameter A chosen among the three criteria and the limitation concerning the radius;
- SV_{cir}: the circumference development in absence of a clothoidic connection;
- τ: deflection angle of the clothoid end point;
- $SV_{cir-res}$: the residual circumference development;
- Vp_{cir}: the speed concerning the circumference radius;
- t: run-time on the residual circumference.

With the logic of Cut Set, the system has been divided in a series of more little subsystems, for each of them, has been calculated more easily the reliability or its complement than the probabilities of crisis:

- the subsystem in series formed by Vp_{clo}, A_{eff} e τ, indicating with G1 its resulting unreliability;
- the subsystem in parallel G1, SV_{cir}, indicating with G2 its unreliability;
- afterwards in series G2 with $SV_{cir-res}$ and G4 will be obtained;
- then, G3 and Vp_{cir} will be examined in parallel and G4 will be obtained;
- at last, R, G4 will be processate in series, in order to obtain the probability that the run-time on the residual circumference is less than 2.5.

The things above mentioned, are expressed through the following formulas:

$$G_1 = 1-(1-qV_{clo})\times(1-qA)\times(1-q\tau)$$

$$G_2 = G_1 \times qSV_{cir}$$

$$G_3 = 1-(1-G_2)\times(1-qSV_{cir-res})$$

$$G_4 = G_3 \times qV_{cir}$$

$$G_5 = 1-(1-qR)\times(1-G_4)$$

Calculation of single components reliabilities

It is necessary more precise information of what has been already said. From the literature is known that reliability, for mechanical or electronic systems, is the probability that the mentioned element performs its function in a prearranged temporal interval and under specific operative conditions. Obviously, the functionality can be also intended in terms of stress or tension.

The reliability, is here defined as the relationship between the domains, in which the examined parameter allows to fulfil the rule requirements and the interval, in which is possible to make change this parameter. For example, the radius R for a local rural road, can vary from a minimum of 45 m to a maximum of 2187 m, prefiguring, in this way, a potential interval of 2142 m; the numerical processings, with a deflection angle of the polygonal α=30g, have allowed to establish that the effective range of the radius deflection, could vary between 486 m and 2187 m, with a domain, then, equals to 1701 m; the reliability, therefore, has been calculated as the relationship between the interval actually used from the variable and that one potentially exploitable, that is 1701/2142=0,7941 (79,41%). Varying α, the reliability of the “component” radius becomes better, and so, α has a meaning similar to the time, defining itself a function $A_R(\alpha)$. The same reasoning has been made for the other involved variables, coming to the compilation of the Table 1.

For each variable, it has been also traced an other function as to α, this time, without having as validity field the standard connections, but only the physical construction of the clothoid.

It means that, they have been accepted values inner the function group that allow to make the transition connection, without the limits imposed by the DM 5.11.2001.

The contemporaneous contouring of these functions highlights a zone between the two curves, in which the rule prescriptions are not respected, but it is still possible to plot the transition connection. Obviously, the requests of derogation will determine a usefulness of these zones more or less near to the edges that are represented from the course state of the two functions. The acceptance or refusal of such demand, must also be a consequence of the effect that the deviation from the rule will produce on the entire system.

In such way, it derives an objective quantification of the unsuccessful respect of the rule, so possible interventions of mitigation can be measured more precisely (Fig. 4, 5 and 6).

Tab 1: Reliability of the principal variables in the case of Road Standard threshold and Physical

Standard threshold

Deflection angle (deg)		30	40	50	60	70	80	90	100
Radius	R	79,41%	85,11%	89,78%	92,62%	94,72%	96,03%	97,81%	99,63%
Clotoid speed	Vclo	0,02%	0,02%	6,67%	24,44%	40,00%	51,11%	68,89%	93,33%
Clotoid parameter	Aeff	0,00%	11,87%	28,78%	40,29%	49,28%	55,04%	66,91%	80,94%
Clotoid defl. angle	τ	12,90%	29,31%	43,39%	57,76%	74,52%	89,80%	100,00%	100,00%
Circle lenght	SV	50,00%	50,22%	54,80%	58,30%	62,23%	64,41%	71,62%	81,66%
Residual circle angle	γ	9,22%	11,14%	14,21%	17,13%	18,88%	21,36%	26,34%	36,34%
Circle speed	V	0,02%	11,67%	30,00%	43,33%	55,00%	63,33%	76,67%	95,00%
Time residual circle	t	35,73%	24,83%	20,53%	17,41%	14,04%	12,52%	11,06%	9,78%

Physical Threshold

Deflection angle (deg)		30	40	50	60	70	80	90	100
Radius	R	86,04%	91,64%	94,44%	96,27%	100,00%	100,00%	100,00%	100,00%
Clotoid speed	Vclo	0,02%	17,78%	37,78%	53,33%	100,00%	100,00%	100,00%	100,00%
Clotoid parameter	Aeff	15,11%	35,97%	47,84%	56,47%	83,81%	83,81%	83,81%	83,81%
Clotoid defl. angle	τ	31,48%	51,86%	71,83%	93,27%	100,00%	100,00%	100,00%	100,00%
Circle lenght	SV	64,63%	69,21%	72,05%	74,45%	89,30%	87,77%	86,12%	84,57%
Residual circle angle	γ	0,07%	0,03%	0,21%	0,35%	6,34%	16,34%	26,34%	36,34%
Circle speed	V	15,00%	38,33%	53,33%	65,00%	100,00%	100,00%	100,00%	100,00%
Time residual circle	t	70,36%	0,05%	0,22%	0,27%	2,25%	5,14%	7,30%	8,92%

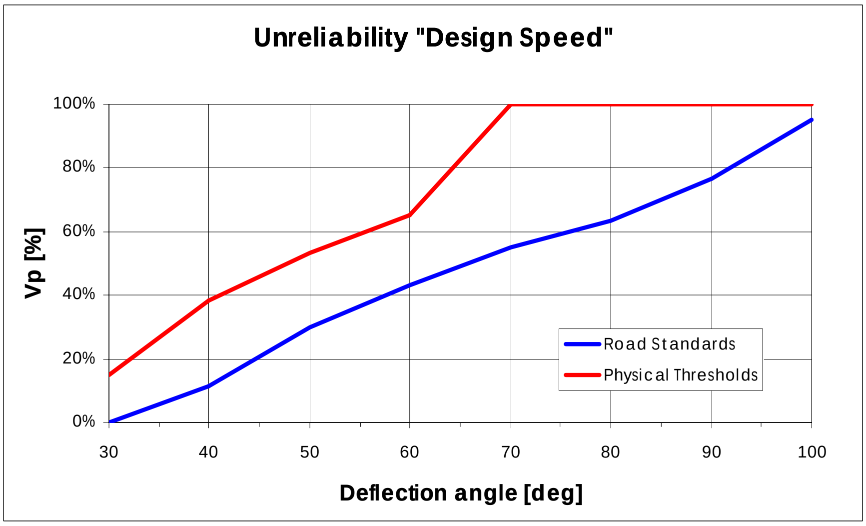

Figure 4: Relationship between Unreliability of Vp and α

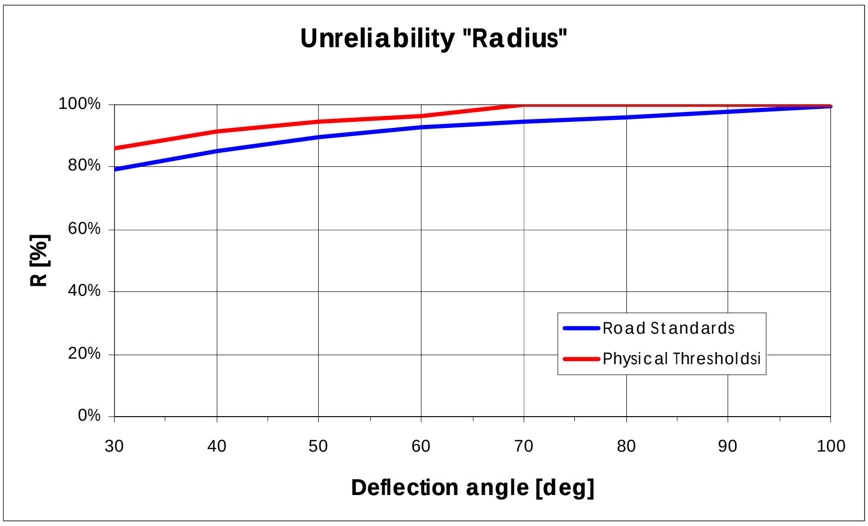

Figure 5: Relationship between Unreliability of R and α

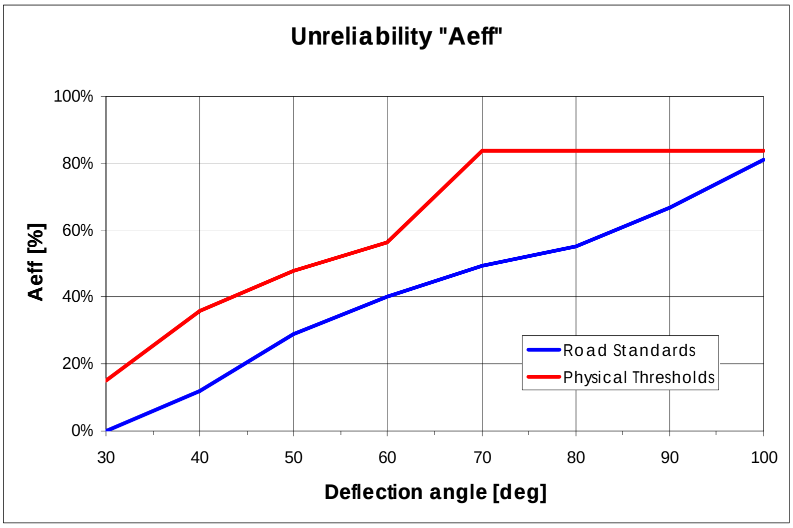

Figure 6: Relationship between Unreliability of A_{eff} and α

Calculation of importance coefficients

The calculation of importance assumed from the different components, has been carried out according to the studies of Birnbaum, because the other theories give similar results. These are resumed in the Table 2, from which the following considerations are deduced:

- the V_{clo} (speed on the clothoid), A_{eff} (effective parameter A) and τ (clothoid final angle) "components" show quite low criticalities for the working of the system;
- the Vp_{cir} (speed on the circumference) parameter is the most representative one, but it is necessary to underline that its contribution decrease at the increase of the deflection angle α; for angles over 80g, it is compared to other variables as radius, angle to the circumference y, circumference development; however, it has to be said that the problems of the transition curve composition derive from little α and they can be solved only increasing the value of the radius;
- the angle at the circumference γ presents the same decreasing trend of R, even though, it is less important of this;
- on the contrary, the parameter R increases lightly with the deflection angle α, but then, it remains constant; it means that its contribution to the standard requests fulfilment is invariant compared with α;
- the SV_{cir} (residual circumference development) parameter is not very important and its rate decreases at the increase of α;

Tab 2: Important Coefficients of the principal variables

α	Radius 1	Vclo 2	Aeff 3	τ 4	SVcir 5	γ 6	Vcir 7
30	1,70E-02	1,69E-07	3,37E-07	2,62E-10	2,60E-02	1,42E-01	2,71E-01
40	4,10E-02	3,60E-04	6,07E-07	2,46E-07	2,10E-02	9,40E-02	2,00E-01
50	7,30E-02	1,04E-03	2,40E-04	1,59E-04	1,80E-02	7,10E-02	1,70E-01
60	8,60E-02	1,52E-03	9,22E-04	6,43E-04	1,50E-02	5,50E-02	1,44E-01
70	8,50E-02	1,57E-03	1,27E-03	8,41E-04	9,64E-03	4,10E-02	1,16E-01
80	8,60E-02	1,66E-03	1,54E-03	9,43E-04	7,04E-03	3,20E-02	1,01E-01
90	9,10E-02	1,26E-03	1,30E-03	8,70E-04	3,58E-03	2,10E-02	8,40E-02
100	9,50E-02	2,63E-04	3,03E-04	2,45E-04	4,33E-04	4,65E-04	6,40E-02

Variables that should have a close relationship and, consequentially, a comparable importance, have a very different influence for the transition arc composition, for example, the radius and the circumference speed. This is due to the analytical formulation structure that determines the schematization of the system, and that makes this last operation very critical.

The generated results could awaken some doubts, because even the apparently less important elements, depend on the speed on the circumference and, therefore, it could be meant that the functional model doesn't simulate in a realistic way the design phase. The exam of the Figure 1, instead, shows that the V_{cir} influences directly the residual circumference run-time, while the maximum speed on the Vp_{clo} clothoid, the parameter A or the angle α depend also from other variables that mitigate the speed effect on the circumference.

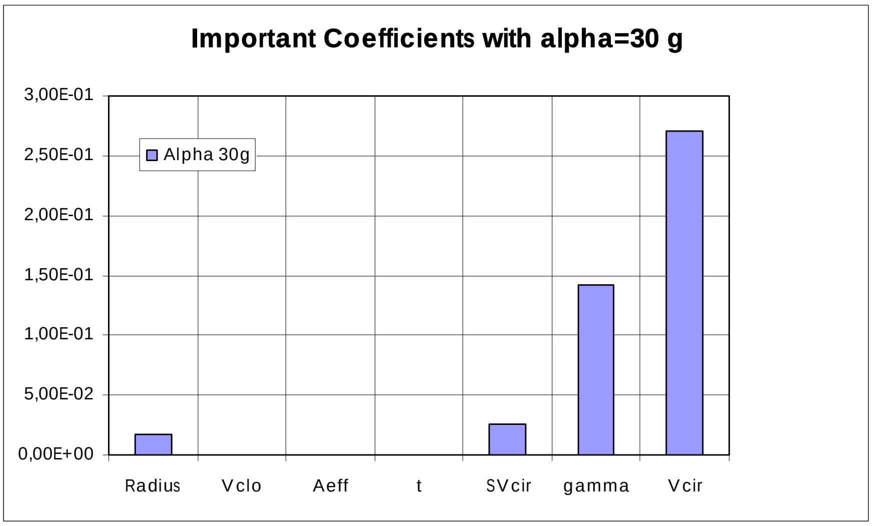

Figure 7: Important Coefficients with α =30g

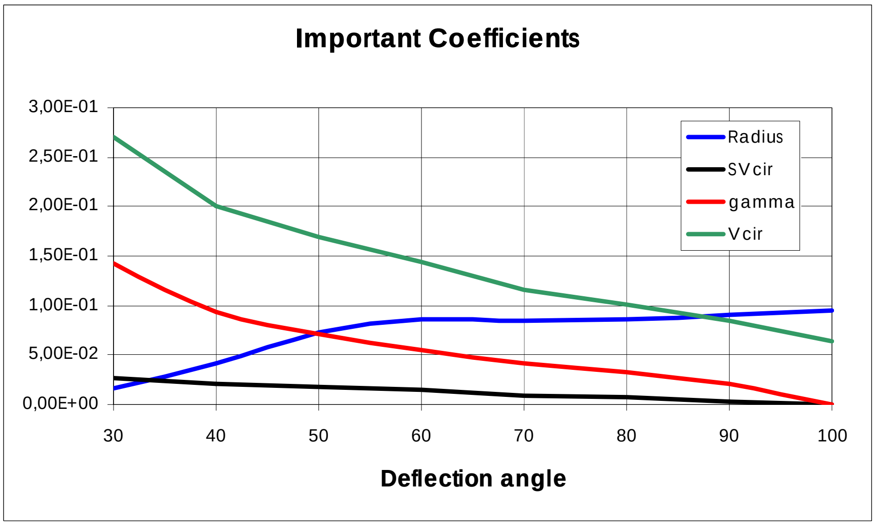

Figure 8: Relationship between Important Coefficients and α

Now the information deduced from the previous simulations have to be used. The following steps can be taken in order to evaluate the possibility to disregard partly the values imposed by the rule without compromising the safety level:

- do calculate the reliability system, accepting higher values only to a prearranged threshold, without specifying which component determines the decay;
- do limit more only the parameters that are more important to the final attainment, leaving free those ones less representative;
- do address the mitigation interventions, with those ones considered from the RSA and RSR with more accuracy and less charges towards the more critical design elements .

CONCLUSION

When the utmost respect of the established limits inner the Italian standard is not possible, it is necessary to plan suitable verifications that allow to demonstrate the maintenance of suitable margins of safety for the run. This paragraph wants to represent a starting point for a methodology that will be further refined, deepened and eventually, extended to all DM contents of 5.11.2001 but that operates on different basis in comparison with the present methodologies referring to the Road Safety Analysis and Review. In fact, the attention has been concentrated only on the parameters involved in the analytic formulations and through a quantification of reliability in systemic form, it has been determined the importance that the single variables have in the achievement of the final result.

The study, therefore, requires further steps, so resumed:

- generalization of the systemic representation to all situations illustrated in the rule and that are more critical;
- verification of the aptitude of such models to represent the phase of design or check;
- introduction of functioning intermediate states of the component, going beyond, therefore, the two-phase element concept (broken or functioning);
- drafting of short summarizing tables of reliability calculations made;
- use of such results in the conduct of derogations to the rule restrictions.

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