

INTRODUCTION OF A NEW APPROACH TO GEOMETRIC DESIGN AND ROAD SAFETY

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1 INTRODUCTION

It is often argued that roads designed to accepted minimum geometric standards are safe. And yet the most recent South African statistics¹ indicate that 9 000 people die in road accidents every year. If fully laden Boeing 747s were to hit Table Mountain at regular fortnightly intervals, the outcome would be the same. The difference lies in the public outcry that, after the second crash, would increase to such deafening proportions that official heads would roll and everybody would refuse to go by air. In 1998, 120 000 people were injured in road crashes, a quarter of these seriously. Imagine a platoon of four Municipal buses transporting the injured to hospital every day of the week. We achieve this carnage through the medium of crashes at the rate of over 1 400 per day. The South African road network is truly a hostile environment. The apparent indifference of the travelling public to road fatalities and injuries is inexplicable but does not absolve transportation professionals from their responsibilities in assuring that the road network is as safe as possible.

Hauer² has suggested that roads designed to acceptable standards were neither necessarily safe nor unsafe and that the correlation between standards and safety was largely unpremeditated. He proved his point by reference to the “myths” that constitute current approaches to stopping sight distance, lane widths and radius of horizontal curvature, all of which are arguably the most fundamental of geometric design standards.

The point was also made that safety is not an absolute concept in the sense that a safe road would be one on which no crashes ever occurred. A road can always be made safer than it currently is with the increase in safety being measured in terms of a reduction in the number of fatalities and/or injuries or in the severity of the injuries suffered.

Two questions arise immediately. If minimum standards are not a guarantee of safety, what is? Furthermore, while the bulk of crashes are attributed to driver error, why is it that so many drivers manage to make the same mistakes at the same places on the road network? The accident black spot is not a myth.

The work described in this paper is based on international databases, which demonstrate that the majority of accidents occur on rural two-lane roads, with many of these accidents apparently related to inconsistencies in the horizontal alignment. In the absence of proper South African accident databases, local information suggests that the majority of local accidents occur in the urban areas. This difference could be attributed to under-reporting of rural accidents. However, fatalities are equally divided between the urban and the rural areas. If we could successfully address inconsistencies in the horizontal alignment, the road network would be a safer place than it currently is.

As stated above, the guidelines or standards do not provide any basic values describing the safety level of a road in relation to design parameters and traffic conditions. And currently available accident prediction models do not conveniently bridge the gap between design and safety

This paper provides criteria whereby the safety of the alignment of a section of road can be tested and required remedial measures identified.

2 CONSISTENCY

It is postulated that departures from consistency lead directly to an increase in accident rate and this hypothesis is borne out by analysis of several large accident databases in America and Germany. Consistency is defined as comprising three elements that are the criteria offered for the evaluation of a road design³

- Criterion I Design consistency – which corresponds to relating the design speed with actual driving behaviour which is expressed by the 85th percentile speed of passenger cars under free-flow conditions;
- Criterion II Operating speed consistency – which seeks uniformity of 85th percentile speeds through successive elements of the road; and
- Criterion III Consistency in driving dynamics – which relates side friction assumed with respect to the design speed to that demanded at the 85th percentile speed.

These criteria provide cut-off values between designs classified as good (safe), tolerable (marginal) and poor (dangerous). The value of the 85th percentile speed (in the case of Criteria I and II) and the side friction demanded (in the case of Criterion III) for each element of the road is calculated for a specific road section and then compared to the cut-off value provided by each of the criteria.

3 CURVATURE CHANGE RATE

The case of two-lane rural roads with traffic volumes in the range of 1 000 to 12 000 vehicles per day as reflected in United States, German and Greek databases was considered in order to assess the impact of various design parameters, e.g. lane width, radius, sight distance and gradient, on the variability of operating speeds and accident rates⁴. It was found that most of this variability could be explained by a new parameter, Curvature Change Rate of the single curve (CCR_s). The other parameters proved to be statistically insignificant at the 95 % level of confidence.

Two circumstances have to be considered, being the curve and the tangent. The tangent is merely a special case of the curve being a curve with an infinite radius. As a special case, its treatment differs from that of the curve with finite radius.

3.1 Curves

CCR_s is calculated as³:

$$CCR_S = \frac{\left(\frac{L_{Cl1}}{2R} + \frac{L_{Cr}}{R} + \frac{L_{Cl2}}{2R}\right)}{L} \cdot \frac{200}{\pi} \cdot 10^3 \quad \text{Eq 1}$$

where:

- CCR_S = curvature change rate of the single circular curve with transition curves [gon/km],
- L = $L_{CI1} + L_{Cr} + L_{CI2}$ = overall length of unidirectional curved section [m],
- L_{Cr} = length of circular curve [m],
- R = radius of circular curve [m],
- L_{CI1}, L_{CI2} = lengths of clothoids (preceding and succeeding the circular curve) [m].

The dimension “gon” corresponds to 400 degrees in a circle instead of 360 degrees according to the new European definition. It is to be noted that curves other than circular take the factor 2 in the divisor. Furthermore, compound circular curves may only be considered as single curves where $R_{max} \leq 3 R_{min}$. If this condition is not met, they have to be dealt with individually.

The general case is illustrated in Figure 1 below.

3.2 Tangents

Having considered the curved portions of the road, the tangents also require attention. A tangent can either be independent (long), in which case it acquires a CCR_S of its own, or not (short), where it is simply ignored. In order to draw a distinction between long and short tangents, it is necessary to consider the operating speed, V_{85} , that can be achieved on the tangent in relation to the operating speeds appropriate to the curves on either side of it. Three possibilities exist. These are:

- Case 1.** The tangent length is such that it either is not, or is just, possible, in going from a shorter to a longer radius, to accelerate to the operating speed of the following curve within the length of the tangent; $T \leq T_{min}$;
- Case 2.** The tangent length allows acceleration up to the maximum operating speed, $V_{85_{max}}$, on tangents; $T \geq T_{max}$; and
- Case 3.** The tangent length is such that it is possible to achieve an operating speed higher than that of the following curve but not as high as that achieved without the constraint of nearby curves; $T_{min} < T < T_{max}$.

The calculation of the tangent lengths, T_{min} and T_{max} requires calculation of the operating speed under the various circumstances. This procedure is described in Section 5.

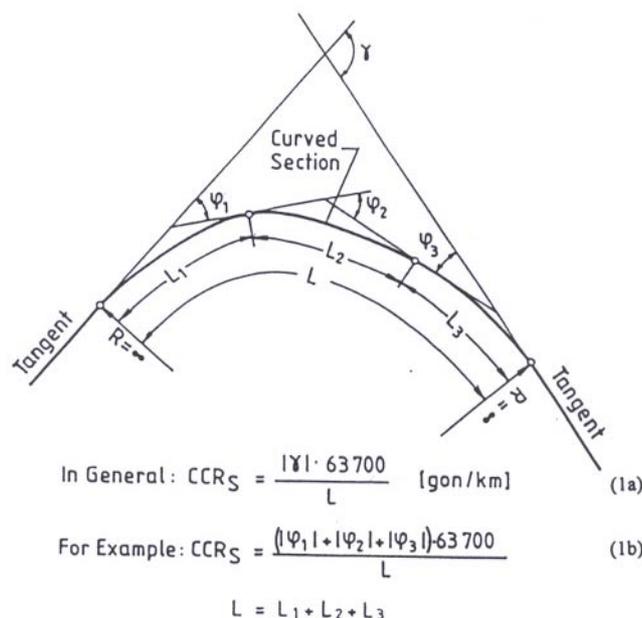


Figure 1: Sketch and equation for determining CCR_S

4 DESIGN CLASSIFICATION

Having defined the new design parameter and also having established that it is the major descriptor of the variation in accidents and operating speeds, it is necessary to establish values of the parameter that will offer guidance on what constitutes good, tolerable and poor consistency as discussed in Section 2. And this is done in terms of accident rates and accident cost rates.

4.1 Accident rates

It is pointless to refer to total number of accidents on any given stretch of road, as this does not allow comparisons to be drawn between different road sections. Accidents are considered in terms of two variables being the accident rate and the accident cost rate. The accident rate is a measure of the exposure to accident risk and is described by the following formula:

$$AR = \frac{\text{Accidents} \cdot 10^6}{365 \cdot \text{ADT} \cdot \text{D} \cdot \text{L}} \quad \text{accidents per } 10^6 \text{ vehicle kilometers per year}$$

where

AR	=	Accident rate
ADT	=	Average daily traffic, (veh/24h)
D	=	Duration of investigated time period, (years)
L	=	Length of investigated road section, (km)

Table 1 provides an illustration of some of the results obtained in respect of analyses of accident rates.

Table 1 : t-Test result of mean accident rates for the different CCR_s classes^{3,5}

Design CCR _s Class (gon/km)	Mean Accident Rate	t _{calc}	t _{crit}	Significance; Remarks
Database 1: United States (261 two-lane rural test sites) All accidents				
Tangent	1,17	4,00	> 1,96	Good design Yes
35 – 180	2,29	7,03	> 1,96	Good design Yes
>180 – 360	5,03	6,06	> 1,99	Tolerable design Yes
>360 – 550	10,97	3,44	> 1,99	Poor design Yes
>550 – 990	16,51			Poor design
Database 2: Germany (2 726 two-lane rural test sites) Run-off-the-road and Deer accidents				
0 – 180	0,22	27,92	> 1,65	Good design Yes
>180 – 360	0,87	15,69	> 1,65	Tolerable design Yes
>360	2,27			Poor design

4.2 Accident cost rates

The accident rate evaluates all accidents equally and does not draw a distinction between accidents of differing severity. The accident cost rate, on the other hand, additionally quantifies the accident severity using cost units. It provides a weighted monetary average as an expression of the risks associated with travel on a given road section and can thus be expressed as

$$ACR = \frac{\sum (F * C_F + I_{Se} * C_{Se} + I_{Sl} * C_{Sl})}{3,65 * ADT * D * L} \text{ monetary units per 100 vehicle-km per year}$$

where

ACR= Cost of personal damages in the monetary unit of the country concerned

F = Number of fatalities

C_F = Cost of individual fatality

I_{Se} = Number of serious injuries

C_{Se} = Cost of individual serious injury

I_{Sl} = Number of slight injuries

C_{Sl} = Cost of individual slight injury

With the rest of the variables as described before

Property damage cost has to be added to the personal damage cost described above.

Accident costs for Germany and South Africa are offered in Table 2. The dramatic differences between the two sets of accident costs derive, in part, from the method of calculation adopted and also from differences in the average earning ability of the inhabitants of the two countries

Table 2 : Comparative accident costs

Accident type	Germany ⁶		South Africa ⁷
	DM	Rands (2000)	Rands (2000)
Fatality	2 358 000	8 606 700	435 772
Serious injury	161 000	587 650	100 187
Slight injury	7 300	26 645	26 132

Analysis of mean accident cost rates demonstrated results similar to those shown in Table 1, suggesting that the design classes of

0	<	<	180	Good design	
180	<	CCR _S	<	360	Tolerable design
360	<				Poor design

were appropriately selected.

As will become clear later, these values of CCR_S represent design ranges based on accident research. In the case of Criterion I, the difference between the operating speed on a particular curve and the design speed selected for the entire road section should fall within the ranges of differences in CCR_S listed above to qualify as good, fair or poor design respectively. In the case of Criterion II, it is the difference between operating speeds on successive elements of the road section that should fall within the ranges of corresponding differences given above. Similar considerations are valid for Safety Criterion III

5 SPEED-RELATED CRITERIA

Criteria I and II are, as previously defined, related to speed differentials. Two speeds are of interest, being the design speed and the operating speed.

5.1 Design speed

Design speed has been used for several decades to determine sound alignments. However, sight should not be lost of the fact that design speed merely defines the lowest standard achieved on the road section. It is therefore possible to introduce severe inconsistencies into the design and maintain with perfect, but totally misleading, accuracy that the design speed has been achieved. At low and intermediate design speeds, road sections of relatively flat alignment may produce operating speeds that exceed the design speed by substantial amounts. It is for this reason that Canada⁹ and Greece have adopted their design domain approach.

In most First World (and correspondingly heavily developed) countries, the design speed is selected on the basis of the functional classification of the road ranging from the 120 km/h of the National or Interstate level to the 60 km/h of the tertiary road, with a modest variation, typically 10km/h up or down, allowing for the dictates of the topography being traversed. In South Africa¹⁰, the topography is the prime selector of rural design speed with, however, some consideration of the status of the road in terms of its functional classification.

In the case of very old alignments, the originally selected design speed may not be known and it is thus necessary to estimate it. This can be done by determining the average CCR_s across the length of the road without consideration of the intervening tangents. This average is thus calculated as³

$$\phi CCR_s = \frac{\sum_{i=1}^{i=n} (CCR_{Si} * L_i)}{\sum_{i=1}^{i=n} L_i} \quad \text{Eq 2}$$

where

ϕCCR_s	=	Average curvature change rate of the single curve across the section under consideration without regarding tangents, (gon/km)
CCR_{Si}	=	Curvature change rate of the i-th curve, (gon/km)
L_i	=	Length of the i-th curve, (m)

This average value of CCR_s will be substantially higher than that applying to large radii curves and exceeded in the case of small radii curves. However, since the design speed should be constant on relatively long sections, it makes sense to apply the average curvature change rate to estimation of the design speed. This average value of CCR_s is input into Eq 3 in order to calculate the average V85, which is then considered as an estimate of the design speed. If the terrain is hilly to mountainous with gradients in excess of 6 per cent predominating, it may be more appropriate to use Eq 4 in the estimation of the design speed.

5.2 Operating speed

5.2.1 Curves

The operating speed on each curve in the alignment is taken as being the observed 85th percentile speed.

In the case of new designs, redesigns or RRR strategies, it is necessary to estimate the 85th percentile speed for each curve. Operating speed backgrounds, which can be used for estimation of the operating speed on individual curves, were derived for eight countries. These are Australia, Canada, France Germany, Greece, Italy, Lebanon, and the United States^{3,8}. Across the entire range of CCR_S, Italy offers the highest operating speed and Lebanon the lowest, with the others running generally parallel to and falling inside this band. An average of the eight operating speed backgrounds was also derived. In Figure 2, the operating speed backgrounds for Italy and Lebanon, and also the average, are illustrated. The curve derived for Australia is the closest to the average curve. For South African conditions, it will be necessary to make use of the average curve until such time as a local operating speed background has been derived.

The average is described by the regression^{4,5}:

$$V_{85} = 105,31 + 2 * 10^{-5} * CCR_S^2 - 0,071 * CCR_S \quad R^2 = 0,98 \quad \text{Eq 3}$$

for the case of longitudinal gradients equal to or less than 6 %, or

$$V_{85} = 86 - 3,24 * 10^{-9} * CCR_S^3 + 1,61 * 10^{-5} * CCR_S^2 - 4,26 * 10^{-2} * CCR_S \quad R^2 = 0,88 \quad \text{Eq 4}$$

for gradients steeper than 6 %¹¹.

Both relationships apply to CCR_S values between 0 (corresponding to a tangent) and 1 600 gon/km (corresponding to a radius of about 40 m). They suggest that, on gradients less than 6 %, the operating speed on long tangents will be of the order of 105,31 km/h on average and 86 km/h on the steeper gradients. On South African rural roads¹², it has been found that average (and not 85th percentile) speeds are described as

$$V_{Ave} = 123,32 - 6,99 G$$

where

$$G = \text{Gradient (\%)}$$

suggesting that local 85th percentile speeds may be higher than those recorded elsewhere.

5.2.2 Tangents

It was stated in Section 3.2 that three possible cases have to be considered being:

- Case 1.** The tangent length is such that it is either not, or is just, possible, in going from a shorter to a longer radius, to accelerate to the operating speed of the following curve within the length of the tangent; $T \leq T_{min}$
- Case 2.** The tangent length allows acceleration up to the maximum operating speed, $V_{85_{max}}$, on tangents; $T \geq T_{max}$
- Case 3.** The tangent length is such that it is possible to achieve an operating speed higher than that of the following curve but not as high as that achieved without the constraint of nearby curves; $T_{min} < T < T_{max}$

The Case 1 tangent length is considered to be a non-independent tangent because, in going from a shorter to a longer radius, acceleration to the higher speed will continue on the following curve. The other two cases are both regarded as being independent because they involve speeds higher than those on the adjacent curves.

In order to determine the appropriate operating speed and whether a tangent is to be considered as being independent or non-independent, the tangent length is evaluated in relation to T_{\min} and T_{\max} . It is thus necessary to calculate values of T_{\min} and T_{\max} . This calculation is based on an average acceleration or deceleration rate of $a = 0,85 \text{ m/s}^2$ which was established by application of car-following techniques³.

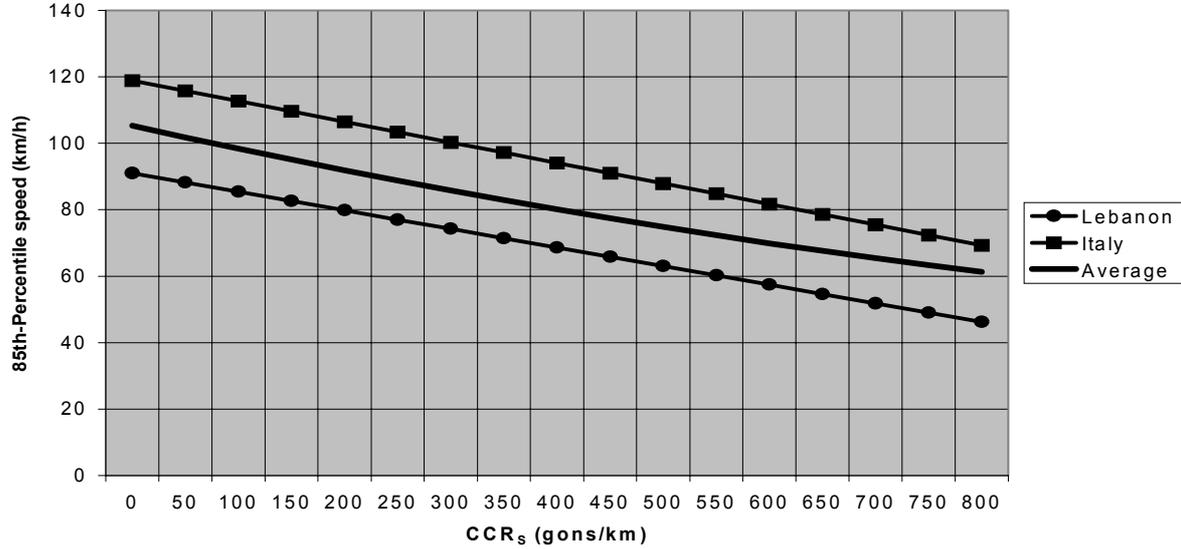


Figure 2 : Operating speed backgrounds for two-lane rural roads

Note: The average operating speed background is derived for eight countries : Australia, Canada, France, Germany, Greece, Italy, Lebanon and the United States

Case 1: For $T \leq T_{\min} \rightarrow$ non-independent tangent):

$$T_{\min} = \frac{|(V_{85_1})^2 - (V_{85_2})^2|}{2 * 3,6^2 * a} \quad (\text{Eq. 5})$$

$$T_{\min} = \frac{|(V_{85_1})^2 - (V_{85_2})^2|}{22,03} \quad (\text{Eq. 5a})$$

In Eqs. (5) and (5a), $T \leq T_{\min}$ means that the existing tangent is, at most, the length which is necessary for adapting the operating speeds between curves 1 and 2. In this case, the element sequence curve-to-curve, and not the intervening (non-independent) tangent, controls the evaluation process according to Safety Criterion II for differentiating between good, fair, and poor design practices

Case 2: For $T \geq T_{\max} \rightarrow$ independent tangent:

$$T_{\max} = \frac{(V_{85_{T_{\max}}})^2 - (V_{85_1})^2}{2 * 3,6^2 * a} + \frac{(V_{85_{T_{\max}}})^2 - (V_{85_2})^2}{2 * 3,6^2 * a} \quad (\text{Eq. 6})$$

$$T_{\max} = \frac{2 \cdot (V85_{T_{\max}})^2 - (V85_1)^2 - (V85_2)^2}{22,03} \quad (\text{Eq. 6a})$$

In Eqs. 6 and 6(a), $T \geq T_{\max}$ means that the existing tangent is long enough to allow acceleration up to the maximum operating speed ($V85_{T_{\max}}$) on tangents.

Case 3: For $T_{\min} < T < T_{\max} \rightarrow$ independent tangent:

$$\frac{T - T_{\min}}{2} = \frac{(V85_T)^2 - (V85_1)^2}{22.03} \quad \text{for } V85_1 > V85_2 \quad (\text{Eq. 7})$$

$$V85_T = \sqrt{11.016 * (T - T_{\min}) + (V85_1)^2} \quad (\text{Eq. 7a})$$

The existing tangent length lies between T_{\min} and T_{\max} . Although the tangent does not allow accelerations up to the highest operating speed ($V85_{T_{\max}}$), a speed higher than that of the following curve can be achieved. In this case, the realizable tangent speed ($V85_T$) has to be calculated according to Eq. 7a for the evaluation of Safety Criterion II.

6 FRICTION

In the field of geometric design, the most important characteristic of the road surface is its skid resistance. This applies to sight distance in all its forms, such as stopping sight distance, passing sight distance, barrier sight distance, intersection sight distance, etc. Side friction supports super-elevation in providing a balance between the centrifugal and centripetal forces operating on a vehicle while it is traversing a curve. In short, there must, in addition to the other forms of consistency, also be consistency in the driving dynamic at curved sites.

Criterion III was introduced to address this aspect of design consistency and relates to the difference between the side friction assumed for design and that actually demanded at the operating, or 85th percentile, speed. While, for good design, Criterion I requires that curve radii should not deviate too markedly from that appropriate to the design speed and Criterion II allows only limited deviation between operating speeds on successive design elements, Criterion III demands that each curve individually should also be safe.

Based on analysis of skid resistance databases in Germany, Greece and the United States, tangential friction is modelled by the expression:

$$f_T = 0,59 - 4,85 * 10^{-3} * V_D + 1,51 * 10^{-5} * V_D^2 \quad \text{Eq 8}$$

where f_T = tangential friction factor
 V_D = design speed (km/h)

The side friction assumed is a fraction of tangential friction and is taken as being

$$f_{RA} = 0,925 * n * f_T \quad \text{Eq 9}$$

where

f_{RA}	=	side friction assumed
0,925	=	parameter relating to tyres
n	=	utilisation factor [% / 100]
	=	0,40 for hilly or mountainous topography; new designs
	=	0,45 for flat topography; new designs
	=	0,60 for existing or old alignments

It is noted that the side friction assumed as derived from Eq 8 and 9 is dramatically lower than values adopted for South Africa, as illustrated in Figure 3.

The side friction demanded is expressed as

$$f_{RD} = \frac{V85^2}{127 * R} - e \quad \text{Eq 10}$$

where f_{RD}	=	side friction demanded
R	=	Radius of curve, m
E	=	superelevation rate [% / 100]

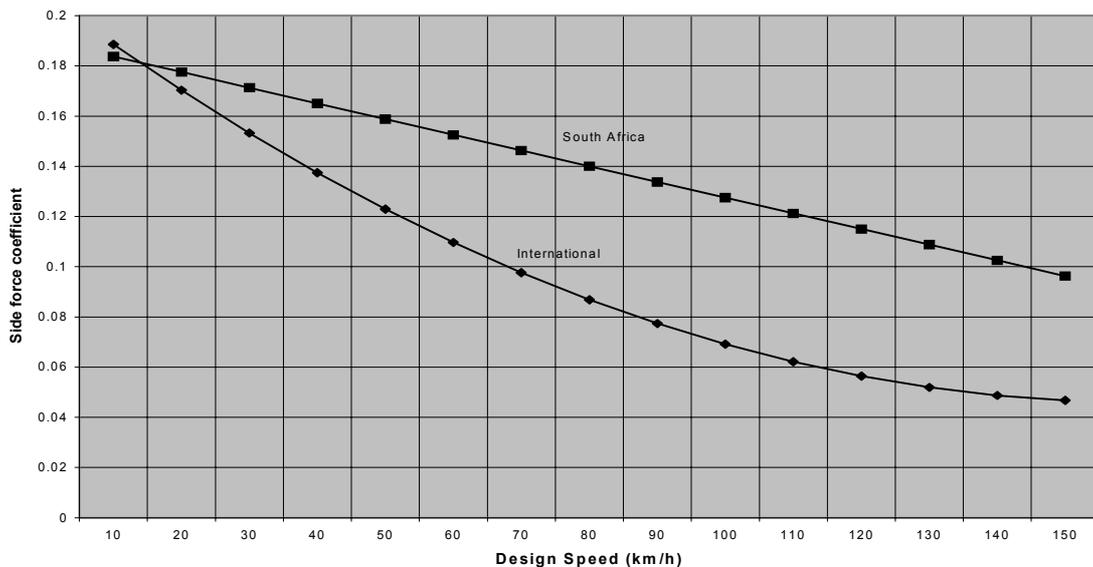


Figure 3 : Internationally assumed versus South African values of side-force coefficient

7 APPLICATION OF THE CRITERIA

In the previous sections, the criteria have been defined and relationships offered whereby the variables of interest can be calculated. To recapitulate, these are:

V_D	=	Design speed
$V85_1$	=	85 th percentile speed on preceding design element
$V85_2$	=	85 th percentile speed on succeeding design element
$V85_{Tmax}$	=	85 th percentile speed on long (independent) tangents

T_{\min}	=	Tangent length necessary to achieve V_{85_2} from an initial speed of V_{85_1}
T_{\max}	=	Tangent length necessary to achieve $V_{85_{T_{\max}}}$ from an initial speed of V_{85_1}
T	=	Existing (or proposed) tangent length between two curves
f_{RA}	=	Side friction assumed for design
f_{RD}	=	Side friction demanded at 85 th percentile speed

It is now necessary to apply these variables in the structured evaluation of a section of road.

- STEP1 The average CCR_S must be calculated from Eq 2 and hence the design speed by applying this value in Eq 3 or Eq 4. This presupposes that the design speed is not known.
- STEP2 $V_{85_{1, 2, \dots, n}}$, being the operating speeds on all curves along the road are calculated by deriving the CCR_S in accordance with Eq 1 and then applying this value to either Eq 3 or Eq 4, depending on the gradient across the curve.
- STEP3 The tangent lengths between successive curves are to be recorded and the minimum and maximum tangent lengths between each pair of successive curves calculated according to Eq 5a and 6a. Where the actual (or proposed) tangent length falls between these two values it will be necessary also to calculate the V_{85} achieved according to Eq 7a

It is necessary to go to the additional step of calculation of operating speeds on the curves because of the presence of intervening tangents of various lengths. If all tangents were non-independent, this step would not be necessary and direct comparison of the CCR_S of the successive curves would be adequate to establish whether the requirements of Criteria I and II are met or not.

The differences in CCR_S in Table 1 correspond very conveniently to speed differences, V_{Diff} of

	$V_{Diff} \leq$	10 km/h	for good design
10km/h <	$V_{Diff} \leq$	20 km/h	for tolerable design
20 km/h <	V_{Diff}		for poor design

Thus the classification values for Safety Criteria I to III are as shown in Table 3.

It is important to note that all criteria must be met for the design of an element to be considered as being good or tolerable. If a particular element is rated as “good” in terms of Criterion I and II but as “poor” in terms of Criterion III, for example, this provides a pointer to the action required to upgrade it to being “good”. The same is true for other ratings possibilities of Safety Criteria I to III.

Note that the value of -0,04 in Safety Criteria III of Table 3 suggests that, in the case of poor design, inroads are being made into the safety factor that is built into Equations 9 and 10.

Table 3 : Classification of Safety Criteria I, II and III

SAFETY CRITERION I		
Design CCR_s Class (gon/km)	Speed Difference (km/h)	Quality of design
$ CCR_{Si} - \Phi CCR_S \leq 180$	$ V_{85_i} - V_D \leq 10$	Good
$180 < CCR_{Si} - \Phi CCR_S \leq 360$	$10 < V_{85_i} - V_D \leq 20$	Tolerable
$360 < CCR_{Si} - \Phi CCR_S $	$ V_{85_i} - V_D > 20$	Poor
SAFETY CRITERION II		
Design CCR_s Class (gon/km)	Speed Difference (km/h)	Quality of design
$ CCR_{Si} - CCR_S \leq 180$	$ V_{85_i} - V_{85_{i+1}} \leq 10$	Good
$180 < CCR_{Si} - CCR_S \leq 360$	$10 \leq V_{85_i} - V_{85_{i+1}} \leq 20$	Tolerable
$360 < CCR_{Si} - CCR_S $	$20 < V_{85_i} - V_{85_{i+1}} $	Poor
SAFETY CRITERION III		
Design CCR_s Class (gon/km)	Frictional Difference	Quality of design
$ CCR_{Si} \leq 180$	$+0,01 \leq f_{RA} - f_{RD}$	Good
$180 < CCR_{Si} \leq 360$	$-0,04 \leq f_{RA} - f_{RD} \leq +0,01$	Tolerable
$360 < CCR_{Si} $	$f_{RA} - f_{RD} < -0,04$	Poor

8 CONCLUSION AND RECOMMENDATIONS

A methodology whereby the horizontal alignment of a road can be tested for consistency has been developed. The methodology is based on the new design parameter, Curvature Change Rate of the Single Curve. This parameter was tested against several databases of accident rates and accident cost rates and found to be the major descriptor of the safety of the road. The same is true with respect to operating speeds.

Three criteria were developed on the basis of this parameter, being

- the comparison between the design speed and driving behaviour as manifested by variations in operating speed;
- the comparison of operating speeds across successive design elements; and
- the comparison of side friction assumed for design with that demanded at the operating speed.

Relationships enabling the calculation of the variables were developed on the basis of American, German and Greek databases. .

It is believed that the basic hypotheses would apply also to South Africa but that the relationships offered may have to be modified to match the South African situation. Acquiring data of horizontal curvature and the related operating speeds is a straightforward, albeit laborious, process. The difference between the relationships for side force coefficient adopted for South African design and that suggested in Section 6 should also be explored

Relating these data to accident rates and accident cost rates is, unfortunately, a far more intractable problem, given the inadequacy of currently available information. It is strongly recommended that South Africa should, as a matter of urgency, initiate the development of a national database of accident statistics that will lend itself to the required analyses.

A pilot study on a local road with a known poor safety history could be initiated prior to major investment into the development of the database referred to. An example that springs to mind is the Moloto road outside Pretoria. In the absence of local information, this would have to make use of the relationships presented above but would offer an indication of the validity or otherwise of the proposed system of safety evaluation.

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INTRODUCTION OF A NEW APPROACH TO GEOMETRIC DESIGN AND ROAD SAFETY

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