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Preliminary Communication

Accepted: Aug. 23, 2011

Approved: Jan. 29, 2013

# OPERATING SPEED BASED ALIGNMENT CONSISTENCY EVALUATION USING DRIVING SIMULATOR: CASE STUDIES FROM TAIGAN FREEWAY IN JIANGXI, CHINA

## ABSTRACT

*Geometric design consistency refers to the conformance of a proposed or existing freeway's geometry with the driver's expectancy. Considerable efforts have been undertaken to develop potential quantitative consistency measures and models to estimate them. However, little work has been focused on the facts of freeways in China, especially in mountainous areas. The primary objective of this study is to examine and quantify the design consistency of a freeway, using an interactive driving simulator, so as to identify any inconsistency on the roadway geometry and improve its overall safety performance. More specifically, the techniques to evaluate the consistency of a geometric design depend on three criteria: design consistency, operating speed consistency, and consistency in driving dynamics, as well as three levels of consistency: good, acceptable and poor. In the case of Taigan Freeway, a part of G45 Daguang Freeway in Jiangxi, China, a 21km long segment has been divided into 38 sections including 22 curves and 16 tangents, and transferred into the graphics models in the simulator system. There were 42 drivers required to take part in the simulation experiment and the speed, location of vehicle, and other real time data were recorded as well. The findings have shown that these proposed measures and standards can identify a geometric inconsistency more effectively when there is a large rate of change in the alignment elements for a successive roadway segment.*

## KEY WORDS

*safety performance, geometric design consistency, driving simulator, operating speed, alignment element*

## 1. INTRODUCTION

Freeway design consistency is an emerging rule indicating that the geometry of roadway alignment is

in conformance with either the expectation or ability of a driver to operate the vehicle in a safe and predictable manner [1]. This method identifies any geometric inconsistency during the design of a freeway or on existing freeways by means of design evaluation criteria. Since the reduction of roadway geometric inconsistencies can significantly reduce both the occurrence of crashes and injury severities, accordingly, it becomes one of the major considerations regarding the smooth and safe traffic operation of a freeway [2, 3]. It even provides the constructive decision references in reducing the geometric inconsistencies of alignment elements below an acceptable threshold at the design stage [4].

By far, previous studies of geometric design consistency have been categorized into three main areas: speed concerns, safety concerns, and performance concerns [1]. The first, speed concerns address the relation between operating speed and geometric parameters and construct the operating speed predication equation, with which the design consistency of alignment elements can be measured [5]. The second, safety concerns examine the different effects of alignment indices and vehicle stability on the freeway safety and put forward low-cost improvement measures [6]. The third, performance concerns keep an eye on the driver's physiological and psychological workload, anticipation, landscape aesthetics and scenery, and interchange design, etc., and all these affect the driver's performance [7].

In the practice of freeway design, in its nature, the concept of geometric design consistency is based on the assumption for parameters associated with driving behaviors [8], such as speed choice, tangential and lateral acceleration / deceleration, etc. Therefore, an inconsistent alignment requires drivers to han-

dle speed gradients so as to drive safely on certain alignment with inconsistencies. As early as in 1988, Lamm et al. reported that a sharp change in operating speed of vehicles indicates the possible inconsistency in alignment geometry [9]. To conduct a geometric design consistency evaluation, therefore, operating speed, often defined as 85<sup>th</sup> percentile speed ( $V_{85}$ ), is widely used to measure the geometric design consistency in literature, and this specific measure of speed examines the difference between design speed  $V_D$  and  $V_{85}$  or the disparities in  $V_{85}$  between any successive alignment elements [1, 2, 10]. The transition sections between tangent and curve are the most critical locations that are prone to cause crashes.

Another method to evaluate the geometric design consistency is the quantitative study of alignment indices, such as average radius ( $AR$ ), average rate of vertical radius ( $AVC$ ), ratio of radius of a single horizontal curve to the average radius of the examined section ( $CRR$ ), and then to develop a relationship equation between crash frequency and alignment indices [11]. Locations that have critical higher frequency of crashes can be considered as geometric design inconsistencies. In the sense of vehicle stability, Lamm et al. defined the assumed side friction ( $f_{RA}$ ) and the demanded side friction ( $f_{RD}$ ), related to  $V_D$  and  $V_{85}$ , respectively, in the "Highway Design and Traffic Safety Engineering Handbook". According to Lamm's criterion, the difference between  $f_{RA}$  and  $f_{RD}$  helps examine the level of geometric design inconsistencies [1].

The third approach for examining the geometric design consistency is by means of drivers' workload. Here Messer has defined the driver workload as "the time rate at which drivers must perform a given amount of work or driving tasks" [7]. It relates to a driver's response to upcoming driving conditions and events. Compared with the other geometric design consistency measures, however, the measurement of drivers' workload is much more complex and easily affected by weather, noise and other environmental factors, so it is less used [12].

To provide a broad overview, freeway presents a hazardous environment to drivers, induced by the presence of complex topography, diverse terrain, environmental barriers and lack of facilities, and it is difficult, or even impossible, to measure the actual operating speed of freeway vehicles directly [13]. Fortunately, the driving simulator provides such a laboratory tool to simulate a visual and interactive environmental condition such as weather, traffic patterns, facilities [14]. Therefore, the primary purpose of this study is to present a methodology of examining the geometric design consistency of alignment elements for Taigan Freeway in Jiangxi, China, using the deriving operating speed from a driving simulator and roadway geometry. This research is structured as follows: First, a summary of current literature on the consistency evaluation

of freeway geometric design is presented. This is followed by a description of the methodology proposed in this study including the simulated data collection, three criteria and three levels of consistency. The third section of findings and discussions focuses primarily on the geometric design consistency evaluation of the sampled 21km segment of Taigan Freeway in Jiangxi, China. Finally, conclusions and recommendations for further research are presented.

## 2. METHODOLOGY

### 2.1 Data collection activity

Due to the limited financial assistance, it is impossible to carry out the real-world test under diverse traffic conditions (e.g., weather, traffic flow, geometrics, facilities, etc.) for most cases; therefore, the driving simulator provides an effective laboratory tool to reconstruct the roadway geometrics and perceived driving environment using graphics based visualization pattern and to verify the performance of planned, constructed or in-service freeway [14].

The simulation experiment has been carried out using the driving simulator at the Key Laboratory of Automotive Transportation Safety Technology, Ministry of Transport, Chang'an University. The 21.0km sample alignment is selected from G45 Freeway from Daqing to Guangzhou in Jiangxi mountainous area with the posted speed limit of 120 km/h, which starts from K2913 to K2934 with 22 curves and 16 tangents. The geometric graphics of roadway alignment are transferred from CAD model in the simulator system, including roadside barriers or guard rails, medians, traffic signs/ markings, weather conditions, etc.

The test drivers have been selected according to the age, gender, status of license, driving experience, crash record, and vision, etc. Finally, 42 drivers aged from 22 to 56 were chosen for the simulation test, with 29 males and 13 females, at least three years of driving experience and average 18.3 years. These examinees were required to operate a full-scale car of MAZID 6 and make the simulation trip from K2913 to K2934 freely, while facing the visual scenes or scenario generated by the simulator on the screen in front of the experimental car, and the real time information of driver's response, vehicle performance (e.g., the status of velocity, acceleration/deceleration, etc.), roadway geometrics, and environment conditions were collected as well. The experiment was repeated several times and the simulation trips with abnormal data due to excessive nervousness and unfamiliarity with simulator driving etc. were removed from the database [15]. Finally, the selected data was averaged to obtain the travelling speed, vehicle stability indices and other parameters in further analysis.

Table 1 - The geometric parameters of test freeway alignment

No	Radius/m	Length/m	Grade/%	e/%	No	Radius/m	Length/m	Grade/%	e/%
1	∞	320	4.7	2	20	∞	653	-1.2/3.3	2
2	2,150	493	4.7/-2.1	2	21	1,200	522	3.3	4
3	∞	665	-2.1/2.2	2	22	∞	650	3.3	2
4	1,450	680	2.2	3	23	900	463	3.3/3.9	5
5	500	470	2.2	7	24	∞	778	3.9/0.8/3.1	2
6	850	360	2.2/-1.1	5	25	750	425	3.1	6
7	∞	617	-1.1/3.8	2	26	∞	451	3.1/1.0	2
8	3,100	483	3.8/-3.4	2	27	550	438	1.0/-0.1	5
9	∞	1298	-3.4/-2.6	2	28	450	670	-0.1/-3.5	8
10	700	384	-2.6/1.7	4	29	∞	615	-3.5/1.8	2
11	∞	1303	1.7/-3.6/-0.4	2	30	1,300	300	1.8	3
12	850	449	-0.4/-1.6	5	31	∞	1360	1.8/-3/-2.7	2
13	∞	390	-1.6/-0.2	2	32	700	415	-2.7/3.5	6
14	2,100	321	-0.2/-0.7	2	33	1,700	389	3.5	2
15	2,150	291	-0.7	2	34	1,400	414	3.5/-2.8	3
16	∞	457	-0.7/-3.4	2	35	∞	421	-2.8/0.9	2
17	1,000	595	-3.4/-1.2	4	36	400	490	0.9/-4.5	9
18	∞	215	-1.2	2	37	450	680	-4.5/2.2	9
19	1,100	420	-1.2	4	38	∞	655	2.2/0.8	2

## 2.2 Consistency evaluation criterion

AASHO defines the design speed as the maximum safe speed maintained over a specific section of highway under favourable weather and traffic density conditions in its "Green Book": *A Policy on Geometric Design of Highways and Streets*, which is used to determine the minimum radius of horizontal curves and maximum grades, etc. The 85<sup>th</sup> percentile speed ( $V_{85}$ ) refers to the speed at or below which 85% of the observed vehicles are travelling [16]. Generally, it is recommended that the expected  $V_{85}$  should not exceed the design speed by more than 20 km/h, otherwise, it will possibly cause higher risk of accident involvement, which requires either the increase of the design speed or modification of the geometry design so as to reduce the expected  $V_{85}$  [17]. The AASHO recommends the use of observed  $V_{85}$  during free flow conditions (30% of average demand, no accidents, good weather) as the operating speed in the former mentioned "Green Book", and the similar standard has been also encouraged by the Chinese Highway Safety Design Manual (JTJ/TB05-2004) released by the Ministry of Transport. Of course, both these standards are determined according to the assumption that the travelling of vehicles is only affected by the designed geometrics of roadway when traffic volumes are low [1].

In this study, three safety criteria are used [18]:

Criterion I: *Design Consistency*. A freeway's geometry should be designed consistent with the driver's expectancy, and the design speed and the expected

speed should be balanced along longer roadway sections.

Criterion II: *Operating Speed Consistency*. The operating speed should remain consistent with the established design speed for longer roadway sections. In case of change in design speed due to changes in roadway geometry limited by the specific topography, any two successive geometric elements and specifically cross sections should be carefully adjusted to each other so as to avoid the abrupt geometric changes in transition sections.

Criterion III: *Consistency in Driving Dynamics*. It seeks a consistent balance between the side friction assumed ( $f_{RA}$ ) accounting for the design speed and that demanded ( $f_{RD}$ ) at the 85<sup>th</sup> percentile speed.

## 2.3 Level of consistency

In many previous studies, design parameters of freeway are reported to be closely associated with the variability of the operating speed and accident rate, and therefore, in the case of Criteria I and II, the values of  $V_{85}$  are determined for each section of roadway alignment and then we assess the corresponding consistency of successive design elements, especially the transition curves. Here we use a parameter, Curvature Change Rate of single curve (CCRs) measured in gon per kilometer, to describe the first two criteria, combining the difference of  $V_{85}$  values of each two successive sections [19], as shown by Eq (1).

Table 2 - Classification of safety criteria by cut-off values

Criteria	Design CCRs / gon·km <sup>-1</sup>	Speed difference / km·h <sup>-1</sup>	Quality of design
I	$ CCR_{si} - ACCR_s  \leq 150$ $150 <  CCR_{si} - ACCR_s  < 300$ $ CCR_{si} - ACCR_s  \geq 300$	$ V_{85i} - V_{Di}  \leq 10$ $10 <  V_{85i} - V_{Di}  < 20$ $ V_{85i} - V_{Di}  \geq 20$	Good Acceptable Poor
II	$ CCR_{si} - ACCR_s  \leq 150$ $150 <  CCR_{si} - ACCR_s  < 300$ $ CCR_{si} - ACCR_s  \geq 300$	$ V_{85i} - V_{85i+1}  \leq 10$ $10 <  V_{85i} - V_{85i+1}  < 20$ $ V_{85i} - V_{85i+1}  \geq 20$	Good Acceptable Poor
III	$ CCR_{si}  \leq 150$ $150 <  CCR_{si}  < 300$ $ CCR_{si}  \geq 300$	$f_{RAi} - f_{RD_i} \geq 0.02$ $-0.03 < f_{RAi} - f_{RD_i} < 0.02$ $f_{RA} - f_{RD_i} \leq -0.03$	Good Acceptable Poor

$$CCRs = \frac{L_{c11}}{2R} + \frac{L_{cr}}{R} + \frac{L_{c12}}{2R} \cdot \frac{200}{\pi} \cdot 10^3, \quad (1)$$

where  $L$  is the entire length of unidirectional curved section accounting for  $L_{c11} + L_{cr} + L_{c12}$ , m;  $L_{cr}$  is the length of circular curve, m;  $L_{c11}$  and  $L_{c12}$  are the length of clothoid curve prior to or after the circular curve, respectively, m;  $R$  is the radius of circular curve, m.

For the reviewed section with  $n$  curves, therefore, the average curvature change rate of the total single curves is estimated by:

$$ACCRs = \frac{\sum_{i=1}^n CCR_{si} \cdot L_i}{\sum_{i=1}^n L_i}, \quad (2)$$

where  $CCR_{si}$  is the curvature change rate of curve  $i$ , and  $L_i$  is the length of curve  $i$ .

For the case of Criterion III, the difference between  $f_{RA}$  and  $f_{RD}$  is adopted from the recorded simulation data at the midpoint of curve and tangent length. The tangential friction is modelled as Eq. (3), depending on the design speed  $V_D$  [18],

$$f_t = 0.59 - 4.85 \times 10^{-3} \times V_D + 1.51 \times 10^{-5} \times V_D^2, \quad (3)$$

and the side friction assumed is a function of tangential friction and is expressed in [18]:

$$f_{RA} = 0.925n \cdot f_t, \quad (4)$$

where  $n$  is a coefficient equalling 0.4 for new designed hilly/mountainous alignments, 0.45 for those of new design and flat, or 0.6 for those of in service.

In addition, the side friction demanded is calculated using the AASHTO findings as [1, 18]:

$$f_{RD} = \frac{V_{85}^2}{127R} - e, \quad (5)$$

where  $R$  is the radius of curve, m;  $e$  is the rate of superelevation, %/100.

These criteria are classified into three levels through the proposed cut-off values: good (safe), acceptable (marginal) and poor (dangerous), as shown in Table 2, in which, good = no alignment correction is required, acceptable = no alignment correction is required, but improvements may be desirable to traffic signs, markings, barriers etc., and poor = alignment re-design is strongly required. It is important to note that

all sections of alignment meet the requirements of the good or acceptable criteria; otherwise, those sections of being rated as “poor” may be potential black spots or accident-prone locations.

The final judgment depends on the worst ranking. If a particular section is identified as “poor” in terms of one criterion but “good” or “acceptable” in the other two criteria, for example, this section’s final recommendation is downgraded to “poor”.

### 3. FINDINGS AND DISCUSSION

Using the recorded traffic flow data and geometric data combined with Eqs. (1) – (5), three criteria can be quantitatively measured regarding the alignment geometry for the reviewed 38 sections between K2913 and K2934 of Taigan Freeway, as shown in Table 3.

Due to the limit of geography, Section 1 has a reduced maximum design speed of 100 km/h, depending on the large slope, and other 37 sections have a uniform design speed of 120 km/h. According to the recorded speed characteristics data, the speed of each type of drivers is summarized to determine the corresponding 85<sup>th</sup> percentile speed at the middle point of each section, and subsequently obtain the average  $V_{85}$  for the overall traffic flow, as listed in Table 3. For each section out of the reviewed 38 ones (22 curves and 16 tangents) in the test, the differences between  $V_{85}$  and design speed  $V_D$ , the  $V_{85}$  changes of any two successive sections, and the assumed / demanded side friction have been calculated through the proposed three criteria.

Since the curvature change rate  $|CCR - ACCR|$  and  $|CCR|$  of the single circular curve with transition curves is smaller than 150, the corresponding curvature consistency is highlighted by “good”, according to the proposed three criteria. More specifically, the change ratio of curvature of a vehicle’s trajectory is closely associated with the consistency of horizontal alignment, and therefore reflects the design quality of alignment [1]. Figure 1 shows the average curvature of vehicle trajectory using the test data, in which the outside straight line and inside curve line represent the curvature of roadway alignment and vehicle travel-

Table 3 - Three safety consistency evaluations

No	CCR	ACCR	CCR - ACCR	$V_D$	$V_{85}$	$ V_{85} - V_D $	$ \Delta V_{85} $	$f_{RA}$	$f_{RD}$	$f_{RA} - f_{RD}$
1	-	-	-	100	113	13	-	-	-	-
2	19.82	50.67	30.85	120	114	6	1	0.125	0.028	0.097
3	-	-	-	120	117	3	3	-	-	-
4	30.22	50.67	20.45	120	110	10	7	0.125	0.036	0.089
5	83.86	50.67	33.19	120	108	12	2	0.125	0.114	0.011
6	45.82	50.67	4.85	120	111	9	3	0.125	0.064	0.061
7	-	-	-	120	122	2	11	-	-	-
8	12.52	50.67	38.15	120	102	18	20	0.125	0.006	0.119
9	-	-	-	120	110	10	8	-	-	-
10	51.98	50.67	1.31	120	121	1	11	0.125	0.125	0
11	-	-	-	120	107	13	14	-	-	-
12	45.91	50.67	4.76	120	108	12	1	0.125	0.058	0.067
13	-	-	-	120	110	10	2	-	-	-
14	20.38	50.67	30.29	120	108	12	2	0.125	0.024	0.101
15	18.87	50.67	31.8	120	105	15	3	0.125	0.020	0.105
16	-	-	-	120	103	17	2	-	-	-
17	46.64	50.67	4.03	120	106	14	3	0.125	0.048	0.077
18	-	-	-	120	109	11	3	-	-	-
19	38.37	50.67	12.3	120	110	10	1	0.125	0.067	0.059
20	-	-	-	120	123	3	13	-	-	-
21	33.90	50.67	16.77	120	121	1	2	0.125	0.076	0.049
22	-	-	-	120	115	5	6	-	-	-
23	44.03	50.67	6.64	120	123	3	8	0.125	0.112	0.013
24	-	-	-	120	129	9	6	-	-	-
25	53.22	50.67	2.55	120	122	2	7	0.125	0.136	-0.011
26	-	-	-	120	108	12	14	-	-	-
27	74.28	50.67	23.61	120	102	18	6	0.125	0.069	0.056
28	97.43	50.67	46.76	120	99	21	3	0.125	0.151	-0.026
29	-	-	-	120	114	6	15	-	-	-
30	27.71	50.67	22.96	120	111	9	3	0.125	0.055	0.070
31	-	-	-	120	106	14	5	-	-	-
32	54.23	50.67	3.56	120	115	5	9	0.125	0.129	-0.004
33	24.75	50.67	25.92	120	113	7	2	0.125	0.029	0.096
34	30.11	50.67	20.56	120	100	20	13	0.125	0.036	0.089
35	-	-	-	120	107	13	7	-	-	-
36	104.88	50.67	54.21	120	102	18	5	0.125	0.095	0.030
37	96.27	50.67	45.6	120	106	14	4	0.125	0.135	-0.009
38	-	-	-	120	101	19	5	-	-	-

Note:  $n = 0.6$  in Eq. (4)

ling trajectory. Obviously, the curvature scope of the vehicle path fluctuates with the horizontal curvature but in a smaller amplitude.

Reconsidering the result of Table 3, the consistency of each section is highlighted by “good”, “acceptable” or “poor” based on Criteria I, II and III, respectively. As listed in Table 4, it can be clearly noted that Criterion

I identifies 19 sections of good consistency, 17 sections of acceptable consistency, and 2 sections of poor consistency, followed by 30, 6, and 2 sections ranked good, acceptable and poor in the case of Criterion II. But for the Criterion III, 11 sections are ranked good, 9 sections are acceptable and only one section is poor. Finally, 12 sections are ranked good for overall



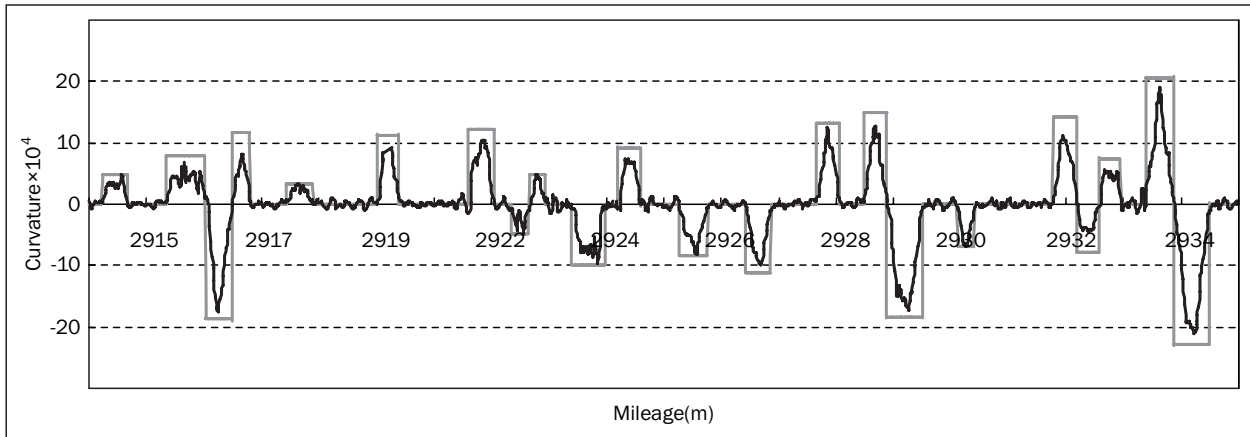


Figure 1 - Curvature of vehicle trajectory in testing

Table 4 - Design consistency analysis of each section

Section	Criterion I	Criterion II	Criterion III	LODC	Section	Criterion I	Criterion II	Criterion III	LODC
1	oo	ooo	—	oo	20	ooo	oo	—	oo
2	ooo	ooo	ooo	ooo	21	ooo	ooo	ooo	ooo
3	ooo	ooo	—	ooo	22	ooo	ooo	—	ooo
4	ooo	ooo	ooo	ooo	23	ooo	ooo	oo	oo
5	oo	ooo	oo	oo	24	ooo	ooo	—	ooo
6	ooo	ooo	—	ooo	25	ooo	ooo	oo	oo
7	ooo	oo	—	oo	26	oo	oo	—	oo
8	oo	o	oo	o	27	oo	ooo	ooo	oo
9	ooo	ooo	—	ooo	28	o	ooo	oo	o
10	ooo	o	oo	o	29	ooo	oo	—	oo
11	oo	oo	—	oo	30	ooo	ooo	ooo	ooo
12	oo	ooo	ooo	oo	31	oo	ooo	—	oo
13	ooo	ooo	—	ooo	32	ooo	ooo	o	o
14	oo	ooo	oo	oo	33	ooo	ooo	ooo	ooo
15	oo	ooo	oo	oo	34	o	oo	ooo	o
16	oo	ooo	—	oo	35	oo	ooo	—	oo
17	oo	ooo	ooo	oo	36	oo	ooo	ooo	oo
18	oo	ooo	—	oo	37	oo	ooo	oo	oo
19	ooo	ooo	ooo	ooo	38	oo	ooo	—	oo

Note: 000 – Good, 00 – Acceptable, 0 – Poor, — – Data not applicable or unavailable, LODS – Level of design consistency

design consistency of alignment, 21 sections are acceptable, and 5 sections are poor, according to the proposed standard, as shown in Table 4. Therefore, the sample road has been designed in a high standard and each section is homogenous with the successive ones.

Figure 2 shows the average  $V_{85}$  with respect to radius of curve, slope, and height. However, the limited geographical conditions affect the operating speed of vehicles, especially at some critical locations with slope larger than 3.5%.

#### 4. CONCLUSION

Freeway accidents are one of the most serious problems in China, especially in mountainous areas, causing thousands of fatalities and injuries every year. To cope with the improvement of freeway safety, this research presents a systemic evaluation model of geometric design consistency that may be used as a surrogate measure of assessing the level of traffic safety of existing freeways or those under design or construction stages.

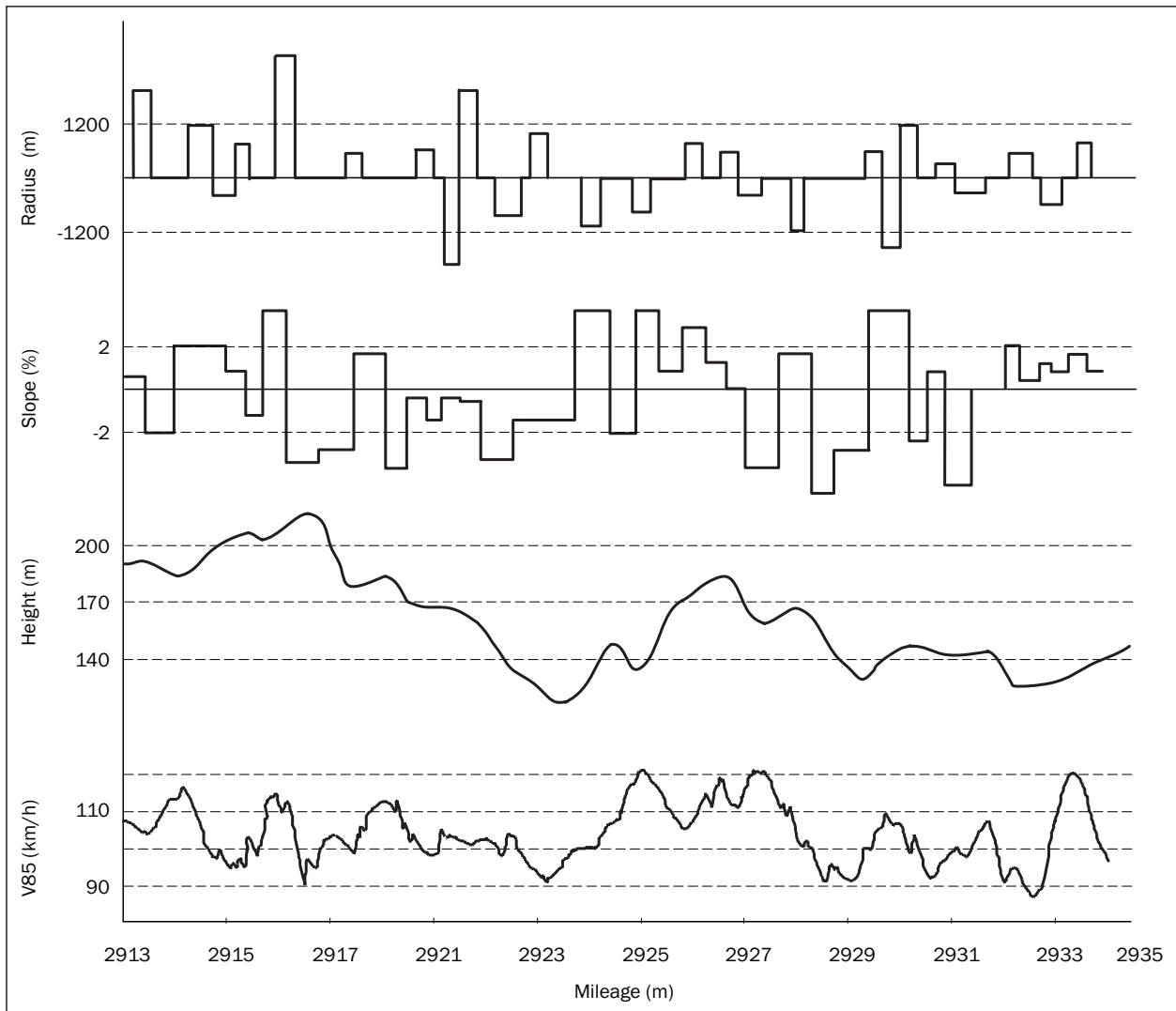


Figure 2 - The average 85<sup>th</sup> percentile speed and geographical conditions

Specifically, three criteria (design consistency, operating speed consistency and consistency in driving dynamics) and three levels (good, acceptable, and poor) have been performed to measure the geometric design consistency quality of roadway alignment. To collect speed and roadway data, a simulation experiment with 42 testers has been conducted through a specific driving simulator on the existing multi-lane section of Taigan Freeway in Jiangxi, China, and the selected 21km roadway segment has been divided into 38 sections (22 curves & 16 tangents) in the form of graphic elements stored in the simulator system. During the simulated driving process, the positions of vehicles, speeds, and other relative parameters were recorded from the simulator. As confirmed by the experiment result, the presented model has given some of the indications on safety condition in specific cases and can serve as the basis for further analysis.

Because the predicted speed reduction is closely associated with accident frequency and severity, speed reduction should be the primary measure in

modelling the quality of alignment design consistency for the whole road segment [20, 21]. Consequently, in order to accomplish this, improved methods to predict speeds should be conducted, including the issues about trucks.

Further research is also proposed to combine the crash rate into consistency index and consistency thresholds and to form an innovative measure to evaluate road safety through the detailed crash data observation and provide decision helps for engineers. This future research should also use safety performance functions associated with the specific localities to describe the level of safety rather than through crash rates. As an effective simulation software, the Interactive Highway Safety Design Model (IHSDM) is strongly recommended for evaluating safety and operational effects of geometric design on freeways in the latter analysis. It is expected that this comprehensive consistency assessment measure that relates to China conditions will provide an effective tool for improving freeway safety.

## ACKNOWLEDGEMENT

This research is partially supported by the National Natural Science Foundation of China (No. 51208051). Also, special thanks must go to two Chinese scholars, Prof. Dr. KM Chen in Chang'an University and Dr. MJ Lei in Jiangxi Scientific Research Institute of Communication for providing help in field data gathering and guiding the driving simulator. Here we thank the editors of *Promet-Traffic&Transportation*, anonymous reviewers and authors of cited papers for their detailed comments and continued support, without which this work would not have been possible.

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## 摘要

基于驾驶模拟器的高速公路线形设计一致性评价：以江西省泰赣高速为例

线形设计一致性指一条规划或运营的高速公路线形与驾驶员期望相吻合, 已有的研究中大量关注了可用于设计一致性评价的量化指标及模型等, 但对中国高速公路的情况却研究不多, 尤其是山区高速公路。本研究的主要目的在于通过交互式驾驶模拟器实验, 测定一条高速公路的线形设计一致性, 以便于识别路线上任何线形不一致的区段、提高其整体安全绩效。为此, 确定了线形设计一致性评价的3个准则: 设计一致性、运行速度一致性、车辆运动一致性, 以及一致性水平划分: 好、可接受、差。选取泰赣高速即大广高速G45江西段的一21公里路段进行模拟实验, 将全线划分为38个小区段, 包括22个曲线段和16个直线段, 并转化为模拟器系统中的图像模型。42个驾驶员参与了在模拟环境中进行驾驶操作, 车速、车辆位置及其它实时交通信息被记录在系统中。研究结果表明当连续路段的线形元素出现突变时, 所建议的一致性判别指标及标准能有效识别其位置。

## 关键词

安全绩效, 线形设计一致性, 驾驶模拟器, 运行车速, 路线元素

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