EXAMINING THE EFFECT OF GEOMETRIC DESIGN FEATURES ON THE SPEED IN HORIZONTAL CURVE ON MOUNTAIN ROAD

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Resume

In this study, the effect of five geometric design features, including radius, superelevation, longitudinal grade, lane and shoulder width, on the average speed in the horizontal curve on a two-lane undivided rural road was investigated. The standardized regression coefficients showed that the most important factor affecting the speed was the radius (10.47) followed by the longitudinal grade (4.46). Superelevation and lane width had little effect. Shoulder width had no significant effect. This would be due to the wide width of the lanes. It was found that the relationships between speed and radius, longitudinal grade, superelevation and lane width were radical, quadratic, linear and linear, respectively. Increasing the longitudinal grade has increased the speed of the drivers. Increasing the superelevation was effective when its value changed from negative to positive.

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1 Introduction

Improper driving strategy is one of the main causes of accidents (roughly 65 %). In general, speed, changes in acceleration and vehicle trajectory are a reflection of the driving strategy. Researches have shown that horizontal curves are a critical location on rural two-lane roads due to the possibility of skidding or overturning [1]. Improper perception and expectation of horizontal curve sharpness also affects the driver's strategy and can lead to dangerous speeds and accidents. Investigating the effect of horizontal curve properties on driver performance has remained a major road safety issue [2].

Accidents are more likely to occur in horizontal curves than on straight segments, as the need for the driver attention is increased and the drivers may take the wrong speed and path. The average number of accidents reported in the United States indicates that the number of accidents in horizontal curves is higher than straight segments. In 2008, the rate of accidents on horizontal curves has been 3 times higher than accidents on other segments of highways.

About 75 % of road fatal crashes have been caused by a car going off the road and hitting fixed objects such as trees [3]. Studies in other countries have also confirmed it [4]:

- The rate of crashes in curves was 1.5 to 4 times than that of straight segments.
- 25 to 30 % of injury accidents occur in horizontal curves.
- Approximately 60 to 70 % of fatal crashes in curves are single-vehicle crashes.

Among all the features of horizontal curves, factors such as small radius, narrow lane width and cross section (including lanes and shoulders) can be mentioned [5]. Andjus and Maletin studied speed in horizontal curves. Nine horizontal curves on rural two-lane roads with radii in the range of 50 to 750 m were examined. The curves were more than 2 km away from any intersection and free flow speed were extracted from data with a time headway of more than 7 sec. The results showed that with the increase in the radius, not only does the average speed increase, but the range between the 85th and 15th percentile speeds increases as well [6]. Dell'Acqua provided equation (1) for environmental speed (V_{ENV}) that depended on two variables: curvature

Table 1 *Relationship between operating speed in horizontal curves and geometric design features*

Researcher(s)	Estimated relationship
Castro at al. [10]	$V_{85} = 102.048 - \frac{3990.26}{R}, R \leq 400\,m$
Camacho et al. [11]	$V_{85}^2 = 127 * R\left(f + \frac{e}{R}\right), R \leq 70\,m$
Kanellaidis at al. [12]	$V_{85} = 129.88 - \frac{623.1}{\sqrt{R}}$
Abbas at al. [13]	$V_{85MC} = 129.88 - \frac{623.1}{\sqrt{R}} + 0.307\,V_{85AT}$
Misaghi and Hassan [14]	$V_{85MC} = 94.3 + 8.67 * 10^{-6} * R^2$
Jacob and Anjaneyulu [15]	$V_{85} = 56.75 - \frac{739.21}{R} - 0.034 * CL$
Dilling [16]	$V_{85} = 5.32 - 1.12 * V_{AVG}$ $V_{AVG} = 25.1 + 5.57b + 0.05R - 0.05CCR$

V_{85MC}: 85th speed in the middle of the curve, V_{85AT}: 85th speed in straight segment, *CCR*: curvature change rate, *b*: lane width, V_{AVG}: Average of speed in the curve, *R*: Radius, *e*: superelevation, *f*: skid resistance, *CL*: length of curve

change rate (CCR) in terms of gradient per kilometer and road width (L) in terms of meter:

$$V_{ENV} = 82.84 - 0.1033 * CCR + 3.44 * L\,. \tag{1}$$

It should be noted that the environmental speed defined as a maximum velocity of 85 % in straight segments or curves with a high radius [7]. Dhahir and Hassan used naturalistic driving study (NDS) data prepared by the second strategic highway research program (SHRP2) to examine driver behavior on curves. They selected 24 curves in flat areas and 25 curves in mountainous areas for study. They presented Equation (2) for the speed in the middle of the horizontal curve. The dependent variable of this model was the operating speed in the middle of the curve (V85MC) and the independent variables included the radius (R), the speed limit (VL) and a dummy variable T (0 for flat, 1 for mountainous areas) [8]:

$$\begin{aligned} &V_{85MC} = 80.352 + \frac{3289.296}{R} + 0.261 * V_L + \\ &+ 5.969 * T \qquad (R^2_{adj} = 0.829). \end{aligned} \tag{2}$$

Malaghan et al. equipped a vehicle with GPS device to study driving behavior in curves. The participants in this study were 49 people in the age range of 21 to 59 years. Six undivided two-lane roads in India were examined. The absolute grade of all curves was less than 4 %. They modeled operating speed (V85) by applying radius (R) and degree of curvature (DC). Equations (3), (4) and (5) show the regression models [9]:

$$V_{85} = 11.68 + 10.37 * \ln(R) \qquad (R^2 = 0.87), \tag{3}$$

$$V_{85} = 84.72 + 10.37 * \ln(D_C) \qquad (R^2 = 0.87), \tag{4}$$

$$V_{85} = 71.7 + 0.01 * R + 1.12 + D_C \quad (R^2 = 0.87), \tag{5}$$

There are other papers estimated the operating speed in horizontal curves that the Table 1 has summarized.

These studies have used the field data to study the horizontal curves. Driving simulator is another source of data that has been used in many researches, some of which are mentioned below. Calvi investigated the features of horizontal curves such as radius, transition, sight distance and cross-section. He examined 34 drivers in 72 different curves under 3 different scenarios in both directions using a driving simulator. The results showed that by improving the geometric conditions, the speed has been also increased [5].

Wang et al. built a highway in China in a driving simulator. They recruited 22 drivers who drove 4 different types of curves (horizontal curve with positive and negative longitudinal grade, horizontal curve with crest and sag vertical curve). For each type of the curves, a model for estimating the maximum lateral acceleration was proposed, in which the radius, the longitudinal grade and the length of the segment were examined. According to the models, the radius was the only affecting factor in all the cases. The length of the road was effective in horizontal curves with crest vertical curve [17]. Shuo et al. examined the effects of lane width, lane position, and shoulder width on driving behavior on a three-lane urban highway tunnel. By using a driving simulator, 24 volunteers were examined. The results showed that lane and shoulder width had significant effect on driving speed [18].

Mecheri et al. investigated the effect of shoulder and lane width and their combinations on drivers. 34 drivers of an average age of 30 years (range of 25-52) participated in the experiment. Their research showed that the best combination of shoulder and lane width was 0.5 and 3 m, respectively, which allowed the driver to find and adjust her/his position in the road properly. The lane width could also be reduced to 2.75 m, where the passage of heavy vehicles such as trucks and buses was very low [19].

Melo et al. investigated the effect of lane and shoulder width on free flow speed using a driving simulator by 15 participants. The results demonstrated the minimum lane-shoulder width combination, after which no further increase in free-flow speed was observed, was 3.6 and 0.8 m for lane and shoulder, respectively [20]. Rosey et al. examined the difference between the effect of lane width reduction on speed and lateral position in real-world and simulation conditions. One of their purposes was to driving simulator validation in this area. The results showed that reducing the lane width has no effect on speed. Furthermore, by comparing the simulator results and reality, the results were relatively valid [21].

Ben-Bassat et al. studied the effects of a combination of three road design features, including shoulder width, barrier (guard rail) and horizontal curve, on driving behavior (speed and position in the lane) and mental measures (understanding safe driving speed and estimating road safety) by recruiting 22 drivers. The results showed that there was a significant effect of road geometry on driver behavior. Shoulder width had significant effect on speed and position on the lane, but this effect was only apparent when there was a barrier or guardrail. These findings demonstrated the role of a barrier in determining the perceived safety margin across different shoulder widths. When there was no guardrail, shoulder width lost many of its benefits and effects on driving behavior [22].

Using the high-fidelity driving simulators, Wang et al. examined the effect of lane width in mountain highways on driving behaviors (lateral positions and speed). First, the validity of the driving simulator was studied. 46 drivers (20 women and 26 men, age range of 23-56 years) were participated in the experiment. Due to the fact that there are many curved segments, including horizontal and vertical curves in mountain roads, they studied the lateral positions and speed in curves. The results showed that the effect of radius on speed was statistically significant and showed that the simulator can be used for mountain road studies. In addition, vehicle trajectory and speed analysis showed that lane width and horizontal curve radius had significant effects on driving behavior. The wider the lane, the greater the speed deviations [23]. Wang et al. used a driving simulator to investigate the amplitude of the effect of the horizontal curves on driver behavior on mountain roads. They found that curves could affect driver behavior, including speed and lateral position, at a distance of 300 m [24]. Zolali et al. studied the effect of experience, sight distance and geometric design on the average speed on a suburban road. It was observed that sight was the most important factor influencing the choice of average speed. Furthermore, the presence of curves on the simulated road, as a parameter in geometric design, encourages drivers to slow down [25].

One of the applications of studying the effect of geometric characteristics on driving behavior is the investigation of fuel consumption and environmental effects, which is important in sustainability studies. A study using real-world driving data in Madrid, Spain, showed that traffic conditions, driving behavior and the road topology were effective on fuel consumption [26]. Another study in Spain showed that vehicle CO_2 emissions decreased as the consistency level of a homogeneous road segment increased. In other words, when the parameters of the geometric design were considered consistent in different road segments, the fuel consumption was reduced [27].

As aforementioned, various studies have been conducted to determine the effect of geometric design features on driver behavior and speed. However, they have considered two or three features of the geometric design. In this research, the simultaneous effect of 5 geometric design features on mountain roads has been investigated. The effect of superelevation has also been studied, which has been rarely addressed in previous research.

In the next section, the methodology and design of experiments has been explained. The third section describes the data collection, apparatus and materials. The properties of the applied driving simulator have been introduce in this section. The fourth section has been devoted to analyze of the results and discussion. The research has been concluded in the fifth section.

2 Methodology

In this research, a driving simulator is used to study the driver behavior in different geometric designs. Features of the geometric design that are studied are: longitudinal grade, superelevation, radius, lane width and shoulder width. Each geometric design is made of a combination of different levels of features or factors. The levels of a feature divide it into different intervals, so its effect can be examined. Table 2 shows the features and levels are used in this research.

After determining the number of features and levels to be tested, the required number of tests must be determined. If a study with all the levels of factors is required, all permutations must be considered in which

Table 2 *Levels of geometric design features of the driving simulator tests*

Feature Level	Radius (m)	Lane width (m)	Longitudinal grade (%)	Superelevation (%)	Shoulder width (m)
1	20	2	0	-2	0.5
2	40	2.5	-10	0	0.8
3	60	3	-15	2	*
4	80	*	-20	4	*

***Table 3** The geometric designs selected for testing*

Road-Geometric design	Radius (m)	Lane width (m)	Longitudinal grade (%)	Superelevation (%)	Shoulder width (m)
1-1	80	3	-20	-2	0.5
1-2	60	2.5	0	2	0.5
1-3	40	2	-15	4	0.5
1-4	20	2.5	-20	4	0.8
1-5	20	2.5	-10	0	0.5
2-1	80	2.5	0	4	0.8
2-2	80	2.5	-15	0	0.5
2-3	60	2	-20	0	0.8
2-4	40	3	0	0	0.8
2-5	20	2	0	-2	0.5
3-1	80	2	-10	2	0.8
3-2	60	3	-10	4	0.5
3-3	60	2.5	-15	-2	0.8
3-4	40	2.5	-10	-2	0.8
3-5	40	2.5	-20	2	0.5
3-6	20	3	-15	2	0.8

384 (4 * 4 * 4 * 2 * 3) tests are needed. Performing this number of experiments by using driving simulator is impractical. Therefore, the number of experiments is reduced to 16 using the Taguchi method. The efficiency of the Taguchi method has been tested in comparison to the full factorial in transportation studies [28]. Using the Taguchi method, only 16 geometric designs are needed to be tested in the driving simulator, and the speed of other geometric designs can be estimated by Taguchi method.

It is not appropriate to put all the geometric designs in one route, because it may make the drivers tired and it is possible to affect the results. Therefore, the geometric designs are divided into three groups and three routes are built accordingly. The geometric designs are randomly distributed between the routes. By doing so, the numbers of geometric designs in routes are 5, 5 and 6.

Table 3 shows the combination of levels of factors for each geometric designs in 3 routes. In the first column of Table 3, the first and second numbers represent the route number and the geometric design number in that route.

Finally, statistical analyses are performed on the speed data that were obtained directly from the driving simulator experiments and the speed data that estimated by the Taguchi method. The relationship between the speed and each of the geometric design features (factors) is first examined separately, then relationship between the speed and all the features is investigated by regression models. Figure 1 depicts the flowchart of methodology. All the speed data recorded in a curve of participants are averaged and it is used in further analyses (each participant drove the experiment path twice).

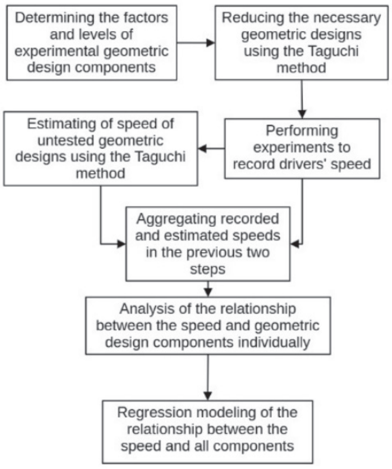

***Figure 1** Flowchart of methodology*

***Figure 2** The simulated two-lane undivided rural road*

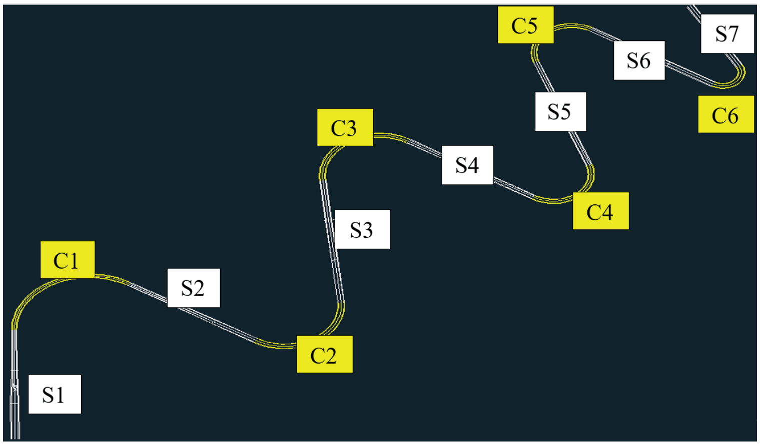

Figure 3 *The scheme of a simulated experiment roads*

3 Apparatus and materials

Thirty men between 21 and 33 years old were recruited to drive a personal car in driving simulator. Driving simulator are accepted tool for the driving behavior studies that has been used in many articles and its validity has been demonstrated [29-30]. Male drivers recruited in driving test to omit the effect of gender, which is out of scope of this paper. The scope of this study was two-lane undivided rural roads in mountainous area (Figure 2).

The weather was sunny with no precipitation and there was no other vehicle on the road. Amirkabir University driving simulator was used for the experiments, which has been used in previous researches [31-33].

Figure 3 depicts one of the experiment roads, in which there are straight segments (S1, S2…) between curves (C1, C2…). The straight segments were added to the experiment to avoid the effect of curves on each other. The effect of curves was found 300 m in Wang et al.`s research [24], to ensure that the straight segments were considered 500 m. There was no vertical curve in the road.

4 Results and discussion

The effect of each geometric design feature on the speed in the horizontal curve was investigated by using box plot and one-way ANOVA (Analysis of variance).

Table 4 *Speed of different radius levels*

Radius (m)	Speed mean (km/h)	Standard Deviation	Confidence interval (95%)
20	26.93	4.146	(25.687, 28.172)
40	39.926	4.808	(38.684, 41.169)
60	42.942	4.256	(41.700, 44.184)
80	49.112	4.212	(47.870, 50.355)

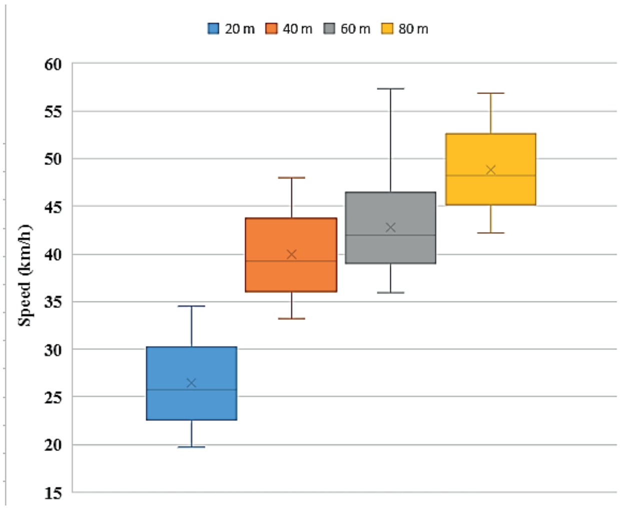

Figure 4 *Boxplot of speed based on the radius*

Table 5 *Speed of different superelevation levels*

Superelevation (%)	Speed mean (km/h)	Standard Deviation	Confidence interval (95 %)
-2	38.25	9.09	(36.417,40.091)
0	40.70	9.14	(38.865,42.540)
2	37.83	9.14	(35.995,39.669)
4	41.35	9.24	(39.508,43.182)

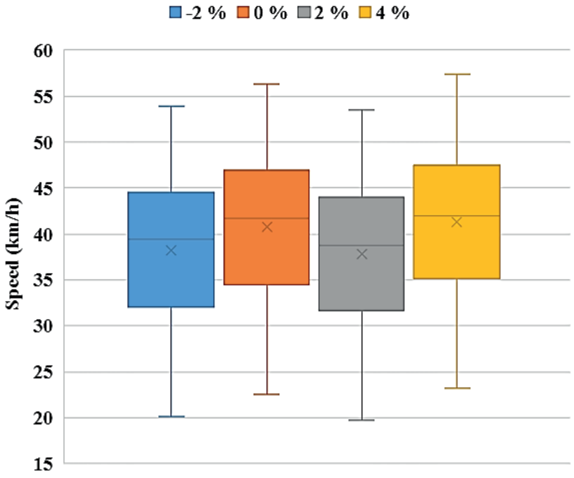

Figure 5 *Boxplot of speed based on the superelevation*

4.1 Radius

Radius can be considered as the most important factor affecting the speed in the horizontal curve. Table 4 and Figure 4 show the speed data for each radius level. As can be seen, the speed has increased by increasing the radius, which is logical. Furthermore, it can be seen that the radius of less than 20 m has been critical for the drivers, and has had a significant effect on the speed. It is obvious from Figure 4. Also, it can be seen that by reducing the radius from 80 to 40 m, the speed mean has reduced by 9.84 km/h while the speed mean has reduced by 13 km/h by reducing the radius from 40 to 20 m.

4.2 Superelevation

Table 5 and Figure 5 show the speed data for each superelevation level. Intuitively, there was no direct relationship between them and indicates an irregular pattern. It is discussed by using a regression model in next sections.

4.3 Longitudinal grade

Increasing the longitudinal grade can affect the speed in two ways, on the one hand, it would increase the risk of the car fall that may lead to speed reduction. On the other hand, it would encourage the driver to higher speed because of the car dynamics. In other words, increasing the longitudinal grade simultaneously can have positive and negative effects on the driver's safety and speed in the curve. Table 6 and Figure 6 demonstrate that the longitudinal grade has had a direct relationship with the speed. Due to the high similarity of speed data of the two levels of longitudinal grade of 0 % and -10 %, it can be concluded that the drivers have not been significantly sensitive to longitudinal grade less than -10 %.

4.4 Lane width

The lane width can influence the safety perceived by the driver, and the speed data for each lane width level have been depicted in Table 7 and Figure 7. It can be seen that the driving speeds recorded at different lane width levels were similar. It can be due to the features of routes and traffic. The drivers could use two lanes as the road was undivided with no traffic. AASHTO (American Association of State Highway and Transportation Officials) [34] mentions that standard lane width for highways is 3.65 m, while here the total width of the road was at least 4 m (excluding shoulders), so it can be said that the road width has been always too large to affect and limit the driver's speed. Therefore, its increase has not had a significant effect on the driver's speed.

It is worth noting that if the road is undivided and

***Table 6** Speed of different longitudinal grade levels*

longitudinal grade (%)	Speed mean (km/h)	Standard Deviation	Confidence interval (95%)
0	36.26	8.36	(34.58, 37.95)
-10	35.42	8.39	(33.74, 37.11)
-15	41.35	8.38	(39.66, 43.03)
-20	45.11	8.45	(43.42, 46.79)

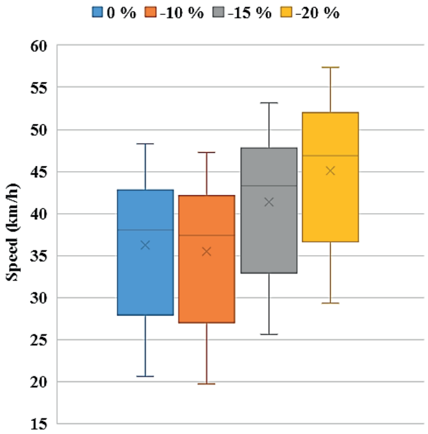

***Figure 6** Boxplot of speed based on the longitudinal grade*

***Table 7** Speed of different lane width levels*

Lane width (m)	Speed mean (km/h)	Standard Deviation	Confidence interval (95%)
2	38.85	9.31	(37.244, 40.461)
2.5	39.74	9.20	(38.128, 41.345)
3	40.01	9.25	(38.403, 41.619)

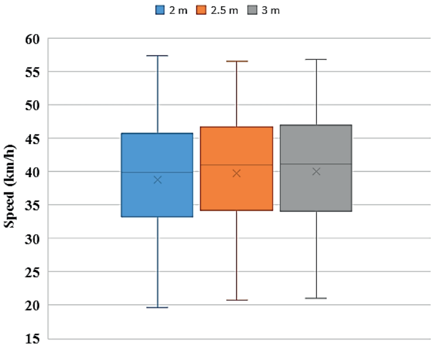

***Figure 7** Boxplot of speed based on the lane width*

there is no traffic, then all lanes (even the opposite direction) can be used by the driver. In other words, the effect of the road width was examined by changing the lane width as the road width is equal to the sum of the lanes and shoulders. The road width is directly related to the lane width, and the road width was checked by the lane width.

4.5 Shoulder width

As the shoulder width increases, the car is less likely to deviate from the road and the driver has more space to control the car, so the driver can achieve higher speeds in horizontal curves. Although a direct relationship is expected between the speed and the shoulder width, Table 8 and Figure 8 demonstrate that the speed difference between the shoulder widths was negligible in this study. As seen earlier, lane width had no significant effect on drivers' speed, so the shoulder width is not expected to be effective, since both of them determine the width of the road. So, when the lane width was sufficient (or even large), the driver would not use the shoulder width. It can be due to the specific experimental conditions of current study including absence of oncoming traffic, lack of guardrails along

Table 8 *Speed of different shoulder width levels*

Lane width (m)	Speed mean (km/h)	Standard Deviation	Confidence interval (95%)
0.5	39.276	9.29	(37.963, 40.589)
0.8	39.791	9.214	(38.478, 41.103)

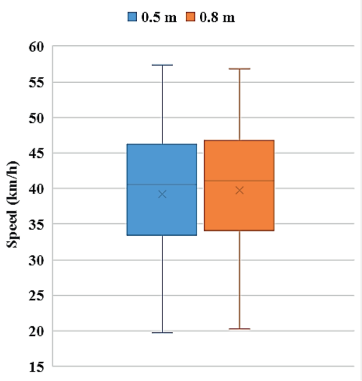

Figure 8 *Boxplot of speed based on the shoulder width*

Table 9 *ANOVA of geometric design features*

Feature	P-value
Radius	0.000
Longitudinal grade	0.016
Superelevation	0.000
Lane width	0.579
Shoulder width	0.586

Table 10 *Comparison between different speed models*

Model Num.	R-sqr (%)	RMSE	MAE
1	61.2	6.9	5.7
2	63.4	6.3	5.2
3	63.8	6.3	5.2
4	65.9	5.4	4.5

the edges, and the absence of lateral distractions in the peripheral vision.

4.6 Statistical analysis of geometric design features

To examine the differences in experiment levels more accurately, ANOVA was used for each of the geometric factors (Table 9).

4.7 Regression models

Four regression models were applied to simultaneously examine the effect of geometric design features, is given by:

Model #1: $V = \alpha * R + \beta * G + \gamma * e + \delta * LW + + \theta * SHL + Constant$

Model #2: $V = \alpha * R\hat{}2 + \beta * G + \gamma * e + \delta * * LW + \theta * SHL + Constant$

Model #3: $V = \alpha * R + \beta * G\hat{}2 + \gamma * e + \delta * LW + \theta * SHL + Constant$

Model #3: $V = \alpha * R\hat{}2 + \beta * G\hat{}2 + \gamma * e + + \delta * LW + \theta * SHL + Constant$

V: Speed (km/h), *R*: Radius (m), *G*: Longitudinal grade (%), e: Superelevation (%), *LW*: Lane width (m), *SHL*: Shoulder width (m), *α, β, γ, δ*, θ: Coefficients.

In the first step of modelling, the shoulder width was found insignificant (p-value > 0.005), so it was removed from the model. Three goodness of fit criteria MEA (mean absolute error), RMSE (root mean square error) and coefficient of determination (R-sqr), were used to compare regression models (Table 10).

It can be seen that model 4 has the best fit, so the coefficients of this model are analyzed (Equation 6).

$$V = 4.78 * \sqrt{R} - 0.02 * G^2 + 0.32 * e + + 0.88 * LW + 15.01. \quad (6)$$

To show the order of importance of the variables, model with standardized coefficients was applied.

The greater the absolute value of the standardized coefficient of each variable, the greater the importance of that variable. The absolute standardized coefficient for radius, longitudinal grade, superelevation and lane width were 10.47, 4.46, 0.96 and 0.44, respectively. It shows that the radius was the most effective factor, followed by longitudinal grade. The other two factors have had very small effect on the speed.

The estimated model showed that shoulder width was not effective in determining the driver's speed. However, there are some researches by driving simulator that demonstrated the effect of shoulder width on the drivers` behavior [18-19]. Melo et al. examined shoulder width by driving simulator and real data, simultaneously. They found the shoulder width as one the effective factors [20].

Ben-Bassat and Shinar found that the shoulder width had a significant effect on speed and lane position, but this effect was only evident when there was a guardrail [22]. Dixon et al. showed that the shoulder width was significant when the adjacent lane was 3.35 m wide, and had no effect on the 3.65 m lane width, indicating that the shoulder width was less important as lane width increased [30]. Their research can confirm the results of this paper. Here, although the width of one lane was less than 3.65 m, considering that the driver could use both lanes, the shoulder effect became meaningless.

Other factors, such as sight distance, can also affect the driver's speed in horizontal curves.

It is obvious that the sight distance is one of the important factors in determining the driver's speed. In this research, the presence of a mountain (continuously) has reduced the sight distance, so the effect of sight distance cannot be examined directly, and instead, other factors, such as the radius and the width of the lane and shoulder, have been studied. These factors can affect the sight distance.

In this research, very high or low values of geometric design criteria have been investigated because there are roads that must have an extreme and unusual geometric design due to environmental conditions. For example, we can refer to military roads and access roads to mines or residences in the mountains. These types of roads have very little traffic, but in critical conditions and also at sometimes, they have a lot of function, so it is necessary to study the speed of the cars in them. In other words, these types of roads are not normal because there are many limitations for their geometric design.

It should be mentioned that if female drivers were also checked, then the number and time of experiments would have to be doubled, which was not practical. It can be said about different age groups. So, this study has focused only on young male drivers, while women and other age groups should be examined as well.

5. Conclusions

Horizontal curves are one of the most important segments of the roads because crash rate is high and can also affect driving behavior. Therefore, it is important to study the effect of curve geometric design features on driving behavior such as speed selection. In this research, a driving simulator has been used to investigate the effect of five features of the geometric design of horizontal curves of an undivided two-lane mountain road, including: radius, longitudinal grade, superelevation, lane width and shoulder width. The experiments were determined using the Taguchi method. The results indicated that the radius was the most important factor affecting the speed, followed by the longitudinal grade. The two other features, lane width and superelevation, had very small effect. Shoulder width did not have a significant effect, which would be due to the large lane width, so drivers did not use the shoulder width to cross or maintain safety.

Regression demonstrated that the relationships between the speed and radius, longitudinal grade, superelevation and lane width were radical, quadratic, linear and linear, respectively. Although increasing the longitudinal grade can be dangerous, it has increased the speed of the drivers. Increasing the superelevation was effective when its value changed from negative to positive.

In this article, it has been tried to study the average speed in the curves. However, it is interesting to investigate other driving behaviors, such as lateral position or speed profile. Furthermore, it is better to investigate validity of the Taguchi method for human behavior such as speed. It suggests studying the effect of gender and age groups. This research helps managers and decision makers to estimate the ratio of improvement of geometric criteria to increase the speed of drivers and to choose the optimal point in terms of road construction cost. Also, the results of this research can be used in traffic safety by determining speed reduction in sharp curves.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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