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Effect of Road Geometry on Driver Eye Blink Rate

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Abstract: Safety on roads is a growing concern as accidents cause social and economic losses. Geometric design consistency can be considered as an engineering tool to evaluate the safety performance of road design. Among different measures to evaluate geometric consistency, driver workload measure directly considers the effect of geometry on drivers. The rate of eye blink can be used as a measure of driver's work load on curves. The objective of this paper is to correlate driver eye blink rate on horizontal curves on two lane rural highways. Preliminary analysis showed that radius, curve length, deflection angle, shoulder width and minimum sight distance available at curves are found to be correlated to rate of eye blinking either directly or based on their deviation from normal values

Keywords: Design Consistency, Driver Workload, Road Geometry, Eye Blink, Road Safety, Rural Highway.

I. INTRODUCTION

Road safety is receiving increased attention of transportation engineers, researchers and government. According to Global Status Report on Road Safety – 2018 by World Health Organization, road traffic accidents are the eighth leading cause of death causing more than 1.35 million lives each year and upto50 million injuries. Actions plans at national and international level is in progress to reduce the road traffic injuries and deaths by 50%, as part of United Nation's Decade of Action for Road Safety (2011-2020). One of the action plan "Safer roads and mobility" taken in Decade activities shifts the responsibility from road users to road system designers. So the future of road safety is in the hand of transportation engineers. Government has initiated steps to review design guidelines and standards of rural and urban roads in safety aspect and bring them in consonance with international best practices keeping in view Indian traffic conditions. To achieve optimum safety performance, engineers and researchers develop different tools and techniques. One such technique adopted to measure road design is to examine the consistency. Design consistency can be defined as the efficiency of highway geometry to perform similarly on different highway features during driving task. Drivers accomplish their task successfully if no risks are encountered along the roadway. So, the concept of design consistency can be better evaluated based on how a driver performs on the highway. The objective of the paper is to understand how the curve geometry and drivers eye blink is related.

II. LITERTURE REVIEW

The measures for evaluating Geometric consistency of highway are based on: operating speed, alignment indices, vehicle stability and driver workload (Gibreel, et al., 1999). Among the measures, driver workload evaluate safety from the viewpoint of driver's performance. Workload measurement techniques can be classified into three (Moray 1979, Green P. et al. 1993, Miller 2001). Physiological measures, Self-evaluated subjective measures (Hart and Staveland, 1988), Performance or behavioural measures. In this study the objective is to understand the driver's visual demand on two lane rural horizontal curves.

Gordon (1966) conducted a study to determine the essential roadway information required by the driver on curved two-lane low traffic density roads. In this study, the driver was forced to obtain visual input in separate visual fixations by decreasing the visual field. A continuous film record of visual fixation was taken to for the area, position, distance from the eye, and duration of each fixation. Road edge and center line were found to be the essential road information to which the driver is responding.

Senders et al. (1967) experimentally investigated the attentional demand of automobile driving. Driver vision was controlled by a vision occlusion device in which translucent screen with a lowering mechanism was attached. Two types of experimental procedures were adopted in this study; one with fixed occlusion and driver-controlled speed and, another with constant speed and varying driver-controlled occlusion time. It was found out that the driver had increased frequency of observation on curves when compared with tangent sections. It was also pointed that that attentional demand was increased with vehicle speed. Even though Wright in 1968 attempted to observe the visual fixation on curved sections, he could not found the relationship between the fixation locations and the driver's dynamic visual field.

Shinar etal. (1977) conducted study to determine effect of roadway geometry on driver's eye pattern in curves. Three cameras were used to capture the data of driver visual scene, corneal reflection of driver and driver's eye movement. Eye movements were studied on tangent, curve and approach sections of two lane hilly rural roads. Observations showed that there was a relationship between road curvature and lateral component of eye movement. Mean eye fixation duration and travel distance between fixations were not significantly different on curves and approach sections. Longer fixed durations were observed on curves with high accident rates.
The visual demand of the driving was determined by Tsimhoni and Green (1999) in which the methodology from Krammes literature was adopted. The visual demand profile obtained in this study totally agreed with Krammes observation. Reciprocal of curve radius and age of the driver was obtained significant parameters with a positive trend in the visual demand linear regression model, but this model explained a small part of variability. In this study also, the visual demand was not a function of deflection angle. The mean visual demand values for tested curves were obtained as 0.34 and 0.61 for straight sections and sharpest sections respectively. The rising point at which the drivers started looking more frequently was obtained as 92±47 meters before the point of curvature. The subjective rating was found to be inversely proportional with the radius of curvature and linearly proportional with the deflection angle.
Wooldridge et al. (2000) defined the driver's visual demand on horizontal curves as a percentage of time a driver observes the roadway. Analytical models that relate visual demand to the inverse of the horizontal curve radius were developed using data collected from a test track, local road, and simulator. Different models were developed for the first run on a curve, representing drivers unfamiliar with the road, and later runs, representing drivers familiar with the road. Both the models showed a inverse relationship with radius of curvature.
Wooldridge et al. (2000) conducted a study to determine visual demand on test track examining single and paired curves and on roads examining single curves. Isolated curve study was done to assess the effect of basic geometric parameters on visual demand. Paired curve study was done to find the issues related to visual demand carryover and expectancy. Visual demand was computed as the ratio of the glimpse length divided by the time elapsed from the last glimpse until the time of the present request, using visual occlusion method. Two types of visual demand were calculated; over the entire length of the curve and first 30 m of the curve. Reciprocal of the radius was found to have a significant correlation with visual demand on test track study and road study. Type of curve pair and curve pair separation did not show great influence on visual demand. He recommended further research to study the effect of curve separation on visual demand.
Anitha et al. (2018) conducted a study in real road conditions to find the influence of geometry on driver workload on two-lane rural highway. Correlation study showed that the effect of the radius was negatively correlated with heart rate. Deflection angle was negatively correlated with Galvanic skin response and eye blink. An increase in workload was found on horizontal alignments with a small radius and higher deflection. An investigative study to correlate the effect of highway geometry on a driver's heart rate was conducted by Anitha et al. (2019). Effect of sight distance on heart rate was positively correlated. Multiple linear regression models and nonlinear regression models were developed to find the relation between road geometry and heart rate. The radius of curvature, Deflection angle, Curve length was found to be highly significant in linear models whereas sight distance and shoulder width were highly significant road geometry parameters in nonlinear regression models.

III. DATA COLLECTION

Geometry Data, accident data, Driver eye blink data, and traffic volume data was collected on about 84 km Shoranur-Kunnamkulam-Wadakkanchery-Pazhayannur two lane rural state highway. The horizontal curves were selected in such a way that grades are of ±2% and tangent length equal to or greater than were 100m, as explained in paper [18]. Geometric data include radius of curvature, curve length, deflection angle, width of road, level difference, degree of curvature, superelevation, Tangent length and sight distance as described in paper [17].

The car drives were so planned that eye blinking data for each horizontal curve could get by at the least 30 driving observations of different drivers during off peak hours. To collect driver eye blink data, one USB camera is fixed on the front glass of car to capture his face and another to record the road conditions. The data corresponding to any abnormal roadway scenario like pedestrian crossing, overtaking manoeuvre, traffic block, etc. were eliminated by reviewing it with the front camera video. Eye blink rate on each curve is noted as Eye Blink rate (EB). To control the variations in the individual eye blink rate, the base values at resting condition of each driver was recorded. Eye blink variation from the base values on each curve were determined as Deviation of rate of Eye Blinking from the base condition (DEB).

IV. DATA ANALYSIS

Average, 85th and 50th percentile values of EB and DEB were calculated for each curve to conduct correlation study. Table 1 gives summary of Correlation study for eye blink rate with geometry. Correlation table shows that EB and DEB do not show any significant correlation with traffic volume or geometry. Further exploration of scatter plot diagram is necessary to identify the nature of correlation, if any.

Table I: Summary of Correlation Study for Different Workload Variables

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Dependent Variable	Traffic Volume (ADT)	Radius of curve (m)	Curve length (m)	Deflection angle (deg)	Width of road (m)	Superel evation (m)	Tangen t length (m)	Shoulder width (m)	Sight distance (m)
85th EB	-0.01	0.06	-0.11	-0.18	-0.09	-0.11	0.01	-0.02	-0.06
50th EB	-0.03	0.04	-0.02	-0.09	0.00	-0.14	0.02	-0.06	-0.02
AVG DEB	0.04	0.27	0.04	-0.21	0.06	-0.18	-0.06	-0.12	-0.12
85th DEB	-0.01	0.18	-0.07	-0.22	-0.07	-0.12	0.02	0.00	0.00
50th DEB	0.09	0.22	0.00	-0.20	0.07	-0.13	-0.09	-0.11	-0.17

Fig.1 shows the variation of average EB with geometry. Fig.2 show the variation of average DEB with geometry & traffic volume

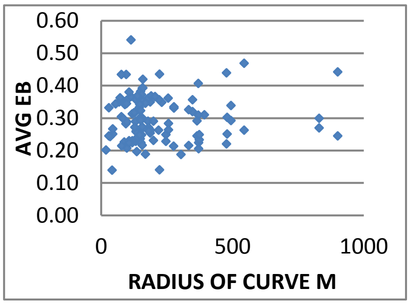

Fig 1 (a)

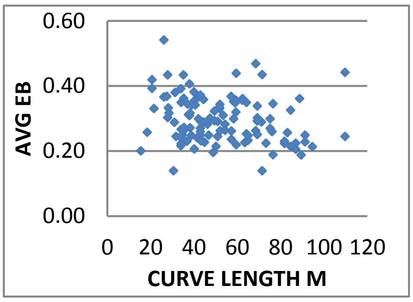

Fig 1 (b)

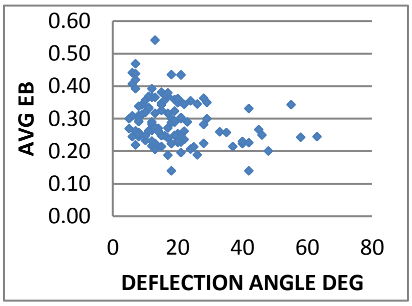

Fig 1 (c)

Fig. 1 Variation of average EB with geometry

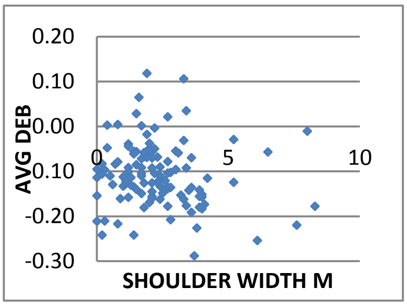

Fig 2 (a)

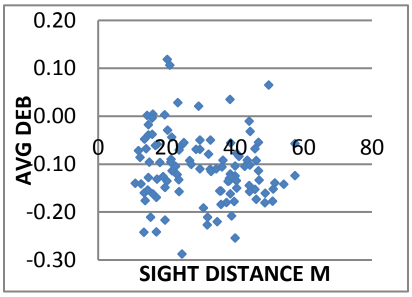

Fig 2 (b)

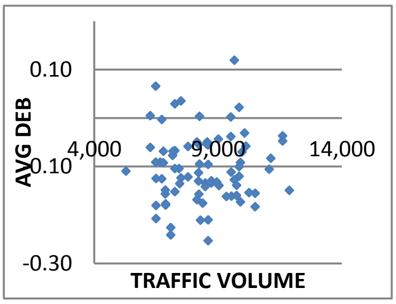

Fig 2 (c)

Fig.2 Variation of average DEB with geometry and traffic volume

Scatter plot shows that radius, curve length, deflection angle, shoulder width and minimum sight distance available at curves are found to be correlated to rate of eye blinking either directly or based on their deviation from normal values.

V. CONCLUSION

Deflection angle and Radius are the influencing variables for EB and DEB. Rate of eye blinking decreases with increase in deflection angle of curves for car drivers. This is because of lack of visibility on to the other side of the curve and the effort required by drivers to cope with the off tracking. With increase in radius of curves, deviation of eye blinking rate from the normal rate of blinking of drivers increases. It means that for driving along flatter curves, rate of eye blinking approaches to normal rate.

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