Influence of Vegetation Density on Vehicle Speed and Position of Roadway

N Amrasingha[1#], KMPA Rodrigo[2], and TN Lankathilaka[3]

Sri Lanka Institute of Information Technology, Faculty of Engineering, Malabe, Sri Lanka
[#] Corresponding author; <niranga.a@sliit.lk>

Abstract *— According to the World Health Organization (WHO), over 1.2 million people lose their lives each year in motor vehicle crashes and disable millions of people annually around the world. Based on crash data in the United States, single-vehicle collisions with trees account for nearly 25% of all fixed object crashes each year, resulting in deaths of approximately 3,000 people and making up approximately 48% of fixed-object fatalities. The injuries and fatalities due to single vehicle-collisions are a significant component of road crashes in Sri Lanka. The objective of the study was to evaluate the drivers' speed selection and lateral position of vehicle from the presence of roadside elements within proximity to the roadway. Parameters affecting drivers' speed and lateral positioning of the vehicles on the road were chosen based on literature review. Random vehicles in each selected location were observed and the information on all the parameters were collected which identified using the literature review. Using the collected data, multiple regression models were developed. The models showed that on the lightly vegetated roadways, people drove faster and drove much closer to the edges of the road. When the landscape changed to more vegetated, people drove much slower and drove closer to the centre of the road. Developed models also predict the speed selection of drivers and lateral positioning of the vehicles on the roadway sections. It was clear that the roadside vegetation influences the drivers' speed selection and positioning of the vehicle on the road. Therefore, it is a necessity that the road designers would consider the effect of roadside vegetation on designing the roadway sections. Ultimately, it would reduce the number of run-off-the-road crashes happening in the country.*

Keywords *—* **Vehicle position on Roadway; Vehicle Speed Selection**

I. INTRODUCTION

Motor vehicle transportation systems are primary infrastructure elements of modern cities, and transportation officials have reviewed roadside elements for potential safety risk because run-off-the-road collisions are significant contributors for traffic injuries and fatalities. Roadside vegetation, utility poles, traffic poles, guard rails, and sign posts are some examples for roadside elements. Roadside vegetation plays a critical role on mitigating negative impacts to the human and environment. Providing shade, leading to lower pavement temperatures and decreased emissions are some of the positives (Cole, 2013). Also, it provides positive psychological implications such as reduced stress, alleviated depression, and expedited recovery from injuries. Even though roadside vegetation provides such psychological and environmental benefits, they pose a potential risk to drivers when placed within proximity to the traveled way (Cole, 2013). When there is an open landscape without trees at the roadway, people drive faster, away from the road center [Antonson, 2009]. The objective of the study was to evaluate the drivers' speed selection and lateral position from the presence of roadside elements within proximity to the roadway.

II. LITERATURE REVIEW

Previous studies relevant to the topic of "Impact of roadside vegetation to vehicle speed and lateral position in rural roadways" have been investigated to understand the parameters affecting to vehicle speed and lateral position.

Calvi and Alessandro (2015) checked the effect of the roadway environment to the driver and experiment was performed with a driving simulator. About 44 volunteer drivers participated for the study at least with four years of driving experience and at least having 3000km average annual driving distance on rural roads. The study was developed considering five different geometrical elements including sharp left/right curves (100m radii), gentle left/right curves (400m radii) and a tangent section. A roadside configuration with no tress was assumed as the baseline. Speed of the vehicle and the lateral position were the dependent variables of the study. It was found that the more vegetated roadways drivers tend to travel in low speed near to the center line of the road compared to those of other road sections. Moreover the spacing of the trees did not affect for the lateral position of the roadway but not for the speed.

Knodler and Fitzpatrick (2016) has done a study to investigate the effect of clear zone size and surrounding vegetation density on driver speed, lateral positioning, and drivers' visual scan patterns. A driving simulator was used to collect data and 24 drivers who have 8.5 years of average driving experience and with average age of 25.6 participated for the study. Three clear zone variations (small- trees near the road edge, medium and large clear zone trees were at 2m, 6m respectively) and two vegetation variations (medium and dense) were utilized to have six combinations. Participants traversed a ten minute drive that consisting the above mentioned six combinations and four tangent sections, two right curves, and two left curves. Throughout the driving time, the driver's speeds and lateral positions as well as driver's eye movement were captured. Results showed that there were no statistically significant differences in speeds between the six combinations. Main reasons for this result was awareness of the drivers that they were in virtual drive and other was the speed limitation signs. Those signs were utilized to make the virtual environment more real, however eye tracking data proved that those signs were detrimental to the study. When horizontal scan patterns were analysed, it seemed to be that drivers used their peripheral vision to watch for hazards in the clear zone though it was assumed that drivers would scan a wider field of view with the increment of clear zone size. No statistically significant differences in lane positioning were observed during the tangent segment and straight or right curved sections when it was left curve, drivers drove almost a foot further from the edge of the road. However, the lateral positioning may be different, if the data will be collected in real situation.

Lankathilake and Amarasingha (2017) studied the effect of the roadside vegetation on vehicle in real situation. The main objective was to obtain the effect of roadside vegetation on drivers' speed selection and positioning of vehicles on the road. Two models were developed after analyzing the gathered data. When doing the analysis roadside vegetation and utility poles were considered. Even though there is an impact from other factors such as traffic poles, guard rails, crash cushions, breakaway posts, roadside embankments, and sign posts, those were not considered due to their lack of continuity and difficulty of having data. Eleven variables were chosen which affect the speed and the lateral position based on literature review and interviewing licensed drivers. To identify the critical variables, an online survey was conducted and some variables were selected to study further. Selected variables were proximity to roadside objects, vehicle condition, gender of the driver, age of the driver, passengers on board, number of pedestrians, width of pedestrian walkway, lane width, vegetation density, vehicle speed, and lateral position of the vehicle. Two roadway geometrical and three vegetation variations were selected for the study. Altogether there were six combinations. Form each combination, about 50 vehicles were observed and collected the data. Since the locations were identified in the same roadway section, the effect of lane width and pedestrian walking path, design speed were not considered as the independent variables. Speed of the vehicles was observed using a radar gun and the lateral position was observed using videos. Collected data were analyzed using the multiple regression method and was achieved a correlation between above mentioned parameters. Final results of the study showed that on straight roadway sections and changing vegetation did not affect the speed selection of the driver, but an increased vegetation density had a positive impact on the lateral position of the vehicle. At horizontal curved roadway sections, there was a significant effect of roadside vegetation to both speed and lateral position. A proper monitoring system was recommended to investigate the reaction of the drivers.

III. METHODOLOGY

The study was planned to do for straight roadway sections. Therefore all the selected study areas contain straight roadway sections, but with different roadway characteristics. Parameters affecting drivers' speed and lateral positioning of the vehicles on the road were chosen based on the literature review and were tabulated in Table 1 with the definitions and were described following section.

1). Gender of the driver (GD): Driving pattern of a male driver compared to a female driver may slightly differ. Men and women show less difference in causing single-vehicle crashes, but women show a higher tendency to be at-fault in multi-vehicle crashes (Citron and Stamatiadis, 2008).

2) Age of the driver (AD): Considering age, drivers were categorized into three different groups: young, middle aged, and old. Age of the driver was identified with visual observation while she/he was driving.

3) Vehicle condition (VC): Vehicle condition was defined as new, old, or in-between. Condition of the vehicle can be determined using the registration number of vehicle as in Sri Lanka, the registration numbers are issued in sequence order. Vehicles registered after year 2013, received three-letters following dash and four-numbers and the rest had two-letters or two- numbers following dash and four-numbers. The vehicles with two letters in the first part were registered between 2000 and 2013 considered as medium-aged and the vehicles with two numbers were considered as old vehicles. Vehicles with three letters in the first part of number plate were considered as new vehicles.

4) Passengers on board (PO): When considering the safety of the passengers on board, drivers might be more selective on their speed and position on the road.

5) Number of pedestrians (NP): It is a responsibility of a driver to ensure the safety of the pedestrian. If there are more pedestrians traveling on the sidewalks, drivers will gradually decrease the speed of the vehicle.

Table 1. The parameters affecting the speed and lateral position of vehicle

Parameters	Notation (Code)	Definition
Gender of the driver	GD	Nominal Variable; 1= "Male", 2= "Female"
Age of the driver	AD	Nominal Variable; 0= "Young < 25 yrs", 1= "Middle aged 26-50 yrs", 2= "Old > 50 yrs"
Vehicle condition	VC	Nominal Variable; 0= "New", 1= "Medium"`, 2= "Old"
Passengers on board	PO	Numeric variable; measured in numbers
Number of pedestrians	NP	Numeric variable; measured in numbers
Proximity to roadside objects	RO	Numeric variable; measured in meters.
Width of the Sidewalk	WW	Numeric variable; measured in meters
Vegetation density	VD	Nominal Variable; 0= "Light", 1= "Medium", 2= "Heavy"
Lane width	LW	Numeric variable; measured in meters
Vehicle speed	VS	Numeric variable; measured in Kilometers per hour
Lateral position of the vehicle	LP	Numeric variable; measured in meters
Presence of vehicles following	VF	Nominal Variable (1= "YES", 2= "NO")
Presence of oncoming vehicle	OV	Numeric variable, measured in numbers
Presence of guard rail	GR	Nominal Variable (1= "YES", 2= "NO")
Posted speed limit	SL	Nominal Variable (1= "YES", 2= "NO")
Shoulder Width	SW	Numeric variable, measured in meters
Vehicle flow	FL	Numeric variable, measured in equivalent passenger car units per hour
Vehicle type (class)	VT	Nominal Variable
Distance to an intersection	DI	Numeric variable, measured in km
Distance to a pedestrian crossing	DP	Numeric variable, measured in km
Radius of the Curvature	RD	Numeric Variable , measured in m

6) Proximity to roadside objects (RO): The distance between roadside elements to the edge line of the pavement shoulder could be a varying factor in roads. If the distance is marginal, it would create doubt on drivers' mind on how to drive safely on the road.

7) Width of sidewalk (WW): If the pedestrian sidewalk lane width is marginal, it would create a doubt on drivers' mind on choosing an appropriate speed on the road.

8) Lane width (LW): if there is a marginal lane width, drivers will not have enough space to maneuver the vehicle on the road. Therefore, they tend to show down the vehicle when there is marginal lane width.

9) Shoulder width (SW): Shoulder width has a high influence for the lateral position of the vehicle as well as the speed because if the shoulder width is low, driver may see it as a risk and move towards the centreline of the road.

10) Presence of oncoming vehicle (OV): If there is an oncoming vehicle, the driver will try to move towards the edge of the road and lower the speed.

11) Presence of vehicle following (VF): The following vehicles may attempt to overtake the front vehicle.

12) Vehicle type/class (VT): Speed of the vehicle depends on its type. Normally heavy vehicles tend to maintain a low speed due to its size and the load.

13) Posted speed limit (SL): According to the Sri Lankan Law, speed limits have been implemented considering the vehicle class. If there is a posted limit driver may understand it as a warning to get prevent from a hazardous zone. Therefore, the speed may get reduced.

14) Presence of guard rail (GR): Having a guard rail beside the road confirm that there is no effect from the adjacent property. Therefore, drivers may tend to travel in high speed at the edge of the road.

15) Distance to an intersection (DI): Drivers always consider an intersection as a conflict place. Therefore they tend to reduce their traveling speed.

16) Distance to a pedestrian crossing (DP): Pedestrian crossing can be considered as a place with high probability for crashes. Hence divers reduce the speed of the vehicle at a pedestrian crossing.

17) Vehicle flow (FL): This is a primary parameter which affects the vehicles' speed.

18) Radius of the curvature (RD): Radius of curvature has a perfect positive correlation with speed and lateral position in the curved roadway section.

Vehicle speed (VS) and lateral position of the vehicle (LP) were the parameters under consideration. Data collection on all the parameters listed in Table 1 together with speed and, lateral positioning was carried out in different straight roadway sections in the same road. The speed of the vehicle was detected using a radar gun. A video camera was set up at each location to measure the lateral position of the vehicle on the road. Lateral position of the vehicle was measured by analysing the videos recorded at each location. Vehicle registration number of each vehicle was observed to determine the condition of the vehicle. The width of the lane and the pedestrian sidewalk were measured using a measuring tape. The gender of the driver, the approximate age of the driver, and the passengers on board were also observed. Since, the locations were identified in the same roadway, the effect of lane width, width of the sidewalk, shoulder width, and design speed were not the variables. The traffic flow was determined based on the 15-minutes classified traffic counts at the same time of the data collection at each and every location. Quantitative data were collected on condition of the vehicle, vehicle type gender, approximate age of the driver, and vehicle condition. Speed of the vehicle, presence of following vehicles, presence of head-on vehicles, guard rail, distance to intersection, distance to cross-walk, number of passengers on board, number of pedestrians in the sidewalk, vegetation density, and lateral position were quantitative data. Vegetation density was determined analysing photograph taken at each site.

Multiple regression analysis was used for the analysis. Multiple regression is an extension of the simple linear regression. It is used to predict the value of the dependent variable based on the value of two or more independent variables. All the parameters which were defined in Table I were used for analysis.

IV. RESULTS

Speed variation with varying roadside vegetation densities has been studied. The average speed on each location was approximately 35 Km/h. The variation of lateral position of each vehicle in varying roadside vegetation densities was also studied. The average lateral position values were shifted in the upward direction with the location change from light to medium. Average lateral position values in light and medium vegetation location are 3.3m and 2.5m respectively. Heavy vegetation density location has more scattered lateral position values when comparing to other two locations with an average of 3.3m.

The correlation matrix for the roadway section was developed to determine the interrelationship of independent variables. Then logistic regression models were developed using backward elimination technique. Developed models showed that in the lightly vegetated roadways, people drove faster and drove much closer to the edges of the road. When the landscape changes to more vegetated, people drove much slower and drove closer to the center of the road. Developed models also predict the speed selection of drivers and lateral positioning of the vehicles on the roadway sections.

IV. CONCLUSIONS

The preliminary analysis in the study was conducted using the variance of vegetation density with speed and lateral position of vehicle. Increasing of the vegetation density had a positive impact on the increasing lateral position of the vehicle. Developed models also predict the speed selection of drivers and lateral positioning of the vehicles. Speed and lateral position of the vehicle depend on different types of variables including the driver characteristics, roadway characteristics, and weather conditions. It was clear that the roadside vegetation influences the drivers' speed selection and positioning of the vehicle on the road. Therefore, it is a necessity that the road designers would consider the effect of roadside vegetation on designing the roadway sections. Ultimately, it would reduce the number of ROR crashes happening in the country.

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