EFFECT OF VARIABLE MESSAGE SIGNS ON DRIVER SPEED BEHAVIOR UNDER FOG CONDITONS*

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1. Introduction

Speed is a core issue in road safety although the relationship between speed and accidents is a complex one. Worldwide 5 to 15% accidents are occurring due to over speed. TRL (1997), and Andersson and Nilsson (1997) reports the reduction of speed by 1mph reduces the casualties by 5% and reduction of mean speed by 10% results in a reduction of number of fatalities by 40%. Finch et al (1994) suggests an increase in mean speed by 2 to 4mph results in an increase of the number of fatalities by 19 to 34%. Small reductions in mean travel speeds have a substantial impact on injuries and fatalities. Environmental (weather) conditions also play a crucial role on speed and accidents, which affects the visibility. Fog and rain reduces driver perception and affects the perceptual judgment of speed and distance. Under these circumstances, driver has less time to react and in turn cause road accidents and fatalities. Enough reduction of speed under fog conditions should be needed and if speed variability is controlled and reduced under adverse environmental conditions can see a reduction in accidents and fatalities. Due to poor visibility under adverse conditions level of dangerous is high compared to normal conditions and driver has no information related to the necessary speed that he has to follow. If road authorities provide necessary information, drivers can change their behavior, which will reduce road accidents and fatalities. Variable Message Signs (VMS) is one of the best tools available for providing necessary information to the driver.

This paper focuses on how well traffic messages (traffic advisory information) will help drivers to divert potentially dangerous road conditions under adverse environment conditions. The techniques used for this study involves a driving simulator in a laboratory setting to examine the effect of VMS on drivers speed behavior while viewing the information provided through VMS. The motivation behind this study is driven by the need to understand whether advisory information will help to reduce the accidents on the road and to do so without unnecessary risks to the drivers. If drivers can be persuaded to modify their driving maneuver by the provided information, road hazards can potentially be avoided.

In this study sample drives the simulator on a graphical representation of Oyamazaki section under fog conditions, with and without VMS. This gives a chance to study how the sample will receive and behave by the provided information and also to find the effect of VMS on driver speed behavior.

2. Driving Simulator - VERS III

Virtual Evaluation for Road Space-III (VERS-III) driving simulator is the third generation of the original version developed by Osaka University and ODEX has been used in the present study. The advantage of using VERS-III includes consideration of driver speed changing behavior as a function of VMS under adverse fog conditions. Figure 1 shows the structure of VERS-III driving simulator, which includes one graphic workstation for the front screen, and 4 PCs for the side screens and side mirrors; three wide 120-inch screens and 2 side-mirror size displays; a driver cabin; a sound generator to simulate the noise of running vehicles; and other measurement equipments such as a gaze point recorder and a heartbeat recorder.

Computer graphics image, generated by the workstation for driver's view, is displayed using the projectors. The driver uses the accelerator, brake pedal and steering wheel of the driving simulator to control the vehicle while viewing the graphical images. Change in usage of accelerator, brake pedal and movement of steering wheel is transmitted to the workstation. The driving information transmitted is used by the workstation to generate the next frame of graphic image for display. The speed of the vehicle is computed by the workstation and displayed on the speedometer in the driver's cab. (Mori, 2003)

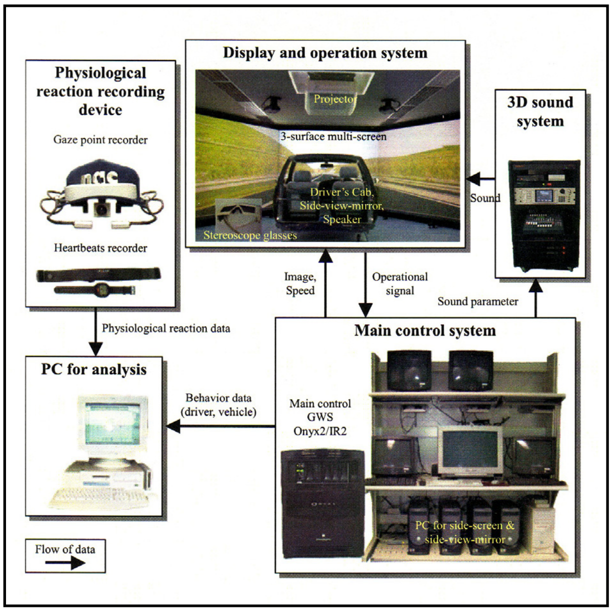

Figure 1: Configuration of VERS – III simulator

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3. Oyamazaki Section

Oyamazaki section is one of the important expressway section, which connects Kansai region to Nagoya and it goes through typical geographical conditions. Considered Oyamazaki section for simulator experiment starts at Km510.000 and ends at Km501.500.

4. Experimental Setup

Fog is a cloud made up of water droplets or less commonly icy crystals. This cloud is formed near the ground and reduces visibility to less than 1km. According to National Oceanic and Atmospheric Administration (1997), fog is designated when the visibility is less than one km. Fog can cause drivers to underestimate his own speed and can lead to accidents. When a vehicle traveling at 90kmph needs 6sec for complete stop under normal conditions. When slippery due to fog, visibility drastically reduces and it will be difficult to stop the vehicle with in the stopping sight distance. Under adverse conditions it is essential to double the stopping sight distance and also reduce the speed by 1/3 or 1/2. (Ritzel, 2001). In this experiment, level of fog is a fixed variable and 60kmph with VMS speed scenario is proposed to consider. Level of fog should be fixed in such a way that stopping sight distance of 100m (AASHTO, 1984) should be available to the sample driver to run the driving simulator under fog conditions.

Placement of passing vehicles in the surrounding lane(s), sample may judge their own speed relative to those vehicles and the objects in the visual field. Schematic diagram for the proposed scenario is shown in Figure 2. Gantry VMS sign is placed on the simulated section and samples are requested to drive in the centre lane. Single maintenance vehicle is placed in the centre lane where sample has been asked to drive the simulator. Maintenance vehicle will be placed randomly after first VMS and will travel with lesser speed so that it will provide an opportunity to study the overtaking behavior. The reason is sample observes the VMS first and then maintenance vehicle. Sample will try to overtake maintenance vehicle by driving in to right lane and will request sample kindly move to centre lane once overtaking is completed.

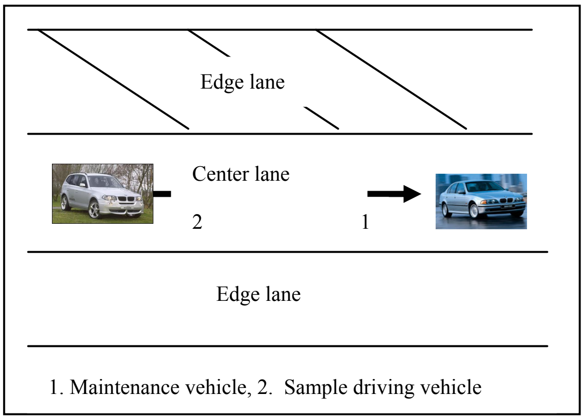

Figure 2: Proposed scenario for experiment

Suggested strategy for placement of maintenance vehicle will be with a speed of 30kmph and will be placed randomly once sample crosses the first VMS location. Position of maintenance vehicle will be at a distance of 300-500m away from the VMS location. The reason to suggest 300-500m is maintenance vehicle travels at a speed of 30kmph and will travel around 300-500m and if sample adopts suggested speed or more than the suggested speed it will give a chance to overtake at a distance of 600-1000m from the VMS location. This distance is less than the minimum distance of the divided sections i.e., 1.920km. The proposed VMS message is same at suggested three locations i.e., km 507.426, km 505.350 and km 503.430 (Figure 3). First VMS message will act as a caution/ warning message to the sample by suggesting careful about fog and the speed to be adopted under fog conditions. If sample drives faster than the suggested speed, second and third VMS messages will emphasize the safety once again by suggesting the speed to be adopted, so that sample can adopt speed reducing behavior suitable to fog conditions.

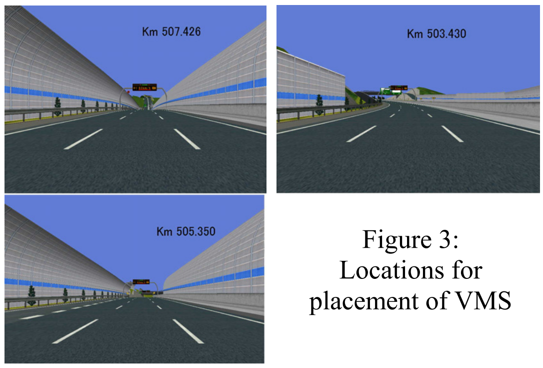

Figure 3: Locations for placement of VMS

Proposed VMS will be as per the guidelines provided by Japan Public Highway Corporation and under fog conditions VMS should display CAREFUL FOR FOG. Due to this reason proposed message will be in Japanese with suggested speed 60km/h in with VMS condition and is shown in Figure 4.

Figure 4: Proposed VMS message

5. Experiment

Data collected by the experiment needs processing before it is usable for the purpose of this study. Collected data includes several parameters, which is recorded in to data files. Necessary data include current lane, speed, trajectory of vehicle, current position of accelerator and current position of brake. Current lane provides whether sample is driving in the requested centre lane or not. Speed is used in the analysis to find the effect of VMS on driver speed behavior under without VMS and with VMS. Trajectory of vehicle provides the position of the vehicle with respect to distance etc. Effect of VMS on driver's speed changing behavior is analysed on Oyamazaki section by considering the two test samples. To avoid discrepancies and simulator sickness, without VMS and with VMS cases were randomly allocated to test samples.

6. Findings

To run the driving simulator, initially 2 test samples were considered and test run was conducted on June 9, 2004. The analytical findings related to the effect of VMS on driver's speed changing behavior are discussed in the following sub sections.

6.1. Findings of test sample 1

- Test sample 1 driven simulator in the order of with VMS and without VMS. Speed changing behavior in both cases is shown in Figure 5.
- Average speed adopted in without VMS is 81.72kmph and in with VMS is 72.93kmph. An average speed reduction of 8.8kmph is observed between these two cases.
- In without VMS case, to finish the task it took 364sec; 52% of the time sample drives above average speed and 48% of the time sample drives below average speed i.e., 81.72kmph.
- In with VMS case, to finish the task it took 409.4sec; 28% of the time sample drives above average speed and 72% of the time sample drives below average speed i.e., 72.93kmph which is more than the suggested VMS speed, 60kmph (20% of the time sample drives with less than or equal to 60kmph).
- In without VMS case, maximum speed was observed at km507.441 i.e., 94.63kmph. Minimum speed 64.1kmph was observed at km507.078 during overtaking of maintenance vehicle.
- In with VMS case, maximum speed was observed at km507.541 i.e., 113.41kmph. After that speed reduction was observed because of first VMS message, which was placed at km507.426. Minimum speed 36.86kmph was observed at km504.920 before overtaking of maintenance vehicle.
- In with VMS case, test sample was driving with more than 100kmph and after passing through the first VMS at km507.426 drastic reduction in speed was observed on the remaining section, which is below average speed.
- One-kilometer average speeds were observed before and after the messages in without and with VMS cases at km 507.426, km 505.350 and km 503.430. In without VMS, before and after the messages observed average speeds were 82.17 and 82.25kmph; and in with VMS average speeds were 78.40 and 70.82kmph. Reduction in average speeds in with VMS was observed when compared to without VMS case after passing through the VMS.
- When test sample 1 was driving on almost free flow section, was shocked by sudden presence of maintenance vehicle in the centre lane. At that point a huge change in the sample behavior was observed. However information related to placement of maintenance vehicle, free flow section etc was not disclosed before the experiment.
- Maximum speed deviations were observed at starting point and also at overtaking a maintenance vehicle. Entire sections speed deviation in without VMS is 1.99kmph and in with VMS is 2.52 kmph. In with and without VMS cases 12% and 24% of the section was driven above average speed deviations.
- Overall average speeds were higher in without VMS case than in with VMS case under fog conditions.

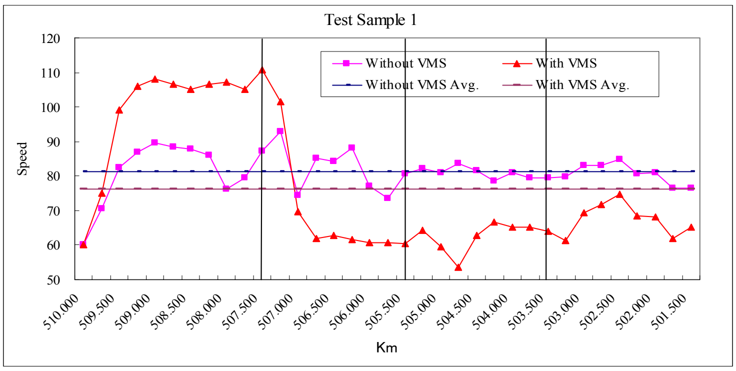

Figure 5: Test sample 1 on speed changing behavior in without VMS and with VMS cases

6.2. Findings of test sample 2

- Test sample 2 driven simulator in the order of without VMS and with VMS. Speed changing behavior in both cases is shown in Figure 6.
- Average speed adopted in without VMS is 123.44kmph and in with VMS is 109.27kmph. An average speed reduction of 14.17kmph is observed between these two cases.
- In without VMS case, to finish the task it took 238sec; 53% of the time sample drives above average speed and 47% of the time sample drives below average speed i.e., 81.72kmph.
- In with VMS case, to finish the task it took 269.5.4sec; 44% of the time sample drives above average speed and 56% of the time sample drives below average speed i.e., 72.93kmph which is more than the suggested VMS speed, 60kmph (1% of the time sample drives with less than or equal to 60kmph).
- In without VMS case, minimum speed 104.27kmph was observed at km509.250. Maximum speed 142.51kmph was observed at km507.222.
- In with VMS case, maximum speed was observed at km507.447 i.e., 129.68kmph. This is just after first VMS, which was placed at km507.426and after that speed reduction was observed. Minimum speed 94.37kmph was observed at km505.303 just after second VMS.

- In with VMS case, test sample was driving with more than 100kmph and after passing through the first VMS at km507.426 maximum time adopted speed on the remaining section is below average speed.
- One-kilometer average speeds were observed before and after the messages in without and with VMS cases at km 507.426, km 505.350 and km 503.430. In without VMS, before and after the messages observed average speeds were 128.29 and 127.71kmph; and in with VMS average speeds were 111.72 and 105.01kmph. Reduction in average speeds in with VMS was observed when compared to without VMS case after passing through the VMS.
- When test sample 2 was driving on almost free flow section, was shocked by sudden presence of maintenance vehicle in the centre lane. At that point a huge change in the sample behavior was observed. However information related to placement of maintenance vehicle, free flow section etc was not disclosed before the experiment.
- More than average speed deviations were observed at several points in both cases. Entire sections speed deviation in without VMS is 3.03kmph and in with VMS is 3.23kmph. In with VMS and without VMS cases 24% and 53% of the test section was driven above the average speed deviations.
- Overall average speeds were higher in without VMS case than in with VMS case under fog conditions.

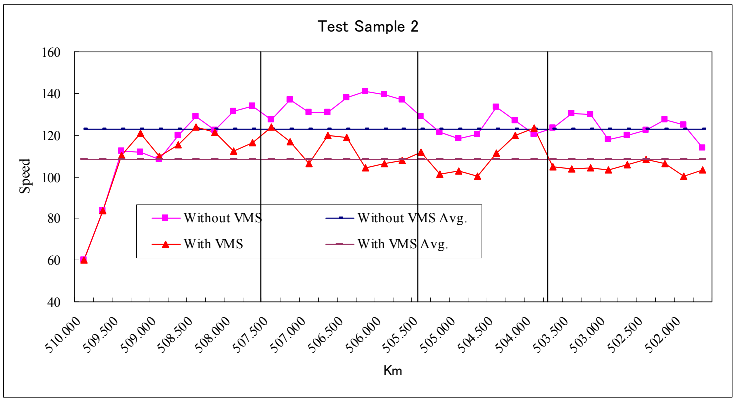

Figure 6: Test Sample 2 on speed changing behavior in without VMS and with VMS cases

7. Conclusions

Based on the analytical findings it was observed that VMS has an effect on test samples with an average speed changing behavior of 10kmph. For these two test samples, also observed variation in speed deviations in without VMS and with VMS cases. Reduction in average speeds was observed in with VMS case when compared to without VMS case after passing through the variable message signs. Test samples responded positively to the installed VMS system by changing the speed behavior. Final experiment was conducted on June 21, 2004 with 8 samples and an in depth study is under progress. Detailed analysis of 8 samples data can give a chance to study whether traffic advisory information has an affect on driver's speed changing behavior or not.

While observing the overtaking behavior, when both test samples were driving on almost free flow section, was shocked by sudden presence of maintenance vehicle in the centre lane. At that point a huge change in the sample behavior was observed. However information related to placement of maintenance vehicle, free flow section etc was not disclosed before the experiment. Reduction of average speed and speed deviations by the provided traffic advisory information through variable message signs under adverse conditions such as fog and rain has an impact on reduction of accident fatalities and severities.

References

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ABSTRACT

VMS used to provide dynamic information and are currently used to show different speed limits under different conditions. As speed is an important contributor to road accidents and also affects driver's speed behavior, present study focuses on how well traffic advisory information will help drivers to divert from potentially dangerous conditions. Graphical representation of Oyamazaki section made easy to isolate the effects of speed etc. by drivers with information provided through VMS under adverse fog conditions. This gives a chance to study how the sample will receive the provided information and also to find the effect of VMS on driver's speed behavior.