Sensitivity of Car-Followers to Moving Warning Sign

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Submission date: 26-Nov-2019 05:58PM (UTC+0700)
Submission ID: 1222069036
File name: Rturnitin.pdf (1.86M)
Word count: 1912
Character count: 10422

ATLANTIS PRESS
Advances in Engineering Research, volume 187
Third International Conference on Sustainable Innovation 2019 – Technology and Engineering (IcoSITE 2019)

Sensitivity of Car-Followers to Moving Warning Sign

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I. INTRODUCTION

There are a number of renowned car-following behavior models and theories, including the model developed by General Motor and Wiedemann called Psycho-Physical Model. The Car-Following Theory developed by General Motor Group is considered to offer the most extensive overview due to the comprehensiveness of the field test as connecting feature for both micro- and macroscopic theories related to traffic flow through the integrated contributions of their internal and external researchers [1].

General Motor had developed five Car-Following Models by proposing the underlying postulate in the form of response = function (sensitivity, stimulus). The response is always recognized through the acceleration and deceleration of the vehicle-following speed. Meanwhile, the stimulus is marked by the relative speed of the following vehicle in accordance with the leading vehicle. In particular, the term sensitivity represents the difference rate of both following and leading vehicle on the same straight track.

In general, the reaction of a following vehicle will depend on several factors, including its speed and track. The reaction is recognized based on its headway that relates to the time and distance between the two vehicles, in addition to how far the following vehicle will converse its speed in accordance with the leading vehicle [2].

A number of relatively simple and common driving activities of a following vehicle on a straight track under the condition that there are no other passing vehicles (by ignoring other secondary activities, such as steering, routing, etc.) relate with three specific subtasks [3], including:

1) Perception: the driver collects visual information, especially that relates to the mobility of the leading vehicle. Simultaneously, the driver, as the follower, will be affected by the information related to velocity, acceleration, distance, and others.
2) Decision making: the driver interprets and relates the information with his previous knowledge or experiences as an attempt to develop strategies in maintaining safety and practical mobility.
3) Control: an experienced driver can perform a management action in accordance with his skills and coordination based on the previous information that he has obtained.

A mobile warning sign is designed based on a number of standard requirements, including the font size, font type, plate dimension, symbols and font color, background color, and type of materials [4]. It commonly uses black symbols and a yellow background. Meanwhile, the warning message should use the Clearview Highway font type in red and black to provide a negative contrast of the sign [5], in addition to the 2-inch font size that should be adjusted with the viewers' reaction, time, and distance [6].

The iOnRoad was firstly developed in 2007 by Piticup and introduced as a brand new innovation at the 2012 International CTIA Wireless Conference. The iOnRoad is functioned to elevate the users' awareness of the traffic accident possibility, improve responsiveness, and assist the drivers to make particular decisions while on the road. The iOnRoad offers those features through a smartphone technological integration. The application also accesses the smartphone camera to locate the following vehicles on the road. Through a constant mapping, the application will screen a real-time monitoring and send the users a heads-up if there is a potential risk. The warning consists of visual and audio warning signs [7]. The iOnRoad augmented reality for Android devices provides the interface, live view, detection on collision, distance headway monitoring, snapshots, car locator, in addition to other features and conclusion [8].

II. METHOD

A. Responden

The respondents consisted of the vehicles that moved behind and followed the car tester. Those respondents were randomly selected along the roadway and recorded by the camera which was installed at the rear part of the car tester. The camera installation was set invisibly for the drivers of the following vehicles. In detail, the car-followers included all vehicles that followed the car tester on the same track with a maximum 50 m away in distance except motorcycles. The car-followers that overtook or were left behind the car tester were excluded from the data. There were 20 vehicles included in respective sessions of the study. The study selected the arterial road of Kartasura-Klaten Segment as part of the Jogja-Solo Road, in addition to the collector road of Dlopo-Baki-Sukoharjo Segment and Baki-Daleman-Pucang Segment as part of the Slamet Riyadi Road in Kartasura.

B. Material

The study operated a type of jeep passenger vehicle as the car tester, as the vehicle supported the installation of a mobile warning sign at its rear. During the study, the car tester moved with constant speed by 50 km/hour on the arterial road and 40 km/hour on the collector road.

The study also utilized an Android smartphone which was installed with a number of supporting applications, including the Google Maps, iOnRoad Augmented Driving Pro, and Lollipop Screen Recording to record and detect the response of the following vehicles in accordance with the movement of the car tester under two conditions. The first condition was set up by the installation of a warning sign at the rear part of the car tester, while the second condition was marked with the uninstallation of the sign. The iOnRoad application was functioned to record the speed and distance of the following vehicles behind the car tester. Meanwhile, the VSDC Video Editor and MS Excel were utilized to record the response of the following vehicles in every one-second time interval. Fig 1 represents the design and installation of the mobile warning sign as mentioned.

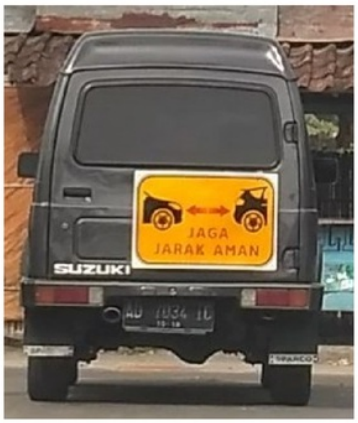

Fig. 1. Design and Installation of Moving Warning Sign

C. Procedure

The procedure of the study aimed to discover the response and sensitivity of the following vehicles under two conditions. The first condition was set up by the installation of a warning sign at the rear part of the car tester, while the second condition was marked with the uninstallation of the sign. The observation also utilized a car tester which was operated on the real road condition. The car tester had previously been equipped with a camera to record the mobility of the following vehicles.

The observation also recorded the speed of the car tester based on the number pointed by the speedometer and iOnRoad application. Meanwhile, the distance between the car tester and the following vehicles was respectively recorded by iOnRoad. The speed of each following vehicle was determined based on the calculation of distance per unit of time (per second). Meanwhile, the acceleration and deceleration were determined based on the calculation of distance and speed between the car tester and following vehicles.

The response of the following vehicles was recorded by the camera and validated through the speed calculation, as if the following vehicle improved its speed ($\Delta V = +$), constantly moved with a null velocity ($\Delta V = 0$), slowed down ($\Delta V = -$), or decelerated its movement. The following Fig 2 shows the cut scenes of the following vehicles on both arterial and collector road.

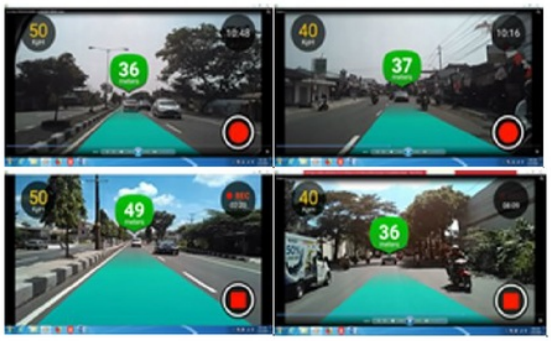

Fig. 2. Design and Installation of Moving Warning Sign

III. RESULT

The Car-Following Theory explains that the response of the following vehicles is marked by either the acceleration or deceleration based on the speed difference between the leading and following vehicles. Meanwhile, the sensitivity represents the parameter of behavior that relies on speed and distance.

The Summary Model and Anova Test were applied to discover the correlation and difference of the speed conversion between the car tester and following vehicles based on the variables of speed conversion and distance which were observed on both arterial and collector road under the two conditions. Based on the investigation, the study revealed the following findings as explained through Table 1.

The sensitivity value derives from the response comparison of the following vehicles in terms of acceleration and deceleration, which is then divided by the value of stimulus to

generate the number of speed difference between the car tester and following vehicles.

The sensitivity value at the condition of the mobile warning sign uninstallation from the rear part of the car tester during its operation on the arterial road had generated a positive alpha (α) value by 0.622 and the negative alpha (α) value by -4.045. In contrast, at the installation of the mobile warning sign, the positive alpha (α) value reached 1.143 and the negative alpha (α) value reached -3.566. Meanwhile, the sensitivity value at the condition of the mobile warning sign uninstallation from the rear part of the car tester during its operation on the collector road marked a positive alpha (α) value by 0.953 and the negative alpha value by -2.647. However, at the installation of the sign, the positive alpha (α) value signified the number 1.723 and the negative alpha (α) value was at -2.229.

TABLE I. CHANGE OF ACCELERATION BASED ON SPEED AND DISTANCE DIFFERENCE IN VARIOUS CONDITIONS

The Condition Related to The Road and Mobile Warning Sign Installation		Correlation	Difference
Arterial Road			
1	Uninstallation of the mobile warning sign	Correlation Found Medium Correlation	Difference Found
2	Installation of the mobile warning sign	Correlation Found Medium Correlation	Difference Found
Collector Road			
1	Uninstallation of the mobile warning sign	Correlation Found Medium Correlation	Difference Found
2	Installation of the mobile warning sign	Correlation Found Strong Correlation	Difference Found

The positive sensitivity (α) value indicated deceleration during the uninstallation of the mobile warning sign. However, during the mobile warning sign installation, the positive sensitivity value increased. It signified that the drivers were aware to keep their safety distance by hitting brakes and performed more significant deceleration during the sign installation. In contrast, the negative sensitivity (α) value signified acceleration during the uninstallation of the mobile warning sign. Meanwhile, the negative sensitivity value decreased at the time of the sign installation. The fact indicated that the drivers of the following vehicles moved with slower speed during the mobile warning sign installation. It implied that the drivers maintained their response to the warning sign that they saw at the rear part of the car tester.

The sensitivity test on the arterial and collector road under the two conditions generated the average sensitivity value as shown by TABLE 2.

TABLE II. AVERAGE SENSITIVITY VALUE OF FOLLOWING VEHICLES IN VARIOUS CONDITIONS

The Condition Related to The Road and Mobile Warning Sign Installation		Sensitivity (α)	
		Positive α	Negative α
Arterial Road			
1	Uninstallation of the mobile warning sign	0.622	-4.045
2	Installation of the mobile warning sign	1.143	-3.566
Collector Road			
1	Uninstallation of the mobile warning sign	0.953	-2.647
2	Installation of the mobile warning sign	1.723	-2.229

IV. CONCLUSION

The investigation of the speed conversion, speed, and distance between the car tester and following vehicles on both arterial and collector road under the two conditions has generated the correlation among the variables, including the acceleration, speed, and distance which appeared in various stages from medium to strong. The data analysis reveals that there is a significant correlation among a number of aspects of the following vehicles, including the acceleration, speed, and distance on the arterial and collector road under the two conditions. To conclude, the installation of the mobile warning sign at the rear part of the car tester could affect the response and sensitivity of the following vehicles.

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