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Analysis of driving behavior with information for passing through signalized intersection by driving simulator

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Abstract

Unnecessary vehicle movements such as rapid acceleration/deceleration or long idling at a signalized intersection increase an amount of CO_2 emissions from a vehicle. In this study, a method to provide the information based on the vehicle running condition and traffic signal status is therefore developed for passing through the signalized intersection ahead, which provides an indication to release an accelerator pedal and recommended speed information. If a driver follows such information, unnecessary vehicle movements can be reduced. The developed method is then introduced onto a 3D driving simulator, UC-Win/Road for evaluating the effects of the information provision on reducing the amount of CO_2 emissions. Driving experiments with 32 participants under some scenarios of the information provision were conducted by using the 3D driving simulator. As a result, participants decelerated slowly at a certain distance from the intersection ahead by the information provision. Providing any information to a participant had a significant effect on reducing unnecessary vehicle movements. It was also found that the most effective information to reduce the amount of CO_2 emissions was the accelerator-off indication, by which the maximum reduction of the average amount of CO_2 emissions attained to 6 %. It indicates that providing the information is effective for reducing CO_2 emissions from vehicles approaching a signalized intersection.

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Keywords: Recommended speed; Accelerator off; CO_2 emission; Signalized intersection; Driving simulator;

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1. Introduction

For preventing global warming, a lot of countries have addressed measures to reduce an amount of CO_2 emissions. In Japan at 2012, the amount of CO_2 emissions from the transportation sector accounts for 17% of the amount from all sectors, in which the ratio of CO_2 emissions from passenger vehicles is over 50% of the transportation-oriented emissions. In particular, the amount of CO_2 emissions is not be negligible from vehicles approaching a signalized intersection around a city area as drivers may hesitate to decelerate and accelerate slowly by a traffic signal changes. That may cause unnecessary vehicle movements such as rapid acceleration/deceleration or long idling at a signalized intersection, which increase the amount of CO_2 emissions from a vehicle approaching a signalized intersection.

In order to reduce these vehicle movements, providing appropriate information to a driver is expected. With rapid development of intelligent transportation systems(ITS)，information provision on a traffic signal change will be available in the near future in Japan. The information provision system helps a driver pass through a signalized intersection or shorten an idling time at signal red, and is expected for realizing the reduction of such unnecessary vehicle movements.

Traffic signal information provision has been researched all over the world. Several studies of green signal countdown device (GSCD) and red signal countdown display (RSCD) installed onto a signalized intersection are researched, like in Singapore by Lum and Halim (2006), in Taiwan by Chiou and Chang (2010), and in Wenbo et al. (2013). The GSCD, which is set beside a traffic signal, shows drivers a countdown of the remaining green time to amber signal. The RSCD shows a countdown of the remaining red time to green signal. The installation of the GSCD in Singapore was found to significantly reduce the occurrence of red-light running violations. However, its effectiveness of the GSCD does not last long. In Taiwan, the RSCD reduced the early start ratios of the leading vehicle only for a short term after the installation of the RSCD. However, the RSCD enhances intersection efficiency such as improving start-up delay, saturated headway and cumulative start-up delay. In research by Limanond et al. (2010), traffic signals in Bangkok typically utilize a long cycle length, and such lengthy signal cycle causes stress among drivers and serious traffic congestion. As a countermeasure, over 400 signal countdown systems are installed at signalized intersections. They reported that the countdown timers have helped to relieve the frustration caused by having to stop for unknown lengths of time during signal red. Also, the vehicle movement when recommended speed or congestion information is provided with a vehicle onboard unit is studied by Farah et al. (2012).

The research of an information provision system is also progressing in Japan. Iwata et al. (2012) has developed deceleration support system (DSS), which will provide an accelerate-off information to a driver approaching a signalized intersection. The effect of DSS was verified on a traffic flow simulator with a result of 7% reduction of CO_2 emissions in suburban roads. In the experiment by Matsumoto et al. (2014), traffic signal information is provided also in a traffic flow simulation, which leads to 3% reduction of CO_2 emissions. However, all of these information provisions are difficult to reflect each driver behavior in calculating the CO_2 emission reduction. Tsukada (2013) tested the efficacy of signal information provision with a real vehicle on an actual road. Most participants in this experiment were able to avoid the dilemma zone when the signal change information was provided. Nakamura et al. (2014) provided “collision caution” information in both a signboard and a voice. The result shows that the voice information will reduce sudden breaking. Theses precedents show the availability of the signal change information for drivers approaching a signalized intersection is effective in intersection safety and also operation. However, researches of driving behavior such as driving speed and motion of breaking/accelerating under the signal information provision are still insufficient. Moreover, although experiments in real field are desired for evaluating a certain developing system, there would have a risk of a traffic accident.

In this study, driving experiment is therefore conducted with an information provision system on a traffic signal by using a 3D driving simulator. The driving simulator can verify the system without a risk of a traffic accident (Rossia et al., 2003). The information provision system provides several kinds of information to a driver, in which an indication to release an accelerator pedal and a recommended speed to pass through a signalized intersection ahead are provided based on current vehicle condition and traffic signal status. If a driver follows such information, the driver can pass through the signalized intersection ahead or shorten the idling time at the intersection. Effects of the information provision on reducing the amount of CO_2 emissions are evaluated by driving experiments with 3D driving simulator where the accelerator-off indication or the recommended speed is provided.