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Modeling Speed Adjustment Behavior of Merging Vehicles at Urban Expressway Merging Sections

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Abstract

This paper modeled speed adjustment behavior of merging vehicles by using video data collected at two merging sections on urban expressway in Nagoya City, Japan. The results showed that the longer acceleration lane results in a higher acceleration rate of merging vehicles. And the denser mainline traffic causes a lower that of merging vehicles. In addition, the leading and following time to collision (TTC_L and TTC_F) were adopted as variables. It is found that if TTC_L is negative, merging vehicles increase their acceleration rate. By contrast, if TTC_L becomes positive and the collision can happen, merging vehicles tend to reduce acceleration rate to avoid the collision with leading mainline vehicles. In case of TTC_F, the positive signs of coefficients indicate that when following mainline vehicles run faster than merging vehicles, they increase their acceleration rate to avoid collision with following mainline vehicles. Furthermore, the validation results suggest a promising applicability of the developed models.

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Keywords: Acceleration; deceleration; gap choice; traffic conditions; accleration lane length

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1. Introduction

Expressway merging sections, which are designed to allow vehicles coming from a ramp to smoothly merge into the mainline, play as important nodes of expressway network. Their performances significantly affect the performance of the whole network. Therefore, the operational performance of these sections has been regarded as an important concern. Recently, traffic simulators e.g. AIMSUN, VISSIM, PARAMICS, etc., are considered as effective tools to evaluate the performance of facilities including merging sections. It is worth mentioning that, in order to reasonably evaluate the performance of merging sections, it is very important to take into account of various influencing factors on driver behavior before implementing it into the simulation models. However, the existing simulation models cannot precisely represent driver behavior under various influencing factors such as traffic conditions, geometry, and individual interactions between merging and mainline vehicles. To cover this gap, a research project has been carried out to develop several driver behavior models which can reasonably represent the whole maneuvers of merging and mainline vehicles. Then, the developed models will be incorporated into a traffic simulator to evaluate the performance of merging sections.

As a part of this research project, this paper aims at modeling the speed adjustment behavior (acceleration/deceleration) of merging vehicles by using video data. The video data were collected at two urban expressway merging sections in Nagoya City, Japan, covering not only uncongested regime but also congested regime of mainline traffic. Note that at the study sites, acceleration lanes were extended in 2011. Moreover, during the extension of these sections, the acceleration lanes were slightly shortened because of construction work. Hence, the video data taken during three periods of extension, which cover different acceleration lane lengths and mainline traffic conditions, supply this study a good database.

2. Literature reviews

Historically, the American Association of State Highway and Transportation Officials (AASHTO) has suggested that the acceleration lane length is based on ramp vehicle acceleration performance. The acceleration performance of vehicles in the acceleration lane was adopted from very old study in the late 1930's. However, its assumption that drivers can freely accelerate without any interaction with mainline vehicles is not realistic.

Michaels and Fazio (1989) found that there is a decline in speed between successive accelerations when merging drivers are searching gap. This implies that mainline vehicles have a pronounced influence on merging vehicle acceleration behavior and that impacts cannot be excluded from the formulation of merging vehicle acceleration. Kou and Machemenhl (1997) reported that when merging vehicles are running in the acceleration lane, they interact with mainline vehicles and with other merging vehicles as well. Consequently, their acceleration characteristics cannot be modeled by simply assuming no other vehicles exist. In order to consider these interactions, they adopted the concepts of car-following for modeling acceleration/deceleration behavior of merging vehicles.

Although Kou and Machemenhl's model is capable of representing the interaction of merging and mainline vehicles, its application is limited to uncongested conditions. Sarvi et al. (2002) overcame this limitation by using data collected under congested conditions on Tokyo Metropolitan Expressway and used the same idea to model acceleration behavior of merging vehicles. It is highlighted that both models of Kou and Machemenhl (1997) and Sarvi et al. (2002) cannot represent how the gap searching and gap acceptance affect the acceleration/deceleration behavior. However, the gap searching and gap acceptance might have significant impacts on the acceleration characteristics of merging vehicles.

Chu et al. (2013) modeled the gap choice behavior by classifying merging choice into three patterns: "direct-", "chase-" and "yield-merging" depending on the interactions between merging and mainline vehicles at assumed decision point. The present paper is the continuation of this work in order to develop behavior models which can represent the whole merging maneuvers. Then, developed models will be incorporated in a traffic simulator for a reasonable evaluation of the operational performance of merging sections.

3. Study sites, data collection and processing