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An Analysis of Merging Maneuvers at Urban Expressway Merging Sections

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Abstract

This study analyzed merging maneuvers namely merging speed and merging position by using video data collected at two merging sections on Nagoya Urban Expressway, Japan. The analysis demonstrated that the longer acceleration lane length is associated with further merging positions. Furthermore, the traffic conditions do not significantly affect the means of merging positions but their variations. The variations of merging positions become significant when the density of mainline is higher. A similar tendency can be observed if acceleration lane length becomes longer. Regarding merging speed, it is found that mainline traffic conditions significantly affect merging speeds. They decrease as traffic conditions become denser. To generalize the results of analysis, a normal distribution was adopted to fit the models of merging position and speed. The results of model estimation and sensitivity analysis indicate that the models give consistent results with the analysis.

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Keywords: urban expressway, merging maneuver, traffic conditions, gap choice; normal distribution

1. Introduction

Recently, as a consequence of rapid motorization, many bottlenecks on urban expressway in Japan have suffered from severe congestions. Among them, merging section is one of areas that traffic congestions are likely to occur.

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Due to this reason, the operational performance of merging sections has become a crucial issue. To evaluate the performance of these sections, traffic simulators e.g. AIMSUN, VISSIM, PARAMICS, etc., are recognized as effective tools. However, for a reasonable evaluation of performance of merging sections, various influencing factors on driver behavior need to be considered prior to implementing it into simulation models. Although the existing traffic simulators can reproduce merging maneuvers, they cannot precisely represent driver behavior under various influencing factors e.g. traffic conditions, geometry, and individual interactions between merging and mainline vehicles. In the direction of overcoming this limitation, a research project has been conducted to develop driver behavior models which can precisely represent the whole maneuvers of merging and mainline vehicles. That makes it possible to reasonably evaluate the performance of merging sections by incorporating proposed models into a traffic simulator.

Being a part of this research project, the objective of this paper is to analyze and model merging maneuvers namely merging speed and merging position by using video data collected at merging sections on Nagoya Urban Expressway, Japan. The video data were recorded in different times of the day and days of the week to cover both uncongested and congested regimes of mainline traffic. It is interesting to mention that at the study sites, acceleration lanes were extended in 2011 as a measure to relieve traffic congestion. In addition, during the extension of these sections, the acceleration lanes were slightly shortened due to construction work. Therefore, the video data taken during three periods with different lengths of acceleration lane and conditions of mainline traffic provide a good basis for this study.

2. Literature reviews

Polus et al. (1985) analyzed merging positions of merging vehicles based on video data collected at four acceleration lanes in Israel. The comparison was given for tapered and parallel acceleration lanes. However, the effects of traffic conditions and acceleration lane lengths on merging positions were not concerned. Ahammed (2008) modeled merging maneuvers including merging speed and merging position based on field data observed in Ottawa City, Canada. The models showed that merging speeds and merging positions increase as the acceleration lane length becomes longer. Nevertheless, the effects of the mainline traffic conditions were not considered since the field observation was conducted during the off-speak hours only.

Calvi and Blastis (2011) studied the driver behavior on acceleration lane by using a driving simulator. Six configurations were used to test the participants in the simulator including different acceleration lane lengths with low (1000), medium (1500) and high traffic conditions (3000veh/h/2-lane). The findings demonstrated that traffic volumes on the mainline significantly affect merging maneuvers. Initial speed, merging speed, and merging position increase as traffic volumes become higher. In addition, acceleration lane length was found not to affect merging position except under high traffic volume. Although both mainline traffic conditions and acceleration lane lengths were considered, it is unrealistic to assume a fixed mainline speed of 120km/h for all of six configurations in the driving simulator. In reality, the speeds of mainline vehicles are quite dependent on the mainline traffic conditions and they cannot be constant under different traffic conditions. That might be the reason why they concluded that initial and merging speeds increase as traffic volumes become higher.

Most recently, Chu et al. (2013a) claimed that effects of geometry of merging sections and traffic conditions on merging maneuvers have not been thoroughly studied yet. They overcame these limitations by considering both effects of geometry and traffic conditions on merging maneuvers. They took into consideration the effects of traffic conditions by dividing them into four levels A, B, C and F depending on thresholds of traffic flow and an assumed critical speed. However, the effects of traffic conditions cannot be precisely taken into account. In reality, the traffic flow is fluctuated, even under the same traffic level (A, B, C or F). As a result, an individual merging vehicle can face with different traffic flow of mainline within a level. Thoughtfulness of this fact, the present paper improves this limitation by using density for each merging vehicle to analyze the effects of traffic conditions. On the other hand, Chu et al. (2013b) analyzed and modeled gap choices behavior by dividing the choices into “direct-”, “chase-” and “yield-merging” depending on interactions between merging and mainline vehicles. The present paper continues this work in order to build the whole maneuvers of merging vehicles, which can be incorporated in a traffic simulator for reasonably evaluating the operational performance of merging sections.