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Evaluation of vehicle control algorithm to avoid conflicts in weaving sections under fully-controlled condition in urban expressway

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Abstract

Weaving section is one of the major bottlenecks in urban expressway network. A field observation showed that approximately 80% of the weaving vehicles changed their lanes within the most upstream 25% part of the entire section length. It means an insufficient use of provided infrastructure, and strategies to use them are necessary. Then this study developed vehicle control algorithms to avoid conflicts in weaving sections and aimed to achieve the capacity improvement. The proposed algorithms were implemented into a microscopic traffic simulation model in order to evaluate their effects. Two types of weaving sections and several scenarios of weaving ratios were prepared. The amount of the throughput at the downstream section was counted and the lane change positions of individual vehicles were recorded. The result showed that the total throughput was decreased gradually as the weaving ratio was increased. However, this drop were improved significantly by applying some algorithms. This means that there is a potential to utilize the existing infrastructure more efficiently and to alleviate congestion without huge construction investment.

Keywords: weaving section; urban expressway; automated vehicle control

1. Background

Urban expressway network in Tokyo has been developed constantly over decades and it works as an essential major arterial routes in the Metropolitan region, carrying millions of vehicles per day (Fig. 1). As the network become densely developed, the number of ramps, interchanges and junctions also increase, and as a result, a lot of weaving sections are formed in short intervals. Weaving section is one of the major bottlenecks in the urban expressway network. A report by the Ministry of Land, Infrastructure, Transport and Tourism (2012) describes that 18 locations out of 30 major bottlenecks in Tokyo Metropolitan region have a configuration of weaving section. They are usually located at junctions that hold two or more different mainlines, therefore congestion at a weaving section tends to influence widely in the network.

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Fig. 1. Expressway network in Tokyo (source: Ministry of Land, Infrastructure, Transport and Tourism)

A weaving section has two traffic streams merging into one at the upstream end and diverging again at the downstream end in a short distance. Here, vehicles from one side to the other side have to cross the course of the opposite vehicles, then conflicts among those vehicles occur. It makes vehicles decelerate and finally reduces the capacity of the section significantly. Weaving sections are also known to have high risk of accidents due to its complicated vehicles movement. Therefore, it is meaningful to develop a traffic control strategy in weaving sections to improve such situation and to realize safe and smooth traffic condition. It can improve not only the weaving section itself but also the whole network condition, considering major junctions in the network hold weaving sections.

ITS technology regarding automated vehicle control has been emerging drastically in these days. A lot of field demonstrations have been carried out and show the possibility of practical applications. In the future, all vehicles might be automated, and traffic flow could be made more smooth and efficient. Current technologies are developed based on vehicle-equipped sensors, however, it would be better to utilize infrastructure-based equipment when applied in complicated traffic conditions, such as weaving sections. Then, cooperated system between vehicles and infrastructure would contribute to solve above mentioned problems by controlling all the vehicles in weaving sections.

Based on this idea, this study aims to develop algorithms that control all vehicles in weaving sections and evaluate the effect of the proposed algorithms using a traffic flow simulation. This is not to describe traffic phenomena at present, but to contribute to improve traffic situation in the future.

2. Current status of weaving sections

2.1. Literature review

There are a lot of researches regarding traffic flow in weaving sections in the past. Cassidy et al. (1991) collected traffic flow data of a freeway weaving section in California from video observation and analyzed flow distribution among lanes. They developed a model to estimate the spatial distribution of traffic movements and it was used to evaluate the capacity and the LOS of the weaving section. Kuwahara et al. (1991) conducted video observation and collected vehicle detector data in Tokyo Metropolitan Expressway. They used these data to examine and compare a couple of existing methodologies to estimate capacities and speeds in weaving sections. Nakamura (1991) also conducted an observation in Tokyo and developed a microscopic traffic simulation that evaluates the capacity of weaving sections. It considers individual vehicles' relative distance, relative speed, gap change in near future, and so on. Uno et al. (2002) focused on conflicts among vehicles by lane-changing behaviors in a weaving section. They conducted video observation to capture vehicle conflicts and proposed a conflict index called PICUD. There are more following researches regarding weaving sections, but all of these previous researches basically tried to clarify current traffic phenomena in weaving sections or to develop models to describe them.

As a practically used guideline, Highway Capacity Manual (HCM) 2010 shows a formula to calculate the capacity of a weaving section as shown in Equation (1).

$$c_{IWL} = c_{IFL} - \left[438.2(1 + VR)^{1.6}\right] + \left[0.0765L_S\right] + \left[119.8N_{WL}\right] \quad (1)$$