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Microscopic Analysis of Climbing Lane Performance at Freeway Uphill Section

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Abstract

Freeways which are designed for high-speed vehicular traffic seems to have some problems with the sections with inclines due to the performance drop in accelerations of heavy trucks and high occupancy vehicles (HOVs). To complement this problem, installing auxiliary lane to laterally separate low speed vehicles from high speed vehicles. This is called a climbing lane. There are mainly two types of climbing lane: 1) pocket type climbing lane and 2) overtaking type climbing lane. In Korea, many sections with inclines are located near urban area, leading to some attentions on the performances of climbing lane at various traffic input flow conditions. To do so, microscopic traffic simulator based on OFFA is used for analysis. Some adjustments are made on the OFFA to depict asymmetric behavior without short gap mode and to demonstrate performance drop of heavy truck vehicles. Total delay is used to evaluate operational efficiency and time to collision is used to evaluate safety performance. As a result of simulation study, the overtaking type usually showed better performance in both operational efficiency and safety performance. However, at some traffic input flow with high truck ratio conditions, the performances of overtaking type climbing lane broke down, showing low operational efficiency and safety performance. Therefore, climbing lane operation depending on the traffic demand should be considered.

Keywords: Climbing lane; Car-Following; Microscopic Traffic Simulator; Moving Bottleneck

1. Introduction

A freeway can be defined as a road infrastructure designed for high-speed vehicular traffic. For this characteristic of freeways, there seems to be some problems with the sections with inclines.

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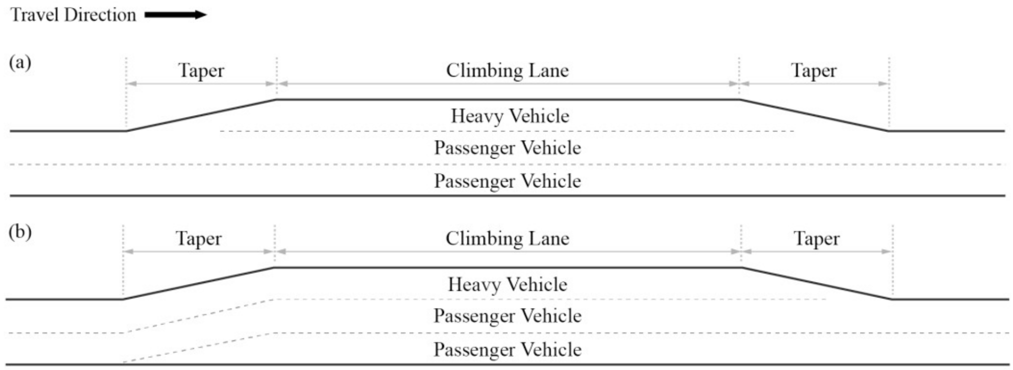

Fig. 1. Types of Climbing lane (a) pocket type; (b) overtaking type

Performance drops in acceleration occurs with heavy trucks and high occupancy vehicles (HOVs) (Lan et al. (2003)). This cause a traffic problem called as "moving bottleneck." Moving bottleneck is caused by a vehicle travelling with a speed which is less than the prevailing traffic. This low speed vehicle forces following vehicles behind lower speed to its speed, forming a vehicle queue behind. (Newell (1998)) This causes system performance drop in terms of total travel time. Also some high speed driving vehicles often attempt to overtake these low speed vehicles that causes safety problems as well.

Due to these problems, installing auxiliary lane to laterally separate low speed vehicles like heavy trucks and HOVs from high speed vehicles like passenger vehicles. In many nations, the auxiliary lane, also called as climbing lane, is suggested to be installed and operated at uphill section. In United States (California Department of Transportation (2012)), it suggests installation of additional lane where speed difference of heavy vehicles and passenger cars is above 15 kilometers per hour (herein after kph). In Germany (European Commission (2000)), the starting point of auxiliary lane is located where average speed of heavy vehicles is lower than 70kph. Japan has regulation of this lane to be installed where longitudinal slope is steeper than 5%. Specifically, in case of freeways where its desired speed is larger than 100kph, climbing lanes are installed where longitudinal slope is larger than 3%. (Japan Highway Public Corporation (1990)) In Korea regulation for installation of the auxiliary lane is same as the one in Japan. (Korean Ministry of Land, Transport and Maritime Affairs (2012))

There are mainly two types of climbing lane: 1) pocket type climbing lane and 2) overtaking type climbing lane. The former one, pocket type climbing lane (see Fig. 1. (a)), is that the auxiliary lane is located at the outer-most side of the lane. This is supposed to enforce slow vehicles to use this auxiliary lane not to disturb faster vehicles. However, from the data achieved from other field researches, the compliance rate, which is the rate of heavy vehicles to use the auxiliary lane, the lateral separation ratio of slow vehicles, is relatively low. With the low compliance rate, it is not enough to relieve moving bottleneck. The fact that heavy vehicles should change lane twice, both at the diverging and merging locations, makes drivers of heavy vehicles feel reluctant to use the climbing lane. Also, some fast vehicles abuse this climbing lane for overtaking slow vehicles. This implies some safety problems, too.

A different type to complement this problems of pocket type climbing lane is overtaking type climbing lane. (see Fig. 1. (b)) In overtaking type climbing lane, an additional lane is installed at the inner-most lane for high speed vehicles. At the diverging location, the entrance to the climbing lane, heavy vehicles do not need to change lane and these vehicles naturally flow into the outer-most lane. This improves the lateral separation of slow vehicles and heavy vehicles, and eventually help relieve the moving bottleneck. However, some reports have reported that the number of accidents have increased since the passing type of climbing lane has been installed, implying there might be a safety problem in overtaking type climbing lane.

As seventy percent of the land in Korea is covered with mountains, it is inevitable to install roadways in sections with inclines. As a result, in Korean freeways, there are 28 pocket type climbing lanes and 53 overtaking type climbing lanes. On the contrary to the countries where mountains are usually located in rural area, in Korea these climbing lanes are usually located near cities where daily traffic using climbing lane sections might be higher than that in other countries. Therefore, there have been increasing attentions to the studies on operational efficiency and safety of climbing lane at uphill sections. Lee et al. (2010) analyzed the effectiveness of the change of type of climbing lane