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Procedia - Social and Behavioral Sciences 138 (2014) 37 – 44

Procedia Social and Behavioral Sciences

The 9th International Conference on Traffic & Transportation Studies (ICTTS'2014)

Calibrating and Modeling Expressway with Different Ramp Distances on Beijing 3rd Ring Road

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Abstract

As a typical bottleneck connecting freeway and common road, ramp is an important traffic congestion area. Various traffic phenomena near ramps can be described by the Cell Transmission Model (CTM). However, real traffic data shows that traffic flow characteristics are far different for the ramp system with different ramp distances. We analyze traffic characteristics of ramp system with both an on-ramp and an off-ramp in Beijing 3rd ring road firstly. Then, it is found that ramp distance between the on-ramp and the off-ramp has a great impact on the capacity, due to the conflict of traffic flow between on-ramp and off-ramp. Finally the traffic conflict is considered in the merge cell and Capacity Drop CTM (CD-CTM) is proposed to embody the conflict. The simulation results suggest that CD-CTM fits the empirical data from Beijing 3rd ring road.

Peer-review under responsibility of Beijing Jiaotong University(BJU), Systems Engineering Society of China (SESC).

Keywords: urban traffic flow; cell transmission model; ramp system; urban expressway

1. Introduction

Traffic congestion is an inevitable problem in most large cities all over the world. In order to suppress traffic jams and increase the capacity of the road networks, the nature way is to build new infrastructures. Particularly, expressways are developed rapidly in some large cities of China, such as Beijing, Shanghai, and so on. Although expressways provide advantage service for traveling, ramps connecting expressways and local roads become new

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Peer-review under responsibility of Beijing Jiaotong University(BJU), Systems Engineering Society of China (SESC).
doi:10.1016/j.sbspro.2014.07.179

bottlenecks, which usually induce congestions. To understand the nature of congestions, theoretical traffic flow models have been developed and calibrated with empirical data. CTM is a famous traffic flow model presented by Daganzo (1994,1995). In CTM, road is divided into homogenous cells. This model clearly describes the interaction between neighboring cells. It relies on a sending function depending only on the state of upstream cells, and on a receiving function depending on the state of downstream cells. CTM provides an intuitively appealing and easy approach to deterministically describe how the number of vehicles in consecutive cells of a freeway evolves over consecutive time intervals. So far, CTM has been extensively investigated and extended, e.g. LCTM (Lagged Cell Transmission Model) by Daganzo (1999), EL-CTM (Enhanced Lagged Cell Transmission Model) by Szeto (2009), and MCTM (Modified Cell Transmission Model) by Muñoz et al. (2004). Furthermore, many applications for ramp systems have been done by using CTM, e.g. Lebacque (1996); Jin and Zhang (2003); Gomes et al. (2003, 2006, 2008); Saidi et al. (2010).

Since real traffic data is the basis for traffic flow modeling, both theoretical and practical methods are combined in this work to promote the reliability of the conclusions. To solve traffic problem near ramps in urban expressway, traffic flow characteristics must be studied firstly. In this work, the famous CTM model is used to depict the dynamics of traffic flow, due to its simplicity, high efficiency, and flexibility for extension. Above all, the most important reason is that CTM can reproduce most phenomena in real traffic, such as shock waves and so on. However, the expressway ramp system, together with the various driving behaviors in China, induces much more traffic flow sates, which cannot well be depicted by the original CTM. As a consequence, based on empirical traffic data obtained in Beijing 3rd ring road, the CTM is validated and calibrated for various systems with an on-ramp and an off-ramp. It is found that ramp distance has a great impact on capacity. Especially in small distance cases, the capacity drops off. For these system, the Capacity Drop CTM (CD-CTM) is proposed to reflect traffic conflict in the merge cell. The model is applied to Beijing 3rd road. The simulation results show that, both CD-CTM can depict traffic flow characteristics for the expressway ramp systems with different ramp distance.

2. Traffic Characteristics of Ramp Systems in Beijing 3rd Ring Road

In this paper, data collecting points are from Beijing 3rd ring road. These points are Zhao Gong Kou Bridge west, Hang Tian Bridge north, and Nong Zhan Bridge south, and labeled by Points 1 to 3 orderly. The inside circle is the inner ring, and the outside one is the outer ring. Points 1 are located in inner road, while points 2, 3 are in the outer road. Traffic data is obtained through Remote Traffic Microwave Sensor (RTMS) during 5:00-23:00 on May 13, 2010.

All systems on these three observation points are ramp systems with an on-ramp and an off-ramp. We define the ramp distance as the distance between two adjacent ramps. The ramp distances on the points 3, 2, and 1 are distinct, and are respectively 95m, 220m, and 360m. The effect of ramp distance on traffic flow characteristics can be investigated in accordance with the real data detecting in these points.

In Fig. 1(a), the flow-density diagrams are plotted according to real traffic data. These scatter points can be classified into three regions, free-flow region with low density, semi-stable region with medium density, and congestion region with high density. In the free-flow region, the flux increases linearly with the density. In the semi-stable region, the flux reaches the maximal value. In the congestion region, the flux decreases with density. By comparing with the flux-density diagram for different ramp distances, an interesting phenomenon can be found. In the system with ramp distance of 360m, scatter data points are mainly located in free-flow region, and more data points are located in large density region as ramp distance decreases. Furthermore, the maximum flow increases with ramp distance, but the corresponding critical densities are nearly the same.