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Research on the Macroscopic Fundamental Diagram for Shanghai urban expressway network

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Abstract

This paper are trying to investigate the existence and the characteristics of macroscopic fundamental diagram (MFD) for urban expressway network in different types of days based on detectors data in Shanghai, China. At first, the features of the urban expressway is discussed relating the speed and occupancy, and then the existence of MFD in Shanghai urban expressway network is proved based on one week's data. Moreover, the hysteresis phenomena exist in most days and the network exhibits different hysteresis loops under different traffic situation. In order to explore the reason of hysteresis loops, all the detectors are categorized into seven types. When the free flow detectors are removed, the hysteresis loop also exist like the MFD of all the detectors. And when those detectors whose flow-occupancy relations exhibit similar hysteresis loop are removed, the hysteresis loop of MFD is not clear. Hence, they are proved to be the important part of all the detectors. And the hysteresis loop of individual detectors are influenced by shock waves and traffic situations. And the transitions of free flow traffic to congested traffic and the transitions of other way around are different. Hence, the fundamental diagram of individual detectors has significantly impact on the hysteresis phenomena of MFD. It is worthwhile to study the key detectors when the hysteresis of the MFD are discussed.

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Keywords: MFD; Hysteresis phenomena; Urban expressway network

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1. Introduction

The problem of congestion in many cities are increasingly severe with the rapid development of urbanization. Actually, the network-level traffic flow relations were discussed by many researchers on last century [1-8]. On 2007, Daganzo proposed the conception of Macroscopic Fundamental Diagram (MFD) which describes the aggregate behavior of traffic in cities. By aggregating the scattered plots of flow vs. density from individual loop detectors in a homogeneous network, the network exhibits a figure which is similar with the fundamental diagram [9]. Hence, the model is called "Macroscopic Fundamental Diagram" which can be used to simplify the urban network modeling and describe traffic operations at a network-wide level.

The idea is proved firstly by the field experiment in the City of Yokohama, Japan which revealed that MFD exists on a large urban area [10]. Geroliminis and Daganzo stated that MFD exists in the homogeneously congested regions of cities. However, many areas on a large scale are not homogeneous. Geroliminis and Sun[11] stated that there were hysteresis phenomena on MFD based on empirical data in the Minneapolis area freeway network. The hysteresis phenomena mean that "the higher network flows are observed for the same average network density in the onset and lower in the offset of congestion" [12]. And then Cassidy et al [13] concluded that when traffic is in the stable regime, the MFD can exhibit well-defined diagram on freeways.

Buisson and Ladier [14] also observed a MFD with a hysteresis loop in the Toulouse freeway network in France and they stated that the heterogeneity can impact the shape of MFD. And Gayah and Daganzo stated that congestion tends more strongly during recovery by use of a two-bin model [15]. They identified four types of pattern: single, clockwise hysteresis loops, counter-clockwise hysteresis loops, and figure-eight. In the study of Mazloumian et al. [16], the spatial distribution of vehicle density in the network affect the MFD. Saberi and Mahmassani [17] discussed the impact of the distribution of congestion on the shape of hysteresis loops. They also concluded that generally the hysteresis loops become larger when the spatial heterogeneity of network increases [18].

Many studies mainly focus on MFD on freeways or urban arterials, and the MFD for urban expressways has not been considered. This paper aims to investigate the existence and the characteristics of different types of days' MFD for Shanghai urban expressway network such as weekdays, weekends and holidays. And the reason of the hysteresis phenomena is discussed.

This paper is organized as follows. Section 2 presents the process of data collection, the feature of the urban expressway, MFD for the Shanghai urban expressway network. The hysteresis loop is discussed in Section 3, and different types of individual detectors are analyzed in that section. The MFD of different types of individual detectors is discussed in Section 4. And then Section 5 analyze the individual detectors' fundamental diagram and their hysteresis loops. Finally, conclusion is drawn in the last Section.

2. Data Description and the characteristics of MFD

2.1. Data Description

About one week's data (September 26- October 1, 2009) are chosen to analyze the MFD. The data records the traffic of the former week before the National Day (October 1) which is one of the biggest holidays in China. And in that festival, many people will go out of the city for holidays. The reason why the days are chosen is that the week consists of typical weekday, unusual weekday (the former day before holiday), weekend, and the holiday. Hence, different types of days' MFD can be obtained.

The urban expressway network is located on the central area in Shanghai. The capacity and speed on the urban expressway network in central city have obvious advantage than on urban arterials. Hence, it plays a very important role to relieve the increasingly traffic congestion in Shanghai. Also the urban expressway network in Shanghai is totally different between the freeways in many western countries which they are all in the downtown of the city. With the limitation of the data, about 1300 loop detector in the mainline of selected network (Figure 1) are chosen for analysis. And the distance between adjacent detectors is 300-600 meters. Most of the urban expressway network has four lanes per direction, while few parts has only two lanes.