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RESEARCH PAPER

# Evaluation on Traffic Congestion Mitigation in Beijing with Variable Message Signs

**ZHOU Yangfan[1], JIA Shunping[1,*], GUAN Wei[2], LIU Shuang[1]**

1. MOE Key Laboratory for Urban Transportation Complex Systems Theory and Technology, Beijing Jiaotong University, Beijing 100044, China
2. School of Traffic and Transportation, Beijing Jiaotong University, Beijing 100044, China

**Abstract:** The variable message signs (VMSs) provide an effective method to mitigate urban traffic congestion and balance traffic demand through publishing guidance messages. For evaluating the mitigating effect of VMS on congestion, a general-purpose model utilizing the data mining method is developed. The data includes published messages and a large amount of historical traffic flow collected from VMS publishing system and detectors which reflects the most realistic traffic conditions in Beijing road traffic network. Specially, road traffic statuses under two types of messages, guidance message and notice message, are compared to recognize which one is more effective. In the case study, spatial and temporal analyses are introduced separately to evaluate the mitigation of congestion under various traffic conditions. The results indicate that guidance messages on VMS make more significant contributions to improve the service level of congested roads. Particularly, guidance messages always appeared more effective than notice messages under severe congestion.

**Keywords:** intelligent transportation; traffic congestion; data mining; variable message sign (VMS); traffic guidance

## 1 Introduction

Variable messages sign (VMS) plays an important role in urban intelligent traffic management and guidance system by publishing real-time traffic information with images or texts. Actually, the key characteristic of congestion presents the imbalanced distribution of traffic demand, that is, some links are seriously crowded while others are quite smooth[1]. With VMS information, drivers are able to effectively select a better route and avoid congestion, so that traffic load is balanced and travel time is decreased.

From exiting researches, road experiment, sample investigation, mathematical model and simulation analysis are the most popular methods to study the effect of VMS. Generally, road experiments involve various VMS publishing plans which are designed to seek driver's response to different messages[2]. The effects of VMS on diverting, driving speed and braking behavior were studied by Erke et al.[3] through recommending an alternative route on motorway outside Oslo. Road experiment methods need some instruments like VMS and detectors and take a long period of time, particularly in bad weather. However it reflects the real situation on roads. Mathematical models like Logit[4] and Probit[5] are frequently established to estimate the effect of VMS on driver's behavior and its influencing factors. For fitting models, data are collected through questionnaires, stated preference survey or road detectors most of time[6]. Zhong et al.[7]chose the graphic VMS near the east gate of Renmin University of China for the investigation which released that predicted guidance mode had better effects on improving traffic flow and balancing traffic load. The advantages of mathematical method is that it can analyze results quantificationally and more sensitive to the factors. But questionnaire survey involves lots of time and money, and respondent's stated preference doesn't exactly show the real driving behavior. Simulation is quite convenient to pursue driver's response to various VMS scenes[8]. Systems are established in advance based on some models. Shang et al.[9] combined cell transmission and Logit-based route choice rule to forecast route travel time. By displaying the predicted travel time to drivers, the system performance was observably improved.

Evaluation of VMS effectiveness on various scenes like

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*Corresponding author. E-mail: shpjia@bjtu.edu.cn

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fog[10], slipperiness[11], congestion[1], parking[12] and safety warning[13]are mainly conducted by means of experiment, investigation or simulation. They considered drivers or vehicles as the key representations reflecting its effect. However, another direct assessment can be conducted by analyzing the mitigation of congestion routes or taking contrasts of road statuses in different guidance conditions. This paper analyzes historical data including VMS publishing history and road condition based on data mining at first. Then the differences of road traffic status within guidance messages or notice messages are calculated, to evaluate the effectiveness of two types of VMS. With the help of computer programs, the proposed method is more convenient and effective. At last, taking the VMS in Beijing as the case, spatial and temporal analyses are performed separately to evaluate the mitigation of traffic congestion.

## 2 Evaluation method based on data mining

### 2.1 VMS messages

Each VMS is recognized by its position, content and active time which are the properties of a VMS. According to the content, there are usually two kinds of information about congestion are shown on the VMS of Beijing. One is named guidance message here whose content displays not only congested segment but alternative road like the first record in Table 1, while the other one is defined as notice message whose content just presents congested segment like the second record. These two types of messages are usually published in the VMS of congestion roads and their upstream links. Therefore, which one is more effective with various road traffic status is a meaningful issues.

Table 1 Guidance message and notice message on VMS

| VMS Content | Start Time | Finish Time | Message Type | VMS IDs | VMS Count |
|---|---|---|---|---|---|
| Dewai Avenue from north to south is congested, alternative XinwaiAvenu | 2010/1/20 17:31:00 | 2010/1/20 19:08:00 | guidance message | 220 25 20 316 961 316 222 213 | 7 |
| Dewai Avenue from north to south is congested | 2010/1/12 17:12:00 | 2010/1/12 19:21:00 | notice message | 222 214 961 316 213 20 25 220 | 8 |

### 2.2 Road traffic status

Road traffic status is the variable studied in this paper to evaluate the impact of VMS on urban traffic congestion mitigation. Road condition value is proposed for convenience in the study to measure road traffic status. The values are obtained from traffic detectors which acquire driving speed at a regular interval like five minutes. In order to calculate road condition values by travelling speed, the ratio of actual detection speed to design speed multiplied by 100 is defined as the road condition value. Specially, if actual detection speed is larger than design speed, then it equals 100. Obviously, the value ranges from 0 to 100 and the road will be more fluent with a higher road condition value. On account of this definition, the operational status of roads and VMSs are usually divided into three groups shown in Table 2. The real-time road condition values during the period of VMS publishing were obtained in advance.

Table 2 Three road status and VMS states based on road condition value

| Road condition value | Road traffic status | VMS states |
|---|---|---|
| (0,25] | congested | red |
| (25,60] | slow | yellow |
| (60,100] | smooth | green |

### 2.3 Data mining and evaluation method

Road traffic status is the object to evaluate congestion. The values while guidance messages or notice messages are publishing released their effects on congestion mitigation. Moreover, the differences of road condition values under these two types of messages prove which one is better for mitigating congestion.

Supposing traffic detectors collect driving speed every five minutes, there will be 288 data for each link every day. This implies that any one sequence number from 1 to 288 suggests a five-minute in one day. For example, the 193rd value means the average traffic status during the time interval from 7:00 to 7:05. Therefore, time and link are temporal and spatial attributes of road condition values. Let $x_{l,i,j,w}$ denote the road condition value of link $l$, and based on the temporal attribute, $i$ represents the date, $j$ is the sequence number from 1 to 288, $w$ is the week number from 1to 7. Week number is also considered here as traffic conditions are significantly different among every day in one week, especially between weekdays and weekends.

Effects on congestion mitigation of two types of messages are compared by calculating corresponding road condition values. Therefore, according to the publishing time of congestion messages, two groups of road are selected condition values from all the $x_{l,i,j,w}$ according to the following rules. For a certain $l$,

$$\begin{cases} a_{i,j,w} = x_{i,j,w}, & \text{guidance message is published during the period of } i \,\&\, j \\ b_{i,j,w} = x_{i,j,w}, & \text{notice message is published during the period of } i \,\&\, j \end{cases} \quad (1)$$