J. Cent. South Univ. (2018) 25: 2014−2024
DOI: https://doi.org/10.1007/s11771-018-3891-8

Springer

Identification and characteristics analysis of bottlenecks on urban expressways based on floating car data

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Abstract: Identifying bottlenecks and analyzing their characteristics are important tasks to city traffic management authorities. Although the speed difference was proposed for the bottleneck identification in the existing research, the use of a secondary indicator has not been fully discussed. This paper strived to develop a method to identify the bottleneck on expressways by using the massive floating car data (FCD) in Beijing. First, the speed characteristics of bottlenecks on expressway were analyzed based on the speed contour map. The results indicated that there was a significant difference between speeds on the bottleneck and downstream links when a bottleneck was observed. The speed difference could indeed be used as the primary indicator to identify the bottleneck. However, it was also shown that a sufficiently large speed difference does not necessitate an activation of a bottleneck. The speed-at-capacity was then used as the secondary indicator to distinguish the real bottleneck from the non-bottleneck speed difference. Second, a practical method for identifying the bottleneck on expressways was developed based on the speed difference and the speed-at-capacity. Finally, the method was applied to identifying the bottlenecks of the 3rd Outer Ring Expressway in Beijing. The duration, affected distance, delay and cause were used to evaluate and analyze the bottlenecks.

Key words: urban expressway; bottleneck identification; speed difference; speed-at-capacity

Cite this article as: ZHANG Jian-bo, SONG Guo-hua, YU Lei, GUO Ji-fu, LU Hong-yu. Identification and characteristics analysis of bottlenecks on urban expressways based on floating car data [J]. Journal of Central South University, 2018, 25(8): 2014–2024. DOI: https://doi.org/10.1007/s11771-018-3891-8.

1 Introduction

With the explosive increase of the vehicle population in China, the traffic congestion has become a severe problem in cities, especially on urban expressways. Bottlenecks are considered to be the main cause of congestions. Thus, it is important to identify and analyze the bottleneck in order to develop strategies for improving the urban traffic operations.

Although studies on the bottleneck have been conducted for several decades, there are still some unresolved issues in existing studies. For different road types and traffic conditions, the determination and use of key parameters in these identification methods remain to be studied and improved. For example, the speed difference was put forward for the bottleneck identification, but for secondary parameters, such as the speed congestion threshold, the systemic method for applications has not been defined and proposed. It should also be concerned about how the speed difference should be extracted and optimized to improve the identification

Foundation item: Project(2018YJS081) supported by the Fundamental Research Funds for the Central Universities, China; Projects(71273024, 51578052) supported by the National Natural Science Foundation of China (NSFC)
Received date: 2017−03−06; **Accepted date:** 2017−09−26
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accuracy. The volatility of the speed data can cause a significant change in the speed difference, which could affect the result of bottleneck identification. Further, the data collection with floating cars has been widely used in Chinese cities, such as Beijing and Shanghai. The massive FCD can be used to reveal well the continuous spatial characteristics of the traffic flow with a great geographical coverage of the road network. The FCD provides a new opportunity to analyze the bottlenecks and congestions on expressways with massive field data. Thus, a systematic method for identifying the bottleneck on expressways should be developed by taking the advantages of FCD. The method is expected to be beneficial to the congestion management in big cities.

2 Overview of existing studies

The bottleneck plays an important role in restricting the traffic flow. It can generate traffic congestions and reduce the operational efficiency of the road traffic network. It was indicated that a bottleneck is the boundary of the upstream queue and the downstream free flow [1]. Bottlenecks are usually divided into the recurrent bottleneck and the non-recurrent or temporary bottleneck.

With the development of the detection technology and data accumulation, researchers have developed many methods to identify and analyze the bottlenecks [2, 3]. BANKS [4] measured the speed upstream of the bottleneck and used the speed drop to identify the congestion. CASSIDY et al [5] proposed the rescaled cumulative curve based on the loop data. Then, the method was applied in the microscopic characteristics analysis of the bottleneck. CASSIDY et al [6, 7] and BERTINI et al [8] put forward an idea where the inflexion of the flow curve could be used to determine the bottleneck activation. And the congestion time and queue length upstream of the bottleneck were analyzed in Ref. [9]. Then, CHEN et al [10] proposed an identification method of the bottleneck by using the speed difference. WIECZOREK et al [11] analyzed the CHEN’ method with the Portland data. The optimal parameters were determined including the largest upstream speed and smallest speed difference. BAN et al [12] built the contour map of the percentile speed to identify the recurrent bottleneck by the archived FCD. DEMIROLUK et al [13] utilized the sudden jump in speed after the bottleneck to detect the recurrent congestion on arterials. JIN et al [14] proposed a method based on the coordinate transformation on the fundamental diagram, which could tolerate the noise and inconsistency of the data. JIN et al [15] also used the proposed evaluation index to test the applicability of methods respectively proposed by CHEN et al [10]. ZHANG et al [16] calculated the occupancy change to determine the location and the bottleneck activation. A congestion propagation model was developed by LONG et al [17] based on the cell transmission model, which was used to identify network congestion bottlenecks. WANG et al [18] utilized the ratio of the speed to occupancy and the speed difference to determine the congestion time. In addition, KERNER et al [19, 20] studied the breakdown and bottleneck by using the archived freeway data based on the three-phase traffic flow theory. In Beijing, SHAO et al [21] analyzed the observational data on expressways. It was found that the congestion often appeared when the speed was lower than 40 km/h.

Despite all the above efforts, however, existing studies on the bottleneck still have some lack facets that need to be improved or solved. While the speed difference or speed drop is widely used to identify bottlenecks, key parameters of the bottleneck identification methods still need to be better defined and quantified in a systematic manner. Besides, it would be of a great interest to transportation professionals to take the advantage of the massive on-road data, such as the FCD, to improve the accuracy of the bottleneck identification. In this context, this study aims to 1) extract the speed characteristics of bottlenecks on expressways (main roads), 2) develop an identification method for the bottleneck on expressways based on FCD and 3) analyze characteristics and causes of the recurrent bottlenecks. It should be pointed out that the objective of this study is the main road of the expressway.

3 Methodology

This paper first analyzes the relationship between the speed difference and the bottleneck on urban expressways based on the speed contour map. The characteristics of the speed difference and the bottleneck are illustrated respectively. Then, a practical method for identifying the bottleneck on expressways is proposed based on the speed difference and the speed at capacity. Finally, the method is applied in a case study by using the FCD in Beijing for multiple days.

3.1 Floating car data preparation

At present, more than 60000 taxis are equipped with the global position system (GPS) in Beijing. They all serve for the FCD system [22], which is further combined with the geographic information system (GIS). All roads in the network are divided into links with different lengths in GIS map of Beijing. The obtained speed is the average travel speed or the space mean speed, which equals the link length over the average travel time. The data from the FCD system are integrated at a time interval of 5 min. It includes such fields as LinkID, Speed, Length, Time, and SampleNum.

In this study, the FCD of the main road of the 3rd Outer Ring Expressway collected in March 2015 is utilized. There are about 3% missing data in the FCD everyday (5:30–22:30), which would affect the shape of the speed contour map. Thus, a linear interpolation is used to fill the missing speed with the average speed of the neighboring time intervals of the same link. Then, the five-point quadratic smoothing approach is applied to smoothing the speed time series on each link in order to reduce the interference of the data noise. The smoothed speed is processed to approximate the original speed with the smallest mean square error.

3.2 Speed difference and bottleneck

The main road of the 3rd Outer Ring Expressway is selected as the case, as shown in Figure 1 (blue line). Its total length is 48.3 km, The main road is divided into 122 links, with an average length of about 400 m. The link division mainly considers the node location of flow change (such as the entrance and exit of the main road) and the length of the link. The node of flow change is the critical point of link division, and the appropriate link length can improve the accuracy of the bottleneck identification. The speed contour map on March 17, 2015 is shown in Figure 3. In this map, the links starting from Wanfang Bridge are expressed by link i (i=1, 2, 3, ⋯, 121, 122) against the traveling direction. The 5-min intervals starting from 5:30 are expressed by time t (t=1, 2, ⋯, 203, 204).

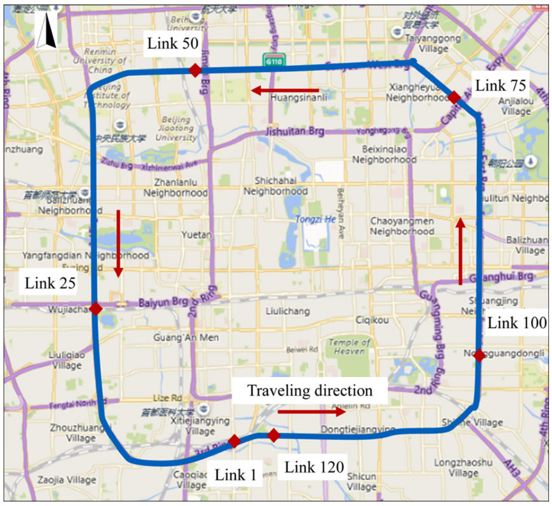

Figure 1 3rd Outer Ring Expressway in Beijing

3.2.1 Speed characteristics at bottleneck

Using Madian Bridge as a bottleneck case on the 3rd Outer Ring Expressway, the spatial-temporal variations of the speed are shown in Figure 2. It is observed that there is a significant speed difference between the bottleneck and downstream links when the bottleneck is activated.

In Figure 2(a), the speeds at all links show a similar trend over time. But there is a difference in the low-speed time period. At 5:30, speeds on all links are high. But, from 6: 30 to 7: 00, the speed on each link gradually decreases with the growth of the commuter demand. From 7: 30 to 10: 30, there is a significant speed difference on these neighboring links. The link 52 keeps a high speed, which is uncongested. The speed on link 53 is lower than that on link 52. However, the speeds on links 54 and 55 are the lowest and the two links are considered in the state of the congestion. It is observed that the location on link 54 is the bottleneck causing the congestion upstream, such as the link 55. It is shown that there is a speed difference between the bottleneck and downstream links when the bottleneck is activated at 7:00, 13:30, and 17:30.

Figure 2(b) shows the speed spatial variations on links from 13:00 to 14:30. The speed on link 52 is almost constant. And both speeds on links 53 and 54 decrease over time. Furthermore, the speed difference between links 52 and 54 increases gradually over time. In the upstream of link 54, the congestion forms and spreads to the upstream after 13:30. And the speed difference between the bottleneck and the downstream links increases

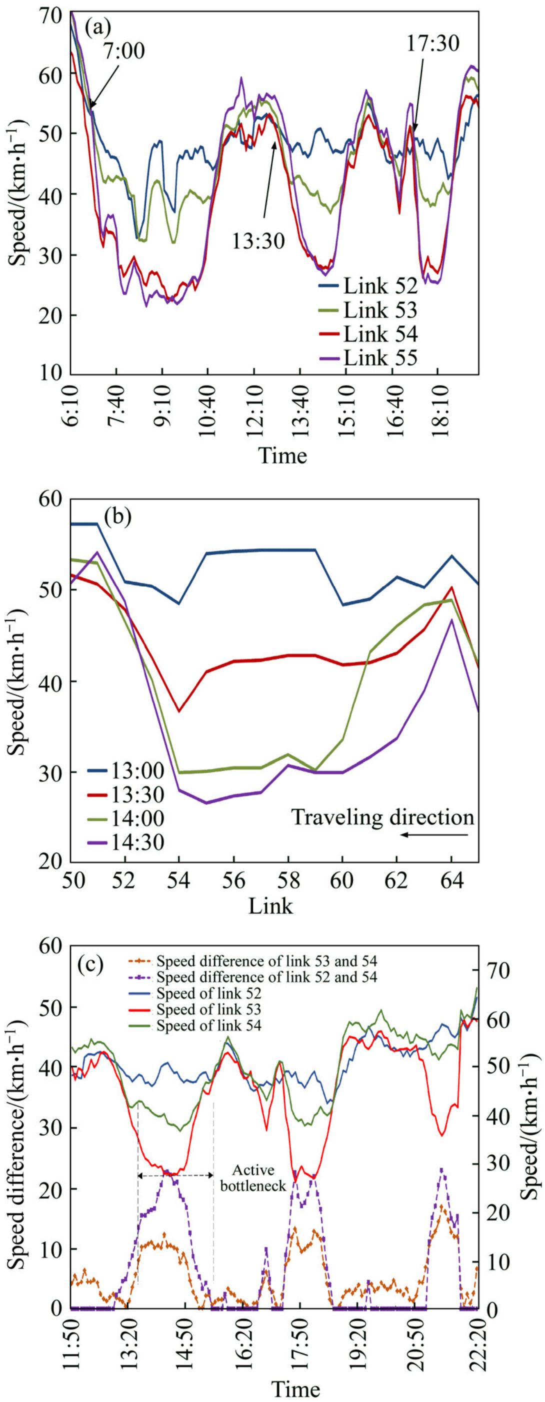

Figure 2 Spatial-temporal variations of speed on Madian Bridge on March 17, 2015: (a) Temporal variations of speed; (b) Spatial variations of speed; (c) Comparison of speed difference

gradually in the process of the congestion formation.

Overall, the speed difference between the bottleneck and downstream links is synchronously activated when the bottleneck is activated. It indicates that the bottleneck can be identified by detecting the speed difference.

In addition, the speed difference of links *i*, *i*+1 and *i*+2 is more stable and noticeable than that between links *i*+1 and *i*+2. First, the vehicles are still in the process of accelerating at the link next to the bottleneck but have not achieved their desired speed. Second, the link speed in the FCD system is commonly derived from vehicles' travel speeds, which may cover multi-links, based on the time weight of vehicles on the link. It reduces the speed difference of the neighboring links in the process of deriving the link speed. As shown in Figure 2(c), compared with the speed difference of links 53 and 54, the speed differences of links 52, 53 and 54 match preferably with the active bottleneck.

3.2.2 Speed difference as primary indicator

Based on the analysis above, the speed difference can be used as the primary indicator to identify bottlenecks. In this section, the speed difference is defined and described. Figure 3 shows the speed variations in a two-dimensional spatial-temporal map. The contour lines and different colors are used to distinguish the speed value (km/h). The deeper the color, the lower the speed. The red and yellow areas in the map represent congestions of different levels. These spots will be explained later, which represent the speed difference.

The congestions and bottlenecks on March 17, 2015 can be observed in Figure 3. It is observed that the downstream boundary or contour line of the congestion is the bottleneck, and the starting of the congestion in time and space represents the bottleneck activation.

By analyzing the data, it is found that the speed difference of two neighboring links is random. In this study, the speed difference is defined as follows: at time *t*, if speeds of three neighboring links (*i*, *i*+1 and *i*+2) meet the following Eq. (1), the speed difference is defined as Eq. (2).

$$v_i^t > v_{i+1}^t > v_{i+2}^t \tag{1}$$

$$sd_i^t = v_i^t - v_{i+2}^t \tag{2}$$

where v_i^t, v_{i+1}^t and v_{i+2}^t are the speeds of links *i*, *i*+1 and *i*+2 at time *t*, respectively (km/h); sd_i^t is the speed difference between links *i* and *i*+2 at time *t* (km/h); link *i* is the downstream of link *i*+1.

The speed difference (≥10 km/h), calculated by Eqs. (1) and (2), is marked with spots in Figure 3. It is worth noting that some downstream boundaries

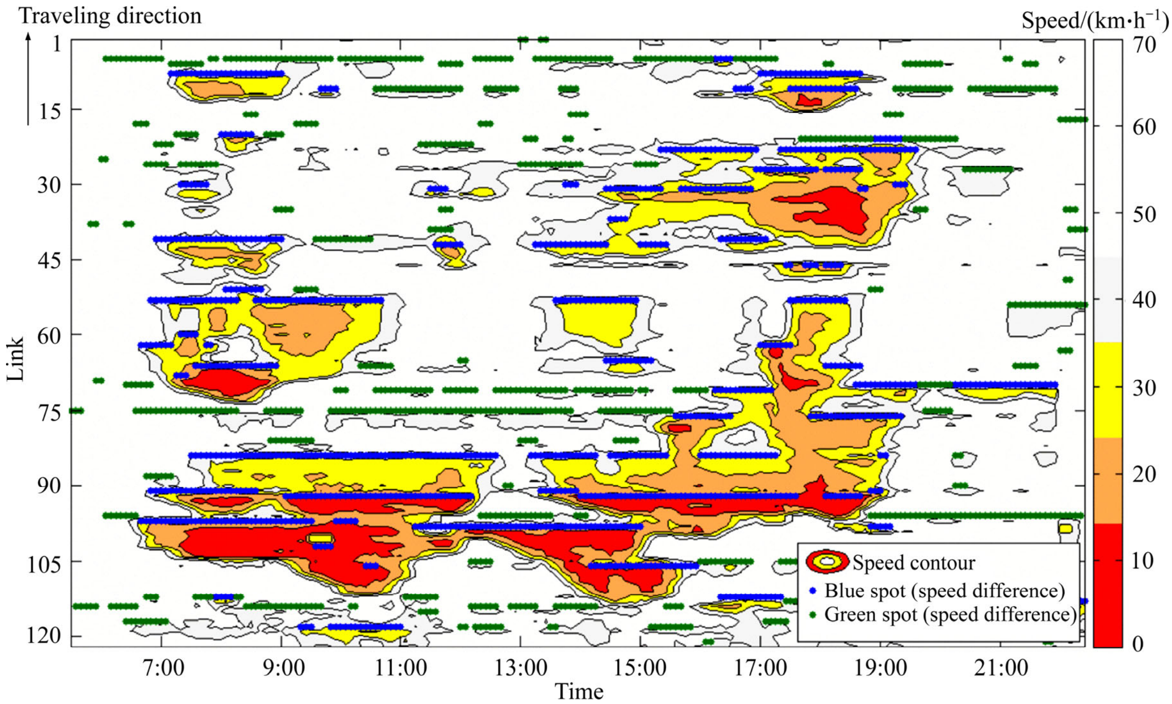

Figure 3 Speed contour map of 3rd Outer Ring Expressway on March 17, 2015

(contour lines) of congestions appear steadily at neighboring links. And these downstream boundaries are always associated with the speed difference (spots). It is possible to identify the downstream boundaries of congestions (bottleneck) by using the speed difference. However, some spots (green spots) are not corresponding to any congestions. Such issue needs a further analysis.

3.2.3 Speed-at-capacity as secondary indicator

Although the speed difference was proposed for bottleneck identification, the calculation and quantification of the secondary indicators have not been clearly given or described in these methods [4, 10].

The section above pointed out that there is a spatial speed difference when the bottleneck is activated. However, there is no active bottleneck at some locations, such as those green spots, where the speed difference does exist in Figure 3. It is because the speed at the location where there is a speed difference is not sufficiently low. According to the definition, the bottleneck is the location where the capacity is relatively low on the road. It can cause the flow rate lower than that of the upstream, which leads to the congestion and queuing. However, according to the speed-flow relationship in Figure 4, the speed drop does not necessarily lead to the flow drop. Instead, the flow increases with the speed drop in the high speed or free-flow range. Thus, a part of the speed drop is not corresponding to any bottleneck. The speed drop corresponding to the bottleneck is where when the traffic demand is greater than the capacity. According to the speed-flow relationship, the speed-at-capacity is a secondary parameter, which can be used to distinguish the two different speed drops.

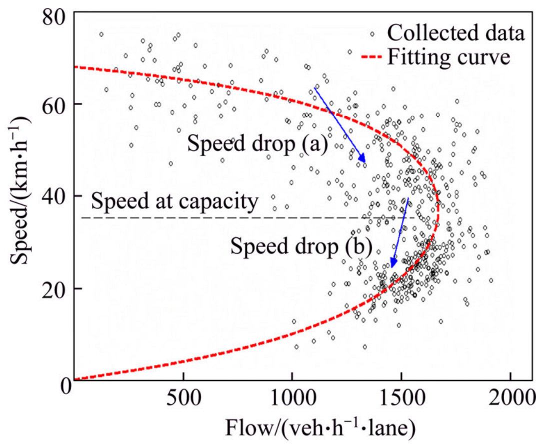

Figure 4 Speed-flow relationship curve of 3rd Outer Ring Expressway in Beijing

The speed-flow relationship curve of the 3rd Outer Ring Expressway was calibrated by using the traffic flow model of VAN-AERDE et al [23] and RAKHA et al [24], as shown in Figure 4. The flows from the remote traffic microwave sensor (RTMS) and the floating car speed at the location of the

RTMS were adopted to obtain the curve. The model was also applied to expressways in Beijing in existing studies [25, 26].

The speed drop (b) in Figure 4 reflects the process that the speed difference and the bottleneck are activated synchronously. The low speed at the bottleneck indicates the formation of the congestion upstream. But the speed drop (a) expounds another kind of speed difference where the speed is greater than the speed-at-capacity. The flow rate at the location of the speed difference actually increases with the speed drop. Hence, the key findings are as follows:

1) The active speed difference could gradually transform into the active bottleneck.

2) The speed-at-capacity can be used as the key parameter to distinguish the real bottleneck from a non-bottleneck speed difference.

3) The threshold to trigger a bottleneck is that the speed is lower than the speed-at-capacity when the speed difference is activated.

In summary, the method for identifying the bottleneck on expressways can be designed based on the speed difference and the speed-at-capacity.

3.3 Identification method of bottleneck

In this section, a systematic method for identifying the bottleneck on expressways is proposed. The key procedures include three steps. Furthermore, this proposed method can be applied to identify both the non-recurrent and recurrent bottlenecks, which can be distinguished by using frequency statistics. It will be introduced in the case study.

Step 1: Extraction of speed difference

First, if the speed difference sd_{i-2}^{t}, defined in Eqs. (1) and (2), is greater than the threshold v_d, the speed difference attribute of link i is denoted as 1, as shown in Eq. (3). It means that the speed difference is activated. Otherwise, its attribute is denoted as 0.

$$d_i^t = 1, \quad \text{if } sd_{i-2}^{t} > v_d \tag{3}$$

where d_i^t is the speed difference attribute of link i at time t, and v_d is the speed difference threshold (km/h).

The threshold of the speed difference is set to ensure the reliability of the speed difference, reducing the random interference of accidental factors. Based on the data analysis, the v_d is subjectively set to 10 km/h.

Step 2: Correction on the continuity of speed difference

Second, the moving window method is applied to correcting the speed difference attribute to improve the continuity of the active speed difference (≥10 km/h). For link i at time T, if $d_i^T = 0$, the frequency of the active speed difference is counted during the time [T–2, T+2] with 5 time intervals. The attribute is changed to 1 when the frequency is greater than 2, as shown in Eq. (4).

$$d_i^T = 1, \quad \text{if } \sum_{t=T-2}^{T+2} d_i^t > 2 \tag{4}$$

After the correction is completed, the time indicator of the active speed difference at link i can be determined, including the start and end times of the activation and the duration.

Step 3: Bottleneck filtration based on speed-at-capacity

Finally, the average speed of link i is calculated at the jth duration of the active speed difference at link i. If the average speed v_{ij} is lower than the speed-at-capacity of the expressway, link i is considered to be an active bottleneck. The bottleneck attribute b_i^t of link i at time t is denoted as 1 where time t belongs to the jth duration of the active speed difference. And the duration of the bottleneck is the jth duration of the speed difference at link i.

$$b_i^t = 1, \quad \text{if } v_{ij}^t < v_{\text{c}} \tag{5}$$

where b_i^t is the bottleneck attribute of link i at time t; v_{ij} is the average speed of the link i at the jth duration of the speed difference at link i (km/h); and v_{c} is the speed-at-capacity (km/h).

Existing literatures [25, 26] provided that the speed-at-capacity of 3rd Outer Ring Expressway was between 30–40 km/h. The speed-at-capacity is set to be 35 km/h in the rest of this paper.

4 Results

In this section, FCD on workdays from March 9, 2015 to March 20, 2015 is used to identify the bottlenecks and congestions on the 3rd Outer Ring Expressway by proposed method. Then, the causes of the identified recurrent bottlenecks are analyzed. The proposed bottleneck identification method is applicable to both non-recurrent and recurrent bottlenecks, which can be distinguished based on the activation frequency by using the historical FCD.

4.1 Bottleneck identification

Figure 5 shows the bottlenecks and congestions of 3rd Outer Ring Expressway on March 17, 2015. In this study, link i at time t is defined to have a congestion when its speed is lower than the v_c, as shown in Eq. (6). The blue spots, calculated by using the above method for identifying the bottleneck in Eqs. (3)–(5), represent the active bottleneck. The proportion graph on the left of Figure 5 is the active proportions of the identified bottlenecks in one day. The proportions are calculated by using Eq. (7).

$$c_i^t = 1, \quad \text{if } v_i^t < v_c \tag{6}$$

$$p_i = \frac{1}{204} \cdot \sum_{t=1}^{n} d_i^t, \quad \text{when } v_{ij}^t < v_c \tag{7}$$

where c_i^t is the congestion attribute of link i at time t; p_i is the active proportion of bottleneck i; 204 is the total number of time intervals in one day.

On March 17, 2015, the map indicates severe bottlenecks causing congestions. There are high active proportions at bottlenecks of links 83, 91 and 96. The congestions caused by these bottlenecks are severe for almost the entire day. But at link 8, the bottleneck is only activated in the morning and evening peak. The different characteristics of these bottlenecks directly affect the types of management strategies to be developed. It should be noted that the propagation of downstream congestion towards upstream can eliminate the bottleneck activation. And there is overlap on the affected distances of adjacent bottlenecks.

Based on the bottleneck identification case above, the recurrent bottlenecks can be distinguished by using the frequency statistics. The frequency contour map of the congestion frequency of 3rd Outer Ring Expressway is drawn on the basis of FCD of 10 workdays. The congestion frequency of link i at time t of 10 d is defined as cf_i^t in Eq. (8). When $cf_i^t > 3$, link i at time t is defined as the link of a recurrent congestion.

$$cf_i^t = \sum_{j=1}^{10} c_{ij}^t \tag{8}$$

where c_{ij}^t is the congestion attribute of link i at time t in the jth day and cf_i^t is the congestion frequency of link i at time t of 10 d.

The recurrent bottleneck is defined as follows: if the bottleneck frequency bf_i^t is greater than 3, the link i at time t is considered to be a recurrent bottleneck, as shown in Eq. (9). The threshold of the recurrent bottleneck is hereby determined in order to ensure a consistency with congestions. It is shown to be consistent with the threshold of the recurrent congestion.

$$bf_i^t = \sum_{j=1}^{10} b_{ij}^t \tag{9}$$

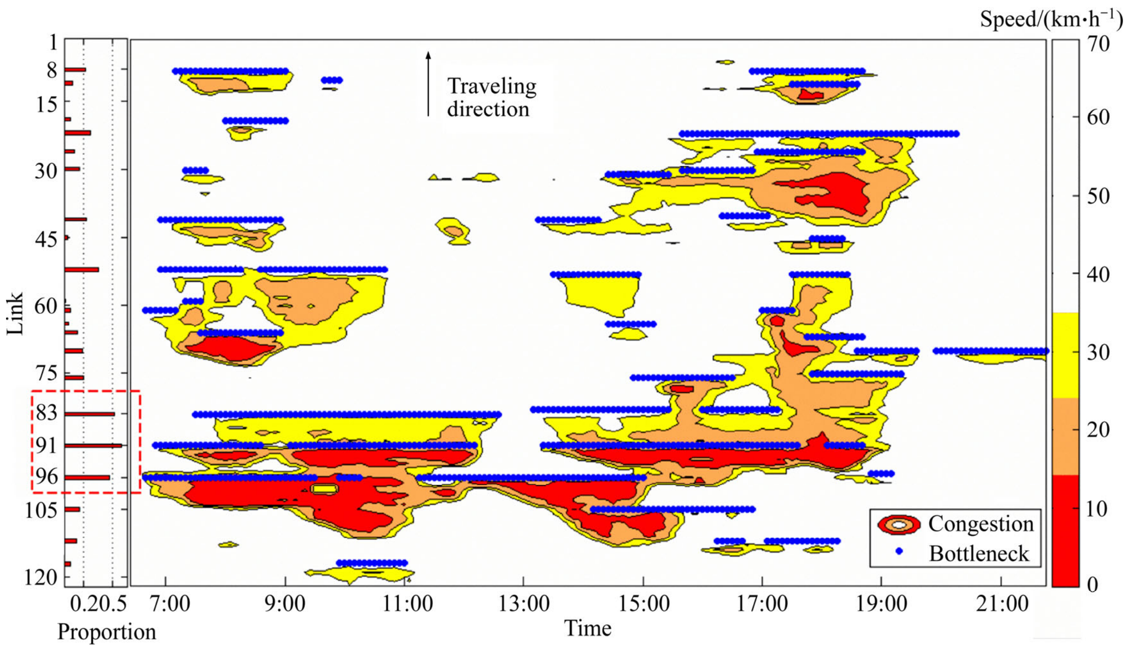

Figure 5 Speed contour and bottlenecks on March 17, 2015

where bf_i^t is the bottleneck frequency of link i at time t of 10 d, and bf_i^t is the bottleneck attribute of link i at time t in the jth day.

The recurrent bottlenecks are shown by using blue spots in Figure 6, where the locations and durations of recurrent bottlenecks match well with recurrent congestions. Compared with Figure 5, the non-recurrent bottlenecks are removed from the Figure 6. It is found that the majority of bottlenecks on the 3rd Outer Ring Expressway are recurrent. And the recurrent bottlenecks represent the causes of severe congestions.

4.2 Characteristics and causes analysis

In this section, the average duration, average affected distance [27] and average delay are used to evaluate the recurrent bottlenecks, as shown in Table 1. The archived flows from RTMS are adopted to calculate the delays by Eqs. (10) and (11).

$$de_i^t = q_i^t \cdot \left(\frac{l_i}{v_i^t} - \frac{l_i}{v_k} \right), \quad \text{if } v_i^t < v_\mathrm{c} \tag{10}$$

$$D_p^m = \sum_{t=m}^{n} \sum_{i=p}^{q} de_i^t \tag{11}$$

where de_i^t is the delay of link i at time t (veh·h); q_i^t is the flow rate of link i at time t (veh); l_i is the length of link i (km); v_k is the free-flow speed (68 km/h); and D_p^m is the total delay of bottleneck p activated at time m (veh·h).

These 10 locations in Table 1 and Figure 6 exhibit recurrent bottlenecks in 10 d. The total affected distances of the 10 bottlenecks are 23.4 km. It represents 48% of the total length of the 3rd Outer Ring Expressway. Especially, the bottleneck of Shuangjing Bridge causes the most severe delays of 18983 veh·h/d. For bottlenecks of Yansha Bridge and Guanghua Bridge, the average durations reach 10 h/d. The activation period of the bottlenecks at Liuli Bridge and Xinxing Bridge reflects the tidal traffic demand. These findings would be helpful for developing traffic management measures for improving traffic operations.

An important purpose for identifying the bottleneck is to determine the causes of recurrent bottlenecks causing severe congestions. Segments of the road could become bottlenecks due to their geometries restricting the traffic flow [28]. After the field survey and analysis on the above recurrent bottlenecks, the main causes are summarized into four categories: 1) excessive traffic demand, 2) road merging and diverging, 3) lane drop, and 4) bus station. The causes of 10 recurrent bottlenecks are listed in Table 1.

Figure 7 shows the physical characteristics of two recurrent bottlenecks. At the Madian Bridge, a bus bay station is at the upstream of the bridge. The arrival and departure of buses have severe impact on the vehicles of the neighboring lane.

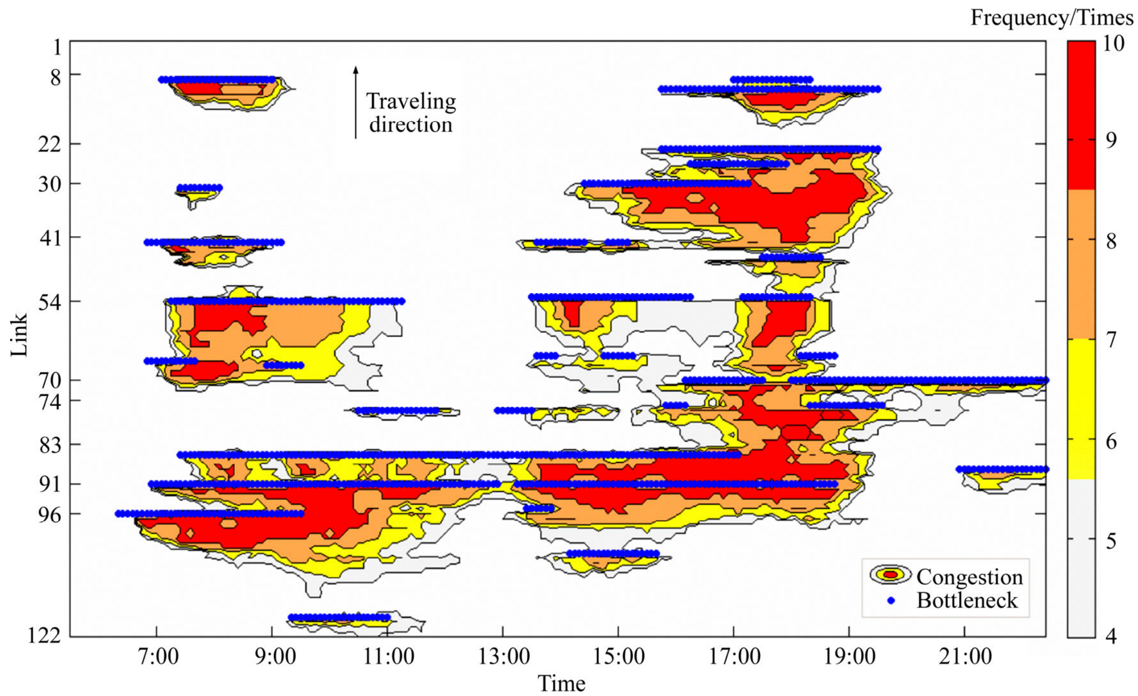

Figure 6 Frequency contour map of 3rd Outer Ring Expressway

Table 1 Evaluation on worst 10 recurrent bottlenecks

Link	Period	Average duration/h	Average affected distance/km	Average delay/(veh·h)	Cause
8	AM/PM	3.3	2.6	4646	(1) (2)
22	PM	3.8	1.1	1893	(1) (2)
30	PM	3.4	4.3	8633	(1) (2)
41	AM/PM	2.8	2.3	4737	(2) (3)
54	AM/PM	7.6	2.6	9021	(1) (2) (4)
70	AM/PM	5.1	1.7	4191	(1) (2)
74	PM	3.5	1.2	2654	(1) (2)
83	AM/PM	10	2.5	12260	(1) (2) (4)
91	AM/PM	11	1.2	14417	(1) (2) (3) (4)
96	AM	3.3	3.1	18983	(1) (4)

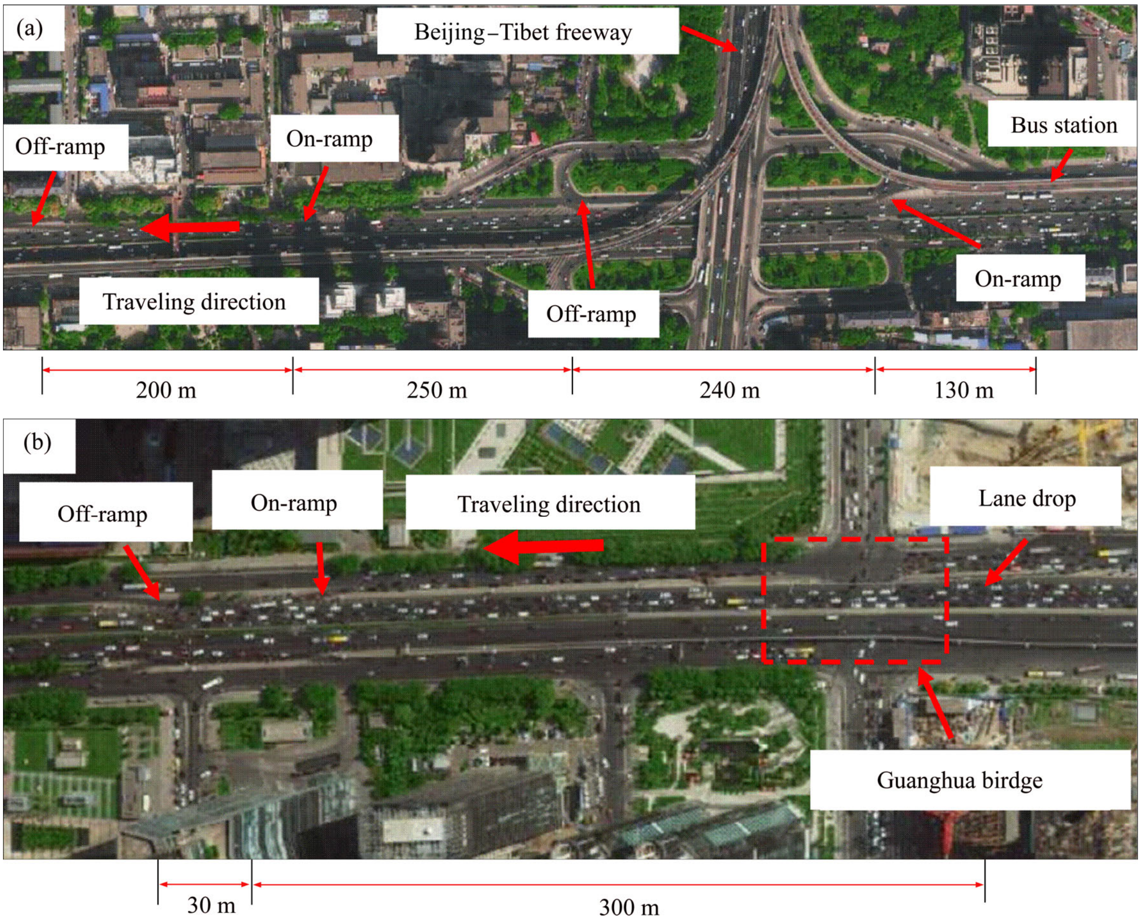

Figure 7 Satellite maps of recurrent bottlenecks: (a) Madian Bridge (link 54); (b) Guanghua Bridge (link 91)

Furthermore, there are four ramps connected with the expressway in the range of about 800 m downstream. Especially, excess vehicles enter the expressway through the on-amp connecting with Beijing–Tibet Freeway in the morning peak. The severe weaving traffic reduces the average speed of vehicles on these segments. Another bottleneck is shown in Figure 7(b). The lane drop and on- and off-ramps together contribute to the bottleneck activation. The segments of the expressway are located at the central business district of Beijing. The excess traffic demand increases the influence of adverse physical conditions of the expressway.

5 Findings and recommendations

This work analyzed the bottleneck characteristics on expressway based on the speed contour map and speed difference, and proposed a systematic method for identifying the bottleneck on expressways by using FCD. Two parameters, the speed difference and the speed-at-capacity, were used as the key indicators in the proposed method. Then, the proposed method was applied to a case study of Beijing. Main findings and recommendations of this study can be summarized as follows:

1) There was a significant speed difference between the bottleneck and downstream links when the bottleneck was activated. The bottleneck can be identified by detecting the speed difference as the primary indicator. But not all of the speed difference was corresponding to the bottleneck.

2) Besides the speed difference as the primary indicator, the speed-at-capacity was proposed as the secondary indicator to distinguish the real bottleneck from a non-bottleneck speed difference in the proposed method. The speed threshold to identify the bottleneck activation was that the speed was lower than the speed-at-capacity when the speed difference was activated.

3) The recurrent bottlenecks on expressways were identified and analyzed by applying the proposed method. The duration, affected distance and delay were used as the indicators to evaluate the recurrent bottlenecks. In the case study, the total affected distances of the 10 recurrent bottlenecks were 23.4 km. Besides, the most severe delay caused by the recurrent bottleneck reached 18983 veh·h/d.

In addition, it was found that the excessive traffic demand, road merging and diverging, and lane drop are the main causes of the recurrent bottlenecks. It is noted that the applicability of the proposed method to other road types remains to be studied. Further, it is recommended that the boundary spread characteristics of congestions caused by bottlenecks should be analyzed.

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(Edited by YANG Hua)

中文导读

基于浮动车数据的城市快速路瓶颈识别与特征分析

摘要：识别交通瓶颈并分析其特征是城市交通管理部门的重要任务。现有研究虽然提出应用速度差识别瓶颈，但辅助指标的利用仍未被充分讨论。本文利用北京市浮动车数据提出了一种识别城市快速路交通瓶颈的方法。首先，利用速度等高线图分析了城市快速路瓶颈的速度特征。结果表明，当瓶颈生效时，瓶颈与下游路段之间存在显著的速度差。速度差可以被用为识别瓶颈的主要指标。然而，分析也发现并不是所有显著的速度差都反映瓶颈生效。而临界速度可以作为辅助指标区分生效瓶颈和非瓶颈下的速度差。 在此基础上，提出了一种以速度差和临界速度为主要指标的城市快速路瓶颈识别方法。最后，应用该方法识别了北京三环快速路外环的瓶颈；并从生效时长、影响距离、延误和成因等角度对瓶颈进行了评估和讨论。

关键词：城市快速路；瓶颈识别；速度差；临界速度