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RESEARCH PAPER

# OD Matrix Estimation for Urban Expressway

**WANG Yuanqing*, YANG Liu, GENG Yin, ZHENG Mengmeng**

School of Highway, Chang'an University, Xi'an 710064, China

**Abstract:** OD information of urban expressway is the basis of analyzing the traffic operation and performance. A proper OD estimation method is capable of reducing the traffic surveys pressure and avoid traffic jams during survey and unreal OD information. This paper proposed a systematic method of OD estimation including traffic zone division in the form of the entrance and exit ramps of one direction on expressway, and established the seed OD matrix of high quality using the Gravity and Frator method. It estimated the OD matrix in the OD estimation module in TransCAD software, which was applied in the Inner Ring Road in Guangzhou city. The results showed that the relative errors of the traffic volumes on the links and ramps, the average trip distance and the traffic mileage are small with the seed OD matrix calculation and OD matrix estimation, which manifests that the estimated OD matrix is accurate and reliable and the proposed method is appropriate for the urban expressway traffic analysis.

**Key Words:** urban traffic; urban expressway; OD matrix estimation; traffic zone division; seed OD matrix

## 1 Introduction

Currently the urban expressway systems of metropolises in China have taken shape. Urban expressways are the main frame of the road system, especially for automobiles, entirely closed and access controlled. As the artery of the urban transportation and economy, urban expressways connect the main roads and the radial roads, gathering and distributing the traffic in central area and connecting the urban and suburban areas. The traffic flow features in trip distance and space on the expressway are the important basis for reducing traffic jams, ensuring the traffic service level in the city center and evaluating the transportation investment performance. Therefore, the origin–destination (OD) information of the expressway is of much importance.

The expressway capacity is about 2000pcu/lane/hour. If the survey on OD information is conducted by the roadside, the traffic jams and the changes on vehicle routing choice will be caused, and the OD information will be distorted. Because the expressway has many accesses and heavy traffics, it needs a lot of photographing equipment and much data processing work to get the OD information by the vehicle number plate survey[1,2]. Consequently, the OD matrix estimation technique has the advantages of cost saving, is much convenient, and has high practical value compared with the traditional methods mentioned above. Wei *et al*. suggested that a high-quality seed OD matrix could play an important role in improving the accuracy of the OD matrix estimation[3,4]. When there is no historical data, it can be used to calculate the traffic volume between zones. To avoid the above problems that will cause difficulty in the traffic flow analysis on the expressway, this paper proposed a systematic method for OD matrix estimation to improve the accuracy and reliability of the matrix estimation result. This method makes use of the traffic volume data obtained by the existing traffic detectors at the ramps and the sections of the expressway, divide the traffic zones according to the ramp service areas to estimate their traffic generation and attraction, and establishes the seed OD matrix using the gravity and double-constraint Fratar method.

This method has been applied and tested in the Inner Ring Road Project in Guangzhou based on the TransCAD software platform. The result shows that this method can achieve a higher fitting precision with lower cost on traffic data collection, and the key issue of establishing seed OD matrix for the OD matrix estimation of the urban expressway has been solved, through the integration of related techniques.

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*Corresponding author. E-mail: wyq21@vip.sina.com
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## 2 Basis of expressway OD estimation: traffic zone division

All the urban expressways are connected with other roads in cities, and all vehicles enter and exit through ramps, so the ramps can be the objects of the traffic zone division, and the traffic zones can be divided according to ramp service areas.

The traffic zones are divided by three ways: first, the area served by a pair of adjacent entrance and exit ramps in the same direction of the expressway as a traffic zone; second, the area served by a pair of entrance and exit ramps in two directions of the expressway as a traffic zone; third, the area served by a single ramp, either an entrance or an exit ramp, as a traffic zone. Whichever approach is adopted, the traffic volumes of the entrance ramp and exit ramp can be summed as the traffic generation volumes $P_i$ of the zone $i$ and traffic attraction volumes $A_i$ of the zone $i$, respectively.

The traffic generation and attraction volumes of each zone by surveying traffic volume data or using the traffic detectors on the ramps can be easily obtained using this method of dividing the traffic zone by ramps compared with traditional methods, in which traffic zones are divided according to the administrative districts, land-use planning, or natural separation. This approach provides the base data for the seed OD matrix calculation and the verification in the next step.

## 3 Seed OD matrix calculation

The seed OD matrix is of great importance, as it is the basis of the OD matrix estimation process. Also it reflects the traffic distribution structure; therefore, Wei *et al*. suggested that a high-quality seed OD matrix could significantly improve the accuracy of the matrix estimation results. When there is no historical OD information except the traffic generation and attraction volumes of each zone, traffic distribution methods can be used to calculate the traffic volume between zones[5]. Among the commonly used calculation models, the gravity model can ensure more practical results since the attracted strength and impedance between the traffic zones have been taken into consideration, so the seed OD matrix can be established by using the gravity model. Travel time or travel distance can be used as the impedance parameters in the gravity model, and the traffic volumes between zone $i$ and zone $j$ are shown as Eq. (1).

$$t_{ij} = K\frac{P_i^{\alpha} A_j^{\beta}}{R_{ij}} \tag{1}$$

where $t_{ij}$ is the traffic volume between zone $i$ and zone $j$; $P_i$ is the observed traffic generation volume of the zone $i$; $A_j$ is the observed traffic attraction volume of the zone $j$; $R_{ij}$ is the distance or free-flow travel time between zone $i$ and zone $j$; $k$, $\alpha$, $\beta$ are the model parameters.

If the relative errors between the generation and attraction volumes drawn from OD matrix through the gravity model and those from survey on the ramps, it is necessary to modify the seed OD matrix with double-constraint Fratar method till the accurate results are achieved. This method is usually used in the OD matrix calculation, so only a brief discussion is introduced below, and the detail information can be found in Refs. [5] and [6]. .

$P_i^{(0)}$ and $A_j^{(0)}$ are the traffic generation and attraction volumes, respectively, after using the gravity model to estimate the seed OD matrix. Define the difference coefficients between generation and the observed volumes, and attraction and observed volumes are as follows:

$$F_{pi}^{(0)} = \frac{P_i}{P_i^{(0)}},\quad F_{aj}^{(0)} = \frac{A_j}{A_j^{(0)}} \tag{2}$$

Therefore, the revised traffic volumes between zone $i$ and zone $j$ are:

$$t_{ij}^{(1)} = t_{ij} \times f(F_{pi}^{(0)}, F_{aj}^{(0)}) \tag{3}$$

where

$$f = \frac{P_i A_j}{P_i^{(0)} A_j^{(0)}} \cdot \frac{1}{2}\left( \frac{P_i^{(0)}}{\sum_j (t_{ij}^{(0)} A_j / A_j^{(0)})} + \frac{A_j^{(0)}}{\sum_i (t_{ij}^{(0)} P_i / P_i^{(0)})} \right)$$

Summing the traffic distributions, we can obtain $P_i^{(1)} = \sum_j t_{ij}^{(1)}$ and $A_j^{(1)} = \sum_i t_{ij}^{(1)}$, if $P_i^{(1)}$. If $A_j^{(1)}$ and $P_i$, $A_j$ are not same and if the error has exceeded the acceptable upper limit standard, then we use $P_i^{(1)}$ and $A_j^{(1)}$ to replace the $P_i^{(0)}$ and $A_i^{(0)}$ in the Eq.(2), we continue to the second iteration until the coefficient values in the Eq. (4) are close to 1, and the corresponding $t_{ij}^{(k)}$ is the initial traffic volume between zone $i$ and zone $j$ in the seed OD matrix for OD matrix estimation.

$$F_{pi}^{(k)} = \frac{P_i}{P_i^{(k)}},\quad F_{aj}^{(k)} = \frac{A_j}{A_j^{(k)}} \tag{4}$$

## 4 OD matrix estimation theory and process based on TransCAD platform

Assume that $V_a$ be the volume of the road section $a$, $T_{ij}$ be the traffic volume between zone $i$ and zone $j$, and $P_{ij}^a$ be the traffic proportion through the road section $a$, between zone $i$ and zone $j$. Obviously,

$$V_a = \sum_{ij} T_{ij} P_{ij}^a (0 \le P_{ij}^a \le 1) \tag{5}$$

The above equation is the basic equation that makes matrix estimation using the traffic volume on the expressway. As long as there is enough traffic volume on the road sections, the value of $T_{ij}$ can be obtained by solving simultaneous linear equations. The randomness of the traffic volume from the survey on the road section is taken into account in the OD matrix estimation module of the TransCAD software. Thus, any of the traffic assignment methods can be used to realize the matrix estimation function through multiple iterations between the traffic assignment and the matrix estimation[1,3].

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