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ORIGINAL ARTICLE

Estimation of origin–destination matrices for mass event: A case of Macau Grand Prix

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Mass events;
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Abstract Mass-event activities attracting a large number of people become important in promoting the culture of a city. The organization of a mass event requires a detailed plan of traffic control and evaluation of transport accessibility, but the design of the plan is usually empirical and received little attention in the literature. In this paper, we study a problem of origin–destination (OD) matrix estimation for the duration of mass event. The OD matrices are an important input in the transportation network analysis, but they are usually difficult and costly to obtain from survey or interviews. A two-stage procedure is proposed to estimate the OD demand matrices during the event using link traffic counts. The Macau Grand Prix motor-racing event organized annually is investigated as a case study to illustrate the performances of the model.

1. Introduction

Mass-event activities attracting a large number of people become important in promoting the culture of a city. Such special events can be very large scale from international events such as Olympic Games to a local scale such as concert and festival parade. During the activity, the transport accessibility, such as provisions of public transport and parking spaces are some of the primary concerns to the successfulness of the event. Limited accesses of the peripheral roads to the venue by private cars are typical strategies in controlling the traffic. In practice, the problem would be very dissimilar in different events and cities, and the solutions are usually experience-based.

The traffic planning for mass events is usually empirical and this topic received little attention in the literature. For one reason, most of the events are once-off (e.g. Olympic for a few weeks), which makes the experience non-transferable and the solution coped with the local knowledge of the city. Federal Highway Administration (2003) of the US Department of Transportation has released a handbook designed to provide some guidance and has recommended practices for the management of travel associated with planned special events. The policies, regulations, impact mitigation strategies and technologies used in advanced applications for managing the travel of planned events were discussed, and a summary version of the updated report is given in Dunn (2007). The report

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recommended that a general feasibility study analysis should include the following steps: travel forecast, market area analysis, parking demand analysis, travel demand analysis, roadway capacity analysis and mitigation of impacts.

The city of Macau Special Administrative Region, China is a famous tourist city with over 20 million visitors in a year. Since 1967, one of the annual attracting activities for tourists is the Macau Formula three Grand Prix (GP) motor-racing held every November. It is well known for its street racing circuit "*Guia Circuit*" in the city, which is located at the southeast region of the Macau peninsula enveloping some buildings, such as hotels and resorts, schools, offices, residential buildings, and ferry terminal. During the periods of the event, it requires traffic management and control measures, such as temporal closure of some roads and parking spaces, and therefore, access of vehicle traffic to and from the area is restricted. There are huge impacts to the level of service of the road network and inconvenience to the local residents. A transportation network analysis approach is proposed in this study to address this issue. This addresses the guidelines in Dunn (2007), which suggested that a study analysis requires the identification of background traffic flows and capacity constraints of the network.

In the analysis of transportation network, the flow pattern in an urban network can be viewed as a result of equilibrium between transportation demand and supply. Users of the system travel with a route selection to minimize their disutility (i.e. travel cost) associated with transportation. This disutility is not fixed but depends on the usage of the system, which is a result of the behavior of other users, such as route switching. Equilibrium analysis to this problem was proposed since the seminal works of Wardrop (1952) who investigated the nature and properties of equilibrium in models of congested networks. Extensions and solution algorithms for the traffic assignment problem were given by Sheffi (1985).

The travel demand matrix is an important input in the traffic assignment problem. Traditional method to collect the OD information can make use of survey or direct measurement to record the travel characteristics of individuals, which is generally difficult and costly. An alternative approach is to estimate the OD matrix by using the observed traffic counts on links (Van Zuylen and Willumsen, 1980). As a reverse problem of the traffic assignment, the OD matrix estimation problem aims to find a matrix that, when assigned to the network, reproduces the observations of link volumes. The OD matrix estimation models can be broadly divided into traffic modeling based approaches and statistical inference based approaches (Wong et al., 2005a). The former includes the minimum information/entropy maximizing models and combined models for traffic planning (Van Zuylen and Willumsen, 1980; Bell, 1983), and the latter includes the maximum likelihood method and generalized least squares method (Cascetta, 1984; Spiess, 1987; Bell, 1991; Lo et al., 1996; Yang et al., 1992). Most of these studies assume a single vehicle class and the link choice proportions are insensitive with the changes of the OD demand. For congested network, formulations of the OD matrix estimation problem have a bi-level structure (Yang, 1995), in which the upper level sub-problem is the OD estimation model, whereas the lower level sub-problem updates the link choice proportions by solving the traffic assignment problem. With the bi-level structure, it is possible to extend the estimation process for the road network with multiple vehicle classes (Wong et al., 2005a) and public transport networks (Wong et al., 2005b). In the traffic assignment problem with multiple vehicle classes, it generally processes multiple link flow solutions, and therefore, the internal inconsistency of traffic volumes among different vehicle class has to be detected by separating the estimation process for each mode (Wong et al., 2005a).

The objective of this study is to develop a methodology to estimate the OD demand matrices during a mass-event activity. The estimated OD matrices can be useful to assist the traffic planning in deriving various control measures and its evaluation of impact to the local network. A case study using the Macau Grand Prix motor racing is used to demonstrate the proposed methodology.

The paper is organized as follows. We first introduce the notations and model formulation of the OD estimation problem proposed in the paper. We then describe the solution algorithm to estimate the OD matrices for the case of normal day, and a two-stage procedure to obtain the OD demand matrices for the special event. Finally, a case study of the Macau GP event is presented with discussions.

2. Notations and definitions

Consider a network with a set of origin zones I and a set of destination zones J. Denote an origin–destination pair, $w = (i, j)$, as an ordered pair of origin zone i to destination zone j, and W is the set of OD zone pairs. Let M be the set of vehicle modes in the network with $M = \{c, mc\}$, where car (c) and motorcycle (mc) are considered in this study. Furthermore, let A be the set of links in the network, and $A' \in A$

Table 1 Notations and definitions of variables.

$i \in I$	Set of origin zones in the network
$j \in J$	Set of destination zones in the network
$a \in A$	Set of links in the network for normal day
$a \in \widehat{A}$	Set of links in the network for special event
$a \in A'$	Set of observed links in the network for normal day, with $A' \in A$
$a \in \widehat{A'}$	Set of observed links in the network for special event, with $\widehat{A'} \in \widehat{A}$
$m \in M$	Set of vehicle modes in the network, $M = \{c, mc\}$ with c for car and mc for motorcycle
$w \in W$	Set of origin–destination zone pair, and $w = (i, j)$ for an ordered pair of origin zone i to destination zone j
$\bar{q}_w^m$	Prior trip demand obtained from household survey for OD pair w and vehicle class m, with the set $\bar{\mathbf{q}}^m = \left(\bar{q}_w^m,\ \forall w \in W\right)$
q_w^m	Estimated trip demand for OD pair w and vehicle class m, with the set $\mathbf{q}^m = \left(q_w^m,\ \forall w \in W\right)$
$\bar{x}_a^m$	Observed link flows of link a for vehicle class m during normal day, with the set $\bar{\mathbf{x}}^m = \left(\bar{x}_a^m,\ \forall a \in A'\right)$
$\bar{\bar{x}}_a^m$	Observed link flows of link a for vehicle class m during the special event, with the set $\bar{\bar{\mathbf{x}}}^m = \left(\bar{\bar{x}}_a^m,\ \forall a \in \widehat{A'}\right)$
x_a^m	Modeled link flows of link a for vehicle class m, with the set $\mathbf{x}^m = \left(x_a^m,\ \forall a \in A\right)$
κ^m	Passenger car equivalence for vehicle class m, and it is assumed that $\kappa^{m=c} = 1.0$ and $\kappa^{m=mc} = 0.4$
p_{aw}^m	Link choice proportions that measures the ratio of trip demand of OD pair w for vehicle class m passing through link a, with the set $\mathbf{p}^m = \left(p_{aw}^m,\ \forall w \in W,\ a \in A\right)$