Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 7 (2015) 192 – 211

Transportation Research Procedia

www.elsevier.com/locate/procedia

21st International Symposium on Transportation and Traffic Theory, ISTTT21 2015, 5-7 August 2015, Kobe, Japan

Estimation of mean and covariance of stochastic multi-class OD demands from classified traffic counts

Hu Shao[a,b], William H. K. Lam[a,c,*], Agachai Sumalee[a,d], Martin L. Hazelton[e]

[a]*Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China*
[b]*Department of Mathematics, School of Sciences, China University of Mining and Technology, Xuzhou, Jiangsu, 221116, China*
[c]*School of Traffic and Transportation, Beijing Jiaotong University, Beijing 100044, China*
[d]*Department of Civil Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand.*
[e]*Institute of Fundamental Sciences, Massey University, Palmerston North 4442, New Zealand.*

Abstract

This paper proposes a new model to estimate the mean and covariance of stochastic multi-class (multiple vehicle classes) origin-destination (OD) demands from hourly classified traffic counts throughout the whole year. It is usually assumed in the conventional OD demand estimation models that the OD demand by vehicle class is deterministic. Little attention is given on the estimation of the statistical properties of stochastic OD demands as well as their covariance between different vehicle classes. Also, the interactions between different vehicle classes in OD demand are ignored such as the change of modes between private car and taxi during a particular hourly period over the year. To fill these two gaps, the mean and covariance matrix of stochastic multi-class OD demands for the same hourly period over the year are simultaneously estimated by a modified lasso (least absolute shrinkage and selection operator) method. The estimated covariance matrix of stochastic multi-class OD demands can be used to capture the statistical dependency of traffic demands between different vehicle classes. In this paper, the proposed model is formulated as a non-linear constrained optimization problem. An exterior penalty algorithm is adapted to solve the proposed model. Numerical examples are presented to illustrate the applications of the proposed model together with some insightful findings on the importance of covariance of OD demand between difference vehicle classes.

Selection and peer-review under responsibility of Kobe University

Keywords: OD demand estimation; multiple vehicle class; covariance matrix; classified traffic counts.

* Corresponding author. Tel.: +852-27666045; Fax: +852- 23659291.
E-mail address: william.lam@polyu.edu.hk

Selection and peer-review under responsibility of Kobe University
doi:10.1016/j.trpro.2015.06.011

1. Introduction

Origin-destination (OD) traffic demand is one of the fundamental input data for transportation planning and traffic management. In the past decades, OD demand estimation from traffic counts has been an important topic in the field of transportation research so as to minimize the cost for data collection. However, most of the existing OD demand estimation models ignore two important features of the OD demands as follows.

- The interactions between different vehicle classes (or types) in OD demand, such as taxis, private cars and goods vehicles.
- The statistical characteristics of multi-class OD demands, such as the covariance of traffic demands between different vehicle classes.

This paper proposes a new model for estimation of the mean and covariance of stochastic multi-class (i.e. multiple vehicle classes) OD demands from hourly classified traffic counts throughout the whole year.

1.1. Covariance of OD demands

Due to daily and seasonal variations in activity patterns, the OD traffic demands of different vehicle classes during the same hourly period (e.g. morning peak, 8:00 am - 9:00 am) are stochastically varied from day to day over the whole year. This type of varying traffic demands is referred to as stochastic multi-class OD demands in this paper. Statistically, the random characteristics of the stochastic multi-class OD demands can be reflected by their mean and covariance. In the conventional OD demand estimation models, focus is usually put on the mean of the OD demands while the covariances of OD demands by vehicle class have not been considered. The covariance of stochastic multi-class OD demands would however reflect the correlations between OD demands by vehicle class. For instance, for the traffic demand of the same OD pair, the higher the private car usage, the less the taxis usage.

It should be pointed out that there are generally three categories of OD demand covariances, i.e. the spatial, temporal and vehicle class covariances. Firstly, spatial OD demand covariance refers to the correlation (or dependency to some extent) of the OD demands during the same hourly periods between different OD pairs in a spatial manner (Shao et al., 2014). Secondly, temporal OD demand covariance represents the correlation of the OD demands for the same OD pair between different time periods (e.g. 8:00 am - 9:00 am and 9:00 am - 10:00 am). Thirdly, the vehicle class OD demand covariance relates to the statistical dependency of traffic demand between different vehicle classes of the same OD pair. These three categories of OD demand covariances simultaneously exist and contribute to the stochasticity of OD demand in reality. However, in order to facilitate the essential ideas on correlations between OD demands by vehicle class, this paper ignores first and second categories of the covariances. Specifically, this paper aims to estimate the third category of OD demand covariance using classified traffic counts for the same hourly period over the year.

In road transportation networks, the covariance of OD demands should not be ignored particularly for OD demand estimation from traffic counts. The ignorance of the correlation between random variables may lead to very different output of the models (Haas, 1999). For example, Waller et al. (2001) found that the correlation level of OD demands plays a major role in determining the degree of error in relation to the expected total network travel time. Zhao and Kockelman (2002) discussed the propagation of errors through the four-step traffic demand forecasting model. They stated that neglecting the correlation of data (e.g., OD demands) would ultimately reduce the reliability of the traffic forecasts, and in turn affect the policy-making and infrastructure decisions. Duthie et al. (2011) found that the assumption of independent demands when correlations do in fact exist could lead to errors in the estimation of system performance and result in poor policy decisions; for instance, building highways may not be able to meet a higher-than-expected demand. Shao et al. (2014) found that the spatial covariance has significant impact of network performance evaluation. In view of the above studies, it is shown that the correlation between OD demands should not be overlooked. This has a great effect on OD demand estimation problem particularly with the use of traffic counts.

The mean and covariance of the stochastic multi-class OD demands to be estimated in this paper can be used in the reliability-based traffic assignment models which have recently been developed for multi-modal transportation