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Original Research Paper

Path sets size, model specification, or model estimation: Which one matters most in predicting stochastic user equilibrium traffic flow?

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ABSTRACT

This study aims to make an objective comparative analysis between the relative significance of three crucial modelling aspects involved in the probabilistic analysis of transport networks. The first question to address is the extent to which the size of generated path sets can affect the prediction of the static flow in the path-based traffic assignment paradigm. The importance of this question arises from the fact that the need to generate a large quantity of paths may be perceived by analysts as a preventative reason as to the application of path-based stochastic traffic assignment (STA) models for large-scale networks. A simulated path generation algorithm, which allows the number of generated paths to be under modeller's control, is applied. Findings show that the size of the generated path sets does not substantially affect the flow prediction outcome in this case study.

Further investigations with respect to the relative importance of STA model estimation (or equivalently, parameter calibration) and model specification (or equivalently, error term formulation) are also conducted. A paired combinatorial logit (PCL) assignment model with an origin–destination-specific-parameter, along with a heuristic method of model estimation (calibration), is proposed. The proposed model cannot only accommodate the correlation between path utilities, but also accounts for the fact that travelling between different origin–destination (O–D) pairs can correspond to different levels of stochasticity and choice randomness. Results suggest that the estimation of the stochastic user equilibrium (SUE) models can affect the outcome of the flow prediction far more meaningfully than the complexity of the choice model (i.e., model specification).

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1. Introduction

Accurate evaluations of the performance of urban transport networks can remarkably affect the precision and effectiveness of the prescribed decisions in connection with implementation of supply or demand management policies such as optimal network design, road pricing or serving commuters by sources of information (Haghani et al., 2015; Sarvi and Kuwahara, 2008; Sarvi et al., 2004). There has been a great interest among transport researchers in developing and using advanced choice models to represent travellers' route choice behaviour and their reaction and adaptation to different changes in the system in a sufficient accuracy.

Modelling route choice behaviour, however, is one of the most challenging issues in travel demand analysis. The presence of a huge number of feasible alternative routes connecting each O–D pair in a typical transport network, as well as the fact that route characteristics, notably travel times, are dependent on user's behaviours and decisions, has made this one of the most challenging areas of transport engineering. In other words, not only the choice sets that decision makers considered are considerably ambiguous (and potentially large) to the modeller in a route choice setting, but also the attributes of alternatives are subject to alteration according to decision makers' decisions, and hence, they should be determined through solution of a large-scale equilibrium mathematical problem.

In recent years, there has been a growing recognition of the advantages of path-based stochastic traffic assignment (STA) methods. It has been established that explicit treatment of path-flow variables allows the adaptation of more advanced random-utility models in the analysis of transport networks to address different behavioural aspects of travellers' decision.

This research focuses on certain primary issues in route choice modelling, specifically choice set generation, model estimation and model (or almost equivalently, error term) specification. Accurately speaking, "model specification" conveys a more general meaning than "error term specification", as error term is part of a random-utility model. However, the authors have focused on univariate STA models, and the error-term specification primarily determines structure of the choice model. Hence, those two terminologies can be used interchangeably in this context without losing much precision. A considerable amount of research has formerly been conducted in the area, though they have mostly been concentrated on the specification of the random error components to accommodate the correlation among utilities of alternative routes. The two other issues have also been studied, but in a far more limited way and mostly independent of each other. This research intends to consider the aforesaid problems in an integrated framework from the perspective of flow prediction.

In addition, a heuristic and approximate estimation method of univariate STA models is proposed which alleviates challenges of traditional model estimation to a considerable degree and can also readily be extended to an O–D-specific-parameter approach. The performance of the proposed O–D-specific-parameter PCL model has also been examined and been compared with its single-parameter counterpart model. The following section is also aimed to further elucidating the structure and the main contributions of the study.

2. Background

Recently, there has been a growing interest in the development and implementation of path-based methods for road network or public transport traffic assignment (TA) (Hickman and Bernstein, 1997; Shahhoseini et al., 2015). Advances in the efficiency of computer analysis have allowed modellers to generate and store path-flow variables explicitly, despite past tendency towards the link-based approach of network loading. Now, most researchers generally concede that the explicit consideration of path-flow variables, as the actual alternatives of travellers would allow application of more advanced choice models with sounder theoretical underlying assumptions (Shahhoseini et al., 2015). The necessity for generation of choice sets by the analyst appears in both model estimation and TA phases, each of which has its own considerations. Having their own theoretical and computational challenges, both problems share a similar concern about how to produce manageable-sized and heterogeneous subsets from universal sets of alternatives which include the actual competitor paths mostly considered by travellers while excluding the irrelevant paths which are rarely considered by users.

Part of this study will investigate the influence of the size of generated path sets on the outcome of TA, which is the equilibrium link flow. Some previous researches have studied other factors in this context, such as the rate of convergence of the equilibrium algorithm (Bekhor et al., 2008). A version of a well-known simulated path generation method, which produces fixed sets of paths prior to the TA procedure, has been utilised to investigate the extent to which the size of generated sets can affect the prediction of equilibrium flow and the whether generation of very big choice sets is necessary. The significance of this issue stems from the fact that the computational expenditure of a path-based TA is highly reliant on the number of generated routes.

A probabilistic approach of network analysis has been originally developed to represent the uncertainties involved in modelling route choice behaviour including errors in perception, measurement and model specification. This class of models can potentially provide a more precise representation of behaviour through the more flexible modelling structure. Along with the developments in random choice modelling area, more advanced models than the simple multinomial logit (MNL) model found their way into the route choice analysis, primarily to address the problem of path-correlation. Advanced generalised extreme value (GEV) models, such as paired combinatorial logit (PCL) (Shahhoseini et al., 2015), practiced in this study and originally formulated by Chu (1989) and adapted by Prashker and Bekhor (1998) for TA, can represent the fact that due to the presence of common segments between routes, they cannot be assumed to be perceived by decision makers as totally independent alternatives.

According to the literature, univariate stochastic user equilibrium (SUE) models have mostly been run and practised