Behavioural Models for Route Choice of Passengers in Multimodal Public Transport Networks

The subject of this thesis is behavioural models for route choice of passengers in multimodal public transport networks. While research in sustainable transport has dedicated much attention toward the determinants of choice between car and sustainable travel options, it has devoted less attention toward the route choices of public transport users. Clearly, identifying relevant factors that affect route choice decisions could guide stakeholders (e.g., local governmental agencies and public transport agencies) toward effective improvement of public transport services in metropolitan areas in order to increase their attractiveness with respect to the car. Accordingly, this PhD thesis faces the multi-faceted challenge of modelling route choices of travellers moving in a metropolitan multimodal network. The analysis focuses on revealed preferences data collected for the multimodal network of the Greater Copenhagen Area and solves the multiple facets of the challenge concerning (i) data collection, (ii) data analysis, (iii) choice set generation, and (iv) model estimation. From the data perspective, this thesis overcomes limitations in the collection of actual route choices of public transport users. The literature shows a lot of effort in modelling route choices of car users, which has benefitted from increasingly accurate GPS devices to track vehicles and increasingly precise map-matching algorithms to translate the GPS points into routes on GIS networks. However, the literature shows scarce effort in the estimation of route choice models of public transport users based upon observed choices. Public transport route choice models have not benefitted from the same technological enhancements as car models because of the necessity (i) to collect additional information concerning lines and transfers, and (ii) to overcome technical limitations related to GPS signals not always being retrievable in tunnels that are used by metro and urban rail systems. In this PhD project, a questionnaire to collect details about the actual route choice behaviour in public transport networks was developed and tested in a full scale test. Afterwards the questions were added to the Danish Travel Behaviour Survey that collects daily travel diaries with a questionnaire covering activities and travel of a representative sample of the population. When the travel is by public transport modes, an additional section of the survey, with the new questions, collects detailed information about access modes, stations, lines, departure and arrival times, trip purposes, transfers, and egress modes. In order to analyse travellers' preferences in the multimodal network, about 6,000 observations from the Greater Copenhagen Area were collected and processed in this study. The characteristics of the collected data are analysed and the actual choices of the public transport passengers are revealed in the thesis. The data were map-matched to the GIS network of the area and quality controlled in a multi-step procedure. From the choice set generation perspective, this thesis generates attractive routes for the origin-destination pair of each traveller. The problem is not trivial when considering the combinatorial nature of the problem, the dense network of the Greater Copenhagen Area includes metro, trains (regional, suburban, urban and local), and buses (high-frequency, express and regular), and access and egress modes comprise both private (bicycle and car) and public transport modes. Accordingly, the universal realm of possible combinations (i.e., access modes, public transport modes, lines, transfers, egress modes) is large. This thesis proposes a doubly stochastic approach for generating alternative routes that are relevant to travellers, since the method allows accounting for both perceived costs of the network elements and heterogeneity in the preferences of travellers. The coverage of the observed choices with the generated choice sets provides a measure of the behavioural plausibility of the applied path generation technique. Notably, the definition of the coverage for public transport networks is different from the one for automobile users because of the increased dimensionality of the problem, as similarity in multimodal networks may be calculated at both the line level and the link level. The thesis describes testing of the choice set generation algorithm with regard to the number of routes generated as well as its ability to generate the observed routes. From the model estimation perspective, this thesis describes the estimation of route choice models able to account for similarities across alternatives. A simple approach is the formulation of a Path Size Logit in which the different definitions of similarity (i.e., at the line level and at the link level) are alternatively tested. A more elaborated approach is the formulation of a Mixed Path Size Logit. For both approaches, the utility function is specified in order to consider the multidimensional nature of the problem in terms of access/egress characteristics, waiting time, in-vehicle travel time, and transfer characteristics. Moreover, travellers' characteristics and trip purposes enrich the model and provide insight into the preference structures of different travellers with different motivations for travelling, and finally the study indicates that the actual length of the trip has an impact on the preferences of the travellers. The estimation confirms the expected importance of waiting and transfer times, shows different preferences for bus and train, emphasize the importance of the trip length, shows the effect of specific modes of access and egress, and indicates the relevance of individual characteristics within and across trip purposes. The results suggest the importance of coordination between different public transport modes, the relevance of transfer locations that allow seamless passage from one vehicle to another, and the significance of access and egress modes in terms of parking availability for both automobiles and bicycles. In this specific study, parameters not only allow assessing travellers' preferences that shed light on the necessary improvements in public transport networks for an even higher attractiveness of sustainable travel options, but also allow providing input to the public transport assignment model of the Danish National Transport Model. The contributions of the thesis are thus to demonstrate a new survey-based data collection technique that can reveal passengers route choices in large and complex multi-modal networks, how such data can be map-matched and choice sets be generated for model estimation, and the results of the estimation of a multimodal route choice model based upon this data. Finally, the thesis describes revealed preferences and behavioural interpretations of the study.