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# Travelers' preferences in multimodal networks: Design and results of a comprehensive series of choice experiments

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ABSTRACT

The modeling of individuals' choice behavior in integrated multimodal transport networks requires the estimation of preference parameters related to the trade-off between unimodal trips and multimodal combinations of private and public modes as well as relevant attributes of access, main and access stages of the trip. The stated choice method is a well-established method to estimate travel choice models empirically. However, including all relevant elements in a single experiment will not only result in choice tasks that are too complex for respondents but will also lead to choice-sets that include options that are not feasible for a given trip distance. To overcome this problem, this paper develops an approach that involves the use of a series of SP experiments to estimate a single comprehensive multimodal travel choice model. In total, four experiments are designed focusing on particular multimodal (including Park-and-Ride options) and public-transport choices for trips of varying distance. A representative national sample ($N = 2746$) of individuals from the Netherlands participated in the experiments through an online questionnaire. The data pooled across experiments are used to estimate the model in a scaled error-component-mixed multinomial logit framework. In this way, valuations of time, costs and service-quality attributes could be estimated on a relatively high level of detail concerning modes and trip stages. Comparisons with previous research indicate that the parameter estimates have reasonable values. The estimation results offer rich information on how travelers tradeoff between travel-time, travel-costs and service-quality attributes in travel choice in multimodal networks.



## 1. Introduction

Considering route choice of travelers in the broader context of a multimodal network is gaining interest in both the analysis of travel behavior and the development of traveler information systems (Rehrl et al., 2007; Zografos and Androutsopoulus, 2009; Yin and Griss, 2005; Zhang et al., 2012). Traditionally, route choice is considered within the confinements of a particular transport mode such as car (or another private vehicle), pedestrian mode or public transport (e.g., bus and train) and modeled as finding a shortest path within the network for the mode considered taking into account travelers' perceptions of time and costs. In contrast, the notion of a multimodal network is that in reality networks for different modalities are interconnected at places where travelers can transfer from one mode to another during a same trip. This requires integrated representations of transport networks which are also known as supernetworks (Sheffi, 1985; Carlier, 2003; Liao et al.,

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2011a). These extended networks are well-established in transportation research and provide a way to model multimodal trips by using ordinary shortest-path routines (Lozano and Storchi, 2001).

The integrated approach does not only allow one to consider mode and route choice in a more integrated fashion but is also becoming increasingly important from a policy perspective. A better integration of networks is generally seen as an important instrument to alleviate congestion and improve accessibility of locations without expanding the capacity of the networks which generally is very costly due to scarcity of space and high investment costs. In particular, development of so-called Park-and-Ride (P+R) facilities at the edge of city centers in combination with restrictive policies for parking inside city centers is considered a promising strategy to alleviate traffic congestion in inner city areas in many countries (Bos et al., 2004; Molin and Van Gelder, 2008). For travelers these developments mean a broadening of travel options. A new generation of mobile, personal information systems is ready to support these new options by providing assistance in the planning and implementation of multimodal trips (Zhang et al., 2012).

To model travel behavior as route choice in a multimodal network, one needs an extensive representation of valuations and preferences individuals have regarding attributes of route components. Travelers generally evaluate wait time and walk time, which are usually involved in public transport, differently from in-vehicle time (Hensher and Rose, 2007; Greene et al., 2006, Hoogendoorn-Lanser, 2005). Also, perceptions of travel costs may not be uniform. For instance, ticket costs for public transport, toll roads and parking tend to be more salient in perceptions than fuel costs (Wardman, 2001). Moreover, travelers generally have base preferences for particular transport modes and service-quality attributes based on considerations such as reliability, safety, health, convenience, comfort and image/status (Horeni et al., 2008). To model travel choice (as finding a least-costs path) in a multimodal network, all these time, costs and service-quality attributes need to be taken into consideration simultaneously (in link costs functions).

Empirical estimation of individuals' preferences in multimodal travel choice has received much attention in the literature. Stated-Preference (SP) and Revealed-Preference (RP) approaches or combinations of these approaches have been used (Hensher and Rose, 2007; Greene et al., 2006; Hensher and King, 2001; Espino et al., 2007; Cherchi and de Dios Ortuzar, 2002; Dell' Olio et al., 2011; Bos et al., 2007; Bovy and Hoogendoorn-Lanser, 2005). Wardman (2001) and Abrantes and Wardman (2011) describe the results of a meta-analysis of studies on time and service quality valuations of travelers in the British context. The large body of evidence accumulated over the years in this field provides insights into how travelers value different travel time components such as in-vehicle time, walk time, access time, wait time, search time and delay time in public and private transport contexts. These insights are valuable for assessing the effectiveness of transport and pricing policies aimed at promoting sustainable forms of travel behavior and for designing transport services that improve user satisfaction (Diana, 2012).

Despite the accumulated evidence, the picture emerging from the literature is fragmentary in the sense that a comprehensive analysis of costs, time and service-quality valuations in multimodal travel choice is lacking. Existing RP and SP studies have focused on certain aspects of the choice behavior to address a particular research question. They either considered public or private transport modes in isolation (Hensher and Rose, 2007; Cherchi and de Dios Ortuzar, 2002, Dell' Olio et al., 2011; Espino et al., 2007; Greene et al., 2006; Li et al., 2010; Hoogendoorn-Lanser et al., 2006) or, when combined with park-and-ride alternatives, reduced the level of detail in which public-transport mode alternatives are modeled (Hensher and King, 2001; Bos et al., 2004, 2007; Molin and Van Gelder, 2008). The goal of this study is to fill this gap. This study is a first attempt to model the full range of choice options in multimodal network settings on a high level of detail concerning the trip stages (access, main, egress), attributes (time, costs and service quality) and trip distances. Using the SP (or discrete choice experiments) approach we design a series of four choice experiments which together cover a representative range of travel options and considerations individuals face in multi-modal route choice situations. The experiments were administered through an online questionnaire and involved a nation-wide and representative sample of individuals from the Netherlands. We estimate preference parameters based on the pooled choice data across experiments in a scaled, error-component-mixed, multinomial logit framework. As the study considers travel choice in multimodal networks, the results shed light especially on how travelers tradeoff travel costs, travel time and inconveniences that influence their choice between using a private vehicle, public transport or multi-modal travel options for their trips.

In the sections that follow we describe the approach, design of the experiments, the model specification, the sample and results of model estimation. We conclude the paper by summarizing the major conclusions and discussing remaining problems for future research.

## 2. Approach

We are interested in short to medium-distance trips that individuals may make on a regular basis for their daily and non-daily non-work activities within a metropolitan region. For such trips individuals may consider non-motorized (e.g., bicycle) as well as motorized (e.g., car) vehicles, and public transport as well as private transport options or combinations of these (multi-modal trips).

Fig. 1 gives an overview of the attributes that we vary in the choice experiments in order to measure their impacts on utilities of travelers. On a main level we distinguish three possible modes for a trip: private-vehicle based, public transport (PT) and a combination of private and public transport (multimodal or, in short, MM). In our model, a trip by private vehicle – say a car trip – has a main stage of driving by car and an egress stage of parking the car and walking to the destination. A