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A behavioural comparison of route choice on metro networks: Time, transfers, crowding, topology and socio-demographics

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ABSTRACT

Understanding travellers' behaviour is key element in transportation planning. This article presents a route choice model for metro networks that considers different time components as well as variables related to the transferring experience, train crowding, network topology and socio-demographic characteristics. The route choice model is applied to the London Underground and Santiago Metro networks, to make a comparison of the decision making process of the users on both cities. As all the variables are statistically significant, it is possible to affirm that public transport users take into account a wide variety of elements when choosing routes. While in London the travellers prefer to spend time walking, in Santiago is preferable to spend time waiting. Santiago Metro users are more willing to travel in crowded trains than London Underground users. Both user groups have a similar dispreference to transfers after controlling for the time spent on transfer, but different attitudes to ascending and descending transfers. Topological factors presented on a distorted Metro map are more important than actual topology to passengers' route choice decisions.

1. Introduction

Understanding how public transport users make their travel decisions and being able to predict their behaviour is essential in transportation planning. The purpose of this study is to advance our understanding of the behaviour of public transport users when choosing a route in a Metro network and to quantify the impacts of the underlying explanatory variables that influence their decisions.

Route choice models have been explored and developed for private transport networks (Bovy and Stern, 1990; Ramming, 2001; Prato, 2009), but not much work has been done in public transport networks (Hunt, 1990; Bovy and Hoogendoorn-Lanser, 2005). The route choice variables normally included in traditional route choice models (either on private transport of public transport networks) limit to some basic service levels attributes of the alternative routes, such as travel time and fare (Ortúzar and Willumsen, 2011). However, other variables, related to both the level of service and the travellers' perceptions, influence the user's route choice process but are generally ignored in traditional modelling. This study presents a route choice analysis on Metro networks, incorporating variables related to the different times involved (travel, waiting and

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walking times), trains and stations usage, transfer environment, network topology and socio-demographic information from the travellers.

This study also conducts an empirical analysis to compare route choice decision making on the London Underground system and the Santiago Metro system, using the same modelling approach and specification. Even though behavioural comparisons can be made between studies found on the literature (mainly between results such as values of time and demand elasticities), these can generally be made based on models with different specification and context. One of the main objectives of this study is to develop a common framework to analyze and compare the preferences of travellers from both networks, and provide general transportation planning insights from the comparison.

The rest of the paper is organized as follows. In Section 2 we address the modelling approach and present the modelling variables considered. In Section 3 we present and discuss the route choice results for the London Underground and Santiago Metro networks. Finally, in Section 4 we present our main conclusions.

2. Route choice modelling

In this study we seek to identify and quantify the different aspects of travelling that are taken into account by public transport users from two cities (London and Santiago), particularly when choosing their travel routes. For this, it is essential to understand and model their decision making process, based on the different characteristics of the alternative routes.

2.1. Discrete choice models and correlation

We consider a random utility model, where it is assumed that each traveller q chooses a route i among a set $A(q)$ of available alternatives in order to obtain the maximum possible utility level U_{iq}. It is also assumed that the modeller, who is just an observer without perfect information regarding the decision making process, is only able to define a representative utility level V_{iq}. Thus, is necessary to associate an error term ε_{iq} to each alternative (McFadden, 1974), typically as shown in (2.1).

$$U_{iq} = V_{iq} + \varepsilon_{iq} \tag{2.1}$$

The representative utility level V_{iq} is a function of different attributes X_{ikq} related to the routes and the travellers (e.g. travel times, transfer characteristics and travellers' perceptions). Generally, V_{iq} is assumed to be a linear function of the attributes, as shown in (2.2), where θ_{ik} are parameters to be estimated.

$$V_{iq} = \sum_k \theta_{ik} \cdot X_{ikq} \tag{2.2}$$

To characterize the individual decisions, binary variables d_{iq} that take values according to (2.3) are also needed. These binary variables correspond to the actual decisions made by the travellers.

$$d_{iq} = \begin{cases} 1 & \text{if } U_{iq} \geqslant U_{jq}, \quad \forall j \in A(q) \\ 0 & \text{in other case} \end{cases} \tag{2.3}$$

If the random terms ε_{iq} are assumed to be i.i.d. Gumbel, a Multinomial Logit (MNL) model is obtained, from which is possible to obtain an analytical expression for the choice probabilities P_{iq}, given by (2.4).

$$P_{iq} = \frac{\exp(V_{iq})}{\sum_{j \in A(q)} \exp(V_{jq})} \tag{2.4}$$

One of the limitations of the MNL model is that it does not consider correlation between alternatives. This may be particularly serious when modelling route choices, as strong correlation between the alternative routes may arise due to overlapping. To address this issue, different models have been proposed. We consider a C-Logit model (Cascetta et al., 1996), which includes a "commonality factor" CF_i in the MNL utility function to capture correlation between alternatives, as shown in (2.5). The inclusion of the commonality factor helps in correcting the models' fit and predictions by lowering the probabilities of choosing similar alternatives.

$$P_{iq} = \frac{\exp(V_{iq} + \beta \cdot CF_i)}{\sum_{j \in A(q)} \exp(V_{jq} + \beta \cdot CF_j)} \tag{2.5}$$

β is a negative parameter that captures the travellers perception towards correlated alternatives (e.g. if β equals zero, all routes are considered independent; if β is large in magnitude, independent routes will tend to be chosen over correlated routes). The commonality factor CF_i can be defined in many ways. The specification used in this study is shown in (2.6), where l_a is the length of link a, L_i is the length of route i, and δ_{aj} is equal to 1 if link a belongs to route j or 0 otherwise. The proposed specification resulted in a slightly better goodness-of-fit than others mentioned in Prato (2009).

$$CF_i = \ln \sum_{a \in i} \left(\frac{l_a}{L_i} \cdot \sum_{j \in A(q)} \delta_{aj} \right) \tag{2.6}$$