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Transfer penalties in multimodal public transport networks

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ABSTRACT

The disutility of transfers in multimodal public transport goes beyond the additional walking and waiting times. Although the magnitude of this pure transfer penalty has been proven to be an essential element in the structural design of public transport lines, the scarce available research reveals a wide range of values. The aim of this paper is to develop and apply a framework to estimate the value perceived and assigned by commuters to this penalty. This framework includes all the other elements considered by users in the case of a trip involving (potential) transfers, in order to obtain the impact of each one. The framework is based on the discrete choices paradigm and applied to data collected in Madrid, Spain. The results show that the pure transfer penalty is comparable to a 15.2–17.7 equivalent increase in in-vehicle minutes; i.e. longer trips may be preferred to faster alternatives with transfers, even if the additional walking and waiting times are zero. As well as the pure transfer penalty, the model also captures the effects of habit, crowding, walking, waiting and in-vehicle times, information, and the additional effect of intermodality on transfers.

1. Introduction

Continuing a recent upward trend, in 2014, 46% of the population of OECD countries lived in urban areas (OECD, 2016), due to the environmental conditions, economic opportunities and the availability of services. The business, cultural, communication, mobility and everyday requirements of city residents will therefore continue to rise and affect urban travel demand. 64% of total trip-kilometres in 2014 were made in urban environments, and this figure is expected to triple by 2050 (Van Audenhove et al., 2014), resulting in higher emissions, traffic congestion, overloaded infrastructures, scarcity of parking places, higher public transport (PT) demand and urban sprawl, among others.

Transport networks in general and PT networks in particular must be optimised and well-designed to respond to increasingly complex travel patterns in urban areas. The attractiveness of the PT network compared to the car can be increased by reducing barriers to transfers (Nielsen and Lange, 2007). Unimodal and multi-modal PT networks generally involve transfers, points where PT lines intersect within the design of a PT network and where users have to –or choose to– move from one vehicle to another. Hub-and-spoke or feeder-trunk systems impose transfers on a subset of users while direct services do not (Fielbaum et al., 2016). Existing transfer points induce a sub-problem in the design of bus or tram stops and subway or train stations, as many PT users need to transfer

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between different modes to complete their daily trips (Jang, 2003; Hernandez et al., 2016). At a higher level, the design of PT networks requires the study of the spatial arrangement of PT lines to decide *a priori* if transfers are in fact optimal. A current priority in the field of urban mobility is to reduce users' perceived disutility while transferring in order to increase ridership (European Commission, 2013). We believe that the need to transfer itself should also be subjected to scrutiny.

The main aim of this paper is to develop and apply a framework to estimate the penalty perceived by commuters when making transfers in multimodal urban trips. The framework is designed to control for all other elements considered by the users when a trip involves (potential) transfers, to obtain the impact of each one (walking, waiting, in-vehicle time). The relevance of the number of transfers required on a trip is also examined based on the discrete choices paradigm, and applied to data collected in Madrid, Spain. The remainder of this section describes previous efforts to capture the perception of transfers in general.

Several authors have investigated the perception of transfers between different modes of transport and the importance of optimising transfer time for multimodal trips (e.g. Ceder et al., 2013a; or Guo and Wilson, 2011), while other studies have analysed the users' perceptions of transfers from different perspectives (e. g. Cheng and Tseng, 2016; Chowdhury et al., 2014; Guo, 2003; Horowitz and Zlosel, 1981; Navarrete and Ortuzar, 2013). The transfer disutility –known as the transfer penalty– has three different elements: waiting time, walking time from one vehicle to another, and the inconvenience of the transfer itself, which is also known as 'the pure transfer penalty'. Although most studies propose policy measures to reduce the disutility perceived by users when transferring, the third component is impossible to avoid.

Even in an ideal transfer in which walking and waiting times were equal to zero, users would perceive a pure transfer penalty related to factors like the availability of adequate information, safety, security, comfort and convenience, familiarity with the PT system, and frequency of PT use (Currie, 2005; Iseki and Taylor, 2009; Douglas and Jones, 2013). It should be noted that these studies address transfer penalties by focusing on only one transfer; perceptions can be assumed to be different for each transfer depending on its location and number in a complete journey. McCord et al. (2006) and Cheng (2010) stated that reliability issues, lack of information about connections and personal safety while transferring in PT services contributed to anxiety in PT users. The presence of an anxiety factor has recently been reinforced by the results of Cascajo et al. (2016) using focus groups, who found that individuals consider two elements when assessing a transfer within a trip: mental effort and activity disruption.

It is still not clear how far the pure transfer penalty affects the users' choice of different alternatives, some of which involve transfers. Gschwender et al. (2016) and Fielbaum et al. (2016) established that the consideration of a pure transfer penalty is a key element when designing the structure of PT lines in a city: *"Although several parameters play an important role, the value of the transfer penalty is particularly relevant. This makes the empirical study of transfer perception a key element in the immediate agenda of public transport design"* (Fielbaum et al., 2016, page 309). It is evident from such findings that transport planners should consider the value of the pure transfer penalty when designing a PT system, noting that some commuters even choose not to travel by PT if the trip involves a transfer.

The present study aims to achieve its objective by defining the following research questions:

- How does the pure transfer penalty influence users' choice of different alternatives involving transfers?
- How do PT users perceive each component of a transfer when making transfers in a multimodal urban trip?
- Are there significant differences in the perception of transfer penalties when making one and two transfers?

This paper is organised as follows. Section 2 shows the theory applied to model transfers in PT. Section 3 presents the case study, the modelling of utility functions, and the survey design and deployment. Section 4 describes the calibration of the Error Component Logit (ECL) model. Section 5 contains the analysis of the results, and finally Section 6 provides some recommendations for transport managers and the main conclusions of the study.

2. Modelling transfers in public transport

2.1. The analytical framework

The essence of our model lies in the formulation of a generic utility specification capable of representing alternatives that differ in (a) the number of transfers; (b) the modes used in each segment of the trip; (c) the characteristics of the transfer site; and (d) the trip conditions. For our purposes it is particularly relevant to capture what we call the pure transfer penalty, and the variable that does this is precisely the number of transfers. This pure effect is incorporated by defining constants associated to each transfer (if any), so it captures this effect for the first and second transfer, which not only allows us to find the values but to test whether the effect changes with quantity. It should be noted that it includes other factors that can influence choice, some of which are unknown to us; however, if they are present in all the alternatives, they will not affect the difference between constants, which can be interpreted as the relative perception of the pure transfer penalty. This approach assumes that the utility function is well suited to capturing the mental effort associated to an activity disruption (related to the pure transfer penalty) through constants. The generic utility specification is:

$$U(T_j) = \alpha_j + \sum_k \beta_{kj} x_{kj} \tag{1}$$

where $U(T_j)$ represents the utility associated to the number of transfers (j); (β) are the coefficients weighting the attributes (x) of the individual's alternative or choice situation in the (k) spectrum; and (α) is a constant which captures other factors unknown to us: the pure transfer penalty.