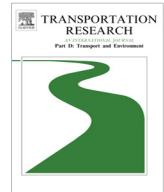




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Modelling the potential for cycling in access trips to bus, train and metro in Rio de Janeiro



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ABSTRACT

Most studies that address the integration of cycling and public transport (PT) focus on developed countries and deal with multi-modal bicycle-train trips. Little is known about the integration of cycling and other main modes such as bus and metro, especially in developing countries, where entirely different socio-economic and trip making conditions prevail. The aim of this study is to model the propensity of current PT users to shift to the bicycle in access trips to bus stops, train and metro stations in Rio de Janeiro, Brazil. Interviews were conducted to collect data on the socio-economic characteristics of the interviewee, trip and spatial characteristics and self-reported barriers and motivators for bicycle use. Two binary logit models were estimated to predict the main factors affecting the propensity to use a bicycle as feeder mode to PT. The results show that socio-economic characteristics as well as barriers and motivators are important factors to explain propensity for bike and ride. The barriers' model reveals that personal constraints, living too close to the PT boarding point, current parking conditions and public safety play a role. For the motivators' model, changing home location, owning a bicycle, implementation of cycle ways and improvement in parking conditions are explanatory. Policy recommendations are formulated to increase bicycle ownership and improve cycling infrastructure.

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1. Introduction: the access trip to public transport

The increasing concentration of people in urban areas has a great impact on the dynamics of cities, as people need to engage in all sorts of activities. Motorization levels have never been so high. This is also happening in developing countries with traditionally lower car ownership levels. For instance, the figures from Brazil show that the number of cars has doubled from 2001 to 2012 (Rodrigues, 2013), whereas in India it has been increased with 10–15% per year (Tiwari, 2002).

The highly motorized cities have a large negative impact on the quality of life of their residents. Congestion, noise and air pollution, time loss and energy consumption are some of the undesirable impacts of the increasing motorization levels. A shift from this individual and motorized paradigm to a more sustainable, active and collective perspective is urgent.

The use of public transport (PT) has been greatly acknowledged as a sustainable alternative (Diana and Mokhtarian, 2009; Grotenhuis et al., 2007; Hensher, 2007; Jiang et al., 2012; Kennedy, 2002; Krygsman et al., 2004; Murray et al., 1998). Public

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transport trips necessarily require an access leg from the origin to access the boarding point of the public transport (PT) system and an egress leg to access the destination. This access trip can be done by different modes, either motorized or non-motorized, private or public, and the more seamless and smooth this sequence of modes is, the more attractive the PT trip will be. Bicycle use when properly integrated with the public transport system is an efficient option as it combines the benefits of the non-motorized modes (NMT) with the strengths of PT.

The benefits of bicycle use as a mode of transport have been widely acknowledged (Advani and Tiwari, 2006; Martens, 2004, 2007; Ortúzar et al., 2000; Rietveld, 2000 b). Especially in short trips the bicycle is attractive, not only for its environmental performance but also for its intrinsic characteristics such as low cost and high speed (Rietveld, 2000a). Cycling is not only environmentally friendly, but also a healthy way of traveling, it demands less public space than alternative modes and - even more important for developing countries - it is a low-cost mode. Once the individual owns a bicycle, there are barely any costs involved in its maintenance (Advani and Tiwari, 2006).

Additionally, the bicycle is a door-to-door transport alternative, as it can make use of the same dense network used for motorized vehicles and pedestrians. Furthermore, it does not require waiting times as PT modes do, and it is, along with walking, an essential element in multimodal trips (Rietveld, 2001).

The use of non-motorized modes such as walking and cycling in access trips influences the way impedances in multimodal trips are perceived positively (Rietveld, 2000a). The average speed of cycling is three times faster than walking; consequently, bicycle use in access trips significantly increases the catchment area of a public transport service. From the users' perspective it means savings in travel time. Advani and Tiwari (2006) stress that the combination of bicycle and PT improves the travel potential for both modes, since it provides benefits that each mode alone is not able to provide, as PT cannot have the network penetration of cycling and the bicycle cannot be as fast as PT over longer distances.

Despite the potential of the bicycle as an access mode to PT, there is still a lot unknown about it. The role of NMT in transport systems is underestimated (Jones and Buckland, 2008; Quarshie, 2007) and there is a lack of information on trip and user characteristics and on the factors affecting such a trip (Martens, 2004). Some authors blame the lack of information about access trips on the fact that trips are usually reported based on the main mode (Martens, 2004; Rietveld 2000a).

Many of the studies about integration of bicycle and PT focus on the Dutch case, where bike and ride is extensively used (Keijer and Rietveld, 2000; Martens, 2007; Rietveld, 2000a, 2000 b). Studies in other countries (e.g. Latin America) are not common. The few that can be found are in Japan (Replogle, 1992), Sweden (Rystam, 1996), New Zealand (Ensor and Slason, 2011) and the USA (Hartwig, 2013). In addition Martens (2004) provides figures on bicycle use as a feeder mode to PT in three countries: Germany, UK and Denmark. Even though there are some self-contained studies in developing countries (Advani and Tiwari, 2006; Bechstein, 2010; Quarshie, 2007), there is still a lack of deep understanding on the potential for bicycle and PT integration, in particular on the integration of bicycle with other modes than train. Moreover, there is a lack of studies that incorporate behavioral factors such as attitudes, motives and preferences, when analyzing and modelling choice behavior (Puello and Geurs, 2015).

This paper aims to fill these gaps: first, by adding to the current body of literature a developing country perspective on the topic; second, by incorporating behavioral factors in the model (self-reported barriers and motivators) and third, by looking at bicycle potential in access trips not only for train stations, but also for metro stations and bus stops. The objective of this study is to model the main factors affecting the propensity of current PT users to use bicycle as an access mode to PT in two low-income areas of Rio de Janeiro. Socio-economic, transport and spatial characteristics as well as behavioral factors are analyzed. These factors are divided in *self-reported barriers* and *motivators* for bicycle use in access trips. Different sets of factors are entered in two binary logit models. The use of logit models has become more popular in travel behavior and mode choice analysis (Cherchi and Cirillo, 2010; Cherry and Cervero, 2007; Debrezion et al., 2009; Ewing et al., 2004; Kim et al., 2007; Larsen and El-Geneidy, 2011; Rodríguez and Joo, 2004; Smart, 2010). Discrete choice models to describe potential bicycle demand have also been reported (Bachand-Marleau et al., 2012; Nkurunziza et al., 2012; Ortúzar et al., 2000; Parkin et al., 2008).

2. Previous studies on bicycle use and behavior

Bicycle share in PT access trips varies significantly over cities/countries and also depends on the next main PT mode used in the trip (Table 1).

Bus and metro appear to attract fewer cyclists than train or express bus. Even when the bicycle is used to access the same transport service, such as regional trains, differences can be noticed across locations: the share in the UK is significantly lower than in The Netherlands or Sweden.

In Montreal, Canada, 43% of the public bicycle system users make a multimodal trip, from which 30% use it as access or egress to/from metro and 12% in similar way for bus (Bachand-Marleau et al., 2012). Unfortunately, figures on bicycle share in access trips for developing countries have not been found, except for the Indian case earlier mentioned.

According to Martens (2007), "(...) the barriers for changing travel behavior in access trips may be substantially lower than those that prevent overall mode change", indicating that it can be easier to tackle the feeder modes specifically. There is a large potential for cycling to substitute this part of the trip, especially in large cities, where the main mode usually covers long distances and the access trip tends to be relatively short. Trip makers can choose from different multimodal chains or

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