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Effect of integration of bicyclists and pedestrians with transit in New Delhi

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ABSTRACT

Traditionally, transportation mode shares in cities have been calculated separately for walking, bicycling and transit. However, it is well known that all transit trips have an access and egress component which is mostly executed through walking or bicycling. Hence, the choice of whether to choose transit for a particular trip depends as much on the walking or bicycling component of the trip as the transit component itself. A major source of inaccuracy in traditional mode share estimation models is the failure to identify this inherent dependence of transit trips on bicycling and walking. In New Delhi, where almost all access and egress trips for buses are made by bicycle/walking, the inaccuracies in mode share estimation could be more significant. This research aims to study behavioral effects of integrating bicycling and walking infrastructure with transit and provide predictions for outcomes of policy implementations modifying bicycle-to-transit or walk-to-transit environment in New Delhi. Four policy variables each are selected that affect pedestrian access to transit (sidewalk width, lighting, crossings and surrounding hygiene) and bicycle access to transit (bicycle lane, bicycle parking, bicycle sharing and on-board vehicle capacity) respectively. To gauge user behavior for hypothetical situations, stated preference survey data is collected through intercept surveys. 90 respondents were interviewed with upto 10 choice scenarios per individual with a total of 897 scenario responses (461 Pedestrian Infrastructure Scenarios +436 Bicycle Infrastructure Scenarios). Choice modelling is performed through a simple Multinomial Logit (MNL) model (in case there is no significant heterogeneity among individual preferences) and Random-Taste Mixed Logit model (to incorporate significant heterogeneity among various types of individual preferences). Modelling results showed that among pedestrian infrastructure, only presence of crossings could affect transit use and there is possibly significant heterogeneity in the population regarding use of sidewalks. Among bicycle infrastructure variables, presence of bicycle lanes and bicycle sharing is expected to positively impact transit use with no significant heterogeneity among the population. Finally, based on modelling results, three policy implementation scenarios are tested – presence of pedestrian crossings near all transit stops, introduction of bicycle lanes throughout the city and introduction of bicycle sharing system throughout the city. The scenario analysis shows possibility of considerable rise in transit mode share and GHG emission savings. This motivates further research to corroborate these findings with a larger sample, evaluation of viability of the ideas and possibly investigating implementation details.

1. Introduction

1.1. Urban transportation in India – need for integrating bicycling and walking with transit

Mode share for public transportation use in Indian cities far exceeds those in western countries like the US (Land Transport Authority (LTA), 2011). Due to mixed land use structure with substantial informal settlements (15–60% population living in slums), average trip lengths in Indian cities are short irrespective of the city size (Tiwari, 2011). The average trip length for all modes is around 2.5–5 km in small cities and around 4–7 km in large cities (Tiwari and Jain, 2008). A significant proportion of the population cannot afford private motorized transport (i.e. Cars, motorized two wheelers and motorized three wheelers) (Mohan and Tiwari, 2000). Non-motorized and public transport thus form the backbone for satisfying transportation needs in most Indian cities.

However, public transport in India, like most developing countries, faces several key challenges (Vasconcellos, 2001). The first major challenge is finance. Due to low per-capita income in India as compared to North American or European countries, India has been forced to keep its public transport fares extremely low. This has limited

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operating revenues, which in turn affects maintenance, modernization and expansion (Pucher et al., 2004). Therefore, a cheaper alternative for expansion of public transport is its integration with non-motorized modes like bicycling and walking. Another major concern is the extremely high transportation demand due to population growth. The current population in India is around 1.25 billion and it is growing at a rate of 1.2% every year (Census of India, 2011). The growth in public transport has not been able to keep up with the growth in transportation demand. A worrying trend observed is the shift in mode shares from public to private motorized transport (Tiwari, 2003; Sundar, 2014). The mode share of private motorized transport (cars, motorcycles and motorized three wheelers) in New Delhi increased from 27.5% in 2001 to 35.4% in 2007 whereas public transport (Bus and Metro) decreased from 59.8% to 45.6% (RITES Report, 2008) even though this was the period when the Delhi Metro was first introduced. This has led to extreme congestion in streets. Slow-moving inefficient traffic has also led to adverse pollution effects. In the period from 2000 to 2010 in New Delhi, CO emissions from transportation have increased by 77% from 193 Gg to 342 Gg, NOx emissions from transportation have increased by 24% from 68 Gg to 84 Gg and PM10 concentration due to transportation has increased by 24% from 8.2 Gg to 10.2 Gg (Sindhwani, 2014). An integrated combination of non-motorized modes (like bicycling and walking) with public transportation modes (like buses and metros) can act as a competing mode for private motorized transportation, while significantly reducing greenhouse gas emissions. However, currently pedestrian and bicycle infrastructure is not properly integrated with public transport. Even the transport master plan for 2021 only talks about adding feeder services and not integrating pedestrian and bicycle facilities with public transit. Hence, the hypothesis is that improper integration of pedestrian and bicycle infrastructure with transit has a significant role in this decrease in mode share.

1.2. Bicycle and pedestrian access to transit infrastructure

Previous studies have indicated that comprehensive bicycle and pedestrian infrastructure integrating transit stations not only encourages bicycle and pedestrian use to access transit, but also increases the utility of all three modes (Pucher and Buehler, 2009; Brons et al., 2009; Givoni and Rietveld, 2007; Hegger, 2007; Martens, 2004, 2007; Schneider, 2005; US DOT, 1998). Increased transit accessibility makes it easier for pedestrians and cyclists to take advantage of transit to increase their trip length, overcome gaps in the bicycle and pedestrian network, and overcome difficulties in the physical environment, such as topography. Integrated transit and bicycle and pedestrian infrastructure may also make transit a more competitive mode to the private motorized automobile (Pucher and Buehler, 2009).

Indian cities currently don't accommodate any bicycle to transit infrastructure like bicycle lanes, bicycle sharing systems or on-board bicycle facility in transit. Advani and Tiwari (2006) found that greater public transportation access and egress time is a major deterrent to transit ridership and suggest bicycle-transit integration as a possible solution. They concluded that bicycle-on-transit service enables bicyclists to travel farther distances and overcome topographical barriers. Tiwari (2002) suggests converting under-utilized service roads to bicycle lanes. Rastogi and Krishna Rao (2003) found that transit access distance affects low income households more severely than high income household. They found that walk mode dominates access/egress trips and suggested better pedestrian to transit infrastructure like safe, protected, and sheltered sidewalks, direct connectivity along pedestrian desire lines, etc. However, these studies still lack quantitative estimates of the mode share prediction when these policies are introduced.

1.3. Stated preference survey and mixed logit models

Stated preference data has been commonly used to develop mode choice models to evaluate policy implementations like clean-fuel vehicles (Bunch et al., 1993), Advanced Traffic Information System (ATIS) (Abdel-Aty et al., 1997), adoption of telecommunication (Bernardino et al., 1993), etc. A stated preference approach has also been preferred to study the effect of bicycle to transit integration. Taylor and Mahmassani (1996) used a stated preference approach to build a nested logit model to measure the effect of three bicycle-to-transit integration parameters: bicycle parking, bicycle access distance, and on-street bicycle facilities. In an Indian context, Rastogi and Krishna Rao (2003) used revealed and stated preference data to study socio-economic factors influencing access to transit.

Mixed logit models with random taste parameters allow incorporation of heterogeneity among various groups in a population which is especially useful for modelling travel behaviors (Ben-Akiva et al., 1993). This concept was used by Bhat (1998) to accommodate variations in responsiveness to level-of-service measures due to both observed and unobserved individual characteristics in travel mode choice. Random parameter models have also been developed to evaluate willingness-to-pay (WTP) with respect to attributes of bus transport in India (Phanikumar and Maitra, 2006). This paper evaluates both simple Multinomial Logit (MNL) and Mixed Logit models to quantify the effects of integrating bicycling and walking to transit. Then, these models are utilized to quantitatively predict mode share estimates in case several of these policies are implemented in the city of New Delhi.

1.4. Inaccuracies in current mode share estimation

Mode share estimation constitutes a key component of transportation planning and travel demand modelling. Transportation by transit not just includes the characteristics of the transit portion of an individual's trip, but the access trip from an individual's origin to the transit station and the egress trip from the transit station to the final destination are also important components. In this context, traditional mode share estimation procedures are insufficient in their sensitivity to this interdependence among modes. When trips are multimodal, such as those that use transit, standard models tend to fail to detect the overall effect of other modes by which passenger's access, egress, and transfer to and from a transit system (Brands et al., 2014). The rigid separation between modes in traditional models (Ortuzer and Willumsen, 2001) follows the assumption of *independence of irrelevant alternatives* (McFadden et al., 1977) between transit and the access/egress components of a trip. A much more realistic scenario is to model the mode choice for an entire trip based on factors which affect each component of that trip.

In India, nearly 90% of all transit trips are made through bus (Pucher et al., 2004). In New Delhi, nearly 100% of trips to and from buses and 78% of trips to and from metro are carried out by foot (DIMTS Report, 2010). However, traditional mode share estimates for bus trips in Indian cities does not include the non-motorized portion of transit trips (Tiwari (2003); Land Transport Authority (LTA) (2011); EMBARQ, 2014; Sundar (2014)). Since the proportion of trips by bus in India is high as compared to most western countries, these inaccuracies are more significant during overall mode share estimation. A possible solution for reducing inaccuracies is to categorize transit trips by access and egress modes. In this study, the access and egress modes are classified as non-motorized (bicycling or walking) and motorized (car, auto-rickshaw, taxi or feeder bus). Therefore, we propose a model wherein we classify mode choices as: (1) Only choosing a motorized vehicle, (2) Choosing a non-motorized mode to transit and (3) Choosing a motorized mode to transit.