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Analysis of bicycle route-related improvement strategies for two Indian cities using a stated preference survey

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ABSTRACT

Bicycle travel needs to be made more attractive in cities of developing countries such as India. Evaluation of bicycle route related improvement strategies becomes necessary to devise suitable policies for such upgradation. In this study, a set of key route related attributes such as *Level of risk*, *Route visibility*, *Road width*, *Bicycle operating cost* and *Bicycle journey time* are used to design a stated preference survey to collect relevant data from users. Based on the collected data, appropriate route choice models such as Multinomial Logit (MNL) and Random-Parameter Logit (RPL) models are formulated. Subsequently, for evaluation of improvement strategies, a set of alternative bicycle routes are generated and compared with the base route. The alternatives are evaluated in terms of shift in bicyclist's probability to choose alternatives with better infrastructure and savings in generalized cost of travel per km compared to the base scenario. To demonstrate the methodology, Kharagpur and Asansol, two small and medium-sized Indian cities with varying urban and transport characteristics are selected. Results suggest that *Level of risk* is perceived as the most important attribute influencing bicyclist's route choice followed by *Route visibility*, *Bicycle journey time* and *Road width*. Overall, alternatives with improved infrastructural characteristics are observed to be associated with significant increase in probability and substantial Generalized Cost (GC) savings compared to the base alternative for both regular and irregular bicyclists.

1. Background

Developing countries such as India have been experiencing rapid urbanization and motorization in recent times. Urban population in India has increased significantly from 62 million in 1951 to 285 million in 2001 and is estimated to be around 540 million by the year 2021 which has led to a huge demand for transportation in Indian cities. Modernization of transportation infrastructure in general, and of public transport and Non-Motorized Transport (NMT) in particular, however, did not take place at the same pace. As a result, the urban poor have been affected most significantly. Bicycle is one of the most affordable and flexible means of transportation in developing countries such as India. For low-income households, bicycle is often the only affordable means of transportation (TERI, 2014). Bicycle allows low-income households or slum dwellers to access their workplaces and make social or recreational trips in an efficient and affordable manner. In this regard, previous studies also reveal that majority of the bicyclists in Indian cities are captive in nature who cannot afford other means of transport (Tiwari and Jain, 2013). Anand et al. (2006) reported a clear preference for bicycling among slum dwellers and low-income working class whose livelihoods are dependent upon frequent mobility such as home-based services, newspaper and courier delivery etc. However, besides the urban poor, a section of urban choice users also opt for bicycle for short distance commutes, health or recreational reasons or for shopping trips. This is particularly true for small and medium-sized Indian cities, where the average trip-length for bicycles varies from 1.9 to 3.1 km for small-sized cities and 3.1–5.4 km for medium sized and other cities (Tiwari and Jain, 2013), which is favorable for bicycling.

Despite being an important mode of transportation with favorable trip length, a sharp decline in bicycle mode share is being observed in Indian cities; even short distance bicycle trips are being replaced by motorized vehicles. Confirming the phenomenon, in their analysis of past, present and future bicycle mode share in Indian cities, Wilbur Smith Associates (2008) forecasted a comparatively steeper decline in bicycle share for small sized cities compared to major cities (Table 1). Besides this, bicycle ownership per household is also decreasing in Indian cities (TERI, 2014). The study finds that share of households owning a bicycle has dropped from 46% in 2001 to 42% in 2011.

In a recent study, TERI (2014) has suggested that the potential bicyclists are not choosing to bicycle mainly due to inadequate bicycle

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Table 1
Estimated NMT Share for the selected City Categories for future (%).

City Type	Population	2007	2011	2021	2031
Category-1-a	<500 thousand with plain terrain	38	36	31	26
Category-1-b	<500 thousand with hilly terrain	58	56	48	40
Category-2	500-1000 thousand	53	50	43	36
Category-3	1000-2000thousand	44	43	38	34
Category-4	2000-4000thousand	43	42	41	40
Category-5	4000-8000 thousand	36	35	34	34
Category-6	>8000 thousand	30	30	29	28

Source: Wilbur Smith Associates (2008).

infrastructure and unsafe bicycling conditions. In this regard, Mohan et al. (2015) has reported that bicycle fatalities account for about 6% of the total road traffic injury-related fatalities in India. However, as bicycle-related accidents are often under-reported, the actual figure could be much higher. Citing the 2009 Ministry of Road Transport and Highways (MoRTH, Government of India) report on road traffic accidents, TERI (2014) notes that bicyclist deaths due to road accidents have risen from 5443 in 2009–6600 in 2012.

In this context, dedicated bicycle infrastructure could be instrumental in improving bicycling safety. Though a number of Indian cities have dedicated bicycle infrastructure, such facilities could not serve their intended purpose due to improper planning and implementation. While cities such as Ahmedabad and Delhi have provided dedicated bicycle tracks along the BRTS corridor, the majority of such tracks are under-utilised due to poor pavement condition, encroachment, on-street parking and intrusion by motorized vehicles (TERI, 2014). While some infrastructure improvements for bicycles were taken up in metropolitan cities, virtually none is seen in medium and small sized cities. It is therefore essential that suitable policies be devised for planning and design of bicycle facilities by incorporating the needs of various user groups in small and medium-sized Indian cities. To formulate such policies and make recommendations for bicycle infrastructure related improvements, it is necessary to obtain user preference on various bicycle route-related improvement scenarios and evaluate them in terms of associated user benefit. User benefit is influenced by individual trip related characteristics such as frequency of bicycle use. For better planning implications, effects of such characteristics should also be appropriately incorporated in user benefit estimation and subsequent evaluation.

As mentioned by Phanikumar (2011), user benefit in terms of transport related improvement can be perceived as a decrease in the disutility of travel. The disutility of travel can be estimated with respect to attributes pertaining to a particular service. Subsequently, several alternatives for improvements can be evaluated with respect to reduction in disutility. Generally, such attributes have dissimilar measuring units and as such need to be transformed into a common unit for comparison. In transport related applications, when a monetary attribute is present, the disutility associated with all other non-cost attributes can be expressed in terms of Willingness-to-Pay (WTP) value. Aggregation of WTP values associated with a set of route related attributes describing an alternative is termed as Generalized Cost (GC). GC can be used as a measure to evaluate the alternatives. User benefit analysis, therefore, involves valuation of the related attributes and simultaneous estimation of the associated WTP. Travel behavior models developed by analysing stated choice data are extensively used for the valuation of attributes (Phanikumar, 2011; Hunt and Abraham, 2007; Hopkinson and Wardman, 1996). With this background, this study conducts a detailed investigation on bicycle route related improvement strategies through explicit incorporation of user benefit. A review of the existing literature on the topic and the specific scope for this study are presented in the next section.

2. Literature review and scope of the research

There is an extensive body of literature on the investigation of the influence of various route specific attributes on users' choice decisions. The studies are based broadly on two types of surveys: a) revealed-preference (RP) survey and b) stated-preference (SP) survey. Revealed Preference studies correlate actual route choice behavior with existing bicycle facilities (Dill and Gliebe, 2008). Among such bicycle route-related RP studies, Shafizadeh and Niemeier (1997) explored the association between socio-demographic variables and spatial-clustering of commuting trip-makers and their commuting journey time. In a related study, Rodriguez and Joo (2004) examined the relationship between travel mode choice and attributes of the local physical environment such as topography, sidewalk availability, residential density, and the presence of walking and cycling paths. Their results found that local topography and sidewalk availability are significantly associated with the attractiveness of NMT modes. They reported that buffering from street traffic, aesthetics, and safety may contribute to the attractiveness of bicycling on a bicycle path. In their study, Dill and Voros (2007) investigated the influence of a set of factors affecting bicycle demand in Portland, Oregon region of USA. They collected Revealed Preference data from users on their existing travel behavior and found that a positive perception of the availability of bicycle lanes and higher levels of street connectivity are associated with increased desire to bicycle. In another Revealed Preference based study, Moudon et al. (2005) collected RP data on bicycling behavior for 608 randomly selected users in King County, Washington, USA. They also collected objective level land use and infrastructure conditions related data and developed Binary Logit models to understand the effects of those environmental determinants on bicycling levels. They concluded that factors such as proximity-to-trails and the presence of offices, clinics/hospitals, and fast-food restaurants influence bicyclists' route choice. Hood et al. (2011) collected GPS data of cyclists' routes and subsequently developed a GPS-based bicycle route choice model for San Francisco, California.

Studies based on a SP survey, on the other hand, present the respondent with two or more options. The SP approach permits researchers to evaluate hypothetical or non-existent options. Since there are virtually no bicycle facilities in the case study cities, investigation of bicycle infrastructure by providing hypothetical options is thought to be a better strategy. SP data help researchers get an idea of user perceptions on various bicycle infrastructure specific factors (both existing and hypothetical). RP data refers to a situation where a choice is made in real or present market scenario, whereas, SP data refers to a situation where a choice refers to a hypothetical situation. Though both SP and RP studies are conducted with similar alternatives, SP dataset is generally defined by "different levels of the same attributes observed in the actual market as well as additional attributes not in the data collected from the actual market" (Hensher et al., 2005). SP data are useful when a combination of existing and new alternatives is used. Morikawa (1989) have pointed out some of the advantages of SP data over RP data. Firstly, SP surveys allow inclusion of qualitative factors as well as pre-specification of choice sets. Secondly, multi-colinearity among factors can be avoided and thirdly, SP surveys are able to elicit preferences for new (non-existing) choices. However, RP data have higher face validity than SP data because revealed preference information reflects actual market behavior. In stated preference surveys, respondents provide their responses based on a hypothetical or stated situation, and there is a possibility that their provided preference could be inconsistent with their actual behavior (Sanko, 2001). However, models based on SP surveys are well established and are considered appropriate for evaluation of bicycle infrastructure related attributes in monetary terms (Hopkinson and Wardman, 1996; Poorfakhraei and Rowangould, 2015). SP survey is therefore adopted for collection of user perception data and travel behavior analysis in this study. Some of the previous SP survey based studies investigating the effects of bicycle infrastructure related attributes are discussed in the following section.