DEVELOPMENT OF A BICYCLE DEMAND ESTIMATION MODEL INCORPORATING LAND USE SENSITIVE PARAMETERS:
CASE OF PUNE CITY, INDIA

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Certificate

This is to certify that the thesis titled "**Development of a bicycle demand estimation model incorporating land use sensitive parameters: Case of Pune city, India**" being submitted by Ms. Himani Jain to the Indian Institute of Technology, Delhi for the award of the degree of Doctor of Philosophy is a record of the bonafide research work carried out by her under my supervision and guidance. The thesis work, in my opinion, has reached the requisite standard fulfilling the requirements for the degree of Doctor of Philosophy. The results contained in this thesis have not been submitted in part or in full, to any other university or institute for the award of any degree or diploma.

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Abstract

Generally, the inherent dense, mixed urban fabric with narrow lanes and compact structure are being fast forgotten in Indian cities, and the personal automobile-oriented planning is rampant. Hence the current travel modal shares favouring walking, cycling, and informal non-motorized transport commerce are fast changing to motorized two-wheelers, cars. However, in the past decade, cities in many other countries especially in Europe, have started to give priority to the integrated approach to urban planning in order to improve the overall quality of life. The focus in transportation planning has been shifting from car friendly planning to transit development and to the development of compact cities that are conducive to walking and cycling.

The benefits of improving transport infrastructure have traditionally been measured by criteria such as minimizing travel time, and delays while maximizing speed of motorized vehicles. The costs of improvements in transport infrastructure are classically defined as construction cost, ongoing operations and maintenance cost. These criteria usually form the basis of the cost-benefit analyses, which judge the feasibility of these projects. However, owing to new research and understanding during the last decade, more importance is now being given to improvements in air quality, health and environment benefits, and to safety, security and social cohesion.

As transport is a derived demand, that is, derived from the need for movement, the use of transport infrastructure is dictated by socio-economic requirements of the users. In cities in the developing world, a heterogeneous mix of users, of different socio-economic classes with varying needs and ability to afford exists, giving rise to varied transport modes and indigenous solutions.

For long, car-centric demand modelling has supported planning and construction of grade separated junctions, and of signal free expressways to ensure high speeds. However,

the demand modelling has not evolved enough to integrate walking and cycling (as personal mobility options), or cycle-rickshaws (as para-transit), hawkers/vendors (as commercial modes) and cycle-rickshaw-trolleys (as intra-city freight carriers).

The objective of this dissertation is to integrate critical parameters influencing bicycling, including land use and street environment aspects, to arrive at a robust and contextual travel demand modelling framework. The growing literature and worldwide experiments indicate that bicycle compatibility is a useful approach for planning bicycle infrastructure. The limited research and efforts in this regard in South Asian cities prompted this research with an aim to address specific aspects of the bicycle travel mode choice model.

A comprehensive review of literature, especially in the South Asian context, suggests several unique aspects, such as captivity (dependence on a travel mode due to certain constraints), various markets segments (groups of users), existing barriers on roads, and the presence of other non-motorized modes and informal commerce. This study is based on two reasonably large surveys. The first survey dealt with socio-economic status, travel behaviour, perceptions and choices of 1400 individuals. The second survey covered 1300 streets for an inventory of the status of road infrastructure and its surrounding environment.

The dataset provided a baseline for employing stated preference methodology for estimation of preferences and weights related to key parameters influencing the use of bicycle for travel. The survey also provided an opportunity for creating a future bicycle-friendly scenario and estimates for modal shifts to the bicycle. While the street inventory helped in correlating and validating perceptions of bicycle users, it also helped in creating a status update of street space, operations, barriers, and intersections for the Level-of-Service (LOS) coding.

The correlation between perceptions/choices and routes illustrates that physical safety on streets and fear of being hit by another vehicle, insecurity due to antisocial elements and

thefts play an important role in bicyclist's route choice. Subsequently, beyond economic constraints, a modal shift to the bicycle is strongly influenced by street safety perceptions, bicycle-friendly infrastructure and the comparative priority or incentives given to bicycles.

The results of the route-choice study clearly show differences in the weights attached to the key parameters influencing route choice by different user groups. For example, the captive bicyclists prefer the presence of the informal sector and perceive street-side parking as a barrier. Potential riders, on the other hand, attach high weights to pavement quality and road width, and consider the presence of the informal sector and slope as key barriers. The revealed preference survey data was aggregated into clusters using the Principal Component Analysis (PCA) to effectively manage datasets, and remove collinearity in variables. The route choice preferences of captive cyclists in stated preference survey were compared with the revealed preference data. The summary is presented in the following table:

No.	Parameter	Stated Preference Result	Validation by Revealed Preference	Notes
1	High landuse mix % (in residential)	+	yes	Mixed use areas and streets are preferred as routes
2	High formal residential density	-	no	Denser mixed use streets are used for commute – probably higher formal residential densities often are not origin and destination of current captive cyclists
3	Informal sector commerce and services presence	++	yes	Liked and highly used
4	Slope	-	no	Sloped streets are used for commute – probably as most sloped streets offer shortest routes between important Origins and Destinations
5	Large road width of carriageway	+	yes	Perceived to be safe and highly used
6	High pavement quality	+	yes	Comfortable and highly used
7	Many pedestrians as barriers	+ -	yes	Not as barrier but as social security and little problem in manoeuvring
8	More parking	-	yes	High negative weightage attached
Notes: + liked by cyclists ; ++ very much liked; - Not liked by cyclists; +- neutral / no strong feelings				

The estimation of weights from stated preference survey helped in the development of Area Bicycle Compatibility (ABC) score estimation of the surveyed streets which was categorically extrapolated to all the streets in the case city of Pune. Three strategies were tested for specific impedance (shortest travel time, best ABC score and combination of ABC score and shortest path –called as safer-shorter path) based bicycle traffic assignment in case study. The inverse ABC score was used as the impedance measure for these streets. These estimations are validated with a different dataset of bicycle volume count on 80 streets. The closest results to directional flow, trip length frequency distribution and traffic volume are identified in safer-shorter path approach (combination of ABC score and shortest path). The results of the traffic assignment study suggest that there is a strong impact of people's perceptions and choices on the routes chosen, and that the street environment does play an important role in the route choice for bicycling. Though the shortest distance still remains a critical aspect to influence the route choice, safety and security aspects also emerge as equally important concerns.

The results of the modal-shifts study lead to the conclusion that 45% of bus commuters, 35% of motorized two-wheeler riders and 14% of car users, travelling short distance (< 5 kilometres), will shift to bicycle if bicycle-friendly infrastructure is created. Safety is assigned high weights by both high-income (car users) and low-income (bus users) groups. Safety and comfort are, in fact, given much more importance than travel time by motorcyclists and car users.

The study developed a traffic assignment framework to assess the impact of preferences of routes and mode choice to generate an understanding for bicycle network planning in the Indian context. The major contributions of this research are:

- The study clearly identifies the predominant Indian market segments for bicycling. The primary survey provides insights into the understanding of socio-economic and

demographic status, and the travel patterns and choices of the current captive users and of a large segment of potential users.

- This study evaluates the perceptions of captive and potential users of bicycles regarding different aspects of route attributes, and the interventions that can be planned in order to promote bicycling.
- The study explores the relationships of land use and risk perceptions of the current and potential bicycle users for evaluating their safety and comfort aspects and for estimating the bicycle use.
- The study develops a robust algorithm of bicycle traffic assignment modelling through the use of Area Bicycle Compatibility (ABC) score application and develops framework for modal-shifts to bicycle.
- The research insights will be useful in planning for bicycle as the mode of choice and its promotion. The study develops guidelines for bicycle-friendly land use strategies for neighbourhoods, and for bicycle-compatibility benchmarking for areas or facilities.

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