



## Ph.D. Scholars

Current

### Naturalistic driving behaviour study

Scholar: Abhaya Jha

### Study of the effect of geometric design features on capacity of hill roads

Scholar: Achyut Das

### Multi objective optimization in construction project management

Scholar: Amit Chandra

### Urban landuse and transport modeling

Scholar: Amit Sharma

### Accident reconstruction based study on motorcycle crashes

Scholar: Amrit Lal

### Design and optimization of air ventilation system for improved heat transfer characteristics in helmet

Scholar: Bhagwat Singh Shishodia

### Methodology for low carbon mobility plan for indian cities

Scholar: Deepty Jain

### Safety issues in project management

Scholar: Dilip A Patel

### Modelling and risk assessment of heterogeneous traffic

Scholar: Gaurav Pandey

### Methodology for design of vehicle front of an urban car for safety of vulnerable road users

Scholar: Hariharan S

### Development of a bicycle demand estimation model incorporating land use sensitive parameters: Case of Pune city, India

Scholar: Himani Jain

### Establishing relationship between elements of highway engineering on crashes on national highways in India

Scholar: H.M. Naqvi

### Issues in human body FE modelling

Scholar: Kanhaiya Lal Mishra

### Human body model (thorax modelling and its validation)

Scholar: Khyati Verma

### Transport needs for disabled people

Scholar: Krishnakant Kushwah

### Statistical modelling to estimate pedestrians' risk and risk taking behaviour on urban crosswalks

Scholar: Mariya Khatoon

### Characterisation of long bones bending under impact

Scholar: Mike Winifred Jimbry Arun

### Road safety risk assessments of modern toll plazas and standardization of its geometric design

Scholar: Navdeep Kumar Asija

### Estimating traffic crash risk to different road users in urban areas and its impact on mode choice: case study Vadodara city, India

Scholar: Pankaj Prajapati

### Thorax model building and validation – diaphragm and aorta

Scholar: Piyush Gaur

### Estimation of externalities in public transport system

Scholar: Pradeep Singh Kharola

### Pavement materials

Scholar: Priyansh Singh

### Finite element human body modelling direction

Scholar: P Devendra Kumar

### Effect of traffic characteristics on vehicle emissions

Scholar: P.V. Pradeep Kumar

## Ph.D. Scholars

Continued

### Human body finite element modelling

Scholar: Rajesh Kumar

### Measuring public health effects of urban transportation in Delhi

Scholar: Rahul Goel

### Mode choice initiators in public transport demand modelling

Scholar: Sandeep Gandhi

### Finite element human body modelling direction

Scholar: Sanyam Sharma

### Vehicle and crew scheduling optimisation of city bus systems

Scholar: S B Ravi Gadepalli

### Estimation of perceived and actual risk faced by pedestrians: case study delhi, india

Scholar: Shalini Rankavat

### Bus transit network planning for small to medium sized cities

Scholar: S.M. Hassan Mahdavi M.

### Service level benchmarks for urban transport systems

Scholar: S.K. Lohia

### Travel demand estimation of informal settlements in Delhi

Scholar: SSLN Sarma

### Impact of traffic control measures on speed and driver behavior in highway work zones

Scholar: Sumeet Gupta

### Human body modelling requirements for vulnerable road users

Scholar: Wondwosen Ayelework Lakew

## M.Tech. Projects

Completed

### Optimization of aggregate gradation using bailey method

Student: Karanjeet Kour

### Caliberating HDM 4 for 4-lane divided highway

Student: Chandrama Prasad

### Study on vehicular speed and delay analysis in Delhi bus transport system using time series analysis /OR/ Analytics in trucking logistics operations/Dynamic routing of pickup/delivery vehicles

Student: Mehvesh Mushtaq

### Development of bus performance measures

Student: Sandeep Gandhi

### Impact of traffic calming at highway work zones

Student: Yogender Singh

### Safety climate in Indian construction industry

Student: Amit Bazaz

### Finding and implementing factors improving safety and productivity simultaneously

Student: Meenakshi

### Low carbon mobility alternatives for intra-urban freight movement

Student: Atul Kumar

### Quality assurance for wearing courses in asphalt pavements

Student: Jiregna Debelo

### Impact analysis of helmets and combined lagrangian-eulerian analysis of head

Student: Arun Baby

### Characterization of polymers under high speed impact for use in FE modelling of Automobiles

Student: Sounak Mojumder

The Transportation Research and Injury Prevention Programme (TRIPP) at the Indian Institute of Technology Delhi, is an interdisciplinary programme focussing on the reduction of adverse health effects of road transport. TRIPP attempts to integrate all issues concerned with transportation in order to promote safety, cleaner air, and energy conservation. Faculty members are involved in planning safer urban and inter-city transportation systems, and developing designs for vehicles, safety equipment and infrastructure for the future. Activities include applied research projects, special courses and workshops, and supervision of student projects at postgraduate and undergraduate levels. Projects are done in collaboration with associated departments and centres at IIT Delhi, government departments, industry and international agencies.





## SAFETY, SUSTAINABILITY & FUTURE URBAN TRANSPORT

*Edited By: Dinesh Mohan*

*Publisher: Eicher Goodearth Pvt. Ltd., 2013*

“Sustainable mobility means that all people can move around the city in safety, security and a pleasant environment. This truly stellar list of international researchers all take their own perspective on this central theme of the book to determine the future of mobility in global cities.”

David Banister, Professor of Transport Studies, University of Oxford

This book is a first of its kind, filling a yawning gap, on the related subjects of safety, built form and mobility. It brings together evidence based research work from various inter-disciplinary fields examining issues of security and movement in the urban landscape. These articles look at the complex question of how the planning and design of buildings and roads in cities affects the sense of comfort and well-being of the citizens because their behavior and choices are influenced by the context in which they find themselves. The scholars and experts all agree that design decisions relating to the environment and humans should decrease exposure to risk and increase the safety of the people in the city.

The expert contributors to this book come from various disciplines and various parts of the globe. In a review of a book on a subject that is complex and often counter-intuitive, it will not be possible to illustrate the points made by all the contributors. It would be worth mentioning here that key extracts from the various articles in the book have been separately issued as a chapbook for the ready reference of the interested reader. Even a casual but diligent reader of the volume will discern an emerging pattern in the findings and conclusions arrived at by the experts in the essays grouped together here.

From the Editor's Preface: The first article in the book, “The contribution and limitations of education and driver training” by Allan Williams drives home an important message that even though the aim of most educational and training programs is to change individual behavior, when used alone, they largely fail to do so. In general, even high quality education programs have rarely worked by themselves in changing individual behavior”. This sets the stage for the rest of the chapters in the book which focus on community action, urban architecture and street design, traffic safety, and vehicles that ensure safety for pedestrians and bicyclists. The fact that educational campaigns and propaganda on their own have limited effect in promoting safety makes it more important that we focus our efforts on changes in infrastructure and product design.

Ian Roberts follows this with a chapter on the importance of physical activity including walking and bicycling. According to him physical inactivity substantially increases our risk of heart disease, stroke and cancer. However, many more people would cycle only if they did not consider it dangerous. The evidence for this is provided by Bruce Appleyard, Andres Villaveces, Roger Beherens and Geetam Tiwari from their studies in USA, Columbia, South Africa and India. Their studies show that people hesitate to get out on the street because of their subjective perceptions regarding fear of crime and road accidents.

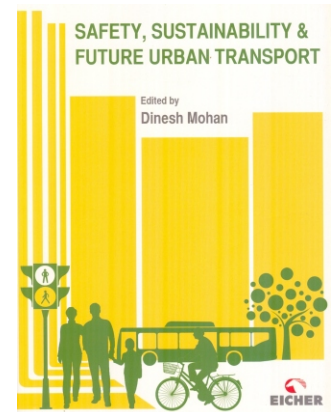
Bo Gronlund, Clara Cardia, Macarena Vargas and Jeff Rissom provide us with details of work done around the world on crime prevention through environmental design (CPTED). According to Cardia studies performed in various European and North American countries clearly

show that personal safety is a determining factor in a person's decision whether or not to use public transport. Configuration of public space and the ways buildings relate to public space is one of the most important issues raised in these contributions. An important point Gronlund makes is that, “It is therefore very important that CPTED concern for public space start with thinking about space and behavior, not with technical solutions like fences or CCTV.

High speed, and separated car traffic creates barrier and a no man's land, empty pedestrian and bicycle routes and empty public transit stops at night, as well as large parking facilities, tunnels and overpasses with even more fear of crime”. Rissom consolidates these ideas further by giving examples from Copenhagen, New York and Chennai on how these ideas can be put into practice so that the multi-dimensional experiences of the pedestrian, cyclist, and passenger can all be considered as one, at the 'eye-level' of humans in the city.

Dinesh Mohan and Eric Dumbaugh give strength to the above arguments by showing that urban form in the structure of its street layout and types of roads have a determining influence on traffic safety. Mohan argues that since cities with the same socio-economic characteristics can have very different road traffic fatality rates, the city form must have a lot to do with it. It appears that those cities that have a higher proportion of wider roads and a lower density of junctions have higher rates of road traffic fatalities. Dumbaugh's detailed work from the USA shows that wider lanes on urban streets have little or no safety benefit, and each strip commercial use (a road with big box stores and shopping malls) has about twice the effect on crash incidence for a million miles of vehicle travel, and each big box store has nearly nine times the effect in increasing traffic crashes. He tells us, “Information is not only communicated through formal symbolic mechanisms, such as language or writing, but through features in the environment. Roadways have a 'meaning' that is communicated to, and interpreted by a driver”. This understanding must be used to design safer roads that actually communicate with the driver. Gord Lovegrove gives more examples of how local street and junction design can have a strong influence on promoting safety.

Christer Hyden, Geetam Tiwari, David Ragland and Nicolae Duduta deal with the nitty gritty of safer urban road design. Hyden's main message is that that until to-day vehicle speeds have been a low priority area in urban road design. The best way forward in the short run is to develop strategies where infrastructural measures like traffic calming are combined with vehicle measures to control vehicle speeds. Tiwari gives many examples from Delhi how road designs can influence road user behavior resulting in increases or decreases in road traffic crashes. Duduta follows this by an international survey of bus rapid transit projects with evidence that details of bus lane and bus stop design have a significant effect on safety.





Sudipto Mukerjee and Yves Page deal with the design of the car: how car design itself can have an influence on whether pedestrians and cyclists get hurt seriously or not. Mukerjee deals with vehicle shape and safer car fronts and points out that much more importance should be given to design of small cars and pedestrian safety as the proportion of small cars is like to increase in the future. Page brings us up to date on new E-safety systems in cars that address accident prevention, accident avoidance, injury mitigation, rescue and health care improvement. He sees promise in new technologies such as automatic speed control, automatic breaking and alcohol locks.

Larry Cohen reminds us again that the presence or fear of violence impedes activity levels and the ability to move outside freely, especially among populations that are more vulnerable to violence such as children, women, people with disabilities, and older adults. Placing public transportation where it is equitably responsive to community needs and encourages links to vibrant centres is valuable. Cohen insists that community involvement and comprehensive approaches and multiple sectors working together is essential for designing safer streets. Dunnu Roy supports Cohen's position by emphasizing that effective and safe road design and transport planning has to address a set of conflicts implicit in the social context within which roads are built and transport is provided. He suggests that planners think in terms of 'mobility' while a majority of road users are concerned about 'livelihoods'. The role of research and analysis for road safety is thus often (and unthinkingly) given to the 'expert' who tries to generate awareness round his/her perceptions, but the 'people' who use the road frequently have a completely different perception of the road but are not allowed to express them in decision-making arenas.

Finally, Hermann Knoflacher reviews all the contributions and remarks that though a clear path to the future has not been laid out, the articles in this collection are an excellent base to prevent the mistakes of urban development in the last two centuries. What is seen and treated in general are the visible effects, the behavior of people, the society, the administration, but not the structures behind or below at much deeper levels. An interdisciplinary approach is therefore necessary. He adds his own analysis and concludes that parking policies are at the centre of urban planning that influences travel behavior. If parking is not removed from homes to at least as far away as public transport stops or even further, all the other goals will be missed.

Sustainable transport solutions are frequently reduced to those concerning cleaner vehicle emissions, provision of public transport and 'encouraging' walking and bicycling. The reasons why people and governments don't or

cannot follow many of the prescribed goals get less attention. Complex issues involving the interaction of urban structures, urban layout, street design and architectural forms and their influence on human behavior in transportation choices get neglected by most transportation planners.

The collection of essays in this book is an attempt to focus attention on this issue. Just the availability of clean vehicles, provision of public transport facilities, and construction of bicycle tracks, will not be sufficient for ensuring that our cities in the future have sustainable consumption and healthy living patterns. All authors in this book focus their attention on how a city can be made safer, independent of enforcement and policing activities. This in the belief that unless people feel safe from crime and traffic accidents they will not willingly walk, bicycle or use public transport.

*Safety, Sustainability and Future Urban Transport* includes articles from a group of experts belonging to very different fields to address issues of future urban transport from a variety of viewpoints. These articles give an idea about how many different design issues can influence the behavior of citizens when making choices about when and how to use a given transport mode, including modes such as walking, bicycling, and public transport. They also give ideas about how to create more liveable streets. The dominant theme of the discussions is how the city and street structure contribute to objective and subjective perception of safety for everyone living there. One important conclusion from the book is the need for city and traffic planners and decision makers to include the perceptions of individuals regarding, safety and security in all steps from the 'door of the home' to the 'end of the journey'. The consensus is that we must move away from planning cities around the car, and this will only happen if there is much more interaction among professionals from different disciplines. All authors agree that the built environment has a strong influence on both people's subjective perception of safety and objective safety indices. A move toward designing safer streets and neighbourhoods has to become an integral part of our efforts to move toward a more sustainable future

***Safety, Sustainability and Future Urban Transport.***

*Proceedings of a workshop held in Delhi in March 2012.*

*Copies of the book may be ordered from  
[www.flipkart.org](http://www.flipkart.org) or [urbanmobility@eicher.in](mailto:urbanmobility@eicher.in)*



***Essential ideas from SAFETY, SUSTAINABILITY AND FUTURE URBAN TRANSPORT***

is forty four page publication containing some of the most important messages contained in the book. Both hard copies and soft copies are available gratis.

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## NEWS

### The Insurance Institute for Highway Safety Issues the First Crash Avoidance Ratings for Cars

Source: Status Report — Vol. 48, No. 7. Washington DC: Insurance Institute for Highway Safety. <http://www.iihs.org/iihs> (Accessed 27 September 2013).

Front crash prevention is part of a larger group of crash avoidance features spreading through the U.S. vehicle fleet. Marketed under various trade names, system capabilities vary by manufacturer and model, and most are offered as optional add-ons. In general, current front crash prevention systems fall into two categories: forward collision warning and front crash mitigation or prevention with autobrake. Forward collision warning alerts a driver when the system detects that the vehicle is about to crash into another vehicle in front, but the system doesn't slow down or stop the vehicle. Some forward collision warning systems are combined with an auto-brake system to reduce vehicle speeds in a crash, but they aren't designed to avoid the collision. Acura's Collision Mitigation Brake System is an example.

Other auto-brake systems can slow down or completely stop the car to avoid some front-to-rear crashes if its driver doesn't brake or steer out of the way in response to a warning. Like the Acura system, these will reduce the speed of those crashes they can't prevent. Cadillac's Automatic Collision Preparation and Volvo's Collision Warning with Full Auto Brake and Pedestrian Detection combined with City Safety are examples. Another design difference involves whether the vehicle ahead is stopped or moving. All of the front crash prevention systems that earn a superior or advanced rating from IIHS are capable of braking for a stopped or slower-moving vehicle. Some other systems are designed to brake for a stopped car ahead only if sensors first detect the car moving before it stops. The 2013 BMW 3 series sedan is available with this type of system. It gets a basic rating for front crash prevention. The point of auto-brake systems is to help inattentive drivers avoid rear-ending another car. It's clear that the ability to automatically brake for both stopped and moving vehicles prevents the most crashes.

The Institute rates models with optional or standard front crash prevention systems as superior, advanced or basic depending on whether they offer autonomous braking, or auto-brake, and, if so, how effective it is in tests at 12 and 25 mph (19 and 40km/h). Vehicles rated superior have auto-brake and can avoid a crash or substantially reduce speeds in both tests. For an advanced rating a vehicle must have auto-brake and avoid a crash or reduce speeds by at least 5 mph (8 km/h) in 1 of 2 tests.

Six models earned an advanced rating when equipped with auto-brake and forward collision warning. These include the 2014 Acura MDX SUV, Audi A4 sedan and Q5 SUV, 2014 Jeep Grand Cherokee SUV, Lexus ES sedan and the 2014 Mazda 6 sedan. In addition, the Volvo S60 and XC60 earn an advanced rating when they aren't equipped with an option called Collision Warning with Full Auto Brake and Pedestrian Detection. The S60 and XC60 are the only models in the new test program with standard auto-brake. Called City Safety, the system brakes to avoid a front-to-rear crash in certain low-speed conditions without warning the driver before it takes action.

Twenty-five other vehicles earn a basic rating. Three models that are available with a forward collision warning system earn higher ratings when they are equipped with auto-brake. They are the 2014 Acura MDX and two Cadillacs, the ATS and SRX. Thirty-six midsize models either don't offer a front crash prevention system at all, or they have a system that doesn't meet NHTSA or IIHS criteria.

"Front crash prevention systems can add a thousand dollars (Rs. 62,000) or more to the cost of a new car. Our new ratings let consumers know which systems offer the most promise for the extra expense," says David Zuby, IIHS chief research officer. "That means a speed mitigation system like Subaru's Eye Sight that can prevent crashes at low and moderate speeds," Zuby says. "At the same time, we want consumers to know that forward collision warning alone can help them avoid crashes, and it's a feature that's available on more models than auto-brake."

Note: Front crash prevention technologies are being marketed in U.S.A and Europe as options in moderately priced and luxury midsize cars and SUVs. These technologies have promise for reducing rear end crashes between vehicles, but their effectiveness has not been evaluated for mixed traffic conditions prevalent in countries like India.

## FUTURE EVENTS

### 12th World Conference on Injury Prevention and Safety Promotion

The 12th World Conference cohosted by the CDC Injury Center, the Center for Injury Control at Emory University, and the Johns Hopkins International Injury Research Unit of the Johns Hopkins Bloomberg School of Public Health and Safety Promotion was scheduled to be held in Atlanta, Georgia, United States of America, on 19-23 October 2013.

The Conference has been cancelled due to unforeseen circumstances. The date and venue for the next Conference is expected to be announced early 2014.

### 4th International Safer Roads Conference

The 4th International Safer Roads Conference will be held in the UK from 18 - 21 May 2014 with the overriding theme that "saving lives through safer roads will not happen by accident". The conference will be held in Cheltenham Spa, located less than 160 km from London

<http://www.saferroads.org.uk>

#### Establishment funds have been received from

Ministry of Industry, Government of India  
Asian Institute of Transport Development, India  
Tata Motors, India  
Volvo Research and Educational Foundations (VREF), Sweden

#### Endowments for perpetual Chairs

CONFER, India: TRIPP Chair for Transportation Planning  
Ministry of Urban Development, India: MoUD Chair for Urban Transport & Traffic Planning  
VREF: Volvo Chair for Transportation Planning for Control of Accident and Pollution

Transportation Research and Injury Prevention Programme

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## Excerpts from a Ph.D. Dissertation : A TRIPP BULLETIN INSERT

**Title: Development of a Bicycle Demand Estimation Model Incorporating Land Use Sensitive Parameters: Case of Pune City, India**

**Scholar: Himani Jain**

**Supervisors: Geetam Tiwari**

**Department: Department of Civil Engineering**

In the past decade, cities have started to prioritize an integrated approach to urban planning in order to improve the overall quality of life. The focus has been shifting from transit development to the development of compact cities conducive to walking and cycling. While European cities are leading the way, most South Asian cities are on a different track. The inherent dense, mixed urban fabric with narrow lanes and compact structures are being fast forgotten, and the personal automobile-oriented planning is rampant. Hence the current modal shares favoring walking, cycling, and informal non-motorized transport are fast changing to motorized two-wheelers, cars, and large shopping malls on the city outskirts.

A review of literature on land use and travel suggests that urban physical form and the functional elements of an area affect travel behavior, especially non-motorized travel. High possibilities of bicycle usage exist in Indian cities owing to short trip lengths. Nevertheless, more scientific research is needed to establish the interrelation of bicycle use and existing land-use, street surroundings and operations among various market segments in Indian cities. This study aims at building an approach towards applicable bicycle route assignment, and mode choice estimation model quantifying the potential shift to bicycles from other modes. The aim of this research is to integrate the critical parameters influencing bicycling, including perceptions and street environment aspects to arrive at a robust and contextual traffic assignment model. The modal shift model further estimates the probability of car, motorized two-wheeler and bus users, who will shift to the bicycle, when bicycle-favoring infrastructure is in place.

This research studied Pune city, representative of a typical medium-sized Indian city, for its land use and other physical planning and transport characteristics. Pune has a population of 3.1 million persons (2010) with high two-wheeler usage (26%). Until the 1990s, Pune had a very high share of bicycle use (34%), which declined rapidly in the last three decades. These characteristics are common to many other medium cities having populations in the range of 2 to 5 million. With the growth in economy and per capita income, similar modal shifts are expected in many other cities.

The benefits of improving transport infrastructure have traditionally been measured by performance criteria such as minimizing travel time, and delays while maximizing the 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 weight 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 modeling has supported planning grand construction of grade separated junctions, and of signal free expressways to ensure high speeds. However the demand modeling 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 the critical parameters influencing bicycling, land use and the street environment, to arrive at a robust and contextual travel demand modeling framework. The growing literature and worldwide experiments indicate that bicycle compatibility is a useful approach for planning urban infrastructure. The limited research and efforts in this regard in South Asian cities prompted the research with an aim to address specific aspects of the bicycle travel mode choice model.

A comprehensive review of the literature on the subject, especially in the South Asian context, suggests several unique aspects, such as captivity (dependence on a mode due to certain constraints), various markets segments, 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 behavior, 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 the stated preference methodology for estimation of preferences and weights related to key parameters. The survey also provided an opportunity for creating a future bicycle-friendly scenario and estimates for modal shifts to the bicycle. While the 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 a 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 priorities 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, captive bicyclists prefer the presence of the informal sector and see 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 estimation of weights from the stated preference technique helped in the development of Area Bicycle Compatibility (ABC) Index estimation of the surveyed streets which was categorically extrapolated to all the streets in the case of Pune city. The inverse ABC index was used as the impedance measure for these streets. The ABC-based traffic assignment estimation is compared against that of the shortest distance and against a combined effect of ABC index and distance. These estimations are validated against a different dataset of bicycle volume count on 80 streets.





## Continued from overleaf:

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 factor influencing the route choice, aspects of safety and security 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 distances (< 5 kilometres), will shift to the bicycle if a conducive infrastructure is created. Safety and comfort are 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 level time by motorcyclists and car users.

The study developed a traffic assignment framework to assess the impact of route preferences and mode choice to generate an understanding for bicycle planning in the Indian context. This study:

- Clearly identifies the predominant Indian market segments for bicycling. The primary survey provides insights into the understanding of the socio-economic and demographic status, and the travel patterns and choices of the current captive users and of a large segment of potential users.
- 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.
- Explores the relation of land use and risk perceptions of the current and potential bicycle users with bicycle planning for evaluating safety and comfort aspects and for estimating bicycle use.
- Develops a robust algorithm of route assignment modeling through the use of Area Bicycle Compatibility (ABC) Index application and develops a framework for modal shifts to the bicycle.
- Concludes that the research insights contained in it 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 neighborhoods, and for bicycle-compatibility benchmarking for areas or facilities.

Most urban areas of Indian cities are dense, compact and multi-nucleated with heterogeneous land-use on a small scale due to its varied income group mix; these conditions offer a large base for short trips. This study and the methodology developed for bicycle traffic assignment provide an in-depth knowledge of relationships between the street environment/operations and current bicycle routes for designing bicycle compatible infrastructure in the near future. The analysis in this research presents the parameters that policy makers and planners should be able to consider early in the transportation and city planning projects:

At the city or urban level, planning policies can influence the level and scale of land-use mixing and also the level to which development is clustered or concentrated. At the local and neighborhood levels, planning policies can be used to influence the density and layout of development. The pattern of buildings, their use, with heterogeneous land-use mix on a small scale, and transport infrastructure in a neighborhood tell people how to travel, within certain broad choice parameters (Banister, 2005). Our research study presents key results relating captive cyclists' route choice perceptions with land use aspects. The insights from land use and bicycle use analysis can be useful in planning for bicycles and developing guidelines for bicycle-

compatible neighborhood design strategies for safer and more comfortable commutes. This can be further used for estimating the relationship between street-environment and bicycle use. The mode shift analysis indicates and prioritizes the improvement projects and policies in city planning. This understanding provides priorities and inputs for promoting bicycle use and infrastructure for attracting potential users.

The stated preference and revealed preference analysis with respect to route choice aspects suggests that the mixed, dense and vibrant commercial and residential streets with the presence of informal commerce are preferred for reasons of security, comfort, access to facilities and amenities and services.

**Bicycle demand modeling and planning routes:** The focus on context-sensitive design in roadways planning, addressing public health and concerns about oil dependence and global warming have raised expectations in transportation engineering. The model and various insights provide more knowledge and easy to use modeling guidelines related to bicycle planning and design. Many attempts to mobilize the potential of non-motorized transport (NMT) have failed because the attempts did not contain the minimum package of elements to ensure attractiveness. Traffic calming measures in neighborhoods, pedestrianization of shopping or market areas, direct/easy connections to transit hubs and safe parking are among the most effective actions for NMT programs. (World Bank, 2001; CROW, 2007) Hence, the study provides key links and relationship insights to integrate such bicycle compatibility aspects into the indicators, parameters and modeling framework itself. It is extremely important that bicycle travel be considered early on in the design of transportation or city development projects in Indian cities, otherwise the opportunities to facilitate bicycle use are often lost. The study provides a network analysis method to integrate bicycling early in the planning process so that improvements are low cost, with increased traffic capacity, reduced accidents and low maintenance costs.

Regression analysis provides insights into key relationships between socio-economic and family factors of an individual and his/her travel aspects using bicycle as the mode of transport in the current scenario. Hence, policy makers and planners should consider socio-demographic and travel aspects early in the transportation and city planning policies.

It is generally a mistake to simply use kilometres of paths or bike lanes as an indicator of cycling network effectiveness, as this encourages the development of facilities where they are cheapest to build rather than where they provide the greatest benefits. For prioritizing improvements and selecting preferred options, four factors should be considered: level of demand, degree of barrier, potential benefits, and costs or ease of improvements (Litman, 2008). A more sophisticated investment analysis technique uses net present values. This involves estimating all future costs and benefits, depreciating them based on a discount rate. However, such "condensed" values may exclude factors which are important to consider (Litman, 2008).

For example, two projects may have the same cost per additional bicycle commuter, but one may provide more recreational bicycling and another more environmental, accessibility, commuting or equity benefits. Hence, a more comprehensive system of valuing necessities is needed with respect to captive users and potential users. The prioritizing of needs should be identified distinctively in the short and long term.

