



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

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

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

Thorax model building and validation – diaphragm and aorta

Scholar: Piyush Gaur

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

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

Ph.D. Scholars

Continued

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

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

Ph.D. Scholars

Completed

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

Scholar: Himani Jain

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

Estimation of externalities in public transport system

Scholar: Pradeep Singh Kharola

Travel demand estimation of informal settlements in Delhi

Scholar: SSLN Sarma

M.Tech. Projects

Completed

Incentivization of public transport in Delhi (Accessibility)

Student: Mohammad Mahdi

Scheduling of diagnostic equipment

Student: Malyaj Srivastav

Incentivization of public transport in Delhi: role of Delhi metro

Student: Vineet Chauhan

Comparative assessment of existing subgrade improvement techniques for transport infrastructure

Student: Abdul Rashid

Impact of construction worker safety on transportation project economics

Student: Lalit Kumar

Estimation of turning movement and capacity of roundabouts

Student: Haroon Zamal

Estimation of PCE values on hill roads

Student: Arstu Gautam

Risk analysis on highways

Student: Sandip Bhattacharjee

Travel time estimation on urban corridors using GPS probe data

Student: Ranadeep Basu

Rheological properties of asphalt containing SBS and HDPEH polymer

Student: Uma Devi Rongali

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.





HOW CAN TRANSPORT CONTRIBUTE TO OTHER URBAN AGENDAS?

*Excerpts from the 6th TRIPP Annual Lecture
David Satterthwaite*

There are important contributions that a well-functioning city transport system can make to a range of goals – including improving housing (and lowering housing costs), reducing poverty (including increasing income-earning opportunities and lowering transport costs), reducing disaster risk, adapting to climate change and climate change mitigation. But to what extent do the transport components of these strategies overlap or conflict? And, perhaps as importantly, is it possible to implement what is needed, especially in regard to land-use management that supports these goals?

As someone who works on urban poverty reduction, I want transport systems that cut housing costs and increase the access of low-income groups to income-earning opportunities. Of course I also want transport systems that are safe and keep down time and monetary costs for users. Most of this lecture is devoted to this issue. But as someone who also works on disaster risk reduction, I want transport systems that are resilient to extreme weather or other potential catalysts of disasters and that allow those exposed to high risks in their homes or workplaces to move to safer locations if needed. Also transport systems with the capacity to recover quickly from disruptions; this has particular importance for low-income groups for whom disruption in their incomes of only 2 or 3 days presents them with challenges to their nutritional status. Avoiding, for instance, the disruptions to livelihoods and the very functioning of the city that was evident in Mumbai in the floods in 2005. And of course, transport systems may have particular importance in getting people away from a site particularly at risk from an approaching storm or flood.

As someone who works on climate change adaptation, transport has importance for reducing disaster risks that are linked to climate change and for building resilience and redundancy within all the infrastructure and service networks that are important for cities. And given how long most transport infrastructure lasts, building into new infrastructure investments new safety margins so they can cope with more intense or frequent extreme weather events and other (likely or possible) impacts from climate change.

There is much common ground between poverty reduction, disaster risk reduction and climate change adaptation. All three have a strong focus on reducing risks, especially for low-income groups and/or those living in informal settlements that lack risk-reducing infrastructure and services. But these three different urban agendas tend to focus on different sets of risks. However, the infrastructure and services that are so important for poverty reduction (good quality, regular water supplies piped to homes, good provision for sanitation, drainage and solid waste collection, health care and emergency services, schools, rule of law/policing and accountable local government) are also key to disaster risk reduction. They (and the institutional and financial systems that underpin them) also provide a valuable base from which to address climate change adaptation.

As someone who works on climate change mitigation, transport has obvious importance. Greenhouse gas emissions per person in any city are much influenced by urban form and by the quality of provision for public transport (and of course provision for public transport also influenced urban form).

One difficulty facing any city government is not really knowing what is happening in their city. Today and everyday, in any city, many individuals or households are thinking of moving. So take Delhi. There are thousands of people who are moving or thinking of moving to Delhi from another city, town or rural area. There are also many Delhi residents moving or thinking of moving to somewhere else within Delhi – perhaps looking for more space or to find somewhere cheaper or better located in regard to income-earning opportunities. Meanwhile hundreds of businesses are considering whether to expand or move within the city or move elsewhere. Then there are many businesses outside Delhi who are considering investing here. All these individual, household and enterprise decisions influence demand for transport – but no city government has a record of these decisions. Every ten years, censuses tell us about how populations have changed for cities and their surrounds and the changes in population within cities. But censuses so often bring surprises – as the city in which I live has a larger or smaller population than expected – but we only learn about this every ten years.

We know that migration flows to a city where there are new investments and economic opportunities. Cities can be seen as labour markets (and as Alain Bertaud

notes, without a functioning labour market there is no city). This is a relief because people are moving to where there are more job or livelihood opportunities. But a large part of the migrants and the “already in the city” residents have low incomes. All need to find accommodation that they can afford and that provides them with access to income-earning opportunities. Here, it is worth looking not only at cities as labour markets and how those with labour seek to insert themselves in this market (or to move to a more advantageous position in it) but also at what this means for their housing and their transport.

There is much discussion in India and elsewhere about ‘slums’ and about how many people live in them. Bhan discusses how the size of Delhi’s slum population (and the proportion living in ‘slums’) is much influenced by what definition is used and notes that many of Delhi’s most vulnerable poor live in makeshift shacks or sleep on the street and remain uncounted in any assessment of who lives in ‘slums’.

Of course, how many people live in ‘slums’ also depends not only on how they are defined but also on how accurately they are measured. The United Nations produces statistics for the proportion of the urban population living in ‘slums’ in most nations and globally but there are serious doubts as to the accuracy of these ‘slum’ statistics. First, there are the criteria used for defining ‘slum’ households. A household is defined as a slum household if it lacks one or more of the essentials like ‘improved’ water, ‘improved’ sanitation, durable housing or sufficient living area. But a large proportion of households with ‘improved’ water or ‘improved’ sanitation still lack provision to a standard that meets health needs (or, for water, what is specified in the Millennium Development Goals as sustainable access to safe drinking water). If there were the data available to apply a definition as to who has provision for water and sanitation to a standard that cuts down health risks and ensures convenient and affordable access, the number of ‘slum’ dwellers would increase considerably in many nations. If we had statistics as to who had water piped to their premises that was of drinking water quality and regular and classified households without these as ‘slum’ households, the number of slum dwellers would increase dramatically.

A second reason for concern as to slum statistics’ accuracy is that they show very large drops in the proportion of urban dwellers living in ‘slums’ in some nations for which there is so little supporting evidence. For instance, the United Nations Human Settlements Programme (UN-Habitat) states that the proportion of the urban population living in ‘slums’ in India has fallen from 54.9 per cent in 1990 to 29.4 per cent in 2009. If this is true, then India has had one of the world’s most successful programmes in reducing slum populations. For Bangladesh, the proportion of the urban population living in ‘slums’ is said to have fallen from 87.3 to 61.6 per cent in this same period. Where is the supporting evidence for this? It may be that most of the apparent fall in the slum population globally between 2000 and 2010 was simply the result of a change in definitions – as a wider range of (inadequate) sanitation provision was classified as ‘improved’. It is also not clear where UN-Habitat gets its annual figures for the proportion of the urban population in ‘slums’ yet these figures are so widely used and quoted.

But perhaps the issue is not to improve the definition and measurement of ‘slums’ and ‘slum’ households but to better understand the ways in which city residents get accommodation in a range of housing sub-markets through which they buy, build, rent or otherwise get to use housing. Then it becomes possible to consider how transport does or could better serve their inhabitants. Some housing sub-markets may be assessed as very poor in terms of housing quality but very good in terms of access to income-earning opportunities. Each individual or household has their own particular priorities in terms of location, size, quality (of building, infrastructure and services) and price. For those with limited incomes, a lot of these are in informal settlements or in overcrowded rental accommodation. It is a big mistake to label all these as slums as this gives no sense of their diversity. What we need to understand is how low-income individuals or households seek the accommodation that provides the best compromise for their multiple needs and how these can be supported.

It is very common for those living in informal settlements to want to stay there because they have a relatively good access to labour markets and they also want to avoid the disruption to social networks that a move would entail. There is also a

literature going back to the 1930s on how moving low-income households to 'better quality' accommodation in peripheral locations actually impoverishes them as this move reduces their access to income-earning opportunities.

So incremental upgrading of informal settlements preserves the locational advantages while also addressing the other needs of the residents. This is perhaps best seen in the work of the Community Organizations Development Institute (CODI) in Thailand that provides loans and support to low-income community residents to develop their own upgrading plan and negotiate secure tenure from the owner of the land on which they live. These have transformed the quality of housing and provision for infrastructure and basic services for tens of thousands of households.

Upgrading is not always the preferred solution; the pavement-dwellers in Byculla (Mumbai) want better quality and more secure accommodation as long as it does not impose too high a monetary cost for the housing and services and too high a time and monetary cost getting to and from work. The 20,000 households that lived along the railway tracks in Mumbai did not want to stay there if there were housing options that better suited their needs and priorities. They agreed to move although what was unusual in this move was the extent to which those who moved were themselves engaged in decisions about where to move to, when to move and how.

As a city grows and expands, so there is a need to upgrade infrastructure. For many cities, there is also a very large deficit in basic infrastructure that needs to be remedied. Many cities also have a high concentration of low-income groups living in areas at risk from extreme weather events – and often also from the increase in risks that climate change is bringing or will bring. So there will be some need for relocations. What stands out from the successful and the unsuccessful relocations is the key role of location and the quality of public transport. And as critically, who chooses the site for the relocation – and who manages the move (as in the example given above of those relocated from beside the railway tracks in Mumbai). Also, with low-income groups in informal settlements allowed to challenge official plans and limit those who have to move to a minimum.

For at least two decades, there have been studies showing the high proportion of household expenditure going to transport among urban populations – or the high costs facing particular urban poor communities. These include studies showing public transport costs representing a significant part of total household expenditure. Travel can take 20-25% of daily wages among the low-income population living in cities such as Delhi, Buenos Aires and Manila and up to 30% in Pretoria and Dar es Salaam. Yet transport costs are often not even considered in the setting of poverty lines.

In Buenos Aires, a 2002 survey found that the poorest quintile spent over 30 per cent of family income on public transport. In Sao Paulo, a 2003 survey showed low-income groups spending 18–30 per cent of their incomes on travel; by comparison, wealthy residents spent 7 per cent of their incomes and were able to travel far more frequently. In Salvador (Brazil), a household survey in two peripheral low-income neighborhoods found that transport expenditures averaged 25% of monthly expenditures. In informal settlements in Nairobi, residents spend 8 per cent of their income on transport although given the variety of locations for informal settlements in Nairobi in regard to how close they are to income-earning opportunities, there is likely to be considerable variation in this between different informal settlements. A study of average household expenditures across Zambia's urban population found that 12 percent was spent on transport.

But averages across urban populations hide the great diversity in costs between different settlements and locations – and many low-income groups live in very poor quality and overcrowded accommodation in more central areas to get quicker, cheaper and easier access to income-earning opportunities. So those living in more distant poorly located settlements may be paying two or more times the average. In addition, what such figures do not show are the other consequences of high public transport costs. These include the time and energy burden of having to walk more. Some studies have shown how many low-income groups walk long distances to keep their transport expenditures down.

In theory, expanding road networks in and around a city should increase the supply and reduce the cost of land for housing. Expanding public transport services to a larger area in and around the city (including rail/light rail, bus-rapid transit and metro) should also do so. This seems to go against the very considerable literature on how improving any location's access to central city locations (or labour markets)

increases land prices. But surely this is only for the locations most favoured by the improved access. I want to know what happens to land prices in locations that benefitted from the new road, BRT, rail or metro but that were further away from the stations or bus stops. When Curitiba developed and then extended its bus-rapid-transit system, land prices must have increased in and around the bus stops – but overall this bus system served to increase the land area in and around the city that was within (say) half an hour and a particular cost of the industrial area or the central city.

However, when I asked friends of mine who are transport specialists, they suggested that I was wrong on this. They pointed to how improving the access of peripheral areas to central city labour markets meant land speculation and real estate interests focusing on commercial developments or developments for wealthy households with very little new land available to low-income groups. They also pointed to how land-use regulations (and how they are applied) constrained any increase in the supply and reduction in the cost of land for housing. But I want to stick with my perhaps naïve hope that expanding the area in and around a city that has access to central city (or other clusters of) income-earning opportunities (and services) can also increase the possibilities of low-income households to get land on which they can build housing. So the key issue here is how improvements in transport can be linked to land-use changes that do increase the supply and reduce the cost of land for housing.

Whether or not an increase in the area in and around a city with good access to income-earning opportunities brings cheaper housing also depends on the price and availability of building materials (and how these are influenced by laws, codes & regulations on building design & materials). It also depends on the cost of getting permission to build, extend, buy or sell and the cost implications of meeting land-use regulations. Like so many other aspects of urban development, it is influenced by the attitudes of politicians and civil servants – in this instance, regarding the best use of government land and attitudes of politicians and civil servants and elites regarding development of unused land for low income groups. It depends on who can get credit for land purchase and housing and who can access it.

There are some strong and important linkages within a good transport policy that can serve the different urban agendas. Public transport systems that are not only used by those with low-incomes that keep down time and monetary costs for users, that widen housing choices for low-income groups, that are pleasant and safe and that help keep down transport-related greenhouse gas emissions. And in doing so, reinforcing the comparative advantage of that city in retaining or attracting new investment?

Can we learn from the way that low-income groups and their own organizations have upgraded their settlements to show how a high quality of life can be achieved with high densities and a high proportion of all trips made by walking, bicycling and public transport?

How can more attention be paid to the five Ds that influence travel demand: Density, Diversity of land uses (jobs and homes, provisions for walking and bicycles as well as cars); Design (street layout that encourages pedestrians and bicycles), Destination accessibility (what can be reached within 30 minutes) and Distance to transit.

Can all discussions of relocation now be done with those 'to be relocated' with particular attention paid to how this affects their access to labour markets and the time and transport costs they would face. Clearly, there are very large variations in upgrading programmes from serving those who live there to those that push them out. Clearly, settlements will be displaced as cities upgrade their infrastructure (and address the often enormous deficits in basic infrastructure). But the cost of doing relocation well (so that all those who are relocated are fully engaged in planning and managing this) is so often a very small fraction of the infrastructure investment budget.

So much of the above depends on changing the nature of the link between city government and those living in informal settlements. Do city politicians and civil servants understand the key contributions to the city economy made by those living in informal settlements and also understand their needs and priorities? Are there forms of redistribution to which transport systems contribute? For instance, where the transport modes that low-income groups use are faster than using private automobiles? Where provision for bicycle use is so good that the middle-class also choose to bicycle (see some cities in Europe with 30-55 percent of trips made by bike).



NEWS

MOTORCYCLE CRASHES

According to the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA), in 2012, 4,957 motorcyclists died in crashes, up 7.1 percent from 4,630 in 2011. In 2012, 93,000 motorcyclists were injured in accidents, up 15 percent from 2011. In 2012 motorcyclists accounted for 15 percent of all traffic fatalities.

By Age: Older motorcyclists account for more than half of all motorcyclist fatalities. NHTSA data show that in 2011, 56.0 percent of motorcyclists killed in crashes were age 40 or over, compared with 44.0 percent in 2002. The number of motorcyclists age 40 and over killed in crashes increased by 78 percent from 2002 to 2011. In contrast, fatalities among young motorcyclists have declined, relative to other age groups. In 2011 fatalities in the under 30-year-old group dropped to 26.5 percent of total motorcyclists killed in crashes from 31.9 percent in 2002. Fatalities among motorcyclists in the 30-to 39-year-old group fell to 17.9 percent in 2011 from 23.9 percent in 2002. NHTSA says that the average age of motorcycle riders killed in crashes was 42 in 2011.

Older riders appear to sustain more serious injuries than younger riders. Researchers from Brown University cited declines in vision and reaction time, along with the larger-sized bikes that older riders favor, which tend to roll over more often, and the increased fragility among older people as the causes. The study used data on riders age 20 and over who needed emergency medical care following motorcycle crashes from 2001 to 2008. The riders were put in three groups by age: 20 to 39, 40 to 59, and 60 and over. The data showed that while injury rates were rising for all age groups, the steepest rise occurred in the 60 and over group, who were two and a half times more likely to have serious injuries than the youngest group. They were three times more likely to be admitted to the hospital. The middle and older groups were also more likely to sustain fractures, dislocations and other injuries, such as brain damage, than the youngest group. The authors published findings in the journal *Injury Prevention* in February 2013. The study is entitled *Injury patterns and severity among motorcyclists treated in US emergency departments, 2001–2008: a comparison of younger and older riders*.

Alcohol use: NHTSA says that in 2012, 27 percent of motorcycle riders involved in fatal crashes had a blood alcohol concentration (BAC) over 0.08 percent (the national definition of drunk driving), compared with 23 percent of drivers of passenger cars, 22 percent of light truck drivers and 2 percent of large truck drivers in fatal crashes. In 2011, 30 percent of all fatally injured motorcycle riders had BACs of 0.08 percent or higher. Another 7 percent had lower alcohol levels (0.01 to 0.07 percent BAC.). Fatally injured motorcycle riders between the ages of 40 to 44 had the highest rates of alcohol involvement. Forty-two percent of the 1,997 fatally injured motorcycle riders who died in single-vehicle crashes in 2011 (for example, those in which the motorcycle crashed into a stationary object) had BACs of 0.08 percent or higher. In 2011, motorcycle riders killed in traffic crashes at night were nearly 3.4 times more likely to have BAC levels at or over 0.08 percent (47 percent) than those killed during the day (14 percent). The reported helmet use rate for motorcycle riders with BACs at or over 0.08 percent who were killed in traffic crashes was 44 percent in 2011, compared with 67 percent for those who did not have any measurable blood alcohol.

Speeding: In 2012, 34 percent of all motorcycle riders involved in fatal crashes were speeding, compared with 22 percent for drivers of passenger cars, 18 percent for light truck drivers and 8 percent for large truck drivers, according to NHTSA.

Licensing: Almost one out of four motorcycle riders (24 percent) who were involved in fatal crashes were riding without a valid license in 2012.

SAFETY ISSUES

Training Courses: The Motorcycle Safety Foundation works with the National Highway Traffic Safety Administration (NHTSA), state governments and other organizations to improve motorcycle safety through education, training and licensing. The organization also works with the states to integrate rider safety and skills in licensing tests. It also promotes safety by recommending motorcycle operators wear protective gear, especially helmets and ride sober.

Antilock Braking Systems (ABS): Motorcycles have separate brakes for the front and rear wheels, and braking hard can lock the wheels and cause the bike to overturn. Not braking hard enough can put the rider into harm's way. With ABS, a rider can brake fully without fear of locking up. The system automatically reduces brake pressure when a lockup is about to occur and increases it again after traction is restored. The Insurance Institute for Highway Safety (IIHS) said in March 2010 that motorcycles with antilock brakes versus those without are 37 percent less likely to be in fatal crashes.

Airbags: Honda Motorcycle Company is the first company to offer the option of an airbag, which is available on one of the most expensive models. The option became available in 2006. A handful of companies have recently developed wearable airbags, which are worn either inside a jacket or strapped on outside.

Motorcycle Helmets: In 2012 motorcycle helmets saved 1,699 lives. NHTSA says that if all motorcyclists had worn helmets, 781 more lives would have been saved. Helmets are estimated to be 37 percent effective in preventing fatal injuries for motorcycle riders (operators) and 41 percent effective for motorcycle passengers.

Motorcycle Helmet Use Laws: According to the Insurance Institute for Highway Safety, 19 states and the District of Columbia had laws on the books requiring all motorcyclists to wear helmets as of March 2014.

Motorcycle Helmets. <http://www.iii.org/issue-update/motorcycle-crashes>

Course Announcement

The Transportation Research and Injury Prevention Programme (TRIPP) at the Indian Institute of Technology Delhi, is organizing an eight day **"International Course on Transportation Planning and Safety"**. The course will be held in New Delhi, India, from November 30 - 7 December 2014. The course will have a common component for the first three days, followed by three parallel modules on Traffic Safety, Biomechanics and Crashworthiness and Prehospital Care and Trauma.

Details of the course can be accessed from -<http://tripp.iitd.ernet.in>

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

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

Title: Travel demand estimation of low income households in informal settlements: Case study Delhi

Scholar: Sadhu S L N Sarma

Supervisors: Geetam Tiwari

Department: Department of Civil Engineering

For the first time, the decadal growth of the urban population has outnumbered that of the rural population in India, in the last decade, in absolute numbers (Census of India, 2011). This rapid increase in urban populations necessitates provision of shelter, employment and urban services. However, most urban economies in developing countries are unable to meet more than a fraction of these needs, so that the informal sector is providing most of the new employment and housing in environments that have come to be known as informal settlements or slums, where more than half of the population in many cities and towns of developing countries are currently living and working (UNHABITAT, 2003).

Poor and migrant population from the rural areas, mainly, inhabit these settlements (UNHABITAT, 2003), with socioeconomic characteristics that are different from those of inhabitants of formal housing. These differences are further reflected in the travel behavior of the poor dwellers of informal settlements. The conventional transportation surveys and transportation planning techniques do not respond to these diversities in travel behavior of informal land use and fail to cater for their travel needs equanimously (Badami et al., 2004).

The inability of urban governance in coping up with this growth through effective land and housing management and land use policies has led to the formation of informal settlements that give shelter to the urban poor, particularly migrant population that have come to the urban areas in search of a better future. The hostile policies adopted by the city administrations to reduce the migration and informal settlements have not been successful. The inhabitants of these settlements constitute the urban poor and due to the inadequacy of formal employment and their general lack of skill and education, most of these inhabitants work in the informal sector, and contribute significantly to the urban economy.

The analysis of data showed that the inhabitants are poor, and household sizes vary from small to very large up to 14 members. The employment was found to be mostly informal and very low vehicle ownership.

The model results show significantly negative impact of both primary tour and secondary tour travel time has on the tour choice. This highlights the importance of quick access quick employment to the inhabitants of the informal settlements. This also explains why the informal settlements brave illegality in the face of hostile authorities to stay close to their employment opportunities and raises questions against rehabilitation of slums in remote corners of city with restricted access to employment.

Similarly, travel cost, with its negative sign also places a burden on the travel options of the residents of informal settlements which accounts for the heavy dependence on walking and non-motorized transport. The usage of even public transport has been very limited as it places a burden on their finances. This shows that, facilities like metro rail system, which is more expensive than the city bus, have questionable utility in providing accessibility for such a large population.

The survey method adopted to capture the activity and travel data has been very effective in capturing the short travel by all modes and, most importantly, trip chaining, which conventional methods fail to capture. All

the data concerning the travel such as modes, origins, destinations, times and data concerning activities such as nature of activity duration of the activity etc have been successfully captured by the survey.

The data on informal settlements are not easily available through open sources. Moreover, there are always conflicts in the data regarding these settlements provided by various government sources in various studies. By resorting to free satellite imagery and GIS techniques, the study has been able to get fairly accurate information on the sizes and locations of the informal settlements, which should encourage other studies where spatial data is hard to come by.

The destination choice model developed in this study has considered unconventional types of land uses that actually provide employment to the inhabitants of the informal residents such as construction areas and offices, based on the information obtained through the survey. The results of the model show a strong relationship between the choice of destination and travel attributes which are not considered by transportation studies that have been carried out in the country in a number of cities.

Thus the model explains the affinity of informal settlements to the employment opportunities such as residential areas, market places and industrial areas. The model points out the adverse policy implications such as reduced education trips in the resettlement colonies, increased stay home tours by more than 2.3% with increase in travel time for primary tours to work place etc.

The model highlights the significance of gender in mode choice with women and children having very little probability of traveling by motorized transport and with male propensity for walking to market and construction areas. The model brought out that the bicycle ownership reduces the walk tours and increase public transport tours in the household – a possible indication of upward mobility of the household. The mode choice model gives important inputs for planning for NMT and public transport facilities to the policymakers. Both destination choice model and destination-tour choice model show the significance of trip-chaining by incorporating the secondary tour travel attributes.

The city planners can use the destination and mode choice models for short-term as well as long-term planning. When improvements to transportation systems in a zone is to be carried out, the destination and mode choice models will give the planners an insight into the routes and types of facilities that can be taken up in a prioritized manner. Such disaggregate models reflect the travel behavior more accurately to enable bottom-up planning rather than top-down planning that is done using the aggregate models like gravity model. Thus, frittering of resources on improving facilities that accrue benefits to only a few can be checked in favor of more democratic distribution of the same.

For the long distance planning, the tour destination model can be used in place of trip generation and distribution models. A modification, one might carry out to make it more related to four step model, will be to replace the tour travel times and costs with some spatial land use variables such as distances, costs and / or travel times to various types of land uses and then the distribution of tours to various types of land uses (and not to zones) can be carried out. This will avoid incorporating the tour distance/time/cost as an independent variable which can be derived from the other variables and then be spatially distributed. There is a need to incorporate different models for different socioeconomic classes of population, which will enhance the accuracy of the model.





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

Title: A systems approach to estimate the optimal modal mix of passenger transport

Scholar: P.S. Kharola

Supervisors: Geetam Tiwari

Department: Department of Civil and Mechanical Engineering

In the context of a city, transportation of people is very challenging as it involves issues of equity, accessibility, environmental concerns, safety, security and provisioning of finances by government against various competing demands. The rapid economic growth in Indian cities has put the physical infrastructure under tremendous strain. Despite these concerns the cities have emerged as engines of economic growth.

The moot point, however, remains whether what is in the best interest of a commuter is also in the best interest of the society? Economic theory states that a society maximizes the utility of any goods or services if the marginal cost of the services is equal to the price which a user pays for that. In transportation systems, this is not easy to achieve as the cost of externalities often by far exceeds the cost to the actual user. The user bears only a small part of these total costs. Governments often intervene to internalize the total cost to some extent by levy of different types of charges or taxes. But experience has shown that these levies are not sufficient to cover the total cost. The reason for this is not far to see. Traditionally the concept of 'externalities' has not been emphasized as a large number of public resources have been treated as 'freely available'. Also the capacities created – especially for infrastructure- had been more than the demand. But with rapid economic growth coupled with fast urbanization the carrying capacity of the infrastructure has been exceeded and so also the assimilative capacity of the natural environment. The consequence has been deterioration in the environment, excessive strain on the infrastructure leading to poor quality of service. Transportation can be viewed as an economic activity. An increase in demand for an economic activity – like transport- has to be met by increasing supply. Any 'economic firm' uses four basic factors of production - natural resources, human resources, capital and entrepreneurship. The 'firm' pays for each one of these resources, consumes them and produces goods or services, for which it charges a price. Normally the price charged for the 'goods or service' brings enough revenue to the firm so as to pay up for all the factors of production. The passenger transport activity could also be modelled as an 'economic firm' as it also requires all the four basic factors of production and converts them into 'transportation services' for which it charges 'fares' from its users. There are however two basic differences. First, unlike a general economic firm, the transportation firm does not own the first factor of production – the road space is not owned by the users and it has to share it with other modes of transport (however in rail systems the tracks are owned by the rail operator). Second, the users do not pay the 'actual cost'. The transport system – whatever mode- generates large amount of externality and all these externalities are not internalised. This thesis has made significant contribution to the available research literature on city passenger transport. In precise terms following are the contributions:

1. The research has been able to bring about integration of the various subsystems and viewing the entire passenger transport system in a holistic manner.
2. The research has developed a computerised mathematical model which links the decision variables to the traffic scenario. It enables a decision maker to assess the impact of any change in the decision variables on the traffic scenario. The model has universal use. Though it has been developed in the context of Bangalore city in India, it can be used for any city. However

this would require collection of some data specific to the city.

3. The research has duly established the two way relationship between the journey speed and traffic density. Similarly, interdependence between the journey speed and the dynamic load factor in buses has been brought out.
4. The research has adopted a new methodology to estimate the number of vehicles on road by having a count of each type of vehicle at randomly chosen locations.
5. The research has brought out the 'Bus rider's paradox'. If people leave the buses to use their own vehicles, a stage may be reached when the crowding in buses instead of reducing may start increasing.
6. An understanding of the holistic approach adopted in the present research would force the governments to rethink and evolve new structures to handle the passenger transport in cities.
7. This research has questioned the basic assumption in the traditional research that the journey speed is a given parameter in any mode analysis. The thrust of this research is that the journey speed itself depends on the modal mix on the roads and cannot be an independent variable.
8. The research brings to light the concept of dynamic load factor in a buses.

Based on the results and the analysis certain basic principles could be enunciated which would help the policy planners:

- a. The existing approach of viewing different sub-systems of urban transport in isolation has to be done away with. A fragmented approach towards the public transport would give sub-optimal or even wrong results.
- b. Financial viability of the bus transport system should not be the criteria for evaluating a bus transport system rather new indices should be evolved for evaluating the passenger transport system in a city.
- c. Parking fees is an important tool to affect the overall transport scenario. An increase in parking fees would push travellers to the buses. But this push has to be simultaneously matched by increasing the bus frequency.
- d. The present fragmented approach towards urban transport cannot be done away with unless there are basic changes made in the structure of the existing organisations. Unification of the existing disparate organisations needs to be carried out.
- e. All cities should have a good database of the various parameters which would then improve the quality of decision making. f. As part of the present research a detailed analysis of the financial viability of a bus company in a city was done. This analysis indicates that a tax relief to these organizations could be a major contribution in pulling them out from the red. The high rates of taxes need to be reduced for the following reasons (Kharola and Geetam Tiwari, 2008).
- g. As a part of this study a detailed analysis of the fatal crashes involving buses was done. The analysis of these crashes suggests that several corrective steps need to be taken. These are listed below (Kharola, Tiwari and Mohan, 2010):
 - i. It should be mandated by law (through the Motor Vehicle Rules) that no city bus shall be permitted to operate unless it has mechanically-operated doors.
 - ii. There is a strong case for making it compulsory for all buses in cities to have their bodies fabricated in a manner such that the side panels of the bus body are low enough to prevent a person from

