International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-1, October 2012

Estimation of Public Transport Demand in Million Plus Indian Cities based on Travel Behavior

Ar Anuj Jaiswal, Ashutosh Sharma, Jigyasa Bisaria

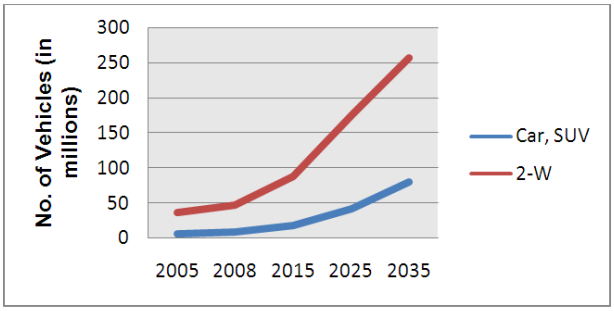
Abstract - The rapid growth in vehicles population has put enormous strains in all urban roads in Indian cities with population between 1 to 2 million. The major factors influencing public transport ridership are poor service quality and more traveling time. This study presents a quantitative model and identified the factors that affect the public transport ridership. A weighed regression model using data of public preferences in travel time, travel cost, and other quality related parameters is build and probability of two wheeler users switching over to public transport is estimated. With this model, the expected increase in public transport ridership for Bhopal and similar Indian cities can be approximated. This model can also assist transport planners and service providers to find innovative and financially viable solutions for better public transport facilities.

Key words: Public transport demand estimation, travel behavior, demand parameters

I. INTRODUCTION

Traffic congestion is one of the most important and critical problems in most of large cities in developing countries. This is due to high urbanization, increase in number of vehicles, rapid growth of population, improvement of income level, inefficient public transport service, poor traffic management etc. Figure 1 shows the growth of vehicles in India.

Fig. 1: Forecast of Vehicle Populations in India



Source: Ministry of urban transport 2010

In large cities especially more than one million populations such as Nagpur, Pune, Surat, Indore, Bhopal etc which will be the metropolitan towns in near future; Delay, congestion, air pollution and vibration are challenging issues [1]. In order to alleviate these problems, various measures and actions have been planned and implemented such as road-network extension, transport management schemes, traffic restraints, public transport policies, etc. It is therefore necessary to understand the travel pattern of commuters and their choice of transport mode.

Fig. 2: Details of Urban Trips in Indian Cities (Based on City Size)

Source: Census 2011

It is evident from Figure 2 that more people prefer private transport to public in medium sized cities specially cities ranging population between one to two million [2]. This is mainly due to poor service quality and more travel time. The current scenario thus differs significantly from the desired modal split (Table 1) of mass transport [3].

Table 1: Desirable Modal Split in Indian Cities (as a % of Total Trips)
Source: Ministry of Urban Development, Government of India, New Delhi (1998)

City Population (in millions)	Mass Transport	Bicycle	Other Modes
< 5 lakhs	30-40	30-40	25-35
5-10 lakhs	40-50	25-35	20-30
10-20 lakhs	50-60	20-30	15-25
20-50 lakhs	60-70	15-25	10-20
50 lakhs +	70-85	15-20	10-15

The main reasons of imbalance in modal split are:

- Inadequate transport infrastructure, and
- Sub-optimal use of existing transport infrastructure.

The existing public transport systems in the Indian cities have not been able to keep pace with the rapid and substantial increases in demand over the past few decades. Particularly the bus services have much deteriorated, and their relative output is further getting reduced as passengers are continuously switching to personalized modes and intermediate public transport [1].

Manuscript published on 30 October 2012.
* Correspondence Author (s)
Ar Anuj Jaiswal, Department of Architecture and Planning, MANIT, Bhopal, India.
Ashutosh Sharma, Department of Architecture and Planning, MANIT, Bhopal, India.
Jigyasa Bisaria, Visiting Faculty, School of Planning & Architecture, Bhopal, India.

Therefore the analysis of issues in public transport ridership is significant.

Recently the research effort focused on increasing the public transport ridership and also increasing the efficiency of existing public transportation system using different strategies to achieve the desire objectives. This paper aims at a quantitative analysis of existing issues in usage of public transport. Further, probabilistic interpretation of increase in demand is studied by means of a weighed regression model on data of significant factors that influence ridership. The rest of the paper is organized as follows: Section 2 presents related research. Section 3 presents details of various factors that influence public transport ridership. Section 4 and 5 presents the details and analysis of pilot survey conducted among two wheeler users in Bhopal city. Section 6 presents details of recommendations on the basis of analysis results. Section 7 concludes the paper.

II. RELATED RESEARCH

Many studies have been conducted previously for identifying similar factors which directly or indirectly affect the demands of public transport & thus, can play a very crucial role in determining the success & efficiency of a public transport system. Some of the similar studies undertaken in past by various authors/researchers have been summarized in ***Table 2*** as follows:

Table 2: Comparative Analysis in Different Countries for selecting Parameters Effecting Public Transport Demand

S. N	Country	Study	Parameters
1	Sweden (1999)	The Demand of Intercity Public Transport: The Case of Business Passenger *by Fredrik Carlsson*	Fare, Cost, Comfort and Reliability
2.	Bangalore India (2006)	Modeling Travel Demand in a Metropolitan City: Case Study of Bangalore, India *by Prem Pangotra & Somesh Sharma*	PCTR, Modal Split, Trip length, Population
3.	Bangkok (1999)	Analysis of Urban Travel Demand for Developing Countries by Integrating SP and RP data *by Dilum Dissanayake el at*	Travel Time, Travel Cost, Income
4.	India (2010)	Public Bus Transport Demand Elasticities in India *by Kaushik Deb, TERI University, New Delhi*	Transit Fare, Service Quality and Social Variables
5.	Shanghai, China (2006)	Study on the Demand Forecast Method for the Inter Urban Public Transport under the High-Speed Railways in Shanghai-Nanjing Corridor *by Prof. Rong Zhang*	Travel Time, Travel Cost
6	Ljubljana, Slovenia (2010)	Eva Mode Choice Model Parameters Estimation *by Irena Ipsnad, Marijan Žur*	Comfort,Time, Frequency
7.	Germany	Free Public Transport *by Herbert J Baum*	Fare, Travel Time, Vehicle Density, Length, Bus Kilometer
8	Great Britain (2004)	Demand of Public Transport: A Practical Guide *TRL Report 2004*	Fare Elasticity, Time and other Quality of Services, Urban Form, Income
9	Sweden (2008)	Study in Local Public Transport Demand for Sweden *by Johan Holmgren (2008)*	Time, Fare Service Qualities
10	Palestine	Ridership Demand Analysis for Palestine Intercity Public Transport	Fare, Population, Origin & Destination, Age Group
11	India, Chennai	Modeling for Optimization of Urban Transit system: A case study	Travel Time, Travel Cost and Accessibility
12	Hyderabad	Discrete Choice Model for Optimization of Urban Transit System	Travel Time, Travel Cost and Accessibility
13	England	Estimating The Demand for Urban Bus Travel by Paul Mullen	Travel time, Cost, Comfort & Convenience

The public transport demand largely depends on the fare structure, service quality, operation plan, system efficiency and route allocation. These can be broadly categorized as the ones which effect public transport demand directly and others, which can play a role of catalyst, known as latent variables. Following are some of the direct and latent variables (parameters) [4].

- Direct variables
  1. Travel Cost: cost form origin to Destination by any mode
  2. Travel Time: time taken
  3. Trip Length: distance from origin to destination
  4. Comfort levels: posses inside and outside
  5. Accessibility: approach to provide transport facilities
  6. Availability of feeder services: vicinity for model interchange
  7. Density: no. of person per square kilometer
- Latent variables
  1. Landuse: type of landuse
  2. Income: for affordability of private and public mode
  3. Per Capita Trip Rate (PCTR): ratio of total trips to total city population.
  4. Urban form and city structure:
  5. System performance: efficiency of available system.
  6. Demographic: working population, age ratio, sex ratio.
  7. Social factor: income, employment, city characteristics.

Several other sources like as mentioned in ***Table 3***, have also identified the factors that directly or indirectly affect the Transit Ridership. More or less, these are more related to personal preferences & thus are largely subjective in nature & very diverse in nature [5].

Table 3: Factors Affecting Transit Ridership: (Kittleson & Associates)

Convenience	Increase transit service coverage and frequency.
Information	Provide information on where, when and how to use transit.
Price	Keep fares low and offer targeted discounts, such as commuter passes
Speed	Provide express commuter services and transit priority measures
Accessibility	Develop more accessible land use patterns and more diverse transport systems
Integration	Provide park & ride facilities, transit service to major transportation terminals.
Comfort	Provide adequate service so transit vehicles are not crowded
Security	Insure that transit vehicles, facilities and service areas are considered secure
Prestige	Treat transit riders with respect, and promote transit as a desirable travel option.

Factors selected for public transport demand assessment vary across studies and are dependent on the characteristics of cities and countries i.e the existing infrastructure, per capita income, land use characteristics and policies of local government. The significant factors vary in Indian context. Most of the studies illustrated above study demand sensitivity to change in fare and travel time [6].

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

In Indian context, the service qualities like the comfort, convenience and accessibility are also major factors affecting the transit ridership. Thus, study of demand with respect to all these parameters is important.

III. PARAMETERS FOR ESTIMATION OF PUBLIC TRANSPORT DEMAND ON BHOPAL

On the basis of previous studies, it can be summarized that the public transport demand may depend on various factors, ranging from travel behavior parameters (travel cost, travel time, trip length, accessibility ratio, comfort level, frequency, convenience etc), to land use, density, PCTR, etc. Although for the purpose & context of our study which was on the city of Bhopal, we selected only the parameters of travel behavior as they directly affected the demand generation in our context. Thus, the selected parameters were travel cost, travel time, convenience, comfort level and accessibility as mentioned in *Figure 3*. These parameters were selected on the basis of a detailed stated preference survey conducted for understanding the travel behavior of Bhopal.

a. Study of Travel Cost: It represents the willingness of the potential user to pay for the journey as compared to what he'll pay for the private mode. As such, this is general perception that if the travel cost will increase in any of the mode, the demand for that mode of transport will decrease.

b. Study of Travel Time: Travel time is an important factor in the mode choice analysis. It includes egress and access time, waiting time, and journey time. Many of the factors that affect perceived travel time and unit travel time costs have significant implications for transit project evaluation. More accurate analysis tends to increase the relative value of transit improvements over a period of time.

It basically means total journey time spent in a mode of transport as compared to the time incurred in the private mode. A reduction in travel time not only adds to the value of the preferred mode, but can also be evaluated in monetary terms in the form of Time-Cost analysis; as very often, the saved time on a preferred mode of transport can result in more productive gain for the user of that transport, making the mode more preferred over others. Also, travel time can be of very important step while determining the traffic management schemes for synchronizing the existing infrastructure with the proposed one for making the public transportation system most efficient within the optimized use of energy & infrastructure.

c. Study of Comfort Level: Comfort level emphasizes on the extent of inside and outside comfort associated with the public transport system. There are basically two type of comfort:

1. Inside comfort: including
   - Bus condition: interior and exterior
   - Spacious and Comfortable sitting
   - Less crowed
   - Air conditioned
   - Display information
2. Outside comfort
   - Designing of waiting areas at bus stops
   - Cleanness, attractive, well-lit
   - Accessibility to bus stops and parking facilities
   - Informative services
   - Direct services without any interchanges

Such service quality factors can be very important but are difficult to quantify. It is quite difficult to monetize these attributes and results may vary depending on how questions are phrased and who is surveyed. For this study we have grouped all the comfort services in five categories for conducting stated preference survey ranging scale of 1 to 5. Comfort level 5 mean optimum level of comfort can be provided by service provider and comfort level 1 is the minimum requirement from the user perspective.

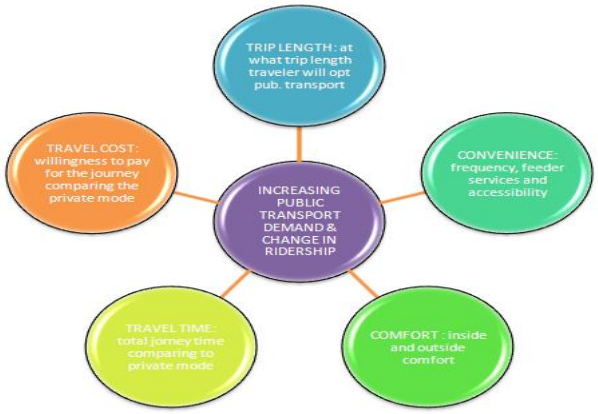
d. Study of Convenience: Similarly the convenience emphasized on the attributes like the frequency, reliable & punctuality, service information's, feeder services and safety. Thus, the steps which determine the good convenience of a public transport system can be like:

1. For reducing waiting time increase frequency with provision
2. Ensuring the reliability and punctuality for the journey.
3. Service schedules and information regarding arrival and departure of buses.
4. Feeder services for interchanges with parking facility
5. Safety and comfort

e. Study of Trip Length: It basically means identifying the minimum trip length above which the traveler will opt public transport over the private mode. It's only up to a certain extent, that the private mode remains the preferred choice for the user, above which the user prefers or can afford the public transportation system even on the costs of other parameters. Thus, a properly considered trip length can hugely affect the observed demands for the public transport services for an area & if managed properly, can significantly increase the efficiency as well as trustworthiness of the public transportation.

f. Accessibility: It is concern of approach and availability of public transport facilities. The demand of public transport is highly depend on the distance for the availability of bus transit facilities, this is general perception that if the public transport is available up to 500 meters which is comfortable distance for walking the bus ridership will be high if the distance is more than 500 meters then the demand for public transport will decrease.

Fig. 3: Most Effective Parameters selected from the Stated Preference Survey



Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

IV. STUDY AREA

Bhopal is the capital of the Indian state of Madhya Pradesh and the administrative headquarters of Bhopal District and Bhopal Division. Bhopal is also known as the *Lake City* for its various natural as well as artificial lakes and is one of the greenest cities in India. Bhopal is planned on a ring radial pattern with a hierarchical road network, as shown in *Figure 4*. The total road length in Bhopal is about 1500 km. The total road length increased from about 531 km in 1981 to about 800 km 1990-91 at the rate of 2.28 % per annum [7]. There are 5 arterial roads of which three are national highway.

Figure 4: Existing Road Network Pattern of Bhopal, Encircling Maximum Demand Nodes

4.1 Public transport scenario in Bhopal: an overview

Bhopal has a decent public transportation system comprising of buses, mini-buses, three wheeled autos and the odd looking tempos that are a major pollution concern for this growing city. Recently, under the scheme of JNNURM, Bhopal City Link Limited operates larger buses, which are under GPS navigation and smaller Metro Buses. In addition, around 600 mini buses are run by private operators. Metro or Radio Taxis and auto-rickshaws are another major means of transport. In some parts in the old as well as new city, the new Tata Magic Vans are running successfully and have replaced the older and bigger diesel rickshaws known as "Bhat". Bhopal is also implementing a "Bus Rapid Transit System", projected to become functional from the year 2013. This study aims at quantitative analysis of increase in transit ridership to public transport if current issues related to the same are properly addressed. Similar model can be adapted to the similar kind of cities in India.

V. MODEL AND METHOD

A stated preference opinion survey was conducted on a sample of two wheeler and car users at 8 locations spread all over the city of Bhopal on major nodes or hubs of transportation activities to understand the reason for not using public transport system and also to identify the condition under which they will ready to shift to the alternate mode. Out of 705 respondents of this survey 81% regarded more travel time as the main reason for not using public transport. Figures 5.1-5.5 represent the proportion of respondents with respect to various reasons for not using public transport.

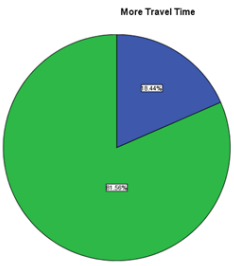


Figure 5.1

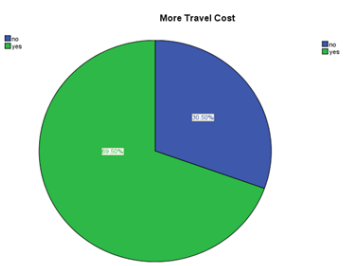


Figure 5.2

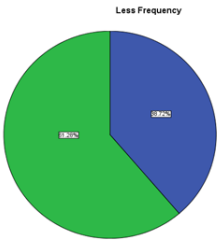


Figure 5.3

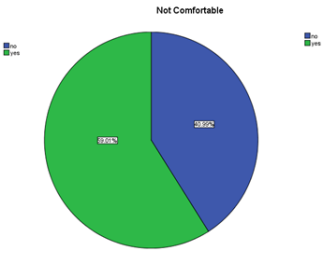


Figure 5.4

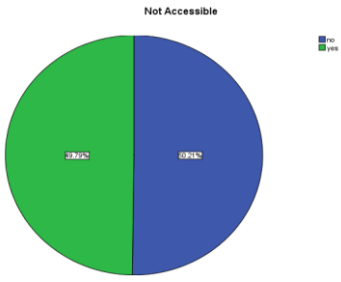


Figure 5.5

Statistical analysis of the use responses reveals that travel time and travel cost are more significant factors followed by convenience, comfort and accessibility for public transport usage. Further, the respondents were queried for their preference rating of significant parameters of interest. The following diagrams reveal number of respondents in the preferred rating.

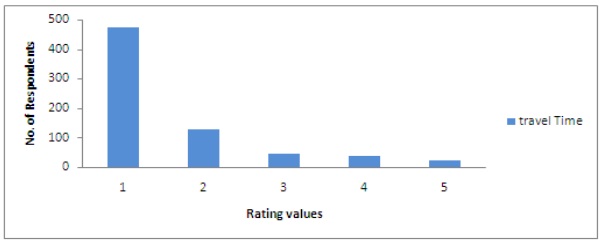


Figure 6.1

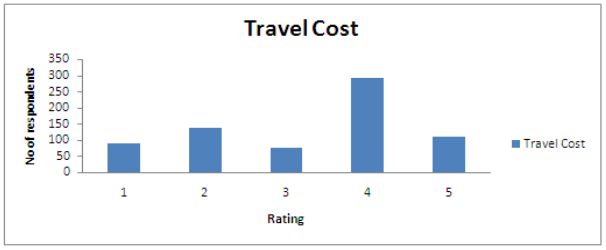


Figure 6.2

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

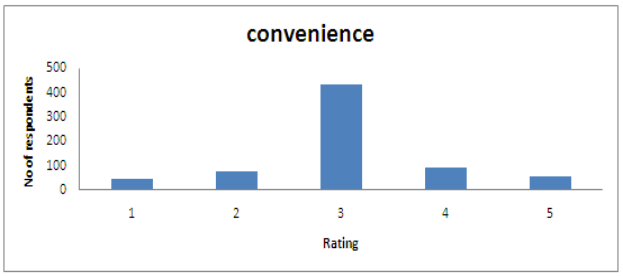


Figure 6.3

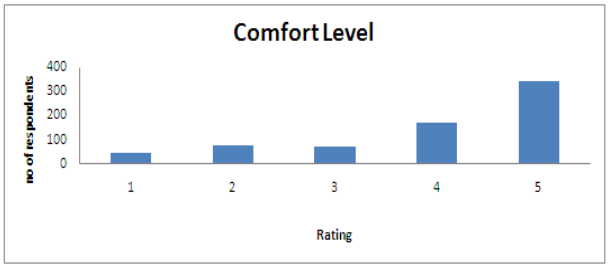


Figure 6.4

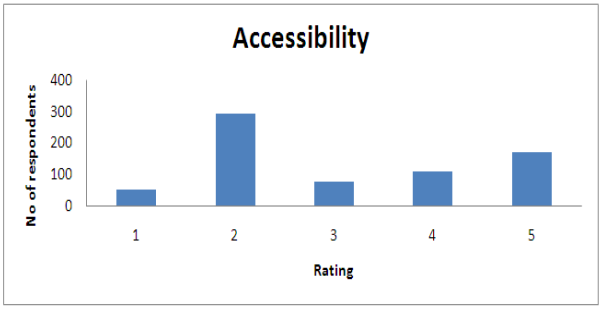


Figure 6.5

The user preferences varied within the sample; on aggregation most of the respondents gave first preference to travel time. This was followed by accessibility, convenience, Travel cost and comfort.

Keeping the rating of underlying factors, two wheeler and car users were questioned about the conditions under which they would switch over to public transport mode. Data of travel time and travel cost were ratio scaled with appropriate weights attached to reflect parameters of higher preference. A regression model was built on the matrix formed by weighed data incorporating factors like convenience rating, comfort rating and accessibility using SPSS Clementine modeling tool. A probabilistic interpretation of results is performed thus enabling calculations of probability of switch over with respect to values of preference parameter.

The analysis of results revealed the following results.

The emerging model is:

Y(Switch over probability)=5.978059+(- 0.35067)*travel time + 2.936463* travel csot + 0.041043*convenience + 0.260799*comfort + -0.00415* accessibility

Regression Statistics	
Multiple R	0.346898
R Square	0.120338
Adjusted R Square	0.001465
Standard Error	3.879848
Observations	43

ANOVA					
	df	SS	MS	F	Significance F
Regression	5	76.19375	15.23875	1.012325	0.424307
Residual	37	556.969	15.05322		
Total	42	633.1628			

The model quantifies the effect of factors level changes and their impact on public transport ridership. The above weighed regression model can be used to determine the optimal values of factors influencing public transport ridership like travel-time, travel-cost, accessibility, comfort, convenience, affordability and flexibility onto the public transport demand. The model fit is validated by means of the chi-square statistic. The model is a reasonable good fit to the data. The sample probability can be scaled to the population of two wheeler owners to determine the absolute value of transit ridership. The absolute quantified values illustrated in the model above in form of ratings and ratio scaled data are explained in the next section.

VI. STRATEGIES TO ACHIEVE THE DESIRED PUBLIC TRANSPORTATION SHARE

Following are some of the proposed strategies for achieving the desired public transport share among the total generated urban trips [8]:

a) **Subsidized Public Transport**: The fare levels in the public transport modes should be targeted to be affordable to a larger percentage of population specially, the lower income group.

b) **Strengthening and Optimization of Bus Services**: In order to provide quick, convenient and economic service, measures like reserved bus lanes, priorities at intersection and good terminal facilities to improve turn round time should be undertaken.

c) **Organized Public Transportation System**: A planned public transport system in terms of routing, scheduling and ticketing system would help in attracting more passengers.

d) **Accessibility to the System**: The system can be made more accessible by expanding its influence area, reducing the walking time and proper information system.

e) **Disincentives for Private Mode Users**: Taxation on motorist, high parking charges and other such ways should be introduced to discourage the use of private mode of transport.

f) **Specific Bus Services**: Bus services targeting people from particular origin or destination can also help in increasing the share of public transport.

g) **Special Consideration:** Consideration of various sections of society such as women, aged people, handicapped etc. while designing the public transportation infrastructure can also immensely help to increase its share.

h) **Interchange facilities:** Provide major interchanges for bus services as in metro trains in Delhi, with proper parking space and informative services

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Apart from these, there are many other possible ways to improve the transit service quality, including reduced crowding, increased service frequency, nicer waiting areas and better user information. Some more measures to improve the comfort ability & the convenience factor are as follows:

- Improving vehicle comfort and cleanliness.
- Increasing service frequency to reduce wait times and vehicle crowding.
- Improving boarding ease and speed, with pre-paid fare collection, wider doors and more convenient loading areas.
- Increasing fare options, discounts and passes purchased through work, school and communities, and for shoppers (similar to merchant-paid parking).
- Integrating fare systems, allowing free or discounted transfers between routes and modes.
- Improving user information, customer service, and marketing programs.
- Parking pricing, parking cash-out, commute trip reduction programs.
- Modal integration, with transit service coordinated with walking and cycling facilities, taxi services, intercity bus, and delivery services (to facilitate shopping by transit).
- Improving security for transit users and pedestrians.

Because discretionary passengers (people who have the option of driving) tend to be particularly sensitive to service quality, these strategies often increase public transport ridership and can immensely reduce automobile traffic. Although few motorists want to give up driving altogether, many are willing to drive less and rely more on alternative modes, provided that those alternatives are comfortable, convenient and reliable. Improving transit service quality can therefore, as mentioned in Transit Service Quality Improvement Benefits (Litman 2005), provide many more benefits like:

a) Benefits existing transit passengers (who would use transit even without the improvements).
b) Benefits new transit passengers (who would only use transit if service is improved).
c) Benefits society by reducing traffic problems (congestion, roadway and parking costs, consumer costs, accidents, energy consumption and pollution emissions).
d) Benefits from economies of scale (increased ridership can create a positive feedback cycle of improved service, increased public support, more transit-oriented land use, and further increase in ridership).
e) Benefits transit agencies by increasing fare revenue.

VII. CONCLUSION

User preferences in public transport have had tremendous impact on its usage. If addressed sensibly it will control traffic congestion and other related problems in time. This paper attempts to evaluate various values of significant factors that influence the probability of public transport ridership. Sensitivity analysis of this model can generate various scenarios that various stakeholders like government, transport service providers can study for optimizing their profitability. From the public perspective this study would encourage government and private public transport providers to improve their service and address issues of public concern.

REFERENCES

[1] Pucher, J & Ittyerah, N 2004, 'The crises of public transport in India: Overwhelming needs but limited resources', Journal of Public Transportation, vol. 7, no. 4, pp 1-20
[2] Akshima, T and Sunder, S 2010, A Focus on the Passenger Transport Sector in Million-Plus Cities, India Infrastructure Report
[3] Sing, S K 2005 'Review of Urban Transport in India", Journal of Public Transport, Vol 8, pp. 67-88
[4] Balcombe, R and Paulley, N 2004, 'Demand of Public Transport: A Practical Guide' TRL Report 2004, TRL Limited, Great Britain
[5] Kittelson & Associates 2003, Transit Capacity and Quality of Service Manual, Report 100, Transit Cooperative Research Program, Transportation Research Board.
[6] Muthukannan, M and Thirumurthy A (April 2008) 'modelling for Optimization of Urban Transit System Utility', ARPN Journal of Engineering and Applied Sciences, vol.3, no.2, pp. 71-74
[7] BCEOM 2009, Study of Bus Rapid Transit system for Bhopal", Bhopal municipal corporation
[8] Jaiswal, A and Sharma, A 2012, "Optimisation of Public transport demand: case study of Bhopal", International Journal of Scientific and Research Publication, vol 2, issue 7,pp 1-16
[9] Wilbur Smith Associates 2008, Study on traffic and Transportation Policies and Strategies in Urban Areas in India final report, Ministry of Urban Development, India

Mr. Anuj Jaiswal is currently working as Assistant Professor in the Department of Architecture and Planning, National Institute of Technology, Bhopal, India. Mr. Jaiswal having total 07 Years Experience of Teaching in Architecture and Planning. He has published five research papers in international journals and six research paper in National Journal.
He has an expertise in field of traffic management road safety and public transport system.

Dr. Ashutosh Sharma is currently working as a Professor in the Department of Architecture and Planning, National Institute of Technology, Bhopal, India. Dr Sharma having total **23 Years Experience** of Teaching in Architecture and Planning. He has published around 50 research papers in National/ international journals. He has an expertise in field of Architecture and urban Planning.

Dr. Jigyasa Bisaria obtained her PhD. in Mathematics in 2010. Her research interests are Statistical Applications in real world, Data mining and Machine Learning. She has served NIC, Govt. of India as Scientist-C. She is currently engaged in various projects related to Statistical data analysis and data mining as an independent Data Scientist. She is teaching statistics and quantitative methods in School of planning and Architecture Bhopal and IIPM Bhopal since last three years.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)