DEVELOPMENT OF EMPIRICAL MODEL FOR PUBLIC TRANSPORT MODAL SHARES FOR INDIAN CITIES

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Abstract— Public transport (PT) is function of various urban factors. As available empirical evidences, PT modal shares are influenced by urban environment variables such as population, urban form, density, average trip length, vehicle ownership, per capita trip rate, bus fare, etc. This paper presents to understand the correlation of various urban factors with PT modal share in Indian cities. As part of the research study, selected about 36 Indian cities and analysed the PT modal share correlation with identified 14 independent variables. The World cities PT modal shares having correlation with Population density, job density, urban form, average trip length, etc. The present study results revealed that Indian cities PT modal shares have correlation with population density, average trip length, population and congestion index.

Keywords— Modal share, public transport, population density, average trip length,

I. INTRODUCTION

India is a rapidly growing South Asian country in terms of urbanization and economic growth. India having 9,391towns/cities and urbanization is around 31% in 2011 and it is estimated to reach 50% by 2039 (Census of India 2011). Urban India presently contributes 63% of India's Gross Domestic Product (GDP) and it has estimated to grow up to 75% by 2021 (Barclays Equity Research Report 2014). Public transportation is one of the key elements of urban development. Public transport (PT) system is one of the key growth factors for urban development. In fact, it's the key shareholder in urban 3e (economy, environment and equality) dynamism. The desirable share of PT in cities will increase employment (economy), reduce the energy consumption, emissions level (environment) and increase the accessibility to all levels of income groups' urban inhabitants (Equality). About 400 out 496 Indian Class-I cities are having population range between 1 and 5 lakhs and where public transport (PT) system is not available.

Public transportation in India is available in the form of city buses, suburban rail, BRTS, Metro rail, monorail and tram (Kolkata). However, bus is the main mode of public transportation in India. The first ever city bus service was started back in 1926 (Dalal, 2014) in Mumbai, 1928 (Jaganath, 2013) in Hyderabad and was gradually introduced in other cities. However, suburban rail and tram are the oldest public transport systems in India started in 1853 in Mumbai and 1873 in Kolkata respectively. Metro rail was introduced for Kolkata in the year 1984, later in Delhi, Bangalore, Chennai and Mumbai. Nearly ten other metro projects are in different stages of implementation across the country. The first BRT system was implemented in India for Pune in the year 2006. Currently, in more than 10 cities BRT system is available and in ten other cities is at various stages of planning and implementation. However, Ahmedabad BRTS is very popular in India due to its successful implementation and operation. Nearly 420 out of 498 Class-I cities public transport system does not exist. This is not because of lack of demand but it is a supply gap. Most of these cities are depending on Intermediate Public Transport (IPT) and Non-Motorized Transport (NMT) systems apart from personal transport like two-wheelers and cars.

Modal share is defined as a share of total trips made from origin to destination by a specific mode out of all modes available for making the trip. Public transport modal shares depend on several influencing factors such as population, land use, density, income level, trip length, road infrastructure, travel speed, per capita trip rate, city size, supply level of PT system, public transport network, frequency, fare policy, etc. However, supply level of PT system is vital for increase in PT modal shares.

In the last decade the Government of India, under Jawaharlal Nehru National Urban Renewal Mission (JnNURM) has funded city buses to select 65 cities during the Mission period from 2005 to 2014. Over 15,000 buses for 61 mission cities and 9,500 buses for select 111 clusters (MoUD, 2014) were sanctioned during the mission period. Due to this, most of these cities PT modal shares have gone up and had shown great impact on supply side. However, at policy side, urban transport reforms implementation progress is not significant. Considering the low PT modal shares in Indian cities, policy makers may enforce on all Class-I cities to implement these urban transport reforms. The authors refer that due to limited funding support, guiding mechanism and policy implementation; cities are taking longer time to introduce the PT system. This is one of the significant factors for turning into lower PT shares in Indian cities.

The present research study on existing PT modal shares revealed that hardly 70 (around 14%) out of 496 Class-I cities (Census 2011) are having organized public transport system in India. In most of these

cities, PT services are providing by state transport corporations and in limited cities by local authorities (such as Mumbai, Pune, Ahmedabad, Delhi, etc.). There are significant research studies and policy level documentations available on Indian public transport system. However, a very few studies have discussed on determinants of Indian cities public transport modal shares.

PT Share Determinants in the World Cities

Public transportation is critical to any city's transportation system and is essential to the economic, social and environmental quality of life (APTA, 2007). Newman (2011) pointed out that high public transport share in a city helps in the following areas:

- Conserve energy and reduce oil dependence
- Increase the road space utilization and reduce the traffic congestion
- Increase the safety and improve the air quality.
- Affordable and accessible to all

Kenworthy et al. (1999) analyzed 100 world cities in terms of automobile usage and tested the correlation among city's characteristics such as density, population, trip length with public transport share. The study recommended that higher modal shares will help the cities in reducing the automobile carbon emissions. The latest study by Land Transport Authority Academy (2011) analyzed the PT modal shares in select World cities (from Europe, America and Australia) and stated that cities have started focusing on increasing PT modal share by implementing large PT projects.

Milakis et al. (2005) suggested optimal density for the sustainable city by referring the case study of Athens city. The study suggests that an increase in density reduces total travelling distances and increase the public transport use. It pointed out that density was positively correlated to trips by public transport and on walk, and negatively correlated to trip by car, mean trip length and energy consumption per capita by car.

White (1974) explains that city's car ownership levels and population density has an impact on PT modal share and developed the regression model for empirical evidence. The author analyzed 12 cities of the United Kingdom (UK) and suggested that low car ownership and high population density cities had higher PT modal shares.

Joly et al. (2004) suggested the determinants of public transport market share. The study identified a strong functional relationship among population density, job density, fuel price, city gross domestic product (GDP) and travel speed. The high population density, job density and higher fuel prices favour higher PT modal share. Higher car ownership and travel speed shows inverse functional relationship with PT modal share. Based on mentioned variables a log-log regression model was developed to estimate the PT market share.

Creutzing (2012) explains PT modal share is a function of urban form, infrastructure investment and marginal transport cost. The author developed a statistical model on optimal provision of public transport and it reveals that the economic feasibility and the spatial scope of public transport depend on urban form and marginal cost of car driving.

Table-1: International studies available on PT modal shares and influencing factors

S.No.	Author/Institute	Year	Parameter/Model	Remarks
1	Paul A.Barter	1999	Density, Car ownership	Impact high vehicle ownership on urban environment, local and global pollutants.
2	Jeffery Kenworthy, Felix B.Laube	1999	Density, car ownership, urban form	High density and high transit based PT system cities are having higher PT modal share
3	F.Nunes da silva , J.de Arreu e Silva	2003	Density, car ownership	Density has no significant impact on car ownership.
4	D.Banister and R.Hickman	2006	Population density, urban form and settlement size, land use	Increase in population density will increase the PT share
5	Jean Vivier	2006	Density, Car ownership. Fuel prices, parking rates, Cost of transport, travel speed	Correlation between PT share and dependent variables in the select World cities (52 cities)
6	Theuns Henning at al.	2011	Travel time, bus fare, coverage area, road safety	A Framework for Urban Transport Benchmarking – Lessons and good practices (Singapore, Colombo, Beijing, Cape Town)
7	Kenji Doi, Masanobu Kii	2012	Travel cost , compact (high density) and CO2 emissions	Compact cities maximize the PT profits and minimize the CO_2 emissions.
8	National Transport Development Policy Committee, MoUD	2012	Population, trip length	Recommended PT share will be at 50% of motorized trips and 35% of total trips
9	Cihat Polat	2012	Population density, travel cost, travel time, travel distance, service levels and land use	PT demand based not only on demand variables but also of supply variables such as marketing strategy, car reduction strategy, environment effects, etc.
10	UN Habitat	2013	Population density, trip length, urban form	Threshold density for introducing PT system and correlation between urban mobility and form.
11	Wang Y. et al.	2014	Urban form, CO_2 emissions	Correlation between urban form and transport CO2 emissions (Beijing). Reducing the travel length will increase the PT modal shares
12	Rajashree Kotharkar et al.	2014	Urban from, average trip length, population density	Trip length is directly related to the city size or area of a city
13	Sean Cooke and R Behrens	2014	Population density and land use	Population density and land use mix influence the PT modal share
14	Litman Todd	2015	Vehicle density, population	Higher densities and lower vehicle ownership increase PT modal share and vis-à-vis reduce the CO_2 emissions
15	Puget Sound Regional Council	2015	Population density	Recommended densities for LRT, MRT and city bus services
16	Wenzhu Zhou and Zhibin Li	2016	Land use and CO_2 emissions	Land use influences city modal split. Compact cities will reduce the travel length and increase the PT share

PT Share Determinants in Indian Cities

The study on Traffic and Transportation Policies and Strategies in Urban Areas of India (1998) by Ministry of Urban Affairs and Employment (MUA&E) has developed a regression model to estimate the public transport modal share of the city. As per the report, PT modal share is function of average trip length. The Ministry of Urban Development (MoUD, erstwhile MoUA&E) has again conducted the study on Traffic and Transportation Policies and Strategies in Urban Areas of India in 2008. The study explains that PT is a function of bus fleet size and urban slum population share.

Table 2: Indian studies available on PT modal shares and influencing factors

S.No.	Author/Institute	Year	Parameter/Model	Remarks
1	GoI Study Group Report	1987	Population, city form	Trip demand model based on city population and urban form.
2	MUA&E	1998	Average trip length	Developed a liner regression model and based on select 21 cities data.
3	Tiwari, ADB	2006	Average trip length	Suggested the desired transport modes for different trip lengths.
4	National Transport Development Policy Committee, MoUD	2012	Population, trip length	Recommended PT share will be at 50% of motorized trips and 35% of total trips

The literature reviews suggest that Public transport modal share is a function of population density, average trip length, car ownership, job density, fuel price, city gross domestic product (GDP) travel speed, urban form, infrastructure investment and marginal transport cost, etc..

Analysis of Indian Cities – PT Modal shares & Determinants

Government of India's Jawaharlal Nehru National Urban Renewal Mission (JnNURM) which is one the major urban missions in India in recent years, has given a strong push in public transport development. Nearly 60 cities have prepared the comprehensive mobility plans (CMP) and nearly 200 cities have prepared city development plans (CDP) during last 10 years. The present study analysis is mainly based on secondary data collection and especially from CMPs, CDPs and related MoUD reports. Most of these reports are in public domain. As mentioned in the earlier section of the paper, in limited Indian cities (around 70 cities) organized public transport system is available. As part of the study, 14 independent variables have been collected and tested regression correlation with PT modal shares of select cities. The analysis has been preformed for select 36 cities. From the literature, we understand that density and average trip length are key variables to influence the PT modal share.

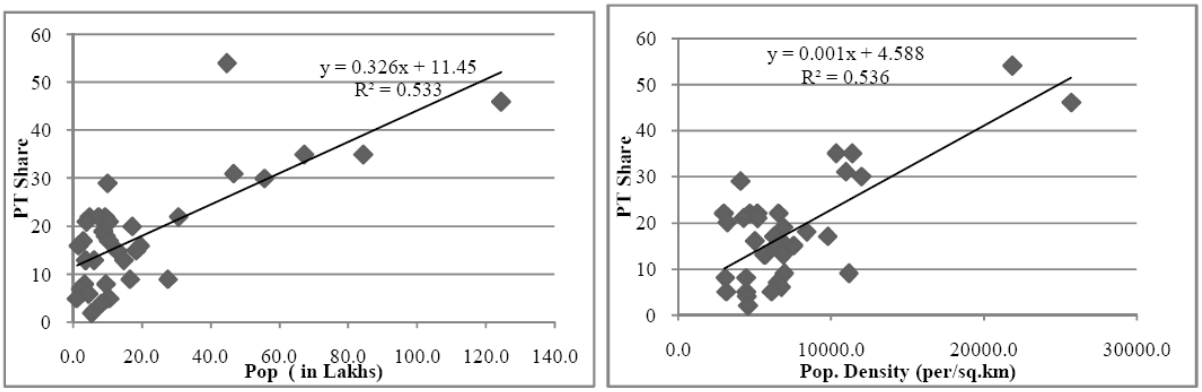

Figure 2. Population and population density correlation with PT modal share

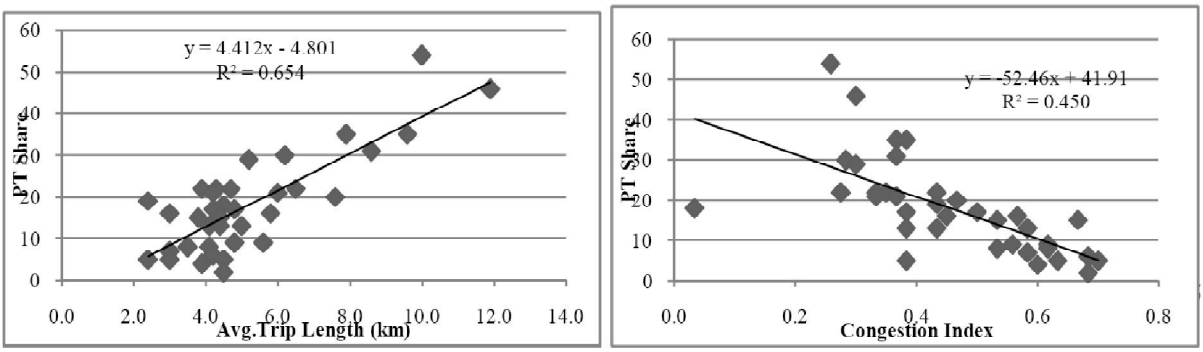

Figure 3. Average trip length and congestion indexcorrelation with PT modal share

Table 4. Indian studies available on PT modal shares and influencing factors

Variable	Intercept	Coefficient	t Stat	p-Value	R Square
Private Vehicle Co2 Emission Index	288.14	-280.06	-13.74	0.00	0.85
Average Trip Length	-4.80	4.41	8.03	0.00	0.65
Population Density	4.59	0.00	6.28	0.00	0.54
Population	11.45	0.33	6.23	0.00	0.53
Congestion Index	41.92	-52.46	-5.28	0.00	0.45
Fleet Size	5.00	0.55	5.01	0.00	0.43
PT Network Density[1]	NA	NA	NA	NA	0.34
Road Network length	13.28	0.00	3.55	0.00	0.27
PCTR	-7.60	21.67	3.38	0.00	0.25
PT Network Share	6.74	55.16	3.35	0.00	0.25
Accessibility Index	9.12	8.52	2.08	0.05	0.11
Vehicle Ownership	26.71	-0.02	-1.28	0.21	0.05
SPM	21.95	-0.04	-1.17	0.25	0.04
Accidents Severity	16.21	0.20	1.07	0.29	0.03

The regression results shows that PT modal shares of Indian cities has a strong correlation with density, average trip length, congestion index, bus fleet size and private vehicle CO_2 emission levels. Private vehicle CO_2 emission levels, average trip length, population and population density having significant correlation with PT modal share. T-stat factors of the four variables are more than 1.96 (as acceptable) and p-values are less than 0.05 which are having more than 95% confidence.

Based on the covariance analysis, five variables have selected for multiple regression analysis for OT modal share model development. All the identified variables are having linear correlation with PT modal share. SPSS software is used for multiple regression analysis and obtained results are presented in Table 5.

Table 5. Multiple Linear Regression Analysis-Results obtained

Variables	Coefficients	t Stat	P-value	R Square
Intercept	162.80	5.99	0.00	0.93
Density	0.02	1.99	0.05	
Average Trip Length	1.85	4.16	0.00	
Congestion Index	-17.36	-3.49	0.00	
Bus Fleet size	0.11	1.96	0.06	
Private Vehicles CO2 emission	-156.28	-5.67	0.00	

Three (density, average trip length and bus fleet size) out of five variables are having positive correlation with PT modal share and remaining two (congestion index and private vehicle CO2 emission) are having inverse relationship. The estimated PT modal share is as follows

PT_{MS} = 162.79+0.02345*D+1.846*ATL-17.356*CI+0.108*FS-156.2*PVCO2

Where,

PT_{MS} = Public Transport modal share

D= Density

ATL= Average Trip Length

CI=Congestion Index (1-existing speed/designed speed)

FS=Bus Fleet size

$PVCO_2$= Private Vehicle CO_2 emission

The observed and estimated public transport modal shares are propitious as presented in Figure 8.

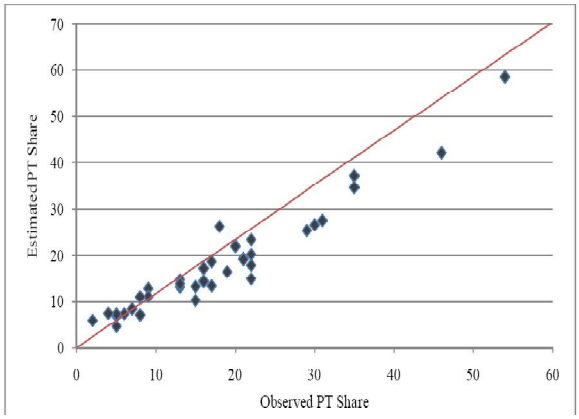

Figure 4. Observed and estimated public transport modal shares of Indian cities

CONCLUDING REMARKS

The major finding from the study is that Indian cities public transport modal shares are significant correlation with five variables i.e. population density, average trip length, congestion index, bus fleet size and private vehicle CO_2 emissions levels. These variables are influencing Indian cities modal shares. As similar to international cities especially as Asian cities, Indian cities have significantly influence the population density and average trip length.

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