A Comparative Study of Bus Rapid Transit System (BRTS) and Metro Rail as an Urban mode of Transport

Vivek Patel[1], Dr. Kedar Bhagwat[2], Deep Patel[3]
[1,2,3] Symbiosis Centre for Management and Human Resource Development, SCMHRD, SIU, Symbiosis International (Deemed University), SIU, Hinjewadi, Pune, Maharashtra, India
[1]vivek_patel@scmhrd.edu, [2]kedar_bhagwat@scmhrd.edu, [3]patel_deep@scmhrd.edu

ABSTRACT

To ensure the sustenance of a high growth in urban population, it is crucial for India to implement reliable and efficient Urban Passenger Transport Systems. According to a UN report "World Urbanization Prospects 2014", by 2030, India will have more than 68 cities with more than one million population and it is expected that, nearly half of the Indian population will reside in cities, which is double the present American population. In India, public transport authorities in metropolitan cities are suffering losses which emphasizes public transport choice to be more relevant. Also, different classes of cities demand different public transport solutions. The selection criteria involve parameters such as Peak Hour Peak Direction Traffic (PHPDT), average trip length, city population, average spending on public transport, cost based comparative approach. This paper examined major parameters to adopt efficient and reliable mode of transport between BRTS and Metro for other cities. This is carried by reviewing the feasibility of BRTS and Metro running in cities with maximize success rate. The focus of the study is also to provide sustainable public transport solution by assessing economic, social and environment factors of existing BRTS and Metro systems running successfully in selected city(s).

Keywords
Sustainable Public Transport Systems, Urban traffic, Passenger Ridership, BRTS, Metro Rail

Article Received: 10 August 2020, Revised: 25 October 2020, Accepted: 18 November 2020

Introduction

India has a highest number of working populations, that means a greater number of people are using urban transport in India than other countries, but when it is compared to the world in terms of quality, quantity and the satisfactory level of passenger, it is not up to the mark. Some of the reason that can be attributed to this is the rapid increase in motorization, country's inability to cop-up with the latest technology, illegitimate management, corruption, overstaffing, low worker productivity due to lack of skill set and other political barriers.

The key decision point for the central government, states and cities is the choice of the Urban Transport System (UTS). Its relevance depends on various types of corridors in same cities and also on different classes of cities as they need different public transport solutions as per their demand. India have been unable to develop proper structure to select the modes of public transport. This study aims to ensure that commercial decisions are taken from the point of view of adequate amount of price discovery to prevent losses. In this study life cycle cost of both modes of transport is included, comparison with other relatable city of the world, affordability, fare comparison, passenger selection criteria to choose among public or private mode of transport. Also, understanding the future forecast to take an appropriate option for public transport in any city. Cities are undergoing unprecedented growth resulting into extension of urban boundaries to accommodate population. National Urban Transport Policy (NUTP) was introduced by federal government so as to provide policy framework for the future to provide sustainable mobility. Federal government, in 2015, presented a new plan to renew 500 cities as well as upgrade 100 cities into smart cities. Consequently, the demand for travel is exploding including growth in number of private vehicles, the problems related to environmental pollution and traffic congestion have also increased rapidly over the last two decades in different urban centers in the entire world. As per the report, The Boston Consulting Group (BCG), the commuters of the major urban centers of India such as Delhi, Kolkata, Mumbai and Bengaluru spend 1.5 hours more on their daily travel compared to other cities of Asia during peak hours. Major Indian cities end up losing about $22 billion per year due to traffic profusion. i.e. cost of fuel burned, opportunity cost, pollution, and accidents. Need to promote public transport as increase in private vehicles lead to around 1.5 lakhs road fatalities every year in India.

Due to high investments on public transport, it is necessary to get a desire return on investment for which a daily minimum number of trips is vital to make it justifiable. The highest attainable trips in the metro cities like Delhi and Mumbai can be 4 crore a day. Due to inefficient public transport if greater share of this trip shift towards personal vehicles than it may lead to saturation of the road infrastructure, and considerable damage is done to environment. To avoid this, minimum of 85-90 percent of daily travel need to be shifted to public transport. It is a conspiracy that even though the travel demands are increasing exponentially but there is a decrease in the share of public transport and thus service providers are running into the losses due to delay in project completion and cost escalation by the time cause to disturb the initial project's financial structure.

In accordance with The National Transport Development Policy Committee estimations, urban transport would be in demand of Rs 10,900–18,500 billion and among them around 55% will be taken by public transport (Centre for

Science and Environment, 2019) [1]. This humongous investment indeed requires meticulous study of all parameters to take legitimate decision and can be eased by integrating government bodies, researchers and related educational institutes.

In the world, after urban bus, Metro Rail is widely used urban transport system. In the recent years, Metro Rail has gained further momentum due to continuously rising in the global crude prices. Currently, in the world, metro rail is operational in more than 175 cities and around more than 50 are work in the progress. Among them, around 9 are in India and about 25 of them are in China. The carrying capacity of the system varies from 20,000 to up to 90,000, and thus is flexible, called as Peak Hour Peak Direction Traffic (PHPDT). The carrying capacity subject to change depending on the type of system.

In general, The Bus Rapid Transit System (BRTS), with dedicated lanes, is a closed mass rapid transit system which gives operational advantage and traffic preference on signals. This concept was first introduced and experimented in Latin America, as it was found more reliable and faster service than ordinary bus services, many cities implemented it, getting mixed outcomes. The experiment was also carried out in Ahmedabad, and since beginning, the experience has been better so far. With some exceptions, the system at its best can carry passenger flow of up to 4,000 to 10,000 PHPDT.

The argument being Metro a premium service for a people of specific income class. Alternately for the one’s it is unaffordable might use bus service or other informal mode instead which does not fulfill the aim of public transport that all modes should be affordable in order to make it feasible. Because for a commuter, nothing prioritizes more than the overall travel cost.

Literature review

If it is motivating the commuters to shift from their private to public mode of transport, only then a public transportation system can come out to be victorious. A good public transportation system may comprise of various public transportation systems including mono rail, metro rail, Municipal Buses, BRTS, etc.). Instead of just competing with each other, it must be complementary to each other in order to share and accommodate the passenger traffic load effectively. For example, in Delhi, metro rail is operated by Delhi Metro Rail Corporation Ltd, suburban rail service by Northern Railway, bus transport service by Delhi Transport Corporation, and taxi & auto-rickshaw by private operators. There is a lack of coordination among these agencies. Since the ultimate objective is to provide an adequate and efficient transport system, there is a need to have a coordinating authority with the assigned role of coordinating the operations of various modes. This coordinating authority may be appointed by the central or state government and may have representatives from various stakeholders such as private taxi operators, bus operators and railways [2].

Since the planning stage itself, it requires an integrated approach. Furthermore, from other countries the experience gained from similar projects on various aspects related to construction, environmental management and its operation can be used for various similar projects in India. Also, many cities might not be dense enough to make metro a cost-effective investment. However, for public transportation projects, most of these future estimations rarely reflect in a real situation. This leads to a flawed decision regarding huge investment affecting government, financial institutions and peoples.

Delhi metro rail construction has brought out several aspects such as social, economic, environment which needs to be addressed to make new mega infrastructure projects more viable.

According to a report by Eurostat, any Indian household spend largely on transportation after food. More spending on transportation result in less spending on basic necessities like housing, health and education services. As per the survey, in the absence of adequate transport facilities, more than 50% of the workforce (excluding agriculture and domestic) either travel to their workplace by foot or continue to work at home. Citizens are heavily dependent on transportation services by private players. The work trips constitute only 18.1% in public transport.

The worst affected class is India’s poor class, due to high rates of public transport, poor class unaffordability for public transport forces them to walk or cycle to reach to their destination. India’s per capita income is 2002 was reported USD 2,600, and as compared to the incomes in the developed nation of western Europe and north America it is less than tenth of their incomes.

In developing countries, due to high level of income disparity the problem of overall per capita incomes becomes more acute. Income is so unevenly distributed that the richest ten percent of the population owns over half of the nation’s income.

Considering the global warming effect, India is on the verge to improve carbon emissions by reducing usage of privately owned vehicles and inclining more towards public transport. Focusing on the emissions and energy requirement for both modes during operations is not sufficient. Over the full life cycle emissions, an electric transit system has more impact on greenhouse gases i.e. CO_2 emissions compared to BRTS as the major source of electricity in India is either by coal or fossil fuels. Recent analysis published in the Journal of Public Transportation depicts that many cities of United States found BRTS as a better option to reduce transportation related emissions which even other cities should implement and that is why BRTS is the only mass transit system to be certified under Kyoto Protocol. Ahmedabad Janmarg Bus Rapid Transit (BRT) system won the Sustainable Transport Award, 2010 for visionary achievements in sustainable transportation and urban livability in a function held at Washington [3].

Policies like higher Floor Space Index (FSI) for development of residential infrastructure in nearby areas of public transport would definitely attract commuters. Also, an efficient governing body could be formed by taking at least one representative from Ahmedabad Janmarg Limited and Delhi Metro Rail Corporation (DMRC) to understand practicability of both mode of transport in particular city.

Methodology

The current scenario of urban transport in the country was studied and the demand forecast of urban transport was assessed based on the population growth of cities. Some of the major mode of urban transport was recognized which are accepted worldwide and majorly in India. It was found that Metro and BRTS (Bus Rapid Transit System) are the two most widely accepted mode of urban transport. The comparison was started by analyzing the suitability of Metro and BRTS as a mode of transport for the city which resulted that comparison should not only be based on the cost, but also on various other parameters which lead to segmentize comparison between BRTS and METRO in to Economic, Environmental, and Social. These parameters were further sub-categorized for more comprehensive evaluation. The first two factors are less static in nature, whereas social factors are dynamic and change from cities to cities, countries to countries. To maximize the success rate of the urban transport mode selected through this model, social factors were also compared at international level to minimise the error. The data was extracted from various government reports available in public domain, surveys done by various private and public agencies, and research papers.

Discussion &findings

A. Economic

To compare among the available alternatives, there is an economic evaluation tool called "Life-cycle costing" (LCC) is used. Here, the important factor is to calculate the operation as well as capital expenditure for both BRTS and Metro. The key factor to note is in a system like metro rail, major constituent is civil structure whose cost is almost 50% of overall cost with a life expectancy of 50 years, compared to normal city bus services having just around 10 years of life span. These different systems have various components which show high amount of variability in terms of their life span as it is and important feature, thus, such variability has been undertaken. For the life cycle cost analysis, due care has also been taken, as a part of analysis, to emphasize how different systems with varying capacity limitation as well as with varying life behave.

Passenger carrying capacity for Metro Rail:

Configuration of Coach	**Train Capacity**	**At 2.5 min. headway Maximum PHPDT**	**At 1.5min. headway Maximum PHPDT**
4	1100	26400	44000
6	1650	39600	66000
8	2200	52800	88000

[4]

As per the observation, generally around 3 min. headway is applicable for most of the Metro Rail.

Passenger carrying capacity for BRTS:

Coach Configuration	**Train Capacity**	**At 1 minute headway Maximum PHPDT**	**At 0.6 minute headway Maximum PHPDT**
1	80	4800	8000
2	160	9600	16000

[4]

As per the observation, generally 0.6 minutes headway is most applicable for BRTS system.

Capital Expenditure of Metro and BRTS:

Mode	**Construction Cost per km per annum (In Crores)**	
Metro	At Grade	160
	Elevated	225-250
	Underground	500-550
	Average	180-200
BRTS		12-14

[5], [6]

Capital expenditure is the initial feasibility criteria for any Infrastructure project and capital invested in Metro is far more than BRTS and can be implemented in very high demand corridors as cannot be possible to recover such huge investment in cities having less demand/less population.

The above-mentioned figures are an actual figures of Delhi metro and Ahmedabad BRTS to create a successful benchmark for the other cities planning to implement either of these. Logically, metro rail is having much demand in the heavy traffic density areas and typically need to run through the inner-city areas to serve peoples and ease the traffic conditions. But this causes disruptions in in the existing traffic control systems and the only way to avoid it is to adopt orientation of metro either elevated or underground which comes at a significant rise in the cost.

Operation & Maintenance Expenditure of Metro & BRTS:

Mode	**Operation Cost per km per annum (In Crores)**
Metro	3.6 - 4.0
BRTS	0.8

Source: Financial Statements of Delhi Metro, 2010 (Delhi Metro Rail Corporation Limited (DMRC)) [4], [7]

Currently, public transport mode is selected by considering the capital expenditure and it's the estimated payback is considered to recover the entire investment. But along with that it is equally important to consider the operational and maintenance cost. The operating cost of Metro is almost 4-5 times the BRTS. So, Metro is not only capital intensive but also operational. The major operating expense of Metro is staff costs and energy cost while in case of BRTS bus operation cost and Intelligent Transportation Management System (ITMS) cost. The bus O & M includes include fuel, staffing, insurance and accident claims, spares and consumables, motor vehicle tax, registration charges and office related expenditure. Initially, Ahmedabad BRTS adopted the model of hiring the buses and pay the fix amount per kilometer to the bus operator which cause to increase the O & M cost. This cost can be further reduced by operating the owned buses instead of hiring as the model adopted by Rajkot BRTS. The purchase of new buses instead of hiring can reduce bus O & M cost by at least half considering the current hiring cost being paid to the operator.

The proposed vs. actual demand of metro of different cities:

In 12th Five Year Plan, for Urban Transport, the Working Group had suggested to change the current selection criteria of DPR based for metro to other different parameters as mentioned in earlier section as DPR assumptions failed to reflect in the practical situations.

City	Existing		Projected		Existing ridership as percentage of the proposed ridership
	Ridership	Year	Ridership	Year	
Mumbai	380,000	2017	1,006,000	2016	-165
Bengaluru	314,166	2017	1,083,000	2016	-245
Delhi	2,700,000	2018	3,950,698	2016	-46
Kochi	33,570	2017	381,868	2015	-1,038
Jaipur	17,649	2017	210,420	2014	-1,092
Chennai	55,000	2017	756,466	2016	-1,275
Lucknow	25,000	2017	429,250	2015	-1,617

[1]

The infrastructure project approved on the basis of just DPR projected ridership can get severely affected as the above data depicts ridership is below 1000% in few cities than projected which ultimately results in to failure of the project. Even government cannot increase the fare too frequent to recover cost on the existing riders as in Delhi after the revision of fare in 2017, 3 lakh ridership per day fell. So, to avoid this kind of situations, few parameters are highlighted here which every city must be critically evaluated before implementing public transport mode.

Life cycle cost (LCC) at variable PHPDT

LCC of metro and brts at same PHPDT would not be able to provide exact scenario and comparison as Metro is high capacity mode i.e. LCC gradually decreases as PHPDT increases and vice versa.

PHPDT	LCC of Metro (In Lacs)	LCC of BRTS (In Lacs)
3000	80.80	41.27
5000	56.94	31.81
7000	45.03	27.81
10000	36.12	24.59
12000	31.88	23.40
15000	27.98	22.17
20000	23.14	21.01
25000	19.97	20.21
30000	18.39	19.75
35000	16.89	19.37
40000	16.05	19.14
45000	15.39	18.92
50000	14.67	18.77

[4]

As per LCC, it clearly shows that the Metro would be more economical than BRTS when PHPDT reaches at least 25000.

Selection Criteria Based on Average Motorised Trip Length:

Mode	Average Motorised Trip Length (In Kms)
Metro	>8
BRTS	>5

[4]

The aforementioned criteria is in integration with "Cost Based Comparative Approach" so as to come up with the suggested appropriate blend of public transport systems. Approving a project based on the capital costs (EPC costs) which is just not enough and that contribute to the reason why transport authorities in huge losses as they fail to consider such practical parameters.

Many tier 2 cities such as Bhopal, Indore, Jaipur, Lucknow, Nagpur etc. have significantly less Motorised Trip Length where metro might not be feasible. Even in the highly populated cities such as Delhi, Bengaluru, Hyderabad, Ahmedabad and Pune are having Average Trip Length of 12.74, 13.71, 13.05, 10.07 and 9.05 respectively.

Fare Comparison:

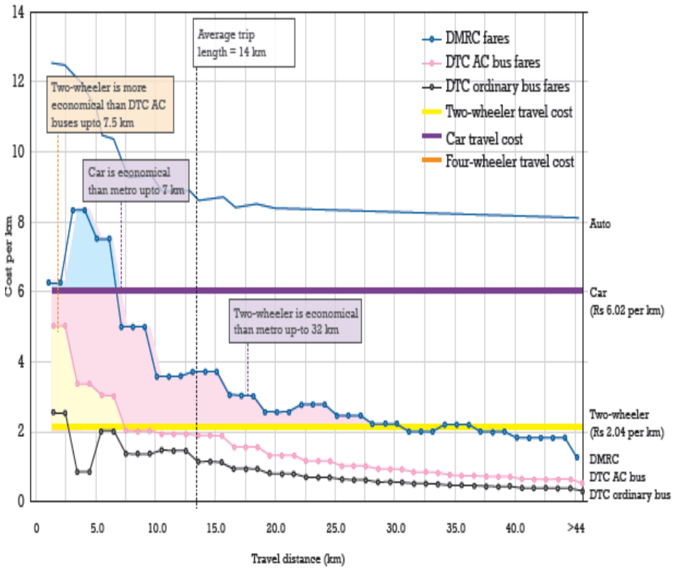
This is the most important parameter to be considered as in India, 269 million people under below poverty line and 340 million middle class people which combine contribute more than 50% of Indian population. The fare of Ahmedabad BRTS and Delhi Metro is as follows:

Range (Kms)	Ahmedabad BRTS (In INR)	Delhi Metro (In INR)	
		Phase I	Phase II
0-2	4	10	10
2-5	7-10	15	20
5-12	13-15	20	30
12-21	22	30	40
21-32	25-27	40	50
<32	29	50	60

[8], [9]

The Metro fare is almost double than the BRTS fare. The one of the reasons for not attaining estimated ridership can be the fare, as commuter prefer to travel in public transport only if it is cheaper mode otherwise, they might shift to private mode. So, Metro must justify the fare by either service, connectivity, Journey time etc. in order to attract commuters.

Mode Wise Travel Cost:



[1]

Since 2009, the fares were hiked twice by DMRC. In May 2017, they implemented the first fare revision and again in October of the same year for second time [10]. Over the 2009 fare, the combined rise was of 91.5 per cent. Due to this, daily ridership was affected and immediately started to decline. This led to people switching to personal vehicles and buses. Two-wheelers and car is more economical up to 32 km and 7 km respectively than Delhi Metro, if the per km cost of two-wheeler and car is considered as Rs. 2.04 and Rs. 6.04 respectively.

For various travel distance categories- percentage of respondents for Delhi Metro (Total number of Respondents – 1112):

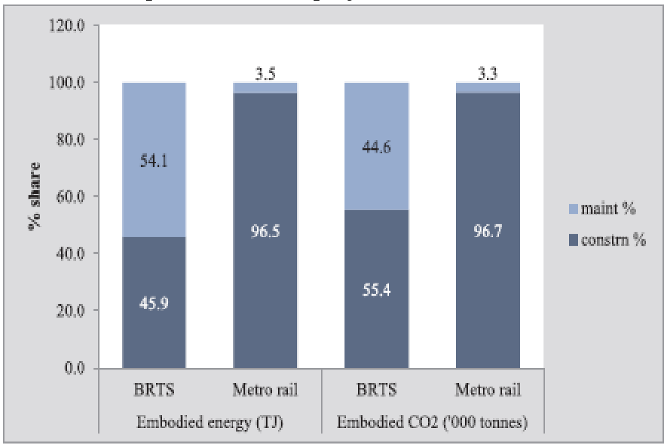
Distance (In Kilometers)	**Respondents (in percentage)**	**Respondents**
Up to 5	4	53
5-10	11.4	127
10-15	17.5	195
15-20	21.7	241
20-25	15.0	167
25-30	12.2	136
30-35	8.0	89
35-40	6.1	68
40-45	3.2	36
45-50	0.7	8
Mean		20.2

[11]

The above survey represents clearly that majority of commuter travel in range from 10-30 Kms. Also, two-wheeler would be more feasible up to 32 Kms as per CSE analysis. Therefore, it becomes difficult to attract the commuter to travel via metro.

B. Environment

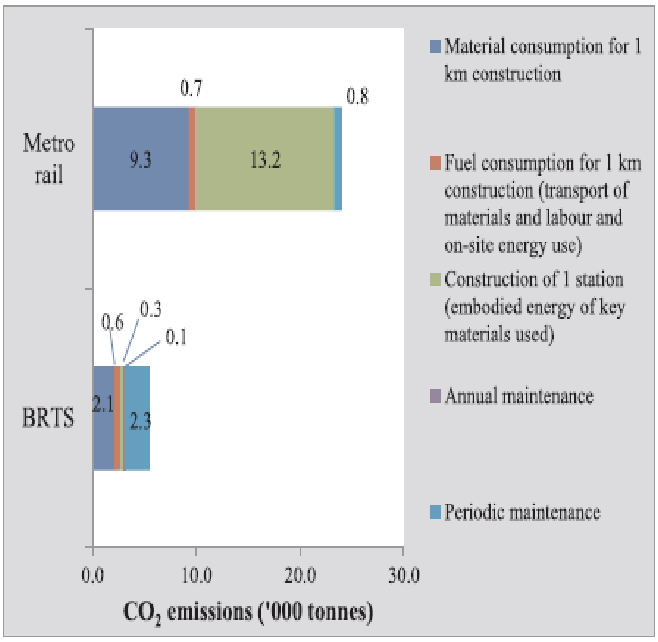
To tackle the issue of rising private vehicles, pollution and congestion, one of the most important measures to be adopted by the city authorities in India is investment in public transport. Many cities in India are in process and many other are planning to implement public transport projects, mostly they are – city bus system, metro rail transit system (MRTS) and bus rapid transit system (BRTS). The technical and financial criteria play crucial role in decisions related to type of public transport system that needs to be developed in the respective city. However, environmental factors are not given sufficient significance while undertaking infrastructure projects especially in the developing countries. In terms of carbon footprint, environmental feasibility can be measured of transport systems throughout its life and it is defined as "An estimation of the total emission of greenhouse gases in carbon equivalents from a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product". India ranks third in the world in terms of CO2 emissions but set a target to reduce emissions by 33% by 2030 compared to 2005 [12]. On 25 November 2019, expressing criticality and sorrow on the pollution of Delhi, the Supreme Court of India said "Delhi has become worse than narak (hell)" which emphasize to attract riders towards public transport. According to the CSE, a bus has the capacity of accommodating commuters of at least 30 cars at a one sixth of the fuel required by 30 cars and ultimately reduction in pollution. The aim here is to determine life cycle environment impacts of public transport projects occurring during all the three phases i.e. construction, operations and maintenance phases of these projects.

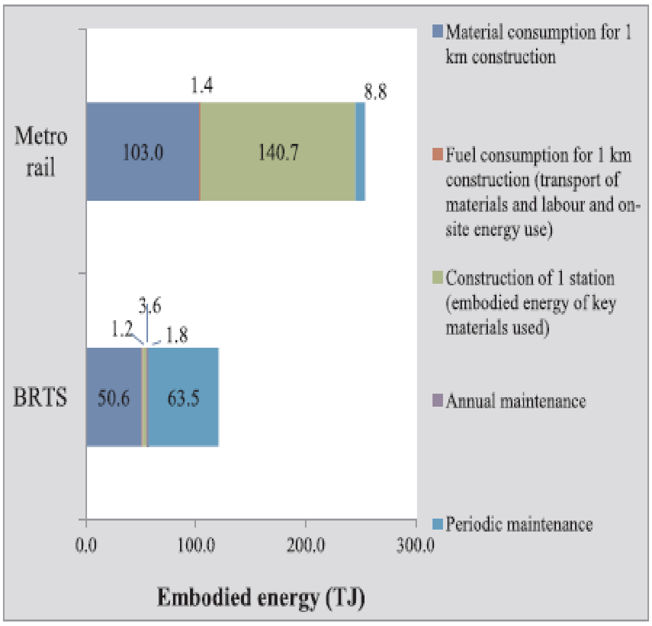


Share of maintenance and construction related activities in embodied CO2 and embodied energy of urban transport projects (Analysis by TERI) [13]

Construction related activities of metro rail contributed as large as 97 percent for both CO2 emission and embodied energy, on the contrary in case of construction of BRTS, total embodied energy contributes 46 percent and for CO2 emission, its 55 percent.

At worldwide, the major reason for opting Metro is to reduce CO2 emissions as it run on electricity and generates significantly less emissions during its operation phase. But it is equally important to calculate the CO2 emissions for the life cycle i.e. Construction and Operation phase. It is evident that majority of emissions by metro is during the construction phase which cannot be neglected.





Metro Rail and BRTS: Energy consumption and CO2 emissions during construction and maintenance of system considering the life span of 30 years (Source: TERI Analysis) [13]

The total embodied energy required per km for construction and maintenance purpose, as compared to 120 terajoules (TJ) for BRTS, Metro rail is projected at 254 (TJ). As compared to 5500 tones for BRTS, the CO2 emissions per km for maintenance and construction of Metro rail for the time frame of around 3 decades is projected at 24,000 tones [13]. It is very much evident from the facts that Metro rail consumes more energy and higher CO2 emissions due to usage of carbon intensive materials like concrete and steel and energy to a larger extent. Construction of a Metro station is the major contributor in emissions and energy consumption.

Rather than taking into the account only the total fuel consumed in operation and total tailpipe emission, it is better to consider the CO2 emission and full life cycle energy for BRTS and metro rail, for better extensive intuition so as to understand how it will affect the overall environmental structure of that area. Environmental damage can be control by timely and efficient maintenance of the vehicles, but Indian automobile system has not given due consideration to it.

C. Social

The success and failure of Public Transport Service depends on following important parameters:

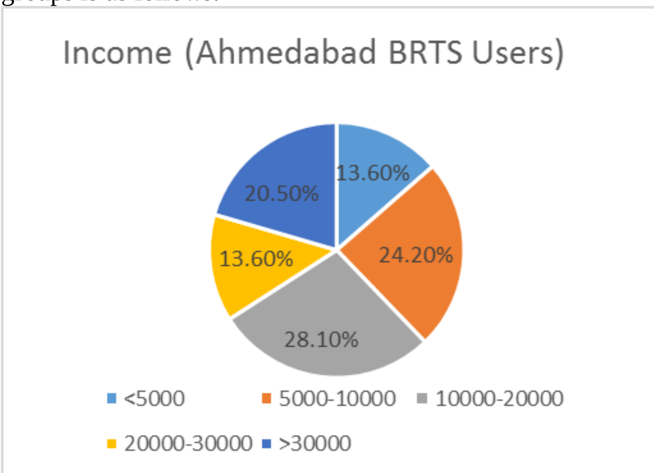
1. Inclusiveness and affordability of the public transport services
2. Financial feasibility of the public transport systems

Affordability comprises of two major following components. Firstly, the market segment of public service must be able to incorporate each and every sections of the society. Secondly, the public transport ought to be cheaper than other private or informal modes of travel otherwise as per the current scenario in India, many people prefer two-wheeler over public transport as it is significantly economical. For transportation, the affordability can be defined as the scale to which any household or an individual can financially afford to travel wherever and whenever they want.

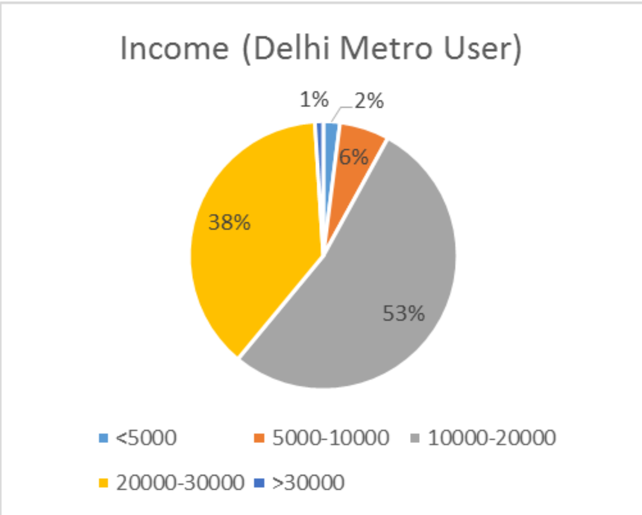
This factor is analysed on the basis of User travel characteristics such as Average Income Spent, Access and Egress distance travelled.

Travel Based on Income slab:

The survey conducted for Ahmedabad BRTS and Delhi Metro users to assess the behaviour of different income groups is as follows:



City	Monthly Income		Average Trip Length	Fare of Public Transport		Expenditure per month on Public Transport	Income spent on Transportation in percentage	
	Skilled	Unskilled		Mode	Fare per trip (INR)		Skilled	Unskilled
Delhi	16,848	13,884	12.9	Bus (Non-AC)	15	1,170	7	8
				Bus (AC)	25	1,950	12	14
				Metro	40	3,120	19	22
Ahmedabad	8,559	8,112	9.71	BRTS	20	1,560	18	19
				City Bus	12	936	11	12



[14], [15]

The above survey clearly depicts that the percentage of users having less than income of Rs. 10,000 are 37.8% and 8% for Ahmedabad BRTS and Delhi Metro respectively. So, it means that it is not financially viable for the lower income group of peoples to travel by Metro in Delhi. BRTS is largely used by labourers, lower & upper middle-class people whereas Metro is a premium service meant for only lower & upper middle-class and higher-class people.

Average Income Spent on Public Transport in Different Cities:

Researchers in general, focus on the percentage of income people spend on transportation to define the affordability of transportation. As per these definitions, in Indian context, an assessment shows that, on transportation, each household spends almost 15 per cent of their income.

In both cities, on premium transportation services, the lower income group needs to spend around 20 percent of their monthly income. In addition to this, these costs increase significantly due to additional trips required to access health facilities and schools. The data signals that premium public transport services are not in the reach of lower income groups which apparently are in significant numbers in any city.

To prevent from shifting to personal modes from public transportation such aforementioned contrasting aspects are collectively responsible for determining as to what extent such public transport will continue to serve the larger population. As personal mode leads to causing the traffic problems to get more worsen, increased pollution and heat-trapping emissions.

Majority of the studies reveal that, for the system to be affordable, the average income spend on transportation must fall in the range of 10-15 percent. Fair setting committee should look upon this scenario and set accordingly. In Ahmedabad, income spent is 18% and 19% for skilled and unskilled workers respectively which is already more than 1.5 times the City bus. Now, as metro is proposed in Ahmedabad, these percentage would definitely get doubled considering the fare of Metro and would not be affordable as the average income in Ahmedabad is half of Delhi. So, metro can be affordable in one city and cannot in other depending on the average income of the city. But one thing that is transparent is that even Delhi which is one of the cities having better pay scale in India, workers need to spent around 20% of their income, Metro cannot be affordable except major cities like Delhi, Mumbai, Kolkata, Bengaluru, Chennai, Hyderabad.

Access and Egress distance for BRTS and Metro:

For any commuter, the overall trip distance and time matters. Above this even cost can be the factor as more the access distance for either of public transport, more the cost incurred to reach station. Government policies support to reduce the distance by allowing more Floor Space Index (FSI), vertical development to provide more accessible public transport. New Delhi is one of the first cities to have adopted TOD in India. For the Master Plan of Delhi (MPD), the Delhi Development Authority (DDA) categorized the city's TOD influence areas into three zones: intense, standard and transition. The intense zone is the most compact, with 300 m around all metro stations, and 800 m around regional interchange stations. The standard zone is 800 m around all metro stations. The transition zone is 2000 m around all metro and regional interchange stations, taking 10 min of cycling into account [16]. The access and egress distance for Delhi Metro and Ahmedabad BRTS as per the primary survey of MDPI and UNEP is as follows:

Mode	Access Distance Range (In Kms)	Percentage of Users	Egress Distance Range (In Kms)	Percentage of Users
Metro (Delhi)	<0.5	12	<0.5	18.4
	0.5-1.0	21.5	0.5-1.0	26.8
	<1.0	66.5	<1.0	54.8
BRTS (Ahmedabad)	<0.5	50.5	<0.5	57.9
	0.5-1.0	15.3	0.5-1.0	13.1
	<1.0	34.2	<1.0	29.0

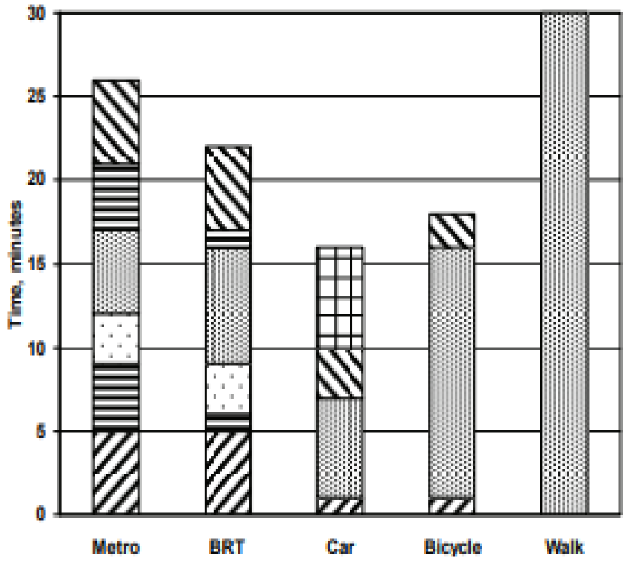
[14], [16]

The median distance for BRTS is 0.38 km, meaning that half the population travel 0.38 km or less to reach the station and 0.27 km to reach destination from station, which is a walk of about 5 to 7 minutes and 65% people travel less than 1 km which means it is reasonably accessible for the commuters. The distance to be travelled for access and egress in case of BRTS is more or less the same.

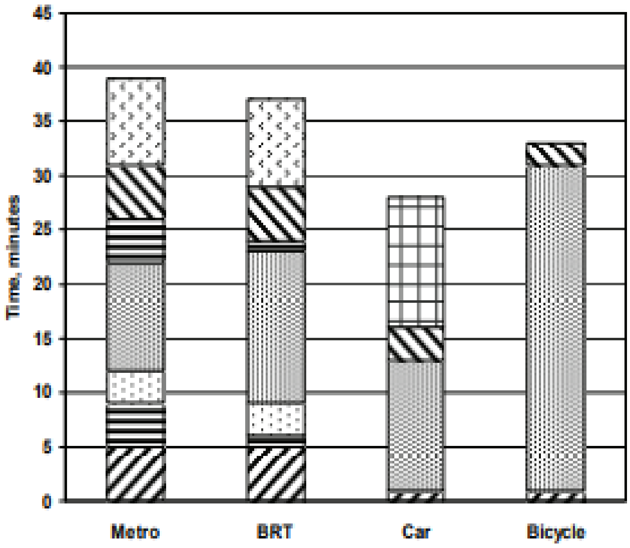
But in case of Metro, 66% people travel more than one kilometer to reach station which eventually need to travel by either informal or public transport as India's national Transit Oriented Development policy stipulates 500-800 meters as the possible walkable distance as beyond that cause to increase in time and cost of journey.

Trip time by various modes of transport:

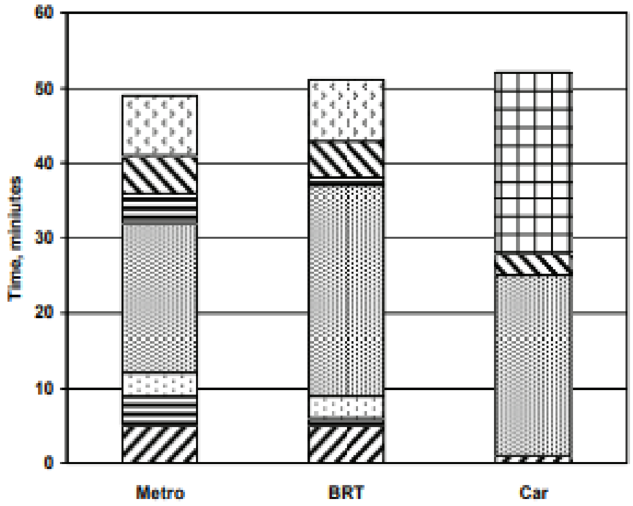
In this busy era where time is most precious for everyone, travel time is the most important factor and commuters might even willing to pay more for the earliest mode of transport. The travel time taken for different trip length is as follows:



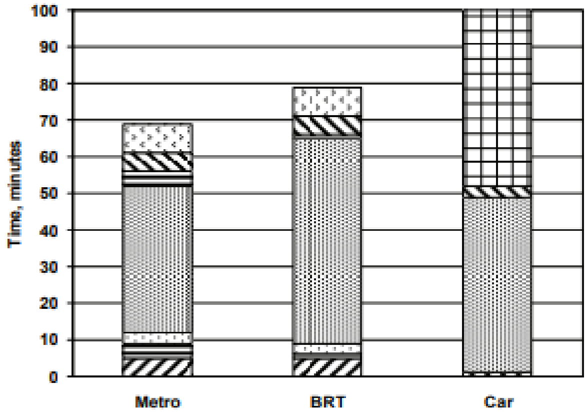
(a) 3 km



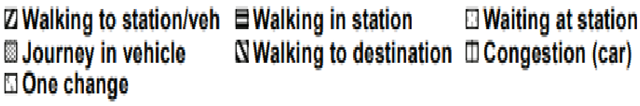
(b) 6 km



(c) 12 km



(d) 24 km



Door-to-door trip times by various modes of transport [17]

The above data shows:

a) For distances less than 6 km, BRT is more time saving mode than the metro.

b) The metro becomes efficient only for trip distances which are greater than 12 km.

c) The time taken for walking in the station to reach the metro train is more than to access bus at the station.

d) Practically even for 12 km trip, Metro cannot be feasible as for saving 1-2 minutes one cannot afford to pay the double fare compared to BRTS. A significant time saving benefit is seen when one travels 24 km or more than that but as per the surveyed sample size data by UNEP, around 55% people have trip length less than 20 km and 15% in range of 20-25 km which means more than a half market segment have also another alternate mode to travel.

Even if there is congestion on road, if you introduce 1 feeder trip or 1 change for a metro trip, then, for trips less than 12 km, travel time by metro is more than by motorcycle or car. Unless the trip is very long or there is congestion on the road, then as compared to motorcycle or car use, underground and elevated public transport systems fails to provide the requisite time saving. For almost all the trips less than about 10-15 km, BRT on dedicated lanes becomes more efficient because of, as shown above, much time is spent on long walking distances inside elevated or underground monorail and on escalators of the metro stations [17].

Percentage of Population Travelling in Metro of World Metropolitan Cities:

City	Population (In Million)	Daily Ridership (In Million)	Percentage of Population	Ridership per Kilometer
Delhi	15.9	1.66	10.44	6,950
Beijing	11.1	6.74	60.72	11,800
Shanghai	15	6.24	41.6	9,860
London	8.57	3.21	37.54	7,980
Tokyo	35.7	8.5	23.8	27,000
Moscow	10.5	6.55	62.38	18,900
Paris	9.9	4.18	42.2	19,000
Singapore	4.44	2.18	21.7	10,900

Note: Data as per 2011/2012, [18]

Though Delhi Metro is considered the success in India but, since its inception, it failed to attract the commuters and not even closer to the percentage of people travelling with the other metropolitan cities of the world. Many cities having significantly lower population still be able to generate more ridership than Delhi. Beyond this, Mexico City's metro system is smaller but carries double riders daily. Singapore, on the other hand, with a track length less than two-third of Delhi's track length been able to fetch 10 per cent more riders than Delhi. The major reason for not achieving proper ridership is the design of the network of tracks. The heart of the city, in many cities, gets special treatment in terms of no. of stations, lines, frequency of train, etc. to serve as much as traffic load with ease. In an 87 square kilometer area, Paris has 245 stations in the heart of the city. There is a centre line in London, a 50 km line in Moscow that encircles the major traffic points of the city unlike in Delhi where much of the track length ends up in the outskirts [19]. Due to lack of stations and last mile connectivity, more than 60% people have to travel more than 1 km distance to reach Delhi metro station. With a figure of 27,000 riders daily, the passenger track ratio is the highest in Tokyo for every kilometre of track and about to 19,000 for Paris, 18,900 for Moscow and lower numbers in other cities: Shanghai and London. At the least, the system should target for a figure of 20,000 or a doubling of riders with the same track length. Delhi, standing last in the queue among all the major metros of the world operates at a passenger-track ratio of less than 7,000 which means heavy investment is locked into infrastructure and unable to reflect in ridership resulting a feasibility question mark on metro. Delhi Metro is underutilized even after the huge investment which can be well understood by comparing it with the Shenzen, China. Both cities commenced the metro around the same time along with similar track lengths. But, Shenzen ridership is 10,000 more people per kilometer than of Delhi in 2017-18 resulting 730 million more ridership per annum [20].

Conclusion &B Recommendations

Out of the Economic, Social, and Environment factors mentioned in the paper related to Metro and BRTS, India need to focus on the Economic factor as other factors are directly or indirectly dependent on it. The metro rail projects are mostly implemented in large cities as they are capital intensive projects. The high cost of construction of such projects can be justified by the accrued, indirect and direct benefits. If the public service is beyond paying capacity of a citizen who is rightfully earning the legal minimum wage defined by the law of the nation, that service cannot be claimed to be an affordable one. Delhi Metro is on the second rank as the most unaffordable Metro among the world's nine metropolitan cities as passengers travelling on it has to spend 14% of the income on metro travel which is just before Hanoi (Vietnam).

Fare of world metropolitan cities:

City	Fare
Caracas	$0.40 - $1.50
Cairo	$0.06
Delhi	$0.12 - $0.46
Mexico	$0.27
Hong Kong	$0.30 - $0.44
Shanghai	$0.44 - $1.31
Tokyo	$1.53 - $2.78
Paris	$2.02
Moscow	$0.87
Dubai	$0.51 - $2.32

[21]

On the contrary, fare of Delhi Metro is much low compared to the other metro cities of the world. But the major problem being still unaffordable is the per capita income, people in India are not able to earn which is required for the Metro. The government authorities cannot argue on the basis of the world metro fares. Government must implement the low capital intensive, affordable, easy & reliable mode of transport such as BRTS. As per the research, akin to the metro at lower costs, suburban and buses have the potential to come up with high quality frequent service. Financing benefits can add more sustainability to it such as higher debt percentage, lower interest rate, longer moratorium and repayment period. Investments in a broader range of public transit systems that ensure last-mile connectivity could make our cities more equitable for everyone. The population of Bogota resembles the population of Bengaluru of around 82 lakhs, the per capita income of Bogota and Bengaluru is 1.7 lakh and 49000 respectively. Even after 4 times the per capita income of Bengaluru, Bogota found Metro as an expensive mode of transport and implemented BRTS along with bicycle paths, improved pedestrian facilities which is having a huge success. Other cities of the world are trying to implement the same. Currently, the ridership of Bogota is around 22 lakh per day which is much impressive as serving this huge ridership must require proper design and network connectivity. A planned BRTS with good connectivity can be the solution of public transport in many tier-2 cities of India because the major reason of implementing Metro is to serve more riders but the same can be done by increasing the BRTS network with very less capital and time. In search of sustainable public transport solution, BRTS must definitely considered in the countries like India where traffic demand is uncertain and cities are growing at varied pace as once the investment is induced can't be revert back. Consulting with the Bogota and Ahmedabad city transport authorities to draft a plan for the city of India can help to improve BRTS feasibility and the success rate by critically evaluating every parameter. Privatization of the public transport services can be one of the options to make it more affordable including lower costs, higher productivity, more passengers per bus resulting into better usage of resources, commuter comfort and higher revenues per bus km of service. Bangalore and Hyderabad public transport authority have already implemented this and to the private operators have handed over much of their bus services at an agreed contract of payment per passenger and gaining better results. Some of the steps that government can take to reduce the private mode of transport are increased vehicle taxes, fuel taxes, levy heavy penalty on illegal parking, instigate pay and park areas, greater priority to normal buses during peak hours etc. An integrated payment system should be design in which the commuters are provided with a single card, which can permit payment for public and private transportation system in the city.

Limitations

This research is done based on the secondary data available from various trusted government reports, News website and survey done by consulting agencies. On primary data collection, data may get varied from the data used in this research. The sample size taken for survey may or may not get completely resemble with the actual population. Similarly, the sample patch of Metro and BRTS project taken for environmental emissions may vary somewhat with overall project emissions.
Secondly, this model would be more successful to the cities having demographic conditions similar to Delhi and Ahmedabad compared to other cities

References

[1] Centre for Science and Environment, "The Cost of Urban Commute: Balancing Affordability and Sustainability," Centre for Science and Environment, New Delhi, 2019.

[2] S. Singh, "Review of Urban Transportation in India," Journal of Public Transportation, vol. 8, no. 1, pp. 79-97, 2005.

[3] National Institute of Urban Affairs (NIUA), "AHMEDABAD BUS RAPID TRANSIT SYSTEM," [Online]. Available: https://carbonn.org/uploads/tx_carbonndata/File1_AHMEDABAD%20BRTS.pdf.

[4] Institute of Urban Transport (India), "Life Cycle Cost Analysis of Five Urban Transport Systems," 2012.

[5] R. Banerjee, "Built at 552 crore per km, Ph-III a costly affair," 24 October 2015. [Online]. Available: https://timesofindia.indiatimes.com/city/delhi/Built-at-552-crore-per-km-Ph-III-a-costly-affair/articleshow/49511400.cms.

[6] J. Pucher, N. Korattyswaropam, N. Mittal and N. Ittyerah, "Urban transport crisis in India," Transport Policy, vol. 12, no. 3, pp. 185-198, 2005.

[7] M. L. Chaudhary, "Urban transport management socio economic cost benefit analysis of brts in ahmadabad," Shodhganga, 2016.

[8] "FARE REVISION OF DELHI METRO," June 2020. [Online]. Available: http://www.delhimetrorail.com/press_reldetails.aspx?id=jkOjxn1IG6Ylld.

[9] "Fare Chart," June 2020. [Online]. Available: http://125.17.144.54:8082/information/fare-chart/.

[10] Hindustan Times, "Delhi Metro ridership takes a hit after two fare hikes in 2017," 16 March 2018. [Online]. Available: https://www.hindustantimes.com/delhi-news/delhi-metro-ridership-takes-a-hit-after-two-fare-hikes-in-2017/story-TqBGkVKl3EPKvtCCAs2DzH.html.

[11] R. Goel and G. Tiwari, "PROMOTING LOW CARBON TRANSPORT IN INDIA," United Nations Environment Programme (UNEP), 2014.

[12] G. Seetharaman, "Why it is difficult to come up with a viable public transport model for all cities," 6 October 2018. [Online]. Available: https://economictimes.indiatimes.com/news/economy/infrastructure/why-it-is-

difficult-to-come-up-with-a-viable-public-transport-model-for-all-cities/articleshow/66101927.cms#:~:text=A%20bus%20roughly%20carries%20as,to%20the%20International%20Energy%20Agenc.

[13] A. T. Ghate and S. Qamar, "Carbon footprint of urban public transport systems in Indian cities," Elsevier, vol. 8, no. 1, pp. 245-251, 2019.

[14] D. Mahadevia, R. Joshi and A. Datey, "PROMOTING LOW CARBON TRASPORT IN INDIA," United Nations Environment Program (UNEP), 2013.

[15] V. K. Yadav, D. S. Ram and D. A. Arora, "PLANNING FOR ENVIRONMENT FRIENDLY TRANSPORT AS A FEEDER TO METRO," [Online]. Available: http://www.urbanmobilityindia.in/Upload/Conference/1492167c-6666-4e95-8289-62c48770d5bd.pdf.

[16] S. Ann, M. Jiang, G. I. Mothafer and T. Yamamoto, "Examination on the Influence Area of Transit-Oriented Development: Considering Multimodal Accessibility in New Delhi, India," Sustainibility (Switzerland), vol. 11, no. 9, 2019.

[17] D. Mohan, "Mythologies, Metros & Future," Transportation Research and Injury Prevention Programme (TRIPP), New Delhi, 2008.

[18] "WORLD METRO DATABASE," 2011,2012. [Online]. Available: http://mic-ro.com/metro/table.html?feat=CIANCOCNSNOPLGSTSSLILSLLSLDPPLAPPYPOUSLRTPTRWDPCVORUDRDYPDACWTRM&orderby=LG&sort=DESC&unit=&status=.

[19] T. Ninan, "Why Delhi Metro carries far fewer riders than almost any other city's system worldwide," 17 November 2018. [Online]. Available: https://theprint.in/opinion/why-delhi-metro-carries-far-fewer-riders-than-almost-any-other-citys-system-worldwide/150654/.

[20] S. Devulapalli, "India's public transport challenge," 16 September 2019. [Online]. Available: https://www.livemint.com/news/india/india-s-public-transport-challenge-1568355574941.html.

[21] R. Wade, "Public transportation prices in 80 worldwide cities," 19 May 2017. [Online]. Available: https://www.priceoftravel.com/595/public-transportation-prices-in-80-worldwide-cities/.

[22] Delhi Metro Rail Corporation Limited (DMRCL), "Ahmedabad Metro DPR," [Online]. Available: https://www.gujaratmetrorail.com/wp-content/uploads/2016/07/Ahmedabad-Metro-DPR-2014.pdf.

[23] Delhi Metro Rail Corporation Limited (DMRC), "Annual Report," [Online]. Available: http://www.delhimetrorail.com/annual_report.aspx.

[24] Economic Times, "Metro ride in Delhi is 'second-most unaffordable' in the world," 5 September 2018. [Online]. Available: https://economictimes.indiatimes.com/industry/transportation/railways/metro-ride-in-delhi-is-second-most-unaffordable-in-the-world-study/articleshow/65681122.cms?from=mdr.

[25] Moneycontrol, "Most expensive metro fares in the world: Find out where Delhi and Mumbai rank," 10 September 2018. [Online]. Available: https://www.moneycontrol.com/news/business/most-expensive-metro-fares-in-the-world-find-out-where-delhi-and-mumbai-rank-2933921.html.

[26] R. Chandran, "Urban transport debate: Is BRTS the answer?," 20 July 2010. [Online]. Available: https://www.livemint.com/Politics/rmrv69KmokVhBrcyee7nHM/Urban-transport-debate-Is-BRTS-the-answer.html.

[27] P. John, "In era of BRTS, users of public transport shrink," 1 January 2016. [Online]. Available:

https://timesofindia.indiatimes.com/city/ahmedabad/In-era-of-BRTS-users-of-public-transport-shrink/articleshow/50404282.cms.

[28] R. K. Kaufmann, A. Bradford, L. H. Belanger, J. P. Mclaughlin and Y. Miki, "Determinants of OPEC production: Implications for OPEC behavior," Elsevier, 2007.

[29] M. Pai, "Ahmedabad takes the bus," 17 May 2006. [Online]. Available: http://www.indiatogether.org/brts-economy.

[30] N. Sharma and R. Dhyani, "Critical Issues Related to Metro Rail Projects in India," Journal of Infrastructure Development, vol. 5, no. 1, pp. 67-86, 2013.