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Smart Urban mobility: Road less travelled

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Abstract

The study attempts to analyse congestion problem with emphasis on having a policy incorporating realistic solution for having affordable, accessible, reliable and acceptable mobility. It has been found that in Indian urban scenario, modal transport system must be capable of having flexible high carrying capacity with low space requirement. The other aspect is to have attractive public transit system which may lure people away from private transport to public transit system because traffic problem is going to only rise with population growth and development. This will put more pressure on road infrastructure which has substantial costs. A possible solution could be introduction of Light Rail Transit (LRT) on a large scale. Finally, an illustration of Bangalore city has been made to examine the benefits of LRT.

Keyword: Affordable, accessible, reliable, acceptable, mobility, flexible high carrying capacity, attractive public transit system

Smart Urban Mobility: Road less travelled[1]

In the present day urban scenario, there is need for providing an affordable, accessible, reliable and acceptable mobility - in short acronym 'AARAM'- a Hindi word meaning comfort. As with increasing congestion, urban mobility has become synonymous with time consuming stressful daily urban commute. And now the government is considering setting up 100 smart cities.

Urban mobility is an important determinant of city's economic function and productivity. It is movement of people from one place to another for some economic activity. The globalized world has led cities to compete against each other for economic opportunities and wealth creation. Ultimately those cities are going to be successful which demonstrate ease of business and comfort of life. Since cities serve to reduce cost of connecting people by providing economies of scale in form of agglomeration, their productivity, efficiency and amenities are significantly influenced by changes in transportation system and technology. Thus, urban mobility plays a major role in shaping the economic contour and destiny of a city.

In India, with rapid growth in population and more economic activities, cities have become the focal point of job creations and prosperity. Rapid rise in population of cities due to natural growth and migration of people from hinterland to urban centers have put immense stress on city infrastructure. Coupled with economic development and higher aspirations, there has been a significant increase in demand of vehicles. Thus, congestion and consequent travel time has increased despite modern modes of transportation. Policies like National Highway Development Program, National Urban Renewal Mission, National Urban Transport Policy and the new scheme of 100 Smart cities have long recognized traffic congestion as a major challenge in urban context. Still, despite efforts, comfortable commute and reduction in urban congestion is yet to be achieved. At many places, interventions like widening of roads and construction of flyovers have for a short time improved local mobility but subsequently they actuated latent demand for vehicles. Such interventions ultimately worsened the traffic situation. Inadequate and inappropriate public transit system, unscientific route rationalization and slow progress of construction of metro rails have increased congestion in many large cities of India.

Congestion is the impediment to urban mobility. In the past, cause of congestion could not be addressed because of faulty planning and improper implementation. Consequently, at many places, scarce urban land resource could not be utilized properly. Thus, many cities have grown haphazardly and are witness to ever increasing congestion and associated problems of air and noise pollution and accidents. Thus

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[1] The paper originated from the PGPPM project report, when Tarun Mittal, Ministry of Urban Development, Government of India was pursuing PGPPM studies at IIM, Bangalore.

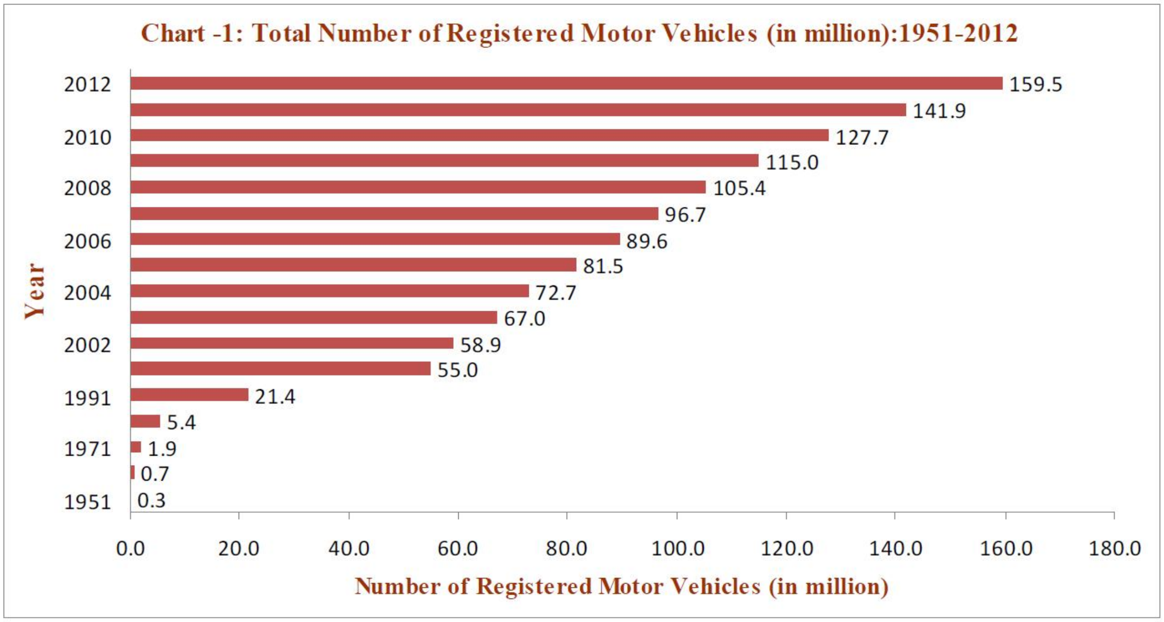
congestion, can have an adverse impact on the economy and growth potential of a city. This paper examines the trend and causes of congestion and suggests alternatives to improve urban mobility based on techno-economic analysis.

The discussion is organized in five sections: Section – II highlights the trend in Indian urban mobility highlighting the inadequacy of urban transport policy in dealing with present situation. Section – III deals with trend of urban mobility in developed countries, various policy initiatives taken by them to improve urban mobility and lessons to be learnt by India. Section – IV evaluates various policy alternatives along with a case study of Bangalore. Issues like risk and uncertainties and implementation issues of policy initiatives are also discussed in this section. Finally, conclusions are presented in Section – V.

Section II: Urban mobility in India

Urbanization in India has been steadily increasing from 17.3 percent in 1951 to more than 31.0 percent in 2011 with accelerated growth expected in coming years. It's an inevitable phenomenon in historical march of any country as cities by virtue of their enterprising nature attract people. Opening up of the economy and socio-economic transformations due to information communication revolution taking place in India and elsewhere in the world has further hastened the pace of urbanisation. New vistas of development have made people to gravitate towards cities for opportunities, avenues and better standard of living. More the people move towards urban centres, more is the demand for commuting. Thus, high population growth coupled with given socio-cultural milieu has led to an exponential rise in number of registered motor vehicles in recent years (Chart 1).[2]

[2] Registered Motor vehicles include cars, jeeps and taxis, two wheelers, buses, goods vehicles, tractors, trailers, three wheelers (passenger vehicles/LMVs).



Source: Ministry of Road transport and Highways, Government of India (2012).

Though number of registered motor vehicles have increased significantly there has been a steady deterioration in percentage modal split of public transport. Buses, which represent public transport, in terms of percentage of total vehicles have declined from 11.1 percent in 1951 to just 1.1 percent in 2011.

Table 1: Composition of India's vehicle population

YEAR END (MARCH)	TWO WHELERS	CARS,JEEPS AND TAXIS ETC.	BUSES	GOOD VEHICLES	OTHER VEHICLES	TOTAL
	(as percentage of total vehicle population)					(million)
1951	8.8	52.0	11.1	26.8	1.3	0.3
1961	13.2	46.6	8.6	25.3	6.3	0.6
1971	30.9	36.6	5.0	18.4	9.1	1.8
1981	48.6	21.5	3.0	10.3	16.6	5.4
1991	66.4	13.8	1.5	6.3	11.9	21.4
2001	70.1	12.8	1.2	5.4	10.5	55.0
2011	71.8	13.6	1.1	5.0	8.5	141.8

Note: Other vehicles include tractors, trailers, three-wheelers (passenger vehicles /LMVs and other miscellaneous vehicles which are not classified separately.
Source: Ministry of Road transport and Highways, Government of India (2012).

As reported in "Expansion of Road Network vis-à-vis growth in Motor Vehicles", the burgeoning population coupled with greater vehicular penetration are placing increasing demands on expansion of road networks in India.[3] The growth of road network has been outpaced with growth in number of registered vehicles. The compound annual growth rate (CAGR) in percentage terms for registered vehicles was 6.4 per cent between 1951 and 2011 as compared with 4.2 percent in the overall road network during same period. During the last decade, the gulf between the two growth rates is widening with number of registered vehicles rising by 9.9 percent compared with 3.4 percent in the road network. In recent years, growth in urban roads has been marginally better than that of rural roads (Table 2).

Table 2: Compound Annual growth rate in per cent in Vehicles and Road Length

Period	Vehicles						Roads					
	Two-wheelers	Cars, Jeeps & Taxis	Buses	Goods Vehicles	Others*	Total	NHs	SHs & PWD	Rural	Urban	Project	Total
1961/1951	12.5	6.9	5.3	7.4	26.5	8.1	1.9	4.0	-0.5	NA	NA	2.7
1971/1961	20.7	8.2	5.1	7.4	15.0	10.9	0.0	2.6	6.0	4.5	NA	5.7
1981/1971	16.3	5.4	5.6	4.9	18.1	11.2	2.9	4.5	5.9	5.5	3.5	5.0
1991/1981	18.4	9.8	7.4	9.4	10.9	14.8	0.6	2.1	4.0	4.3	1.2	3.0
2001/1991	10.5	9.1	6.7	8.1	8.6	9.9	5.5	3.1	1.4	3.0	0.6	2.1
2011/2001	10.2	10.5	6.9	9.1	8.0	9.9	2.1	3.0	4.4	5.0	2.6	3.4
2012/2002	10.7	11.0	9.6	9.9	8.0	10.5	-	-	-	-	-	-

Note: NHs: National Highways: SHs: State Highways: PWD: Other Public Works Department roads
*Others include tractors, trailers, three-wheelers (passenger vehicles/LMVs) and other miscellaneous vehicles which are not classified separately.
NA: Not Available
Sources: 1. Offices of State Transport Commissioners/UT Administrations.
2. 'Basic Road Statistics of India, 2009-11'.

The two indicators viz. roads and vehicles show that urban mobility is increasingly becoming difficult over period of time. National urban transport policy was envisaged in 2006 basically to address issues of ever increasing level of congestion, vehicular air pollution, road safety aspects and promotion of commuter friendly sustainable technologies. In-spite of providing a ground breaking innovative path, the implementation and operationalization of such policy could not occur at the desired level. This probably could be because choice decisions did not take into account sound, logical commuter friendly technology and system performance. The policy makers did not adopt a scientific approach in dealing with urban mobility and generally resorted to quick and easy solutions rather than under-take long term planning after taking all perspectives of urbanisation into account. Naturally, percentage of private vehicles have increased tremendously at expense of public transit resulting in exponential rise in traffic congestion. This places tremendous stress on urban infrastructure which gets distorted in form of improper land use and fund allocation. Consequently, allocation to other urban facilities like water supply, sewerage and sanitation also suffers. All these problems can be attributable to disproportionate allocation of funds to road infrastructure which could have otherwise been met by a cost effective public transit system.

[3] Government of India, Ministry of Statistics and Program Implementation (2012).

Urban mobility particularly in million-plus cities and urban agglomeration can be addressed on priority on basis of technology and system performance. It can incorporate determinants of economic geography, land use policy, prevailing societal norms, developmental issues and distributional and environmental goals.

In view of scarcity of land for road width augmentation, high resettlement and rehabilitation costs involved in expanding road network and environmental issues, a good and reliable public transport system seems to be an obvious solution for mitigating traffic congestion woes. Such public transit systems, while occupying less space, may be flexible enough to meet huge diurnal variation of traffic demand in the city with ease and acceptable level of service performance. It should have appropriate attributes to attract public to use it for daily commute. Thus, there is need of application of combination of push and pull factors towards public transit system which may desist people from using private transport.

Section III: Urban Mobility-Experience and initiatives of the world

A look at history of urban mobility shows that urbanisation and mobility are intricately linked. Cities in pre-industrialisation era functioned mainly as administrative units which were served by small number of artisans and craftsmen. Then cities were small and intra-urban commuting was mainly done by foot. Industrialization saw technology progress, delineation of property rights, labour specialisation, differentiation of products and mass produce. Cities started growing in size where professionalization and commercialisation breed new classes of capitalists, entrepreneurs, white and blue collared workers and labourers. With rise in manufacturing and trading, cities outgrew in size and commuting by foot was no more possible.

Earliest means of transport system which appeared in the cities were stage-coaches and omni-buses. As roads were not metalled then, the horse drawn omni-buses used to get stuck in muddy roads. Horse drawn and later steam power driven tramways running on rail guidance improved efficiency and riding comfort factor and increased the passenger capacity. With introduction of electric streetcars and trams, commuting by rail guided public transit system became so popular that in in 1920 alone, United States witnessed 13,770 million of intra-city unlinked passenger trips which is a landmark never surpassed by bus transport system in later years. The latest corresponding figure for year 2012 stood around 500 million unlinked passenger trips. Maximum bus passenger trips consisting of both intra-city and intercity bus travel touched a peak figure of 12,130 million[4] of all unlinked passenger trips in 1949 with corresponding 2012 figures as 5,747 million trips including 446 million of intra-city unlinked passenger trip.[5] Thus historical data of US intra-city commute shows that in year 1920, number of trips performed in urban public transit system was nearly 30 times than what it is today and there has been a considerable decline in usage of public transit system over last sixty years.

By 1940's, transformation in automobile technology and low gasoline prices brought a rapid change in life style of people especially in the West. Cities which were concentrated in small and dense areas started depopulating. Introduction of cheap personal automobile along with liberal funding of freeways gave people opportunity to move away from dense city areas to countryside. This gave birth to concept of suburbanisation. Evans (2012) explains" low-density suburban sprawl is partly a consequence of the availability of cheap land and partly the result of a permissive land-use regulatory system. However, it has been facilitated by the car, which has opened everywhere for residential development".[6]

Developed countries invested heavily in road infrastructure. Cities which were once closed and compact, and dominated by public transit were replaced by modern sprawling suburbia type of culture. Modern freeways and motorways were constructed with liberal grant from federal funds.

A number of more advanced countries with lower population density became a car-dependent society. To date, this is feasible because petrol in such societies is still relatively cheap in relation to their household incomes. Individual decisions about where to live and work have been deeply impacted by the budget balance between housing and travel/fuel costs.

Facility of door to door travel at one's own leisure coupled with good engineering technology and some favorable timely legislation in the western countries like large quantum of federal assistance for development of highways and cheap housing policy led to primacy of automobile industry in the urban mobility. As number of car ownership increased to level of more than 40 percent of households, investment in form of more freeways and motorways became ineffective. "Most research indicates that the initial interstate highway investments in the mid-twentieth century brought high marginal increases in private-sector economic growth (Garrison and Levinson 2006) and may have been a one-time increase in

[4] Only combined historical figures of intra-city and intercity bus unlinked passenger trips has been tabulated by American Public Transportation Association (APTA) in its fact book. Segregated data of above mentioned trips have been tabulated by APTA for year 2011 onwards.
[5] American Public Transportation Association (2014).
[6] Evans (2012).

productivity (Fernald 1999). However, subsequent public-sector investments in highways generated diminishing marginal returns on private-sector growth”.[7]

Policy planners of developed countries, as early as 1970s, realized the folly of ‘automobilsation’ and ‘car-isation’. However dominance of automobile industry was extreme that a famous epithet came into vogue – “What is good for General Motors is good for America”. Engel and Galetovic (2012) observe - “Many urban commentators blame congestion on an irrational preference for car travel—a harmful part of urban life akin to excess noise or pollution. They argue that building more infrastructure, especially highways, just fosters sprawl and fails to reduce congestion—that people respond to more capacity by driving more and wasting even more time”. In fact over a period of time, congestion first decreases, then increases with increase in road capacity which is driven by increase in number of vehicles (Appendix 1).

Gleaser (2013) is of the view –“The Interstate Highway System, seemingly the poster child for benevolent federal intervention in infrastructure, has itself been subject to heavy criticism. Many urbanists have argued that highways have badly damaged the cities that they were supposed to serve. The suburbanization of households offers private benefits but imposes social costs, as the spread out population drives more and uses public transit less. While the logic of having free, public roads for low density communities is easy to see, the practice of free road use can lead to problems as urban densities increase. Since individuals do not internalize the externalities created by their travel on others, the roads can become overused and slow to a crawl. Rotemberg (1985) provides a classic analysis of the economics of traffic jams. The most typical means of addressing traffic congestion is to build more roads, yet this approach creates a behavioural response that can easily undo the benefits of new construction. Duranton and Turner (2009) empirically investigate the “fundamental law of road congestion,” which says that vehicle miles travelled increase one-for-one with highway miles built. That law suggests that construction on its own is unlikely to eliminate the congestion externality, at least at reasonable levels of construction. Likewise, subsidizing alternative modes of transport is, on theoretical grounds, a highly inefficient means of reducing traffic congestion and empirically does not seem to solve the problem”.[8]

The federal government started subsidizing urban transit after the Federal Highway Aid Act of 1973. While these subsidies were justified as a means for combating traffic congestion, Baum-Snow and Kahn (2005) have found that new subway stops had a minimal effect on luring people away from car for daily commute to work. The probable reason is that US suburbs are based on cul-de-sac urban landscape which are not public transit friendly and surrounding areas have very low population density in comparison to

[7] Sweet (2011).
[8] Glaeser (2013).

cities of developing nations like New Delhi and Beijing. A large number of people, commuting from surrounding areas which are mainly urban sprawls, have to take multimodal transport system after long walk and crossing inhospitable road intersections. People generally use at least three transport system to reach from home to office. A multimodal transport approach often have inbuilt time delays. Since time has its monetary value, people in US have still not adopted public transit system in a big way. Total time travelled, comfort level and cost of alternative modes of transport play a major role in deciding the modal choice.

The greatest irony with many US cities is that in spite of having elaborate public system, people prefer to commute by car probably due to high per capita income and purchasing power. This results in high congestion in spite of having elaborate system of wide road network system. Congestion is measured in terms of planning time index (PTI)[9] and travel time index (TTI).[10] A look at Washington DC, leading road traffic data shows PTI ranged from 2.6 to 4.73 and TTI ranged from 1.27 to 2.26. Both values are very high and shows actual loss in fuel consumption and notional loss in productivity as number of man-hours lost in traffic jam could have been better utilised.[11]

In a renewed effort to fight congestion and to reduce their carbon footprints, developed countries have of late encouraged public transit system along with change in land use policies. They are trying to densify downtown area and encouraging people to move closer to central business district to reduce both journey time and fuel consumption (Appendix 2 and 3). Thus urban planners of United States and elsewhere are promoting transit oriented development (TOD). In TOD, people get a chance to move closer to their workplace, marketplace, schools and hospitals which they can easily access by clean comfortable public transit system.

Relevance to India

The Indian economic boom following liberalisation and globalisation has opened new vistas. A significant chunk of population is moving towards big cities for employment opportunities. Thus rural-urban migration has put lot of stress on the city infrastructure especially urban roads and public transport. Glaeser and Joshi-Ghani (2012) explained that - "Urbanization is undoubtedly a key driver of development—cities provide the national platform for prosperity, job creation, and poverty reduction. But urbanization also poses numerous challenges - congestion, air pollution, social divisions, crime, the

[9] Planning Time Index (PTI) which is a measure of reliability is the ratio of 95th percent peak period travel time to the free flow travel time. For example, when PTI has value of 2.50, it implies that for a 30 minute commute in light traffic, planning for 75 minutes should be done.
[10] Travel Time Index (TTI) is the ratio of a measured travel time during congestion to the time required to make the same trip at free-flow speeds. For example, a TTI of 1.3 indicates a 20-minute free-flow trip requires 26 minutes.
[11] Texas A&M Transportation Institute (2014).

breakdown of public services and infrastructure and the slums that one billion urban resident's call home. Urbanization is perhaps the single most important question in development today".

Inadequate urban road network, and unreliable and rickety public transport system in majority of cities have fallen short of meeting the increasing demand and expectation level. However changed perception has made both national and sub-national governments to have a relook at this vital piece of infrastructure. According to Kahn (2014), "Cities in developing countries are making major investments in urban transportation infrastructure — investments that will determine a city's urban form and its ability to move goods and people around the metropolitan area. There are environmental consequences of these investments and associated pollution costs. As urbanites grow richer, they tend to use public transit less and private vehicles more—because private vehicles are convenient, high status, and time saving".[12]

A recent study (Kutzbach, 2009) done for more than 50 countries over a period of 2002-2007 revealed that rising income levels in developing country lead to increased car use (Figure 1).

Figure 1: Motorisation and Economic Growth in developing countries (2002-2007)

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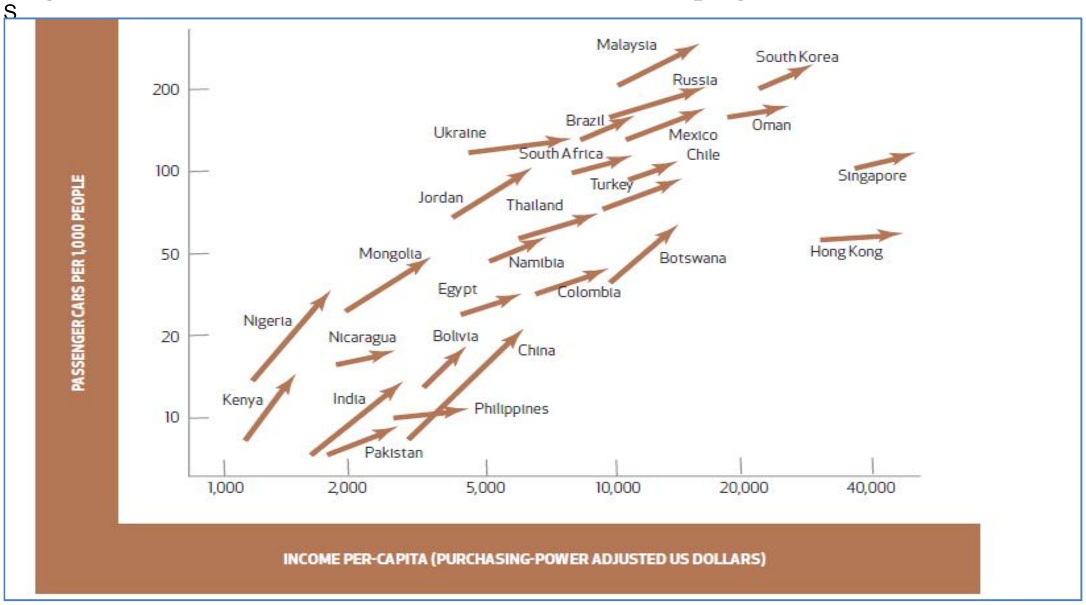


Source: Kutzbach (2009).

Similar income across countries may not lead to similar car use. In fact within a country similar income level cities also show wide variation in car ownership. Vehicular use vary according to variations in numerous factors which may include income distribution levels, individual choices, nature and type of urban economy, occupational structure, city demographics and morphology, cultural and environmental

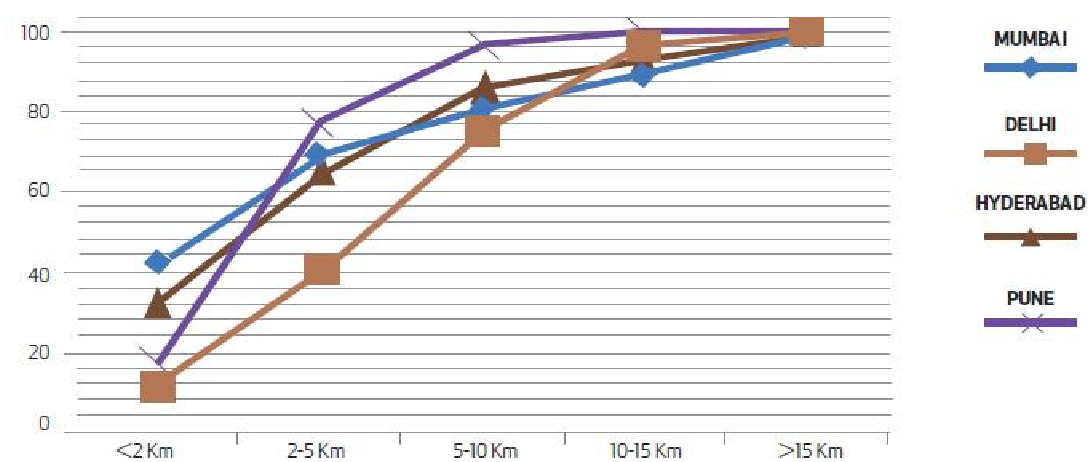
[12] Kahn (2014).

aspects. However general trend is that as income level rises people tend to use private transport because of instant accessibility and comfortable ride.

As number of people using private vehicles increases, there is reduction in occupancy of public transport which results in reduced operational profitability. Public transport operators respond to the situation by reducing service performance. This ultimately encourage more private transport which in turn leads to more congestion. However, interventions which discourage private transport and encourage public transport have a positive impact on overall traffic scenario. "Transport substitution is relevant for urban environmental performance because public transit tends to have much lower air pollution and greenhouse gas emissions than private vehicles. Buses and subways feature economies of scale, with fossil fuel consumption per mile of travel much lower than for private".[13]

The urban road chaos is increasing with ever burgeoning automobile ownership. Infrastructure shortages in developing countries like India has led to greater traffic snarls and grid locks with time. As a result, poor mobility has potential to cause major dampening effect on economic growth which will lead to deterioration in quality of life. As cities grow in size and population, number of vehicles plying on road increases and total number of trips on road as well as length of trip goes up. In smaller cities number of trips within 2-5 km are much more in comparison to metropolitan areas where people travel longer distance to access same facilities. For example, in small cities schools, workplaces and markets are situated closer than those in big cities (Figure 2).

Figure 2: Trip lengths in selected cities vis-à-vis cumulative percentage of commuters



Source: Tiwari (2011).

[13] Kahn (2014).

Hence it is necessary to have pragmatic policy shift in urban areas to discourage private modes (Appendix 4). It becomes imperative to encourage appropriate and technically sound public transport once traffic density along any travel corridor in one direction exceeds 20,000 persons per hour.

Though India's case is different from that of developed countries in its origin regarding urbanisation and transportation, still the end problem which is 'Congestion' is same. Lately, India has put lot of emphasis on roads, highway construction, development of megacities, urban agglomeration and Metrorail, these are still inadequate. It is still not known whether pumping more money in already congested urban space is productive. In US, it led to diminishing returns as explained by Sweet (2012).[14]

Both land and financial resources are a scarce In India. They have to be distributed between competing needs and objectives. Any wrong allocation means creating an asset with suboptimal utilisation. Prices of land are generally high and especially so in urban areas which in turn leads to affordability problems. Thus, infrastructure expansion which involves land acquisition for road widening and road network relaying etc. may not be easily possible in India due to costs, economic rational and political compulsions, causing inherent delays.

Section IV: Evaluating Policy Alternatives

To fight the menaces of traffic congestion there are three alternatives-

1) Building more road infrastructure: The policy which is being aggressively followed by the government.
2) Building metro system in some of the large towns along with regular Public Transport System.
3) Choose affordable Light rail transit system with land use policy change.

Policy alternative 1: To provide more roads without any intervention of public transit system

Throughout the world, greater regulation or freedom of market forces have always proved to be counterproductive. The moot evidence can be seen in case of urban land planning and urban mobility. In Indian scenario they represent the two ends of spectrum of regulation. Urban land planning in most of cities are highly regulated due to various land laws, rules and regulations. This stifles a proper balanced

[14] "In a study of different industries between 1953 and 1985, Fernald (1999) found that rising traffic congestion may have slowed national economic growth. He argues that beginning in the early 1970s, using the jargon of economists, congestion may have contributed to diminishing marginal elasticity of private-sector productivity in response to public-sector road construction. The utility of transport services are not only a function of speed or distance but also of the accessibility of specific destinations at specific times city's economy changes in response to congestion patterns—positing that congestion would induce variable returns to agglomeration benefits and may increase polycentrism. Congestion as an inconvenience or functional ingredient contributing to competitive disadvantages between cities vying to attract growth congestion affects process of urban economic change by focusing on geographic changes within a given city. Slower travel speeds induced by congestion would change land values and may redistribute economic activity"

natural growth of city and also leads to haphazard and short sighted development of the cities. In contrast, urban mobility is totally unregulated.

Nearly all Indian cities have significant portions consisting of unplanned and often unauthorized constructions probably because planners could not ascertain the correct demand for urban infrastructure. Consequently, development gets distorted and it puts severe stress on existing urban infrastructure of road, water supply and sanitation. Large parts of cities thus remain devoid of quality urban amenities.

On the other end of spectrum, the city planners have overemphasized provision of more funds for roads but left market forces to determine urban mobility. The result is weak public transport system and boom of private vehicles. Hence private vehicles in form of cars and motorcycles become most convenient mode of intra-city transport. They provide door-to-door travel with less consumption of time. Private vehicles can be used at convenience but are not publicly efficient mode of transportation as they occupy large space (Table 3).

Table 3: Land requirement for parked cars/moving cars at different speeds

Footprint of Car	square metre
Parked car on street	14
Parked car in public parking	22
Car stopped in a traffic jam	24
Car at 15 km/h	40
Car at 30 km/h	65
Car at 60 km/h	115

Source: Direction Generale de l'equipement de I'lle de France. [15]

Private vehicles demand excessive public space. Illustratively, land requirement of cars is further compounded by the fact that one car requires several parking space during its commuting life. One parking space is required at the origin of trip next to residence, other at the place of work and third one at intermediate stops like shopping malls, marketplace, schools, colleges or recreational place.

Chronic congestion on roads due to disproportionate space being consumed by automobiles defeat the advantage of mobility and comfort. More private vehicles, mainly cars, means more space consumed inefficiently which in turn paralyzes movements of other vehicles like emergency vehicles. In congestion, buses do not maneuver easily which leads to deterioration in service. This lead to more people shifting to private vehicles and vicious cycle of congestion sets in. Traffic congestion imposes large external costs which are mainly in terms of lost time and increased pollution.

[15] Source: The Growth Dialogue (2014).

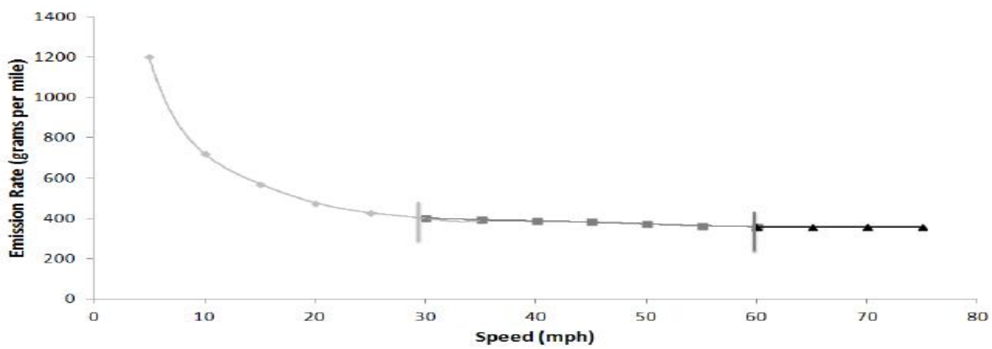
Large metropolis of both developed and developing countries are witnessing substantial amount of congestion though the genesis of congestion are entirely different. Developing countries do not have adequate road infrastructure. Generally, percentage of land allocated to road infrastructure in developing countries is far less than developed countries either due to historical reasons or due to improper land use. Inadequate transport carrying capacity of roads causes overcrowded conditions both on roads and public transport. People commuting for work and service delivery and all related servicing offices and business establishment become less productive when time is consumed in travelling in overly crowded conditions. This takes toll both on mental and physical health. These situations act as a constraint on employment and growth, as employees are unwilling to accept increasingly difficult commute trips.

According to Agarwal (2010), "Travel demand is determined by size of the population, average number of commuting performed by a person per day and the average trip length. Over a period of time it has been observed that travel demand grows faster than population because it is a function of both increasing number of trips undertaken by the incremental population as well as increased trip lengths necessitated by expanded city size". Further, as observed earlier, it has been found that residents, on an average, tend to perform more trips per day as per capita income levels go up".

Victoria Transport Policy Institute (2014), a Canadian agency has observed that "The dependency on private motorized transport tends to increase per capita transportation costs and reduce transportation affordability. As most road infrastructure is subsidized, there is no incentive for car owners to shift to cleaner travel options, as his travel cost is less than what he should pay".[16]

All transport activities, however small, create benefits and costs. However, not all of these costs and benefits accrue only to those who pay for their private transport. Some of these expenses gets externalized and falls on other persons or on country as a whole. Thin line difference exists between external costs and internal costs. Externalities arise whenever others are affected by activities of one who ignore this "spillover" while taking his/her decision. Illustratively, if a transport user has to pay for the use of a resource like energy usage, infrastructure usage, then the associated expense will be considered as internal costs otherwise if the commuter affects well-being of others like polluting the air, using roads which are far costly to build without paying for those then resultant costs are external to that person. Congestion decreases the overall speed which in turn increases external cost like increase in air pollution (Figure 3).

Figure 3: Vehicle emission rate curve-set showing three emission rate curves: more emission at lower speed



Source: Urban Mobility Report Methodology (2012).

Vuchic (2005) reported that "It seems quite logical that urgent actions should be to redesign and widen streets so that it can carry more motorized traffic and have traffic engineering controls, and to construct more parking facilities. However, it has been observed that these measures get neutralized by further increase in traffic volumes due to actualization of latent demand. The situation calls for analytical study of relationship between public and private modes, their roles and impacts on cities, and means of achieving such roles."

Policy makers in India need to look at cost and benefit ratio of providing urban roads without supplementing with public transit system. There are two ways to calculate it. The first method involves adequacy of the expenditure incurred either only on maintenance of existing paved roads or only construction of new roads against revenue collected from tolls and taxes on road infrastructure and vehicles. This excludes expenditure on maintenance or construction of bridges, underpasses or culverts. The second method looks at additional space requirement by introduction of new private vehicles on the roads provided no revenue is spent on maintenance.

An attempt has been made to compute these costs. As an illustration, 2012-13 has been considered as more information is available which is fairly representative in character.

- In India, cost of construction of road ranges from Rs.3-5 crore per lane per km excluding construction cost of bridges and underpass. 12th Five year Plan has estimated it at Rs.2.5 crore per km/lane though the present day cost per km/lane comes in range of Rs.4 crore for urban road.
- Maintenance cost, including periodic and for full life cycle of road i.e. 15 years, is approximately within a range of Rs.1.3-1.7 crore /km/lane on conservative estimate.
- Total length of road is 48.65 lakh km out of which 26.99 lakh km is paved.[17]

[17] Government of India, Ministry of Road Transport and Highway year book (2012).

- Further paved urban road is just 3.39 lakh km which on a conservative estimate requires Rs.10 lakh per lane per km per annum of maintenance cost.
- Total yearly revenue collected from road surface transport sector by Centre and State together is Rs.1.34 lakh crore (Appendix 5 and 6).
- Rate of obsolescence of vehicles is considered to be 4 percent due to accidents, theft etc. As per Motor Vehicle Act, vehicles more than 15 years old need to be registered again to prove their road worthiness.
- Effects of LMVs, Trucks and Autos have been neglected.

By first method, calculations show that each km of road may be able to get about Rs. 5 lakh[18] of repair cost as against needed cost of Rs.10 lakh[19] provided no new road are being built. This excludes cost of maintenance to bridges, culverts etc. The other scenario is that if no maintenance cost is incurred and total money is invested in construction of roads, length of road that can be built with total yearly collections from road surface transport sector will be approximately 53,600 km single lane or 26,800 km two lane road.[20] This figure excludes expenditure incurred on construction cost of bridges and underpasses. Figure of 26,800 km represents only 0.99 percent of 26.99 lakh kilometer of total paved road length which shows there will be meagre growth in road infrastructure if it has to sustain itself.

On basis of either routine maintenance and repair cost or investment in new roads from revenue earned through toll and taxes on road infrastructure and vehicles, it can be inferred that self-generating financial resources are neither sufficient nor self-sustainable.

The second method to look at inadequacy of just providing road infrastructure is to compute space requirement of new vehicles introduced on the road on yearly basis.
Annual production of cars in India is approximately 27 lakh. Approximately 267 lakh of motorcycle and scooters are produced annually (Appendix 7). Around 6 lakh cars and 20 lakh two-wheelers are exported. Thus annual increase in numbers of car on Indian road is 21 lakh and number of two wheelers increases by 247 lakh. Considering that a space of 40 square meter a moving car occupies and 10 square meter a two wheeler needs, average space requirement by virtue of getting plied on road may be considered as 0.96*(21,00,000 cars*40sq m+2,47,00,000 two wheelers*10 sq. m)/3.5=90,788km (single lane)[21] or 45,394km (double lane) yearly i.e. 248 km of additional road length is required each day which is almost twelve times daily target of 20km/day of road construction set by the government. Thus, with given funds we can only provide 26,800 km of road against yearly requirement of 45,394 km double lane road

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[18] Repair cost= total revenue from road surface transport sector/paved roads. Hence, Rs. 1.34 lakh crore revenue/26.99 lakh km= Rs. 5 lakh.

[19] General estimation adopted on thumb rule basis is Rs. 10 lakh per km per lane.

[20] Length of road constructed= total revenue from road surface transport sector/average construction cost of per lane of road. Hence, Rs. 1.34 lakh crore/2.5 crore) = 53,600 km single lane.

[21] Factor of 0.96 is taken to account for some vehicles losing road worthiness due to accidents, thefts etc.

at national level provided no money is invested in maintenance. Considering that 80 percent of cars[22] and 60 percent[23] of two wheelers are being sold in urban areas, total urban road length required will be 0.96*(0.80*21,00,000 cars*40sq m+0.60*2,47,00,000 two wheelers*10 sq. m)/3.5=59,081 km single lane road or 29,540 km double lane though at present urban road length including paved (3,39,000 km) and unpaved roads (1,25,000 km) in urban areas is just 4,64,000 km (Appendix 8). Thus, there is annual need of 17 percent increase in urban road length against 5 percent provided currently. This is incremental road deficit of 12 percent annually on conservative basis in urban areas for year 2012-13.

Alternative policy No. 2: Metro system in some of the large towns

Metro rail transit is the most superior system by virtue of having exclusive right of way. As it is capital intensive and requires large sum of money for maintenance of its civil structures, it is quite cost prohibitive for a developing country like India and can only be implemented in some of the large cities and conurbations. The present cost of construction on an average is Rs. 250 crore per km for elevated section and Rs.500 crore per kilometer for underground portion. Even considering 50: 50 percent of elevated and underground portion for minimum 50 km in 15 cities (15 cities have been considered for metro), total cost will be 375*50*15= Rs. 2.81 lakh crore which is an estimated amount required for construction at present price. Such substantial investment cannot be made for large number of cities. Thus, its reach is limited and can be applied only in very large metropolitan areas.

One of the issues with metro is that it is a grade separated transit system which causes inconvenience to commuters for reaching metro platforms. People prefer at grade[24] mobility transfer. At grade mobility reduces time in transfer from one mode to another. On other hand, metro system has greater susceptibility to earthquake and structural associated problems. In spite of the best but costliest solution, metro rail transit system consumes much more energy while in construction as well as in its maintenance during entire life cycle.

Over a period it has been observed that metro rail system instead of bringing desired densification, leads to sprawling of the city. This phenomenon is encouraged by huge variation in property rates across the city in India where core areas' property rates are high and fringe areas' property rates are low. Since for stations situated further away from core area, incremental travel time and cost of metro commute is less,

[22] The definition of an urban area for government statistics is as per census 2011. It differs from the definition of urban areas adopted by auto manufacturers who usually consider urban centers to be top 150 or 250 cities so value may differ slightly.
[23] The definition of an urban area for government statistics is as per census 2011. It differs from the definition of urban areas adopted by auto manufacturers who usually consider urban centers to be top 150 or 250 cities so value may differ slightly.
[24] At grade: Technical term for same level.

people move towards fringes of the city or conurbation where property prices are low. Thus, they travel for longer distance to reach their work place leading to suboptimal utilization of metro system for intermediate stations. Illustratively, once Delhi metro rail operations were stabilized after completion of second phase, initial average trip length of 10 km in 2011 increased to almost 18 km in 2014 within a short span of 3 years. The probable reason is that the capital cost of metro has not been internalized due to cheap fares which barely covers the operating cost of metro. The fares cannot be increased beyond competing cost of other transit system or private vehicle operational costs. Thus, this encourages people to economize their private cost by moving farther to less rental costly areas. As average trip length increases and people do not bear the whole cost of metro, the rate of revenue return earned by providing additional facility starts diminishing and expenditure on capital cost of metro increases. Thereby the effectiveness of metro decreases with increasing trip lengths. Also metro station capacity cannot be enhanced once it has been constructed.

Another aspect is that the metro network has far less density than roads. Also stations are spaced around 2 kilometers. Most of stations do not have adequate parking space due to space constraint and economic rationality. This situation compels commuters to take another mode of transport to reach Metro-station. Thus multiple mode of transport with poor linkages to metro stations discourage people to give up use of private vehicles for metro transit. Often poor connectivity to metro stations dissuades people to travel by metro leading to underutilization of this system.

Metro solution may be very useful where the urban landscape of the city has latent demand. For example Delhi showed horizontal expansion at a high rate since Asian games 1982. The city has such a urban landscape that people from new areas have to take long circuitous road route to come to central business district or areas having very high service based occupancy. By introducing much shorter commuting time and cheap fares with high quality riding experience, Delhi metro in first two phases became a success story even though it could not achieve the projected ridership numbers. However, there is apprehension whether the same success story can be replicated in much less populated and less dense cities of India.

Alternative policy No. 3: Affordable light rail mass transit with land use policy change

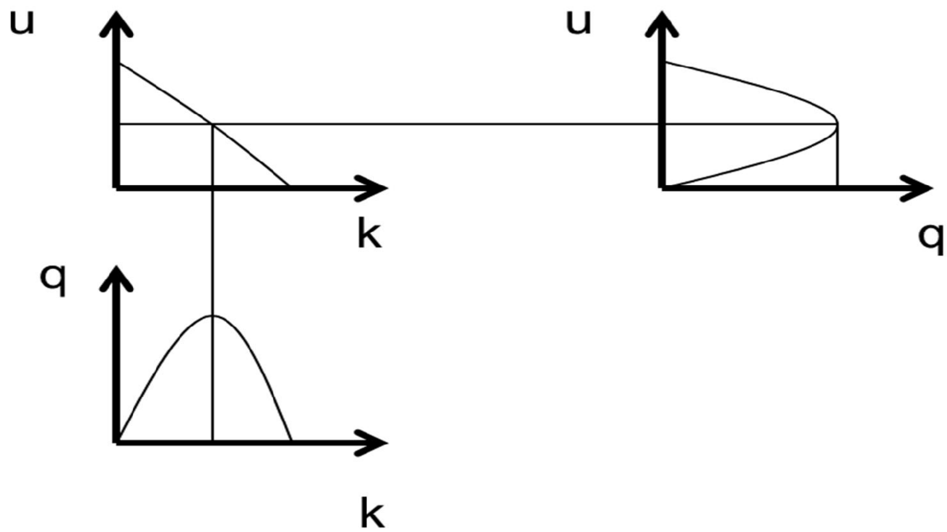
As discussed earlier in alternative 1, Most of the city planners have emphasized on construction of roads for ameliorating problem of traffic mess but road traffic issue is far complex. Almost every developing country policy planners including that of India have left it to market forces to determine its mobility. Thus there are rudimentary reliable public transit systems in most of the developing countries. Most of transit demand is met by unorganized, ill equipped and often obsolete private transit facilities.

In India, due to large number of traffic from informal sector, there is dominance of three wheelers and other vehicles affecting mobility and congestion in both large and small cities like ‘jugaads’, rickshaws and even e-rickshaws. As these vehicles provide employment to large population, governments generally has a soft corner on plying of such vehicles mainly for political reasons. Most of these vehicles are hazardous and negatively impact urban mobility. On daily basis, commuters suffer from traffic snarl by virtue of improper parking of buses and bunching of autos and rickshaws at certain points thereby causing congestion on otherwise normal roads.

The Government needs to play a role before situation becomes more complex. Urban planners and traffic engineers have been trying hard to make more space available for traffic movement but increasing number of automobiles require wider street and more street parking lot. In many cases valuable land must be sacrificed to the ever increasing traffic but the change only converts latent demand into actual demand and more private vehicles, especially cars, come on to the road. It’s a vicious circle. More roads attract more vehicles which in turn need more roads thereby meaning more investment and fund allocation and consequent more complex road solutions to meet this ever increasing vehicular congestion. Thus traffic ‘monster’ is not a metaphor but it’s a real thing wherein, it can be seen that it devours more resources to demand for much higher allocations. Traffic congestion reduces both livability and productivity of the city. Already capitals and cities of most powerful country are witnessing increasing greater congestion and substantial time delays. Congestions of Washington DC, Beijing, Paris, and New Delhi are some notable examples.

The problem is that instead of moving people, most city planners laid stress on moving vehicles. This has been captured aptly in fundamental theorems of transportation and game theory (Figure 4).

Figure 4: Diagram of fundamental theorem of transportation



Where u represents the speed in km/hr,
k represents density of vehicles in terms of vehicle/km,
q represents flow of vehicles in terms of vehicle/hour
Thus, q=u*k.

As per fundamental theorem of transportation, initially when vehicles are few and road occupancy is below its capacity, there is no marginal cost of adding a vehicle till a certain limit beyond which addition of every vehicle decreases average traffic speed and vehicular flow thus increasing travel time and congestion.

The vehicle accrues an external cost on the whole society as the driver pays for the vehicles cost but not for total infrastructure cost. This leads to a situation where, as per Wardrop principle (explained later in this section), everyone wants to move as quickly and easily as possible. Commuters have a choice of driving or taking public transport. Since commuter does not pay full value of road on equity principle, his personal utility of driving a private vehicle is more than a public transport commuter. Hence driving private vehicle is dominant strategy even though commuting by public transport like bus is economical and causes less congestion if everyone takes public transport. However traffic volume increases because each individual follows his/her own dominant strategy so individual self-interest defeats collective goal. Consequently traffic congestions occur.

One of the way to internalize cost and to discourage people to take private vehicles is congestion tax but in a developing country like India which is bereft of high quality road infrastructure, imposing congestion tax is neither desirable nor politically viable. In view of the above scenario, it can be seen that either increasing highway capacity or just providing buses will always lead to Pareto-inefficient condition. Thus there is need to develop public transit system which has a dedicated right of way so that there is no competition between private vehicles and transit system for the shared space. Bus Rapid transport system (BRTS) and Light rail transit (LRT) are two main solutions besides Metro train.

Though BRTS is considered to be a good option but long term solution for longer commutes will show it to be a myopic solution. Since buses experience greater jerks and higher lateral movements when compared to a rail transit, so riding comfort level in buses is comparatively inferior to rail travel. Thus, buses are always considered to be a secondary option in case of urban travel. The sideway and zigzag movements of buses along with driver's tendency to compete against each other makes journey uncomfortable with increasing chances of traffic collision. This poses a greater risk to pedestrians and fellow vehicles. Finally, BRT do not wean away people from automobiles (Lesley, 2012).

A comparison between BRT and LRT regarding carrying capacity shows that carrying capacity of each BRT vehicle is 70 persons per vehicle in comparison to 200-340 persons per vehicle in case of LRT. A comparative study of Metro, LRT and BRT may give insights regarding their operations, characteristics, suitability and feasibility as public transit system (Table 4, 5 and 6).

Table 4: Carry capacity of BRT in ideal conditions

vehicle capacity	load factor	headway (seconds)	no. of bays	capacity
70	0.85	60	1	3570
70	0.85	45	1	4760
70	0.85	60	1	3570
70	0.85	45	2	9520

Source: Authors calculations.

Table 5: Carry capacity of LRT in ideal conditions

vehicle capacity	load factor	headway (seconds)[25]	no. of bays	capacity[26]
200	0.85	60	1	10200
340	0.85	60	1	17340
200	0.85	90	1	6800
340	0.85	90	1	11560

Source: Authors calculations.

[25] LRT in dedicated right of way follow signalized control system from master control facility. Hence minimum headway in such sections is 60 seconds. LRT in mixed traffic follow visual control system where minimum headway may be less but LRT travel slow in mixed traffic situation.

[26] Capacity is defined as persons per hour per direction.

Table 6: Comparison of LRTs vis-a-vis BRT

Sl.	Characteristics	Metro	Light rail	BRT
1	**Roadway space**	3-8 m in case of elevated. Nil in case of underground	2 lanes narrow 5-8 m	2-4 lanes(8.5-15m)
2	**Stoppage distance space**	>1 km	400m min	400 m min.
3	**Station space**	large space during construction, otherwise less	platform 3-6 m wide serves both sides train	4-8 m wide unless special vehicles ply
4	**platform length**	100-300 m	30-35 m to serve one train	35 m to serve 2 buses at same time
5	**Route Flexibility**	Low	Low	High but low in special buses
6	**Carrying capacity of each vehicle**	300-900	200-400	50-70 ,130 Bi-articulate
7	**Construction time and impact**	huge	much less,, comparable with new technology	less but comparable
8	**Construction cost (Rs. Crore/km)**	200-250 elevated,500-750 underground	15-80 depending upon technology used and urban landscape design	25-45
9	**Max frequency**	20-30	Up-to 60	Up-to 60
10	**Reliability**	High, no traffic interference	less in comparison to metro	comparable to Light rail when BRT upgraded fully
11	**Human safety**	full segregation	segregation to large extent	Segregation very low and cost increases with it.
12	**Pollution**	construction time high, afterwards low in urban areas	construction time low afterwards low	construction and maintenance time medium, operation - very high
13	**Noise**	Low	medium	very high
14	**Greenhouse gases**	68-38 gm per passenger km	100-38 gram per passenger km	204-100 gm per passenger km
15	**Passenger experience**	Smooth, high comfort	Smooth, high comfort	Irregular ride, sudden acceleration, side-way movement

Source: Perrott and Menzes (2010), Authors calculations.

Table 7: Characteristics of different transit modes

Mode Category	ROW Category	Mode	Support and Guidance	Propulsion	Vehicle Control	Car per transit unit	Transit unit Capacity
Street transit	C	Bus, trolley bus	Road steered	ICE/Electric	Visual	1	70-125
	C	Tramway	Rail guided	Electric	Visual	1 to 3	100-300
Semi rapid transit	B	Bus rapid transit	Road steered	ICE	Visual	1 to 2	70-180
	B	Light rail transit	Rail guided	Electric	Visual/signal	1 to 4	100-720
Rapid transit	A	Light rail rapid	Rail	Electric	Signal	1 to 4	100-720
	A	Metro rail	Rail	Electric	Signal	4 to 10	720-2500
	A	Regional rail	Rail	Electric/diesel	Signal	3 to 10	540-1800

Notes: ICE: Internal combustion engine
ROW: Right of way
Source: Vuchic (2002).

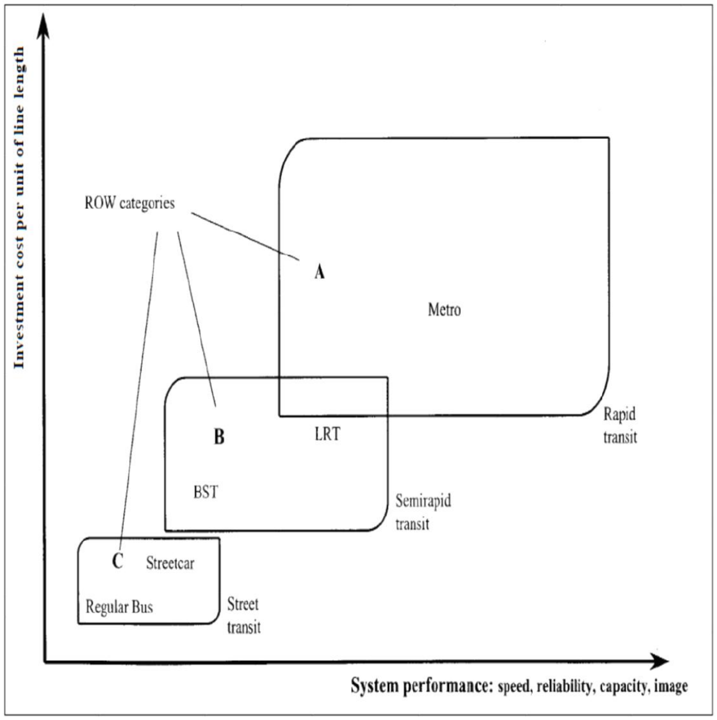
On basis of above study of various transit systems, following diagrammatic chart has been derived which explains their system performance vis-a-vis investment along with their right of way (ROW) (Figure 5). ROW represents degree of separation from other traffic and is classified into three categories.

ROW A: Fully controlled right of way with exclusive use by transit vehicles.

ROW B: Partially/fully separated from other traffic but has crossings at grade.

ROW C: Urban streets with mixed traffic

Figure 5: Performance/investment costs of modes with three Right Of Way (ROW) category is as follows



Source: Vuchic (2002).

The above diagram showed that metro rail as transit system is superior but it is also the costliest system. LRT comes next in terms of speed reliability, capacity and image (Vuchic, 2002). However Indian planners have not taken it as a viable public transit option because they wrongly believe that BRT is cheaper but BRT as a system covers a very broad spectrum. As level of segregation increases in BRT, the cost becomes comparable to LRT. On the basis of prevailing public attitude towards buses, socioeconomic conditions and urban morphology along with judicial pronouncements and implementation issues, the scheme barring Jan Marg of Ahmedabad has not been successful. Most of BRT system in India belong to category of BRT 'lite' system which is cheaper but not technologically superior. Moreover, UN habitat study conveys that BRT ride is always uncomfortable in comparison to fixed guide rail travel.

An analysis of some of the famous urban transit systems which has been constructed in the recent past will shed some light on the operational and functional aspects of the transit system. The first three transit system are regular mass rapid system which is more or less the regular metro (Table 8).

Table 8: Performance of various Public transit system

System	Delhi Metro	Bangkok (BTS)	Mexico (line B)	Kaula Lumpur	Tunis (SMLT)	Recife (Linha sul)	Quito Busway	Bogota (TM Phase I)
Category	Rail Metro	Rail Metro	Rail Metro	Light rail	Light rail	Suburban rail conv.	Busway	Busway
Technology	Electric steel rail	Electric steel rail	Electric rubber tyre	Electric driver less	Electric steel rail	Electric steel rail	AC electric duotroll y bus	Articulated diesel buses
Length (km)	65.1	23.1	23.7	29	29.7	14.3	16.2	41
Vertical Segregation	80 per cent elevated, 20 per cent tunnel	100 per cent tunnel	20 per cent elevated, 55 percent at grade, 25 per cent tunnel	100 per cent elevated	At grade	95 per cent at grade, 5 per cent elevated	At grade, partial signal priority	At grade, mainly segregated
Stop spacing	0.9	1.0	1.1	1.3	0.9	1.2	0.4	0.7
Capital cost ($ million) of which:	2349	1700	970	1450	435	166	110.3	213 (infrastructur e only)
-infrastructure		670	560	-	268	149	20	322
-vehicles		1030	410	-	167	18	80	Not included (private op.)
-capital cost/route km	36	73.6	40.9	50.0	13.3	11.6	10.3	5.2
Initial passenger capacity	20000*	25000	19500	10000	12000	9600	9000	-
Maximum passenger capacity	75000	50000	39300	30000	12000	36000	15000	35000
Avg. operating speed (km/hr)	33	45	45	50	13 to 20	39	20	20+ (stopping) 30+ (express)
Ownership	Public	Private (BOT)	Public	Private (BOT)	Public	Public	Public (BOT)	Public infra. Pvt Vehicles
Year completed	2005	1999	2000	1998	1998	2002	1995 (ext 2000)	2000 (1998 prices)

Source: Agarwal (2010).

Kuala Lumpur light rail is actually a metro which is classified as light rail because of its technical configuration. A grade separated light rail is usually considered as a metro rail. In Tunis, the track in majority of sections does not have separate right of way which results in reduction of LRV speed while Recife has a separate right of way. Bagota is most successful BRT till date but the urban landscape with very wide road space allows to have multiple bus unit which is not possible in Indian urban landscape. Also the project does not show the cost incurred on buses which is major component as can be seen from Quito busway.

The key issue for the policy makers is to have an attractive, economical and less space consuming transit system which may able to wean away people from private transport. Looking at the above scenario and experience of metro train and BRTS in India, the policy makers need to explore the feasibility and usefulness of LRT which till date has not been implemented anywhere in India.

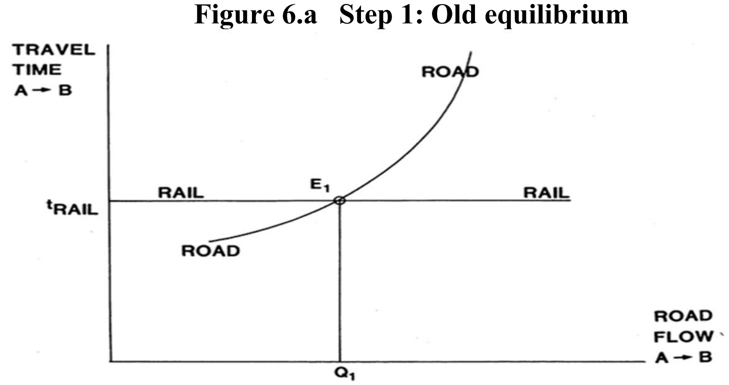
The history of streetcar carrying more than 90 percent of commuters can never be replicated but it is necessary to understand basic principles behind demise or deterioration of public transit services in post-world war period and to use corollary of same principles to revive public transit.

The Wardrop's principles convey that every commuter tries to minimize his/her time of commute. It is similar to the principle of minimizing cost. Thus Wardrop's principle mimics basic concepts of microeconomics where every entity tries to minimize cost.

Wardrop's first principle states: "The journey times in all routes actually used are equal and less than those which would be experienced by a single vehicle on any unused route. Each user non-cooperatively seeks to minimize his cost of transportation. The traffic flows that satisfy this principle are usually referred to as "user equilibrium" (UE) flows, since each user chooses the route that is the best. Specifically, a user-optimized equilibrium is reached when no user may lower his transportation cost through unilateral action."[27] Wardrop's second principle states: "At equilibrium the average journey time is minimum. This implies that each user behaves cooperatively in choosing his own route to ensure the most efficient use of the whole system. Traffic flows satisfying Wardrop's second principle are generally deemed "system optimal" (SO). Economists argue this can be achieved with marginal cost road pricing."[28]

Figure 6: Equilibrium travel time and road flow determined by meeting point of road and rail production function

Figure 6.a Step 1: Old equilibrium

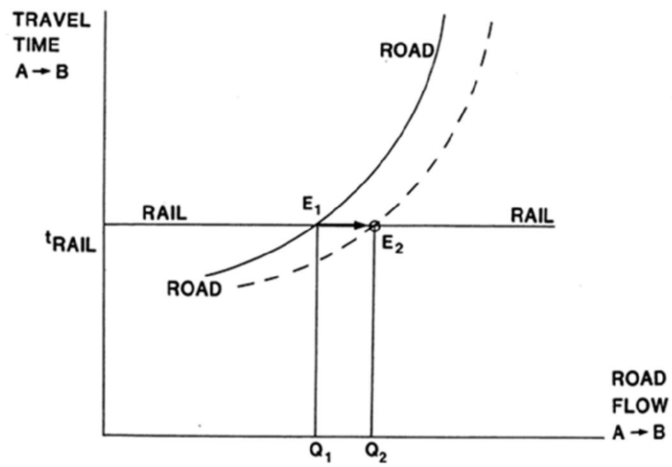


Source: Holden (1989).

[27] Wardrop and Whitehead (1952).
[28] Transportation (1989).

Every one tries to minimise one's travel time so every one adopt own dominant strategy of travelling by either private vehicle or train which leads to an equilibrium travel time between rail and road user for a given commuting capacity Q_1

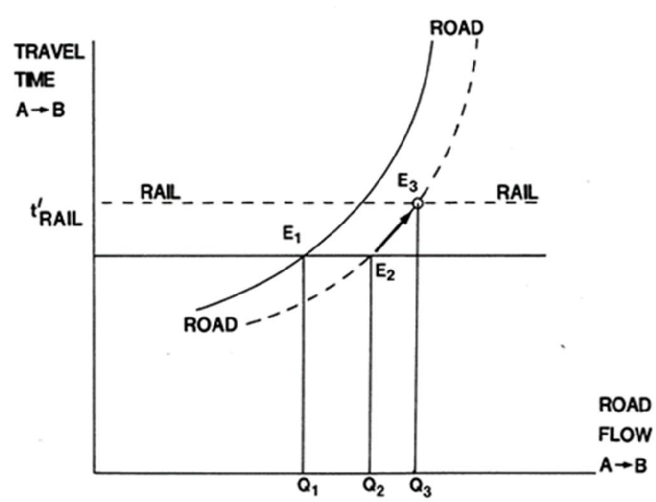
Figure 6.b Step 2: Intermediate stage on increased road capacity



Source: Holden (1989).

On increasing Road capacity from Q_1 to Q_2, users normally shifts to private vehicles as self driving is dominant strategy. Since train has fixed schedule, no change in time but its carrying capacity remains underutilised leading to reduced profit margins.

Figure 6.c: New equilibrium: Third stage



Source: Holden (1989).

As rail operator reduces frequency of train due to poor response which further shifts some more commuters to road. This leads to more travel time, less carrying capacity of transit system and higher congestion.

On the basis of above two principles, Holden (1989) concluded that since World War II, public transport systems of Western cities have been declining as access to private vehicles has increased along with the development of highways and interstates. During this period, public transport systems have largely proven to be unprofitable, resulting in reduced service levels.

The corollary of the above fact is that when LRVs will have dedicated right of way on roads where vehicles will not interfere except at intersections which will be designed in such way that prioritized signaling will be for light rail vehicles then the road capacity will decrease resulting in greater time travel on road which will shift people towards rail transit resulting in higher occupancy. The rail operator will increase frequency which will lead to lowering of waiting time. Thus total travel time will decrease which will further attract people towards the rail transit. Such reinforcement cycle will continue till a new equilibrium for a given capacity will be achieved. In the end, better utilization of same land allotted to transport sector can be achieved. This happens as the rail transit while occupying same land-space has dramatic flexibility with respect to carrying capacity while roads show more inflexibility in terms of carrying capacity.

One of the basic advantages of rail transit over roads is its greater flexibility in carrying higher number of persons with little degradation in the service. During peak time, rail transit capacity can be increased dramatically by having more coaches run by same number of personnel. This will address issue of the peculiar feature of any traffic which shows two peaks occurring during the daytime. These peaks coincide with office rush hours. Thus, the capacity of roads remain underutilized for a longer period of time.

Road transport due to greater friction and acceleration and deceleration suffers more wear and tear in comparison to rail transit. Average life of rail transit systems are about two and half times to that of road transport. Riding comfort factor is much more in rail transit as horizontal sway as well as vertical jumps are much less. Transit ridership increased significantly (from 95 percent up to 350 percent) after rail replaced bus service on major travel corridors in Los Angeles (Berg 2012).

Critics of Rail based transit system often compare LRT with trams/streetcars. The key difference is that trams operate in mixed traffic situation whereas light rail transit system have dedicated right of way and follow their own signaling system while streetcars had to follow traffic signaling system leading to slow speed. The mixed traffic situation of bygone era in case of streetcar always created lose-lose situation for all as vehicles of dissimilar nature share same road space neutralizing their respective advantages. The worst sufferers were the transit commuters. Thus the modified strategy which is being increasingly adopted in LRT is of partially segregated system with priority passage on intersections. BRTS and LRV which is upgraded version of streetcar belongs to this semi rapid transport system.

The clear advantage of segregated LRT will be that it will discourage jaywalking and discipline the traffic. The segregation and gated traffic system will promote discipline and lower probability of traffic accidents. LRT stations near major squares may able to eliminate building of costly flyovers as pedestrian and vehicular movements will be more synchronized. LRT stations, being at grade, can be upgraded easily and economically, according to demand at a later stage.

When compared with automobiles, a single LRT unit may eliminate up to 150 cars based on average occupancy which may reduce heat, noise and air pollution. As LRT runs on rails, it may also help in reducing suspended particulate material, a pollutant which is a major source of urban pollution in India because of poor quality as well as poor cleaning of roads.

Though in other countries, cost of LRT is high but Indian policy makers should implore that LRT may not be cost exorbitant in India as very few services are embedded in the middle of the existing roads. This implies a faster construction speed unlike as in case of metro where lot of time gets consumed in shifting of services and disruption in traffic system during construction time. A good planning may lead to lowering of cost of laying LRT tracks which may be only two times higher than regular rail. Present cost of laying conventional ballasted track lies in range of Rs.6-10 crore per kilometer and ballast-less track is in range of Rs.12-18 crore per kilometer. Ingenious Indian solutions may be explored to make it further cost effective. LRT with given characteristics will be feasible and sustainable for all Indian million plus cities and may enhance their growth potential by reducing congestion and promoting transit oriented development.

An illustration: Bangalore

The provisional population of Bangalore is about 95.88 lakh as per 2011 census with a growth rate of 3.9 percent per annum. It is among the fastest growing Indian metropolises. Average density is 4,378 persons per square kilometre with a distribution range from 613 to 41,905 persons per square kilometre. Approximately 84.74 lakh person reside in the jurisdiction of Bruhat Bengaluru Mahanagara Palike (BBMP) area.

Only 8.40 percent of total district land use is allocated for transportation. As per Directorate of Urban Land Transport, Government of Karnataka, the total length of urban road is about 700 km out of which 41 percent i.e. 287 km is having either 4 lanes or more than 4 lanes. Approximately 700 km of road length except the one leading to airport is mainly concentrated in BBMP area (841 Square km). These roads usually are major arteries of the city. They normally are utilised for all major daily intra-city trips and commutes of the people. All transport buses with few exceptions ply on it. As 43 km of road length is envisaged to be covered by metro rail, 244 km of 4 or more lane road can be considered for developing light rail routes. Both road and exclusive rail road can be accommodated only on roads having at least space of 4 lanes. Since network of 4 lane roads are fairly dense in BBMP area, the approach to these roads are fairly easy and within walking distance for majority of residents. Thus LRT routes may be conveniently located on these roads. Route alignment and station locations are important parameters for success of any transit system because people do not prefer to travel for more than 500 m to access any public transit system which is equivalent to 7-9 minutes of walking (Appendix 9). After ascertaining the physical suitability of light rail transit system, there is need to determine economic feasibility of LRT for Bangalore.

There are two methods to indicate that LRT will be advantageous for the city of Bangalore (details and cost calculations are in Appendix 10).

1) Fuel Cost saving to Bangalore Municipal Transport Corporation (BMTC) and savings in operation and maintenance costs by running LRT instead of buses.
2) Savings of foreign exchange through adoption of LRT by city of Bangalore which entails replacing of oil with coal/hydro based energy which is abundant in India.

As the first step, 75 percent of buses are assumed to be replaced with LRT. Hundred percent removal of buses is not possible as some buses may be plying to very remote or sparsely populated areas where putting up LRT may not be economically viable. On basis of BMTC data, against present annual expenditure of Rs.667 crore on fuel for running buses, annual expenditure on electrical energy for operation of LRT will be approximately Rs.100 crore, therefore an indicative expenditure incurred on energy will be reduced by Rs.567 crore yearly.[29] Cost of operation and maintenance (O&M) annually on an average is Rs.1808 crore/year. Since no corresponding Indian data for LRT operation and maintenance is available, corresponding US data has been used as an approximation. A comparison of St. Louis BRT and LRT systems for 10-year period showed that the BRT incurred an annual average O&M cost of $104.6 million against O&M cost of $26.2million for the LRT. Further, the study on St. Louis BRT and LRT system found that in 2005 the total cost per passenger mile was $0.97 for the BRT which was higher when compared to $0.82 for the LRT.[30] Similarly US National transit data as per appendix 11 shows average operating ratio per capita of $0.55 for the BRT in comparison to that of $0.45 for LRT. Though

[29] See Appendix 10 for calculations.
[30] Metropolitan Area Planning Council, Boston, MA (2014).

there may be individual differences in various transit projects, ratio of operating cost of LRT to BRT is roughly 82 percent. Applying the same ratio of O&M costs for LRT in India, BMTC can save additionally Rs.325 crore on account of O&M expenditure.

Secondly on basis of saving to nation from city of Bangalore alone in terms of foreign exchange outflow, there will be net savings of Rs.502 crore (Appendix 10).

Risks and Uncertainties

In case of alternative one, the main issue with regard to widening of the road is that it may not ameliorate the problem of congestion. As discussed in previous sections, widening of roads in fact aids congestion. Roads may provide flexibility of operation of road vehicles but it is increasingly becoming a vexed issue for the government as road infrastructure requires huge amount of land space which is getting scarce. Many times numerous road projects get stalled due to land acquisition problems. One of the components of National urban renewal mission (NURM) scheme related to widening and decongestion of urban streets in old city areas could not be successfully implemented in various cities as land acquisition was a major obstacle and became one of the sensitive issues. Also infrastructure cost of road is high. If governments want to recover the infrastructure cost of roads through user pay charges, it may have political ramifications. Politically, congestion pricing like Electronic Road Pricing (ERP)[31] in Singapore may not be feasible and successful in India.

In alternative two, it has been observed that construction of metro takes a long time due to procedural delays. Any engineering mishap like poor construction quality of any structural component may halt operations. Delhi airport link express metro is the recent example where operations of the metro was halted for more than a year due to technical snag. This leads to inconvenience to commuters as well as drain on public exchequer because of idling of such huge capital investment.

In alternative three, LRT appears to be most appropriate option but its success depends upon intelligent planning and route rationalization so that minimum private land is required for implementation.

Section V: Summary and conclusion

Though LRT is far superior to tram and streetcar, still it has to go a long way in attracting the capital for its construction. The most appropriate time to make LRT companies to invest in India is when the prices of oil are low. This will make them willing to invest in India as the developed countries during low oil

[31] ERP is amount charged per vehicle electronically when an automobile enters in a congested but popular city area during peak hours. Thus for same stretch, different amounts may be charged depending upon congestion level and speed of vehicle.

prices regime do not favor public transit systems. In such a scenario, public transit companies may be willing to invest in India at a relatively lower cost. The modern urban commuting can be totally indigenized and this can become a mantra of success with regard to “Make in India” concept. The challenge is that most of Indian policy planners don’t look beyond Kolkata trams which are vehicles of bygone era. It’s necessary to understand that ridership of Kolkata trams decreased as it was later forced to share right of way with other vehicles. No efforts were made to infuse either new technology or adequate funding to modernize it. Thus, when the developed countries are embracing LRT in a big way with approximately 200 cities running it and more than 50 cities modernizing and expanding its LRT network. Interestingly Washington DC has reintroduced LRT system in 2014. Indian planners could also consider it as a viable option. The other main issue is with respect to organizational framework and fare revision structure within which Light rail entities have to work. Lastly, success of any transit system however excellent it may be, depends upon accurate forecasting of origin destination studies and consequent ridership demand. In India, these studies need to be undertaken extensively.

To conclude, it can be inferred that to combat traffic congestion, Indian cities have to move towards integrated multimodal transport system with emphasis on rail based transit. Only Rail based transport system has capability of providing flexible, safer and more comfortable commuting experience. Segregated guided rail based transit system not only occupies smaller space but also creates an environment conducive for less congestion and ensure better utilization of scarce land resource. It may help India to combat vagaries of oil fluctuation and will enable cities to have lower carbon footprints. It will also equip India to face a difficult situation when eventually oil resources will dry up.

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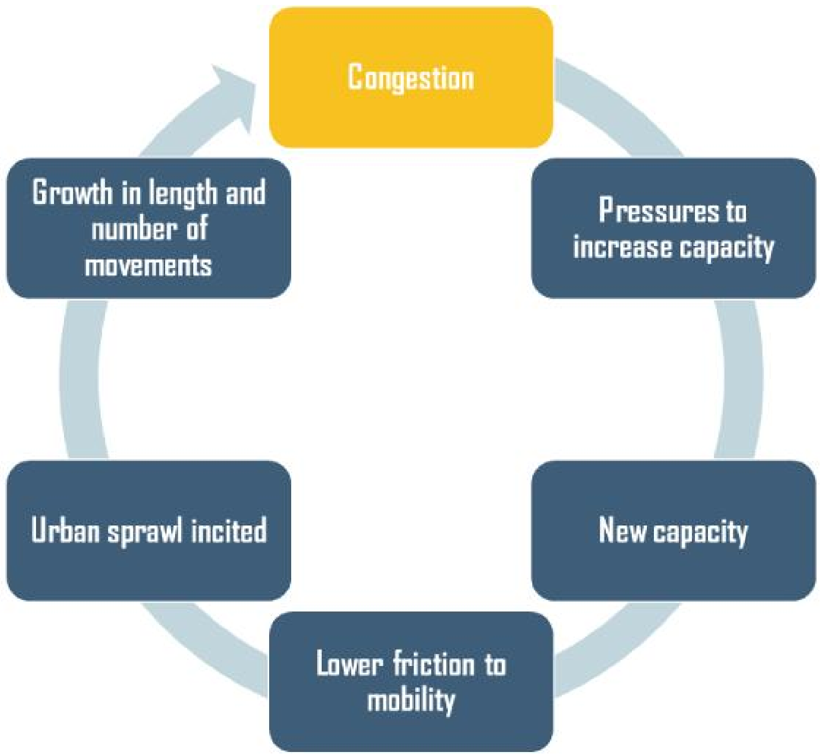
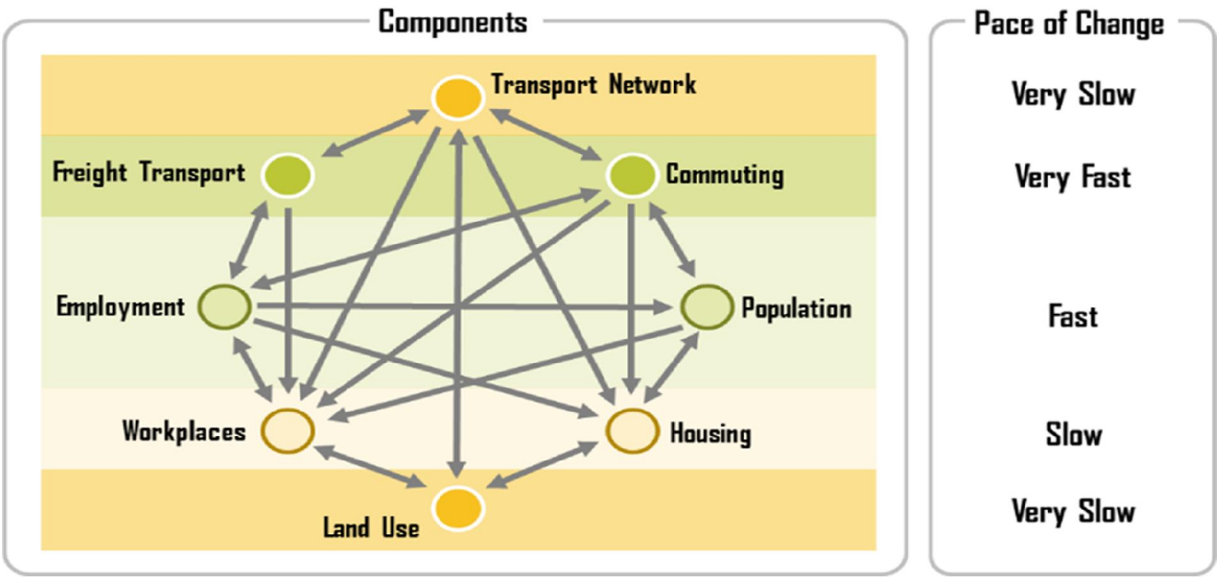
Appendix 1: Congestion



Source: Rodrigue (2015).

Appendix 2: Components of trip



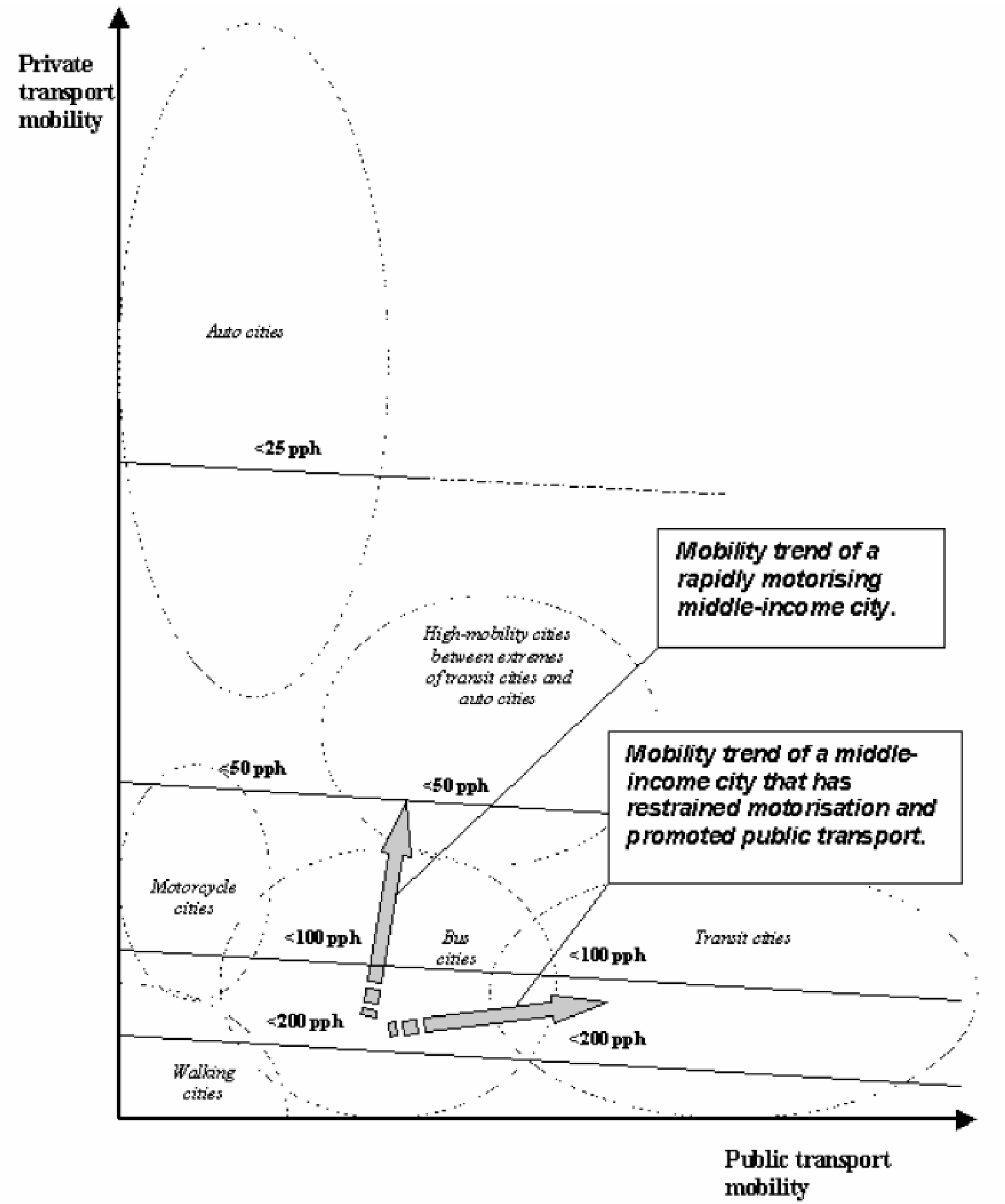
Source: Wegener (1995).

Appendix 3: City characteristics and functions while considering option of transit facility

Transit friendly	Transit neutral	Transit unfriendly
Retail		
High rise residential		Warehousing
Recreational		Manufacturing
Mixed use development	Education	
Administrative	Services	
Health		require large land areas
more trips/area		less trips/area

Source: Joseph (2012).

Appendix 4: Schematic diagram to illustrate connection between motorised mobility trends, city types and urban density



Pph—persons per hectare.
Source: Barter (2012), Transport dilemmas in dense urban areas: examples from eastern Asia.

Appendix 5: Revenue from Road Transport (Centre)

Revenue Realised from Road Transport (Centre): 2009-10 to 2011-12

(Rs. Crore)

Year	Motor Vehicle and Accessories		Tyres and Tubes		High Speed Diesel Oil		Motor Spirit		Total
	Import Duty	Excise Duty	Import Duty	Excise Duty	Import Duty*	Excise Duty	Import Duty	Excise Duty	
2009-10	4,121.7	6,294.2	1,470,9	596.8	4, 376.6	3,339.1	3,378.2	24,809.5	48,386.9
2010-11	6,508.7	8,667.6	2,552.5	939.8	17,546.2	3,731.9	8,735.6	26,770.9	75,453.2
2011-12	8,126.7	9,331.2	2,961.2	1,115.4	15,280.1	4,723.0	5,239.5	28,795.5	75,572.5
2012-13 (P)	9,096.4	12,305.8	3,513.4	1,357.7	9,947.9	5,725.3	3,754.9	23,710.1	69,411.5

*Includes petroleum oils, oils obtained from bituminous minerals, crude, other mineral fuels, oils, waxes and bituminous substances.

Source: Road Transport Year Book (2011-12), Ministry of Road Transport and Highways, Government of India.

Appendix 6: Revenue from Road Transport (States)

Revenue Realised from Road Transport (States): 1950-51 to 2012-13

(Rs. Crore)

Year	Motor Vehicles Taxes and Fees	Sales Tax/VAT on Motor Spirit and Lubricants	Tax on Passengers and Goods	Total
1950-51	-	12.5	0.1	12.6
1955-56	13.9	8.9	3.0	25.8
1960-61	29.9	16.9	8.4	55.2
1965-66	61.8	31.5	33.4	126.7
1970-71	107.7	63.2	60.5	231.4
1975-76	209.7	92.0	160.5	462.2
1980-81	356.3	154.5	239.6	750.4
1985-86	835.5	322.0	395.7	1,553.2
1990-91	1,566.3	631.5	1,061.8	3,259.6
1995-96	3,726.3	1,703.8	1,507.7	6,937.8
1996-97	4,117.3	2,755.9	1,662.6	8,535.8
1997-98	4,853.9	3,502.4	2,003.9	10,360.2
1998-99	5,024.0	3,862.2	1,979.2	10,865.4
1999-00	6,153.1	4,728.8	2,098.7	12,980.6
2000-01	6,665.6	4,161.4	2,074.7	12,901.7
2001-02	7,644.4	5,645.0	3,671.4	16,960.8
2002-03	8,441.0	5,106.0	3,569.3	17,116.3
2003-04	10,138.2	4,967.5	4,189.9	19,295.6
2004-05	10,811.0	6,657.0	5,206.0	22,674.0
2005-06	11,964.0	2,951.0	6,450.0	21,365.0
2006-07	13,630.1	1,331.6	6,808.3	21,770.0
2007-08	15,594.9	1,623.2	6,807.7	24,025.8
2008-09	17,340.3	8,438.1	8,462.6	34,241.0
2009-10	19,637.8	10,017.8	9,857.0	39,512.6
2010-11	23,497.7	11,198.3	11,296.4	45,992.4
2011-12 (R.E.)	28,679.7	13,815.7	12,665.7	55,161.1
2012-13 (B.E.)	34,173.7	15,528.8	14,725.0	64,427.5

R.E: Revised Estimates; B.E: Budget Estimates.
Source: State Finances – A Study of Budgets 2012-13 by Reserve Bank of India.

Appendix 7: Production of Vehicles in India

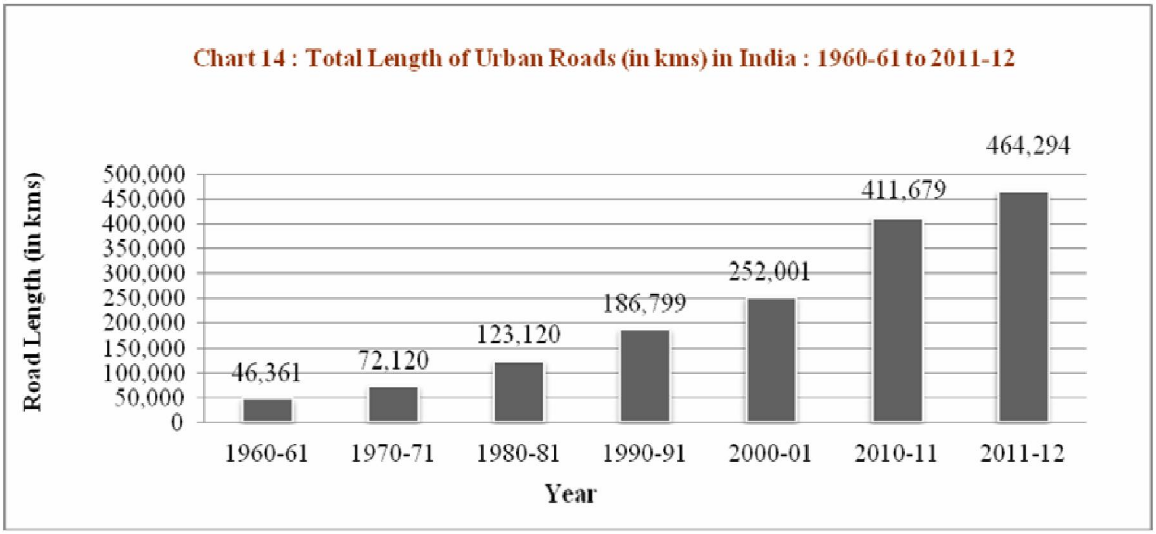
Production of Motor Vehicles in India: 2005-06 to 2012-13

(In numbers)

Category	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
M & HCVs	219,295	294,258	294,957	192,283	250,133	344,542	384,801	278,560
LCVs	171,788	225,724	254,049	224,587	317,423	408,193	544,335	553,184
Total Commercial Vehicles	391,083	519,982	549,006	416,870	567,556	752,735	929,136	831,744
Cars	1,046,133	1,238,021	1,426,212	1,516,967	1,932,620	2,453,113	2,775,124	2,668,633
Multi-Utility Vehicles	263,167	307,202	351,371	321,626	424,791	534,183	370,945	564,928
Scooters	1,021,013	943,944	1,074,933	1,161,276	1,494,409	2,144,765	2,659,340	3,025,014
Motor Cycles	6,207,690	7,112,281	6,503,532	6,798,118	8,444,857	10,527,111	11,982,669	11,904,212
Mopeds	379,994	379,987	430,827	436,219	571,070	704,575	785,523	791,954
Electric Two-Wheelers	-	30,454	17,389	24,179	2,567	-	-	-
Total Two-Wheelers	7,608,697	8,466,666	8,026,681	8,419,792	10,512,903	13,376,451	15,427,532	15,721,180
Three-Wheelers	434,423	556,126	500,660	497,020	619,194	799,553	879,289	839,742
GRAND TOTAL	9,743,503	11,087,997	10,853,930	11,172,275	14,057,064	17,916,035	20,382,026	20,629,227

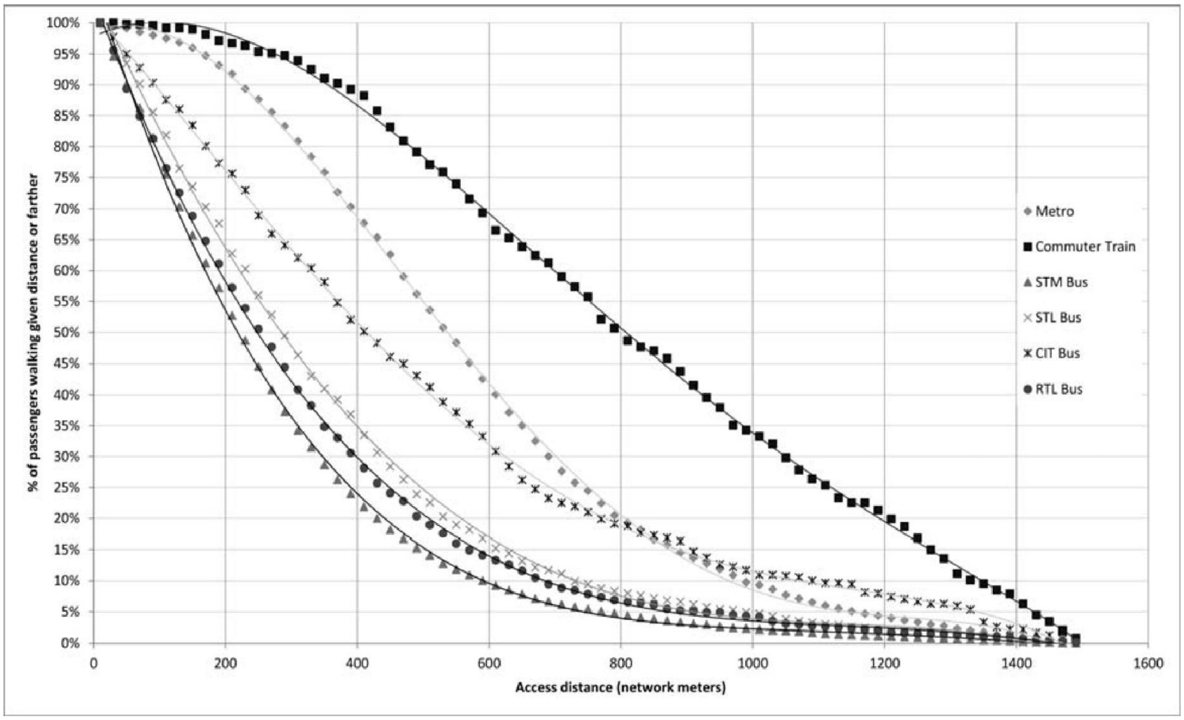
M & HCVs: Medium and Heavy Commercial Vehicles. LCVs: Light Commercial Vehicles.
Source: Society of Indian Automobile Manufacturers, New Delhi.

Appendix 8: Urban road length



Source: Road Transport Year Book (2011-12), Ministry of Road Transport and Highways, Government of India.

Appendix 9: Distance decay to metro, train and bus services



Société de transport de Montréal (STM),
Réseau de transport de Longueuil (RTL), and
Société de transport de Laval (STL)
Source: El-Geneidy, et al (2014).

Appendix 10: Savings in replacement in Bangalore

Assumptions

- 1 LRV consumes 4 KWh units of electricity per km[32] and carry 340 passengers at 0.85 capacity factor.
- 264 ml of HSD used by bus per km and carry 70 passengers.
- Unit charge of electricity Rs. 5/unit as per applicable to Indian railways.
- Cost of diesel: Rs. 54/litre and cost of petrol Rs. 65/litre.
- $1=Rs. 62.00
- Average trip length by all modes is 7.59 km with 18 percent people commuting by foot. After deducting number of people taking trip on foot, average trip length comes out to be 9.04 km.
- Total person travelling on BMTC are 43.5 lakh/day out of which it is assumed that 75 percent of bus travellers will shift to LRT and 11.25 lakh people which constitute 25 % of private vehicle owning population will shift to LRT from their private vehicle. Therefore total 44 lakh persons approximately will be travelling.

Case 1

Fuel cost daily incurred by BMTC=12.80 lakh km/3.78km/l*Rs.54*365=Rs.667.4 crore.

Electricity charge= Rs.5*4KWh/340=Rs. 0.588 per capita/km.

Yearly cost=Rs.0.0588*9.01*44 lakh*365/.85= Rs.100.09 crore.

Therefore savings Rs.567.31 crore.

Based on US experience, savings in O&M cost: 0.18*1808 (O&M cost) = Rs.325 crore.

Case 2

I unit consumes 20 ml of furnace oil per unit of electricity considering that all electricity is generated in thermal power plants (accepted consumption level is 10 ml/KWh and energy losses in distribution and low quality coal is factored in, though recommended value is 5 ml/KWh).[33]

Each BMTC bus has fuel mileage of 3.78km/litre of high speed diesel therefore per km consumption is 264 ml/km.

Diesel saved is 264-80=184 ml for per km of operation

Assuming price of HSD as Rs.54 per litre

Total consumption by BMTC is 12.80 lakh km/4.01 km/l= 3.39 lakh litre/day.

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[32] Vuchic (2007) and Trancossi (2014).
[33] Government of India, Ministry of Power, Central Electricity Authority (2013).

Therefore total diesel saved will be 184/264*3.39 lakh/ l=2.37 lakh litre/day.

Supposing 75percent of trip is replaced by LRVs, then amount of motor fuel saved is 1.78 lakh litre/day

Considering all taxes and cess forming around 35 percent and another 15 percent for refining cost and margins total revenue saved in terms of foreign outgo will be 1.78 *0.5*54=Rs.48 lakh(on daily basis) which is equivalent to $77k on daily basis which is equal to $28.2 million.

Considering that only 25 percent of two wheelers and 25 percent of car owners switch to LRVs,

Amount of motor fuel saved will be-

1) Two wheelers (given average is 60 km/l) = 17 ml/km*9.01km* = 153 ml per vehicle trip /day

   There are 34.78 lakh two wheelers so if 25 percent chooses then 8.7 lakh shifts to LRT, then saving 1.33 lakh litre of petrol for 25 percent of total two wheelers/day.

2) Car (given average of 15 km/l) = 0.6 l per vehicle trip.

   There are 9.95 lakh cars. If 25 percent switches to LRT 1.49 lakh litre per trip per day.

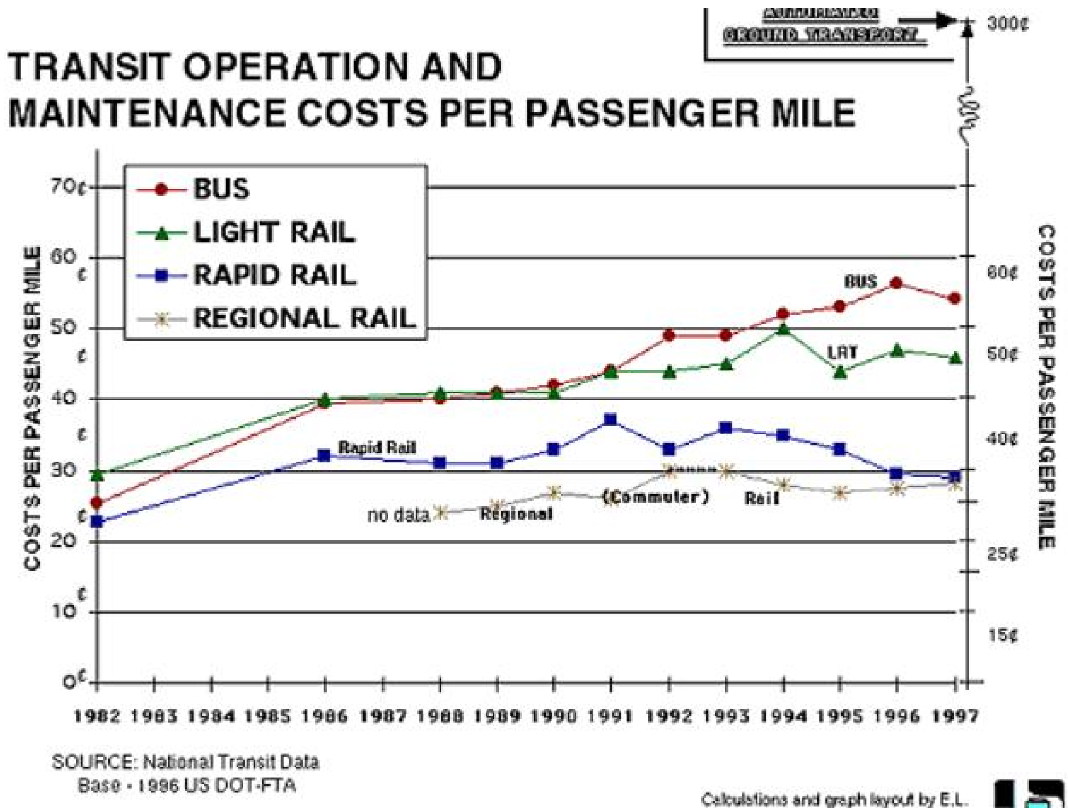
   Considering each vehicle makes 1.4 trips/day.

Total saving will be=3.93 lakh litre

Considering all taxes and cess forming around 50 percent and another 15 percent for refining cost and margins total revenue saved in terms of foreign outgo will be 3.93 *0.35*Rs. 65=Rs. 89.4 lakh which is equivalent to $145k on daily basis which is equal to $53 million on yearly basis

Therefore total foreign outflow in Bangalore due to import of oil can be reduced by $81 million i.e Rs 502 crore considering that about 11.25 lakh people can be weaned away from private vehicles to LRT and Metro.

Appendix 11


TRANSIT OPERATION AND MAINTENANCE COSTS PER PASSENGER MILE
BUS
LIGHT RAIL
RAPID RAIL
REGIONAL RAIL
COSTS PER PASSENGER MILE
70¢
60 ¢
50 ¢
40 ¢
30 ¢
20
10 ¢
0¢
300¢
60¢
50¢
40¢
25¢
15¢
BUS
LRT
Rapid Rail
no data
Regional
(Commuter)
Rail
1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997
SOURCE: National Transit Data
Base - 1996 US DOT-FTA
Calculations and graph layout by E.L.