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Developing a hypothetical scenario for assessing the impact of modal shift towards public transport in Delhi

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ABSTRACT

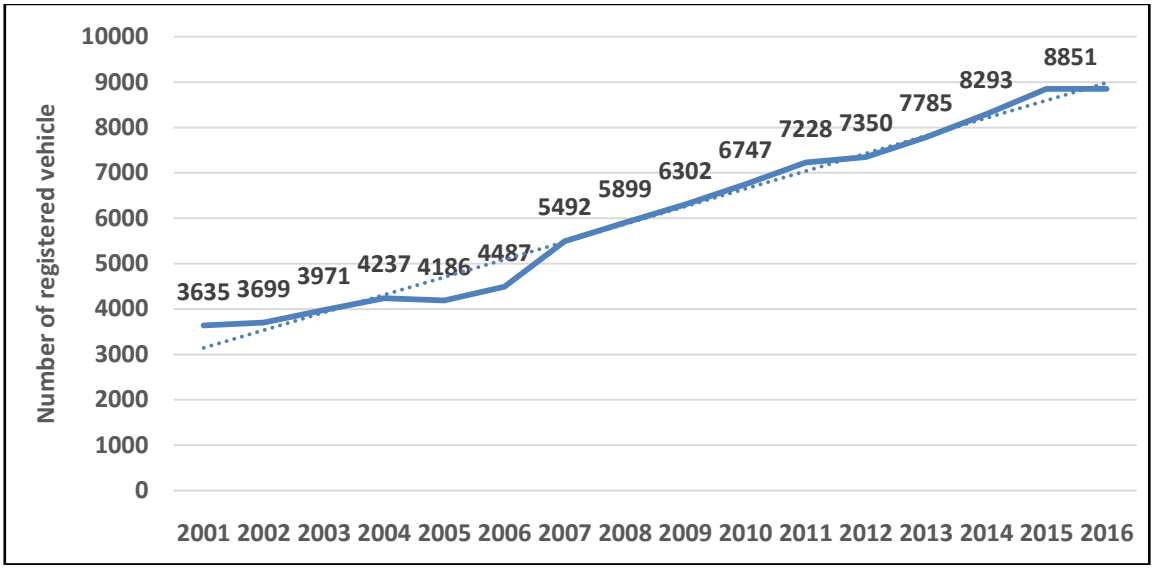
India is a developing nation with one of the greatest-increasing economies in world. Theories of microeconomics establish a direct and positive relationship between increase in per capita income and disposable income, which relates to high vehicle ownership. As per the data released by Ministry of statistics and programme implementation, the total vehicle ownership rose by 55.09% from 2010 to 2016 in India. Although, the increase in vehicle ownership indicates growth in the economy, but somehow these figures are myopic and can't be trusted to portray a complete picture of rise in economy.For a clear assessment, it is prudent to assess the growth of vehicles based on the ownership status and their typology. The total number of two-wheeler and four-wheeler rose by 83.7% and 79.88% respectively from 2010-2016, whereas the total number of buses rose by 11% only.The negative externalities (congestion, vehicular emission, noise pollution, accidents, and road damages) associated with the use of private transportation are immense and cannot be ignored. A World Bank study revealed that India lost more than 8.5 percent of its GDP in 2013 due to air pollution, while a study by Uber suggests that Indian commuters take 1.5 times longer to travel a given distance in peak hours compared to travel time during non-peak hours. In the current scenario, private vehicles occupy 90% of the total road space, whereas a bus which carries 45% of the passenger by occupying only 8% of total road space (Ashok Srinivasan, 2008), (Hemant Kumar Suman, 2018).Delhi being the Capital of India is one of the frontrunners of this issue. In a very little span of time, the urban transport system in Delhi has significantly shifted towards private vehicles. The present study is an attempt to illustrate the changing mode share of study area and create a hypothetical sustainable scenario in favor of public transit.

Keywords*: High Motorization rate, Negative Externalities, Mode Share Change, Sustainable Scenario, Public Transport*

1. BACKGROUND- URBAN ROAD TRANSPORT SYSTEM IN DELHI

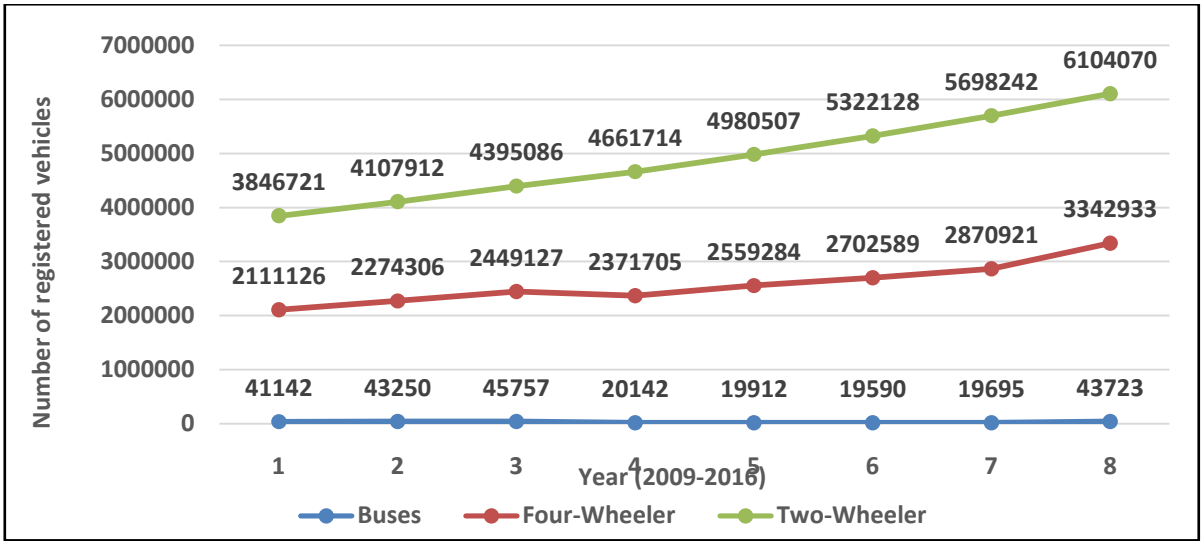
The National Capital Territory of Delhi has a population of 13.5 million (2011 census) and an area spread of 1483 sq. (Ltd., 2016). Delhi is the magnet of the NCR, with strong impact or high order interdependence on regional setups in surrounding towns (Gurgaon, Noida, Greater Noida, Ghaziabad and Faridabad) in terms of housing, employment, higher education and health facilities, and other goods & services. Over the years, the growth of private transportation could certainly be observed in the case of Delhi. The total number of registered vehicles in Delhi rose by 85.6% from 2001 to 2010 and by 31.18% from 2010-2016 (TRANSPORT RESEARCH WING, 2016). The rapid increase in motorization rate is most often well associated only with rise in population. The population of Delhi rose by 20.8 % form 2001- 2011 and by 17.6% from 2011-2016 respectively, which directs linear population growth of the city(Vehicular Pollution in Delhi, 2018).This indicates that population is not the only criteria,as suggested by the theory

of microeconomics, the increase in per capita income which thus implies the increase in disposable income is a major parameter for the increasing use of private transport.



Graph 1 Total Registered Vehicles in Delhi (2001-2016) in 000'
Source- Statistical Handbook 2017, MORTH (Ministry of Road Transport and Highways)

As per the Ministry of Road Transport and Highways, total number of two wheelers and four wheelers rose by 58.1% and 58.3%, whereas the total number of buses rose by only 6% from 2009-2016 respectively.



Graph *2* Mode wise growth of Vehicles from 2009-2016
Source- Statistical Handbook 2017, MORTH (Ministry of Road Transport and Highways)

According to the data released in census, the national figure for vehicles per thousand population is as low as 13, contrary to it, Delhi however has around 556 vehicles per thousand population, but has only 248 buses per million population (Kiran; TRANSPORT RESEARCH WING, 2016) which is way less than the standard set by the Indian government of 600 buses per million population.

2. TRANSFORMING MODAL SHARE OF DELHI

In 2011, the share of bus service is noted to be as high as 42% which depletes to 27%, whereas the share of private transportation increases from 19% to 28% form 2011-2014. Still, majority of the population id dependent on the public transit services in Delhi which caters to 30% of the total modal share (27% from bus service and 3% from metro), followed by 23% of private owned vehicles (14% from two-wheelers and 9% from car

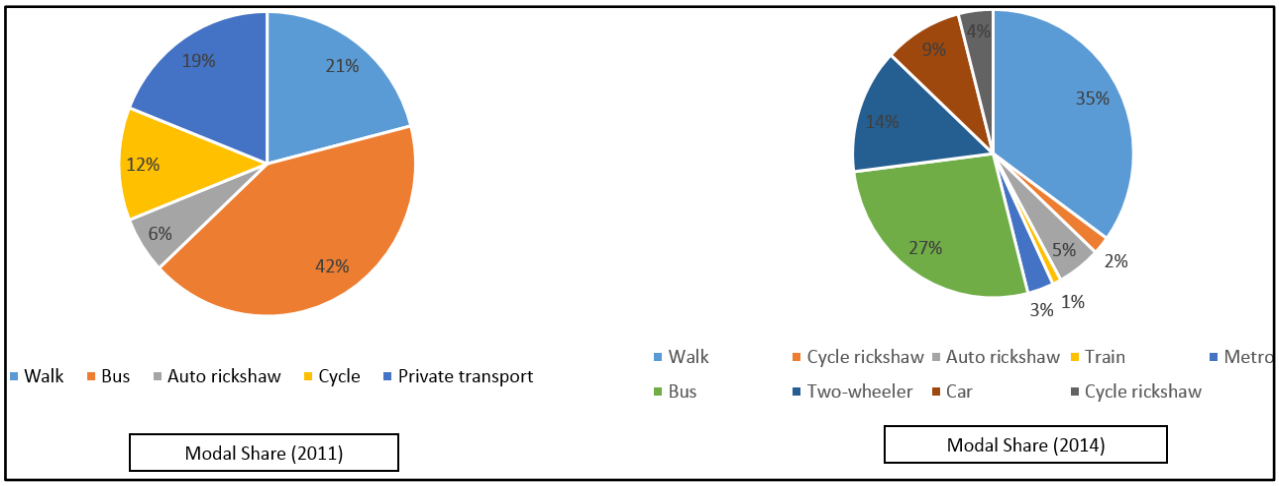


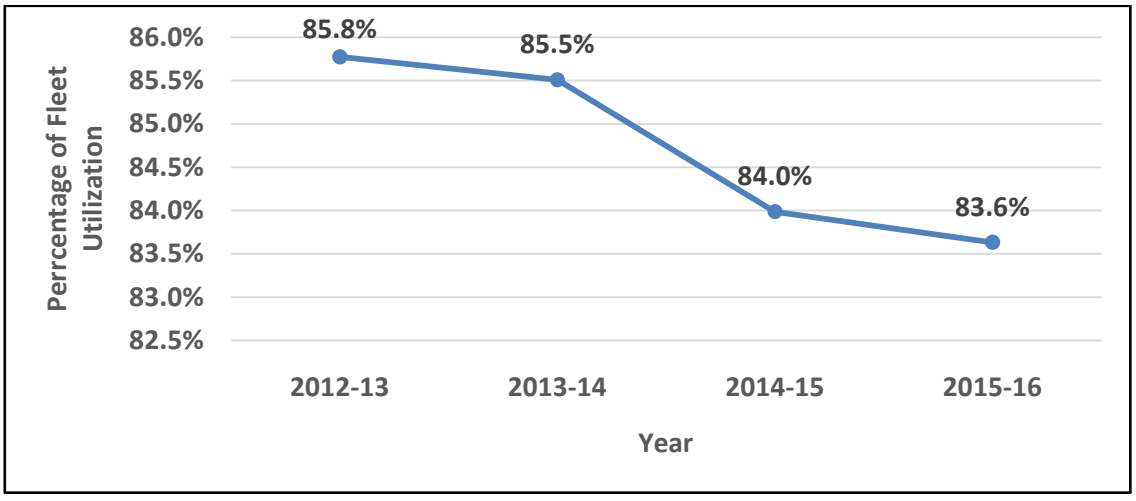
Chart 3 Change in Modal Share of Delhi (2011-2014)

Source- (Report of High Powered Committee on How to Decongest Delhi, 2014),(Sh.Manoj Kumar)

3. PARAMETERS AFFECTING THE BUS TRANSPORT SERVICES (DTC) IN DELHI

The depleting quality of bus services provided by the Delhi Transport Corporation (DTC) is another major reason for hefty shift in modal share towards private transportation, along with the increase in disposable income. The fleet strength, average age of fleet, staff productivity, vehicle productivity and fleet utilization are the major factors for dropping quality of bus services, while the reduction in total no. of passengers carried (bus/day), occupancy ratio, financial performance parameters and fuel efficiency can be the measures to assess the decline in quality of bus service in Delhi. As noted from the State Road Transport Undertaking reports(TRANSPORT RESEARCH WING, 2016), the factors affecting the quality of bus service in Delhi are illustrated as follows.

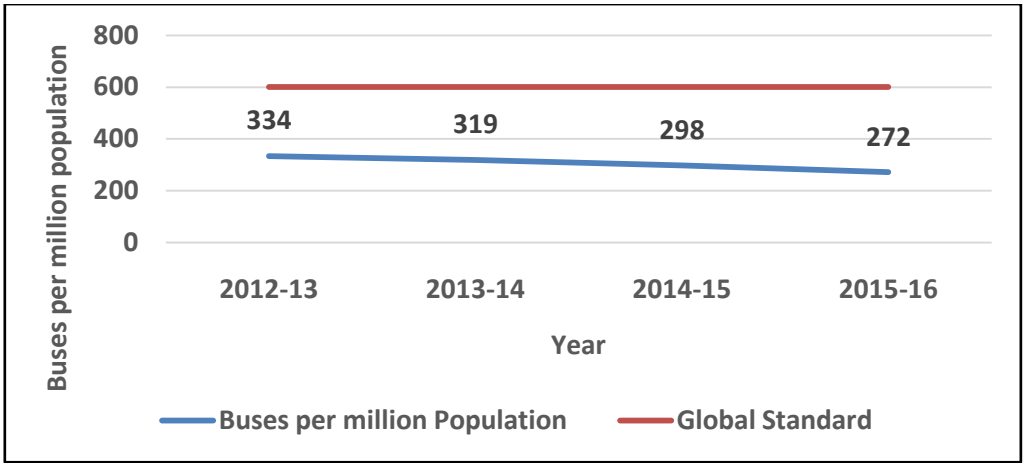
Fleet Utilization: Fleet utilization is measure to assess the extent to which vehicles are utilized. It is calculated based on the total number of buses available against the total number of buses operating. Low Fleet utilization percentage indicates poor or deteriorated quality of rolling stock, lack of driving or conducting staff, and inefficient scheduling etc. High fleet utilization or increase in percentage of fleet utilization directs to adequate and efficient use of available resources(Group, 2006). According the state road transport undertaking reports (SRTUs), the fleet utilization percentage has reduced from 85.8% in 2012-13 to 83.6% in 2015-16, in the case of Delhi.



Graph 1 Variation in Fleet Utilization

Source- State Road Transport Undertaking Repots,(TRANSPORT RESEARCH WING, 2016)

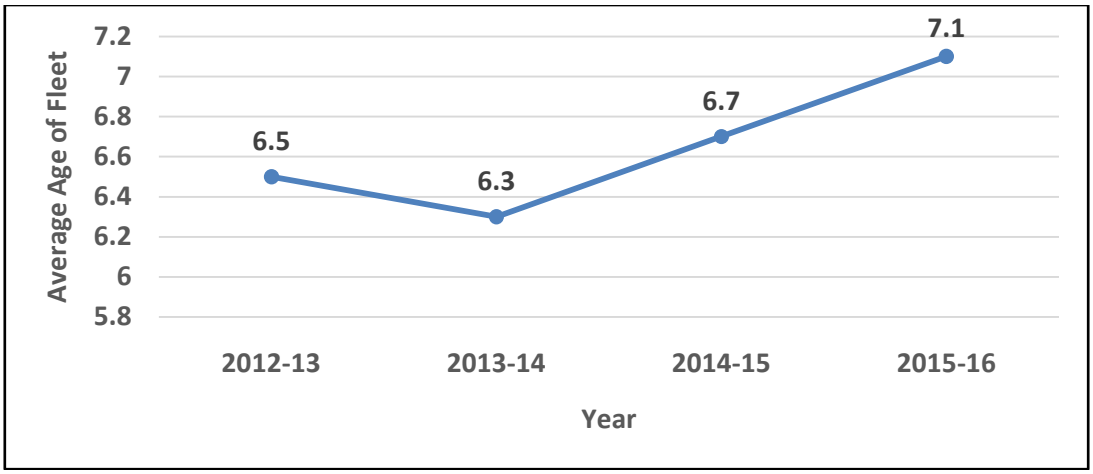
Fleet Strength: The total number of buses available for service is indicated by fleet strength. The fleet strength is often measured based on the population of the city. As per standardglobal standard, a city must have 600 buses per million population for providing adequate and efficient bus services(Rohit James, n.d.). In the case of Delhi, the total fleet strength reduced from 5602 (2012-13) to 4564 (2015-16), while the number of buses per million population has declined from 334 (2012-13) to 272 (2015-16).



Graph 2 Variation in Fleet Strength

Source- State Road Transport Undertaking Repots,(TRANSPORT RESEARCH WING, 2016)

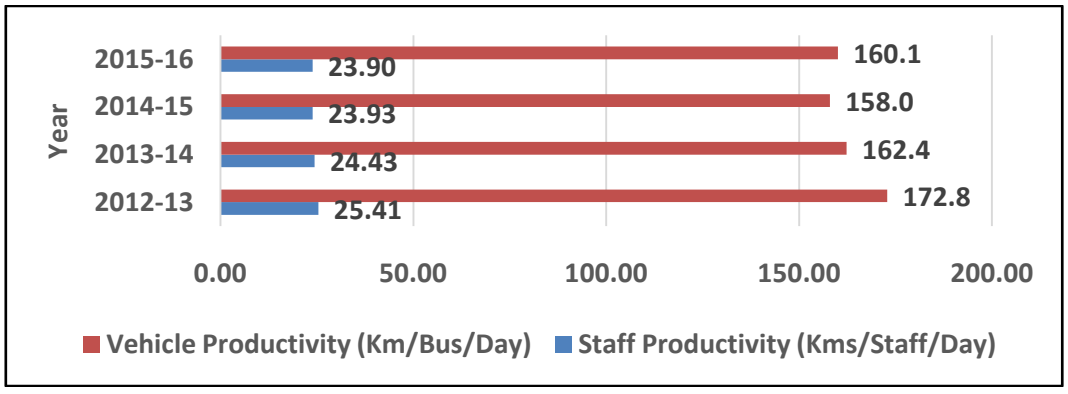
Average Age of Fleet: It is one of the most vital indicator for understanding the quality of services provided. An acceptable average age depends on factors such as the types of vehicles operated, levels of utilization and operating conditions. Often, it is assumed that for reasonable well maintained service quality, average age of fleet should be near 5 to 6 years(Group, 2006). The average age of buses in Delhi has been increasing over the years, reflecting insufficient funds to purchase more buses, or not as many purchase of buses corresponding to increase in population.



Graph 3Variation in Average Age of Fleet

Source- State Road Transport Undertaking Repots,(TRANSPORT RESEARCH WING, 2016)

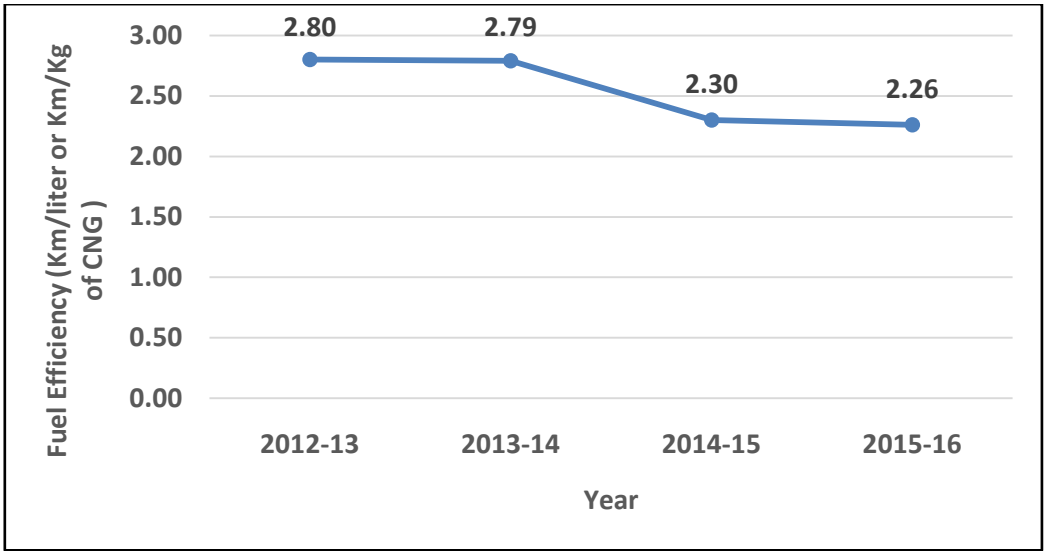
3.2. Staff Productivity and Vehicle Productivity: Staff productivity is expressed as km/staff/day, while the vehicle productivity is measured as km/bus/day. Increase in staff and vehicle productivity reflects to efficiency of services. As per the, dataset from SRTUs, the staff and vehicle productivity has decline over the years in the case of Delhi.



Graph 4 Variation in Staff and Vehicle Productivity

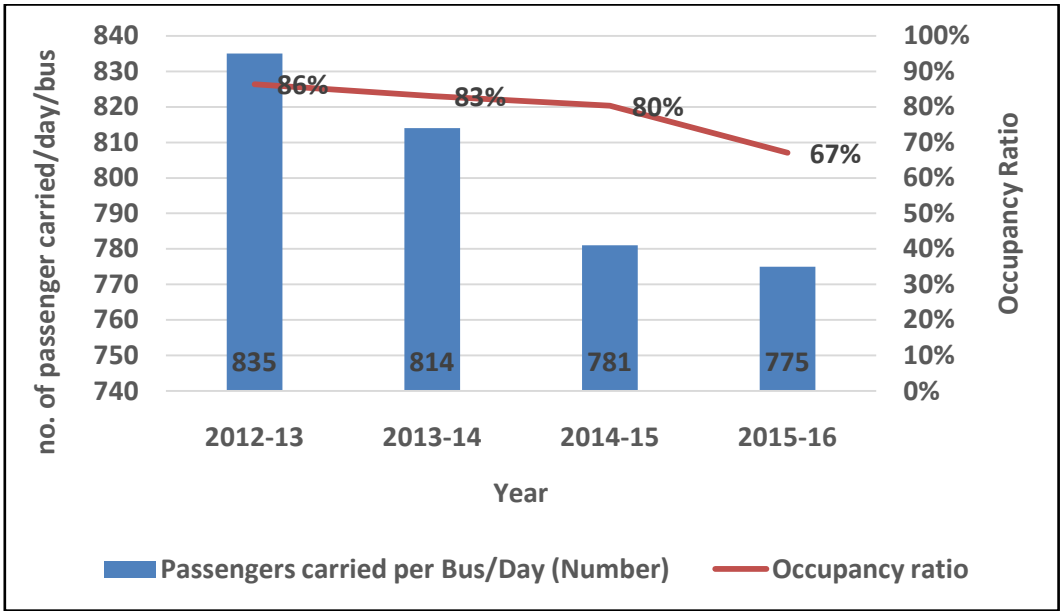
Source- State Road Transport Undertaking Repots,(TRANSPORT RESEARCH WING, 2016)

Fuel Efficiency: The maintenance and condition of fleet determines its operating cost. Fuel cost is one of the major capital investments a transit service provider has to look for. The decrease in fuel efficiency can be directly related to congestion, overcrowding of buses in peak hours, low maintenance and poor condition. The fuel efficiency decreased by almost 20% from 2.8 Km/liter or Km/Kg of CNG in 2012-13 to 2.26 Km/liter or Km/Kg of CNG in 2015-16.



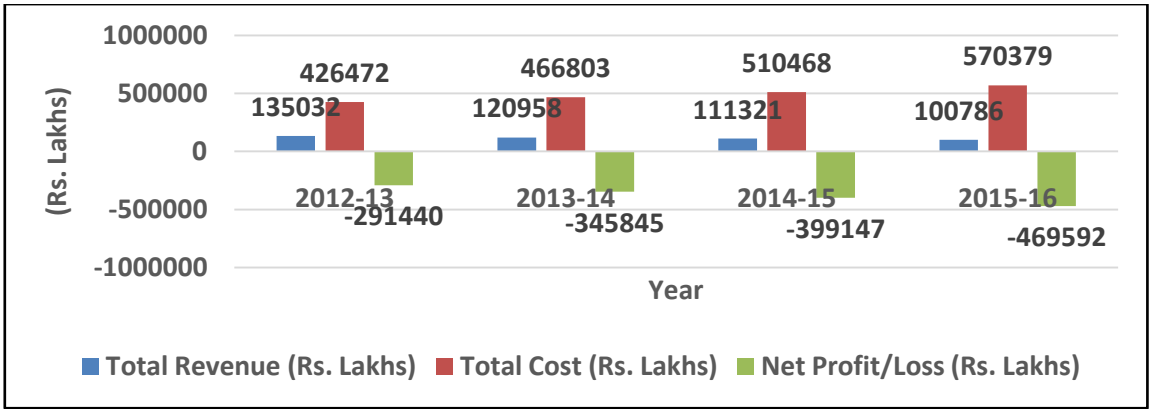
Graph 5 Variation in Fuel Efficiency
Source- State Road Transport Undertaking Repots,(TRANSPORT RESEARCH WING, 2016)

Occupancy Ratio and no. of passenger carried/day/bus: Occupancy ratio is the total number of people using the transit service against the optimum number of people that can be accommodated. Low occupancy ratio or decline in occupancy ratio indicates decrease in popularity or demand of transit. Form 2012-13 to 2015-16, the occupancy ratio and number of passengers carried by a bus per day has dropped significantly, thus reflecting poor quality of service and modal shift towards private vehicles.



Graph 6 Variation in Occupancy rate and no. of passengers carried/day/bus
Source- State Road Transport Undertaking Repots,(TRANSPORT RESEARCH WING, 2016)

Financial Performance parameters: The loss or profit to an transit authority determines its funds and capitals. The investment for new and better fleet is directly related to quality of service provided by the transit authorities. In the case of India, most of the transit authorities are running at hefty losses which restricts them to increase their fleet strength, invest in technologies for enhancing service quality and finally ends up losing ridership. Delhi is not an exception either. The loss to Delhi Transit Services (DTC) has considerably increased over the years.



Graph 7 Variation in Financial Parameter
Source- State Road Transport Undertaking Repots,(TRANSPORT RESEARCH WING, 2016)

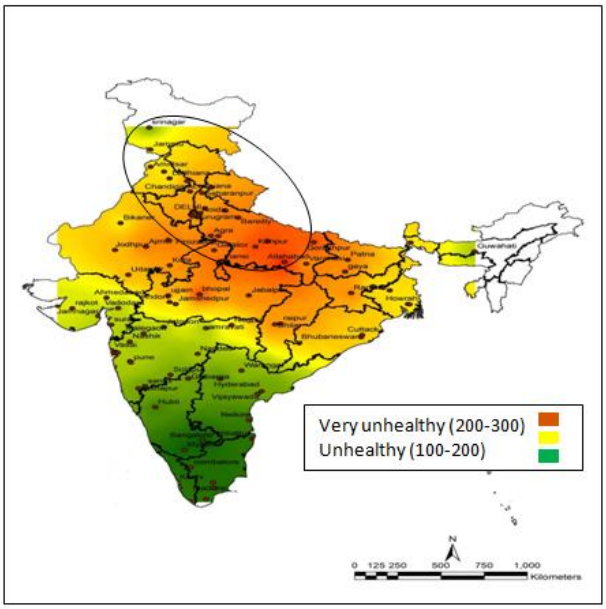
4. IMPACT OF NEGATIVE EXTERNALITIES FROM PRIVATE TRANSPORT IN DELHI

The use of private vehicles helps generate the economy but causes various negative impacts. The negative externalities like congestion, vehicular emission, noise pollution, accidents, and road damages generated by its use create a significant economic loss. Out of the top 10 Congested cities in the World, 4 of them are present in India, as per TomTom congestion index released in 2020. Another study by the World Bank, depicts that India lost more than 8.5% of its rise in GDP in 2013 due to air pollution.As much as two thirds of deaths from air pollution in India can be attributed to exhaust emissions from diesel vehicles, which were responsible for nearly 385,000 deaths in 2015.

Though, majority of the commuters prefer public transit services, the negative externalities arising due to the use of private transport is certainly high in the case of Delhi. As per the study conducted by TERI and ARAI, the contribution of vehicular emissions in Delhi's air is up to 30% if secondary particles are taken into account. Air pollution not the only cause of increase use of private transit, the noise pollution level Delhi are also hazardous.

Majority of the residential and commercial areas experience noise above 55db and 65 db respectively, which is above the limit set by CPCB (Central Pollution ControlBoard). Noise pollution leads to a decrease in property prices and affects our health that directly leads to serious issues ranging from economic loss to hearing loss.

Lastly, addressing the issue of congestion, as per the study conducted by CSE (Centre for Science and Environment) Average traffic speed on 13 arterial roads 50-60 per cent lower than their design speed. Also as per a study conducted by IIT Madras, the annual congestion cost wasINR 54,000 crore in 2013. This is 12.5 per cent higher than Delhi's total annual budget for the year 2017-18



Map 1 Air Pollution Map of India
Source- - Author generated (ArcGIS), CPCB (Central Pollution Control Board), Air visual

METHODOLOGY

The Present study follows a systematic methodology to calculate the amount of fuel consumed and corresponding carbon emission per day, and estimate the change in amount of fuel consumed and relative carbon emissions if 20% of the trips currently made by private transport shifts towards bus transport.

The per trip rate of Delhi was adopted from literature review as 1.22 (Sandhya Dhameniya, 2016).The per capita trip rate of Delhi is then multiplied by the total population which then yields the total number of passenger trips happening in a city per day. The total number of passenger trips are distributed as per the mode share of the city to estimate the number of passenger trips performed by each mode. The mode share of Delhi is adopted from literature review(Anumita Roychowdhury, 2017). The total number of passenger trips served by each mode is then divided by the occupancy rate of corresponding mode which then gives number of total trips performed by each mode. The mode wise average trip length is then multiplied with the total number of trips to get the total distance covered by different mode per day. The amount of fuel consumed and the value of emission factor corresponding per kilometer of distance covered is adopted as given by Central Pollution Control Board (CPCB). For estimating the amount of fuel consumed, a standard value of mode specific mileage is considered which is adopted from stakeholder discussion.

For estimating the change in fuel consumption and corresponding carbon emission, 20% of the trips performed by each of the other transit mode (Car, Two-wheeler and Private Auto) is then shifted to the number of trips performed by buses.

Calculations

The per capita trip rate of Delhi is 1.2 (Sandhya Dhameniya, 2016), which when multiplied by the total population yields 3, 42, 16,800 trips a day. Private transit accounts for 95, 80,704 trips daily, while Public bus services undertakes 92, 38,536 trips daily. As per the current mode share of Delhi, 28% of the population commutes by private transportation (two-wheeler, car and private auto), whereas 27% of the population prefer bus services. If 20% commuting of the each of these private

Mode of transport shift towards public transit, the implications of this modal shift will be as follows:

Table 1 General Profiling

Mode	Modal Share	Average Trip Length (km)	Total Trips per day
Bus	27%	10.7	92,38,536
Car	9%	11.3	30,79,512
Two-wheeler	14%	10.3	47,90,352
Private Auto	5%	12.8	17,10,840
Total	**55%**		**1,88,19,240**

Source- (Sandhya Dhameniya, 2016), (Anumita Roychowdhury, 2017)

Estimation of Carbon Emissions- Business as Usual (BAU)

The total amount of Carbon Emission is evaluated by the given formula:
Carbon Emission= Fuel Consumption*Emission Factor*(Source-CPCB)*

Table 2 Vehicle Specific Emission Factor

Parameter	Emission factor/vehicle (kg CO2/km)	Emission factor/passenger (kg CO2/km)
Bus	0.97	0.02
Car	0.18	0.09
Two-wheeler	0.04	0.031
Autos	0.13	0.046

Source- India GHG Program, 2015

The total distance covered by a specific category of vehicle is given by the formula:
Total Distance covered= (Total trips/Occupancy rate)* Average Trip Length

Table 3 Daily Fuel Consumption in Current Scenario

Mode	Average Occupancy	Mileage (km/l)	Total Distance covered in a day (km)	Fuel Consumed (liters)/day	Total Carbon Emissions (kg)
Bus	50	5	19,77,046	3,95,409	3,83,546
Car	2	15	5,12,99,242	34,19,949	6,15,591
Two-wheeler	1.5	50	3,28,93,750	6,57,875	26,315
Private Auto	2.5	20	87,59,500	4,37,975	56,937
Total			**94,929,538**	**49,11,208**	**10,82,389**

Source- Author's Calculations

At the current scenario, the urban road transport system of Delhi emits 10, 82,389 kg CO2 per day.

Estimation of Carbon Emissions (If 20% of the private vehicle using shift towards bus services)

If 20% of the trips currently made by private transport shifts towards bus services, then the total number of trips would change as follows:

Table 9 Mode wise Total Trips (20% in bus services)

Mode	Motorized Modal Share	Average Trip Length (km)	Total Trips per day
Bus	27%	10.7	11154676
Car	9%	11.3	2563609
Two-wheeler	14%	10.3	3832281
Private Auto	5%	12.8	1268672
Total	55%		1,88,19,240

Source- Author's Calculations

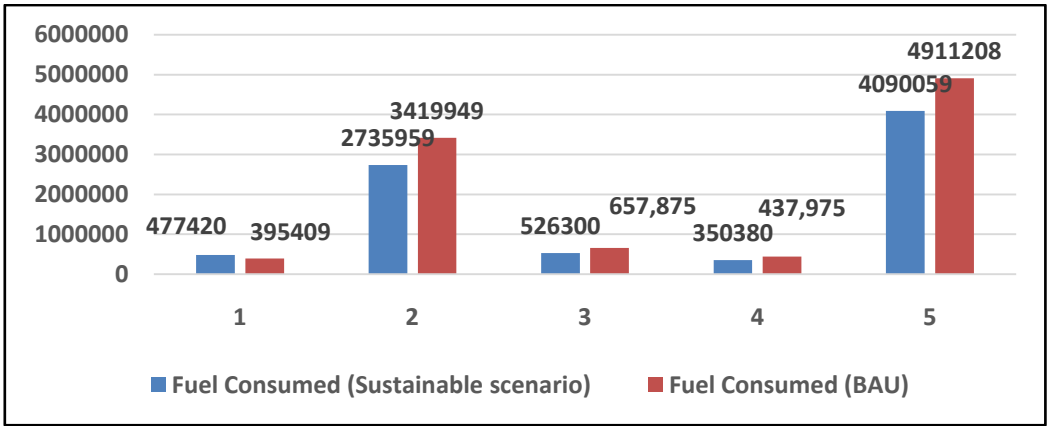
Result

The implicationsof 20% modal shift towards public transit are follows:

Table 10 Implications of Modal Shift

Mode	Motorized Modal Share	Total Trips per day	Total Distance covered in a day (km)	Fuel Consumed	Total Carbon Emissions (kg)
Bus	31.7%	11154676	23,87,100	4,77,420	4,63,097
Car	8.1%	2563609	4,10,39,393	27,35,959	4,92,472
Two-wheeler	11.2%	3832281	2,63,14,996	5,26,300	21,052
Private Auto	4%	1268672	70,07,600	3,50,380	45,542
Total	55%	1,88,19,240	76,749,089	40,90,059	10,22,163

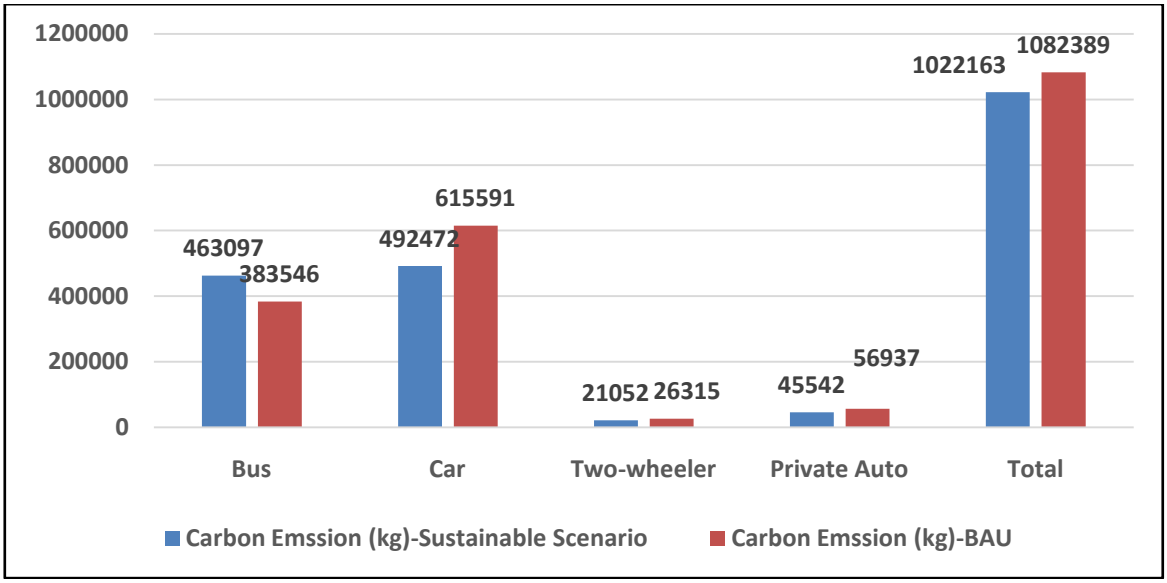
Source- Author's Calculations



Graph 8 Scenario Specific amount of per day fuel consumption (liters)

Source- Author's Calculations

If 20% of the private transport trips shift towards bus services then, the modal share for bus will increase by 31.7% from 27%, whereas the modal share of car, two-wheeler and private auto will reduce from 9%, 14% and 5% to 8.1%, 11, 2% and 4% respectively. The total overall distance covered will reduce by 23.68% per day. The total amount of fuel consumption will reduce by 20.07% per day. The total amount of carbon emissions will reduce by 5.8% per day.



Graph 9 Scenario Specific amount of GHG emissions (kg) per day
Source- Author's Calculations

CONCLUSION

The rate of motorization in Delhi has rapidly increased, as the quality of bus services is are declining, reflected by the modal shift in favor of private transportation. As per the state road transport undertaking reports, majority of the public service providers are working at financial losses, which in turn make it harder for them to maintain a standard service quality, thus resulting in loss of public transport ridership and modal shift in favor of private vehicles. The draft Master plan of Delhi 2041, also envisages for improving connectivity and public transport infrastructure. The formation of Unified metropolitan transport authority (UMTA) for enhancing coordination between different public transit authorities is also recommended.

The need of the hour is to invest more on public transport services to attract sustainable modal shift and think beyond investing in flyovers and parking lots, which directly or indirectly promoted the use of private vehicles. It becomes paramount to allot more funds to public transport service operators and develop novel financial and economic strategies for the same.

The increasing use of private transport produces hefty negative externalities, which if not abated will cause immense loss in economy.The introduction Delhi EV policy which advocates to reduce the use of conventional ICE based vehicles by offering incentives for purchasing of electric vehicles is one of the steps taken by government for curbing air pollution (TRANSPORT DEPARTMENT, 2020). Other than this the initiation towards Pigovian taxin India is another way to solve this issueand counter the losses due to negative externalities of private transport.

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