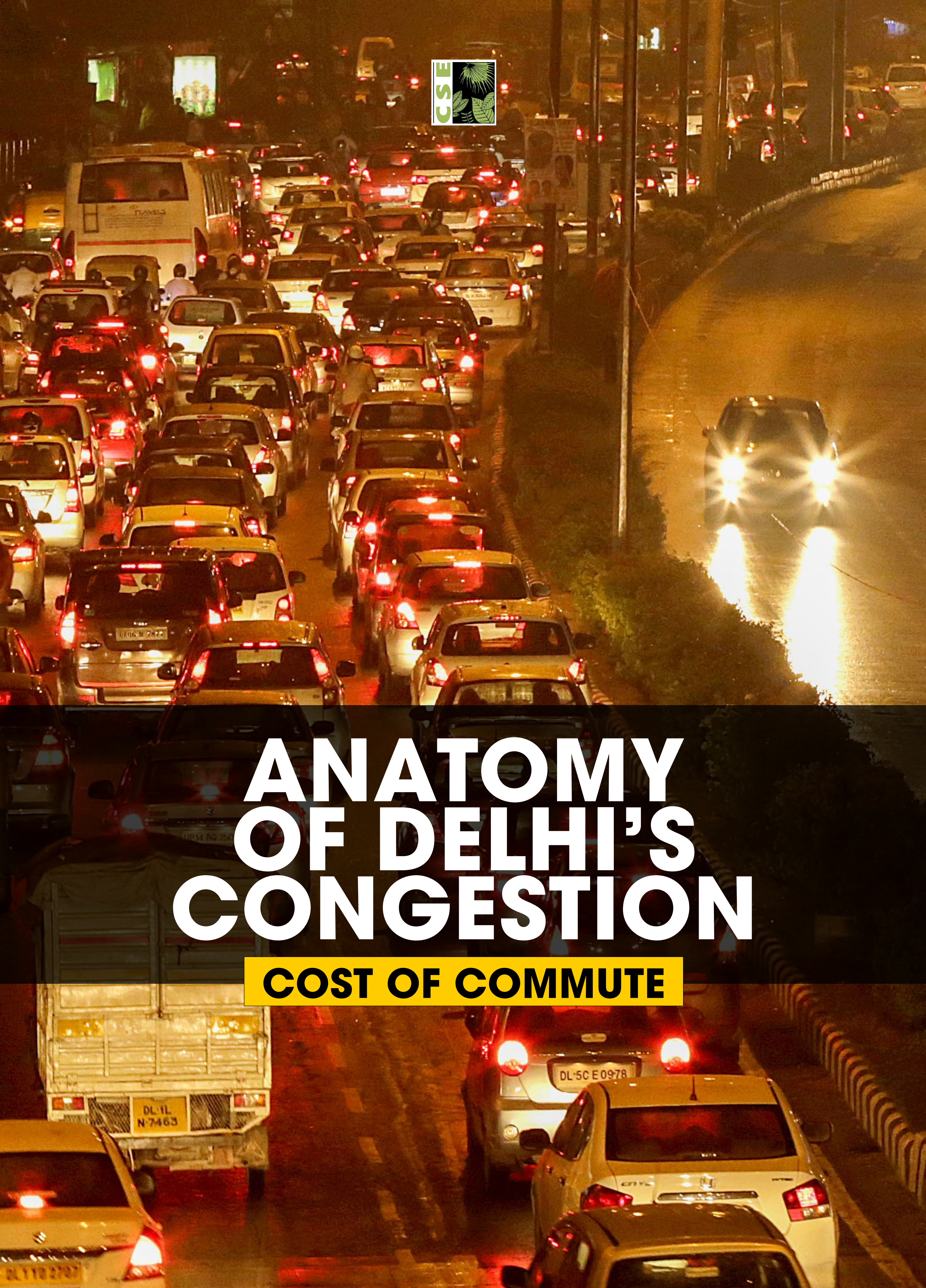

ANATOMY OF DELHI'S CONGESTION

COST OF COMMUTE

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1. Why this study?

Indian cities are battling one of the toughest pollution battles and are struggling to implement multi-sector strategies to meet the clean air benchmark. One of the most difficult challenges is to curb emissions from the urban transport which is one of the fastest growing sources of pollution in cities. Vehicles are among the top or top three polluters in cities and also the third highest contributor to the green house gas emissions in India.

Even as cities are ramping up technology measures to control tailpipe emissions from vehicles, often the impact of such interventions get negated because of the explosive traffic exacerbated by the growing dependence on personal vehicles to meet the growing demand for travel. This explicit link between technology transformation and mobility management to control emissions is not well integrated and mainstreamed in policy priorities for resource mobilization and implementation.

This dilemma is starkly evident in the difficult experience of the capital city of Delhi that is fighting one of the toughest pollution battles for more than two decades. Delhi mirrors the pollution crisis. Its priority technology intervention to control vehicular pollution include the largest ever CNG programme for public transport and local commercial transport; phasing out of 10 year old diesel vehicles and 15 year old petrol vehicles; bypassing truck traffic and restricting non-destined trucks; Bharat Stage 6 emissions standards and 10 ppm sulphur fuels; control dieselization with imposition of Air Ambience Cess on each litre of diesel sold; pollution charge on big diesel cars and imposition of environment compensation charge on each truck entry; and the ongoing electrification of the new fleet.

Even after taking these measures and contributing to the overall downward trend in pollution in the city, vehicles remain the top contributor to Delhi's PM2.5 concentration—more than half, especially during winters. The reality check shows that emissions benefits are being undermined by the mobility crisis in the city.

Visibly choking congestion due to explosive, slow and stagnant traffic, and growing personal automobility are the next generation challenges that cannot be ignored either in Delhi or in any other city and smaller town of India. Yet the factors responsible for congestion and its solutions do not find the priority space in policy action. It is very clear that either the goals of clean air or the targets for low carbon pathways cannot be met if this agenda is not addressed.

It is from this perspective that the Centre for Science and Environment has turned this spotlight on what ails mobility in Indian cities. Against the national backdrop, a spotlight has been put on the anatomy of congestion in Delhi—what are the factors that are contributing to this challenge and what is needed to address the mobility crisis for clean air and low-carbon pathways? The capital city only reflects the nation-wide crisis. If not addressed, this can lead to irreversible changes at an enormous economic, environmental and social cost.

Spotlight on explosive traffic and congestion

Traffic congestion, the most visible symptom of the mobility crisis in India cities, is a reflection of a much deeper malaise. Growing congestion is snuffing life out of the cities. Congestion, which is essentially the crowding of personal vehicles—two wheelers and cars—on roads, indicate several challenges with mobility planning in cities.

Understanding the underlying causes and far-reaching consequences of traffic congestion is critical for shaping urban policies. This is needed to identify and scale up solutions to enhance the quality of life and also safeguard economic productivity. The solution has to go much beyond traffic management and seek deeper solutions in urban planning and design. Some of the key factors contributing to this trend include:

- The lack of sufficient sustainable transportation options to efficiently connect origins and destinations for the urban majority, combined with inadequate infrastructure for walking, cycling, last-mile connectivity, and walkable neighborhoods, is leading to a growing reliance on personal vehicles.
- Despite the rising travel demand in cities, the quality of public transport and ridership are declining sharply, while the share of personal transport is steadily increasing.
- For a sizable share of the urban population, the cost of journey by public transport is unaffordable. Due to poor integration of different public transport systems, number of interchanges involved to reach destination, and diverse fare systems of different modes increase the journey cost. It is often much cheaper to drive a two-wheeler compared to using public transport.
- Road design to make car commuting more convenient and seamless is compromising the ease of safe access to public transport and to walkable destinations within short distances. The rapid shift towards very wide roads, removal of crossings, installation of foot over bridges, and inadequate pedestrian facilities, are increasing the degree of difficulty in accessing public transport services, destinations and neighbourhoods. This is discouraging active mobility and usage of public transport

- There are various hidden subsidies for personal vehicle use that have not been removed or recouped, meaning that vehicle owners are not paying the full cost of owning and using their vehicles, including the impact on public infrastructure, congestion, and pollution. In fact, the tax burden on public transport is often higher than the personal transport.
- At the same time, cities are expanding, primarily beyond their municipal boundaries. This has increased travel distances, and trip length. With increased vehicle miles travelled, more pollution and carbon are getting locked into the infrastructure.

All these factors are contributing to an irreversible trend in congestion that is making cities unliveable.

Productivity loss: This daily ordeal is not just an inconvenience but has profound social consequences. Time lost in traffic could have been spent on work, rest, or with family, diminishing the overall quality of life. For many, commuting in congested conditions leads to elevated stress levels, fatigue, and general dissatisfaction with urban life, exacerbating mental and physical health problems. Indian cities, especially metropolises like Delhi, Mumbai, and Bengaluru, are now infamous for their gruelling traffic, and without dedicated efforts to address this problem, the situation threatens to worsen as car ownership rates increase and urbanization continues.

Welfare loss: From an environmental standpoint, traffic congestion is a major contributor to air pollution, an issue already at critical levels in many Indian cities. When vehicles are stuck in traffic, they continue to burn fuel inefficiently, spewing harmful emissions into the atmosphere. This increases the concentration of pollutants such as nitrogen oxides and particulate matter, which are linked to respiratory illnesses, cardiovascular diseases, and premature deaths.

Prolonged exposure to these pollutants, particularly in cities like Delhi, poses a significant public health crisis. The deterioration of air quality is not only an environmental concern but also places a financial burden on the public health system, which must contend with the rising costs of treating pollution-related diseases. In this context, studying congestion is inseparable from addressing India's broader environmental and health challenges. By reducing congestion, cities can cut emissions, improve air quality, and safeguard public health, making urban living more sustainable.

Increase automobility: At the same time, it creates a vicious cycle where the inefficiencies of public transport push commuters towards greater reliance on private vehicles. Buses particularly, which should ideally be the backbone of urban mobility, become stuck in the same traffic jams as private cars, leading to longer operating hours, increased fuel consumption, and higher maintenance costs. Delays make public transport less reliable, less convenient, and ultimately less appealing to commuters.

This further undermines public transport systems financially. As buses take longer to complete routes, fewer trips are possible in a day, reducing operational efficiency and revenue for transport agencies. Additionally, overburdened and delayed services deter new users, resulting in a downward spiral of declining ridership and revenue. The system becomes financially unsustainable, with insufficient funds to invest in necessary improvements like better buses, cleaner facilities, or expanded routes.

With personal vehicles offering the perception of greater control over one's journey, commuters opt for cars or two-wheelers to bypass the inefficiencies of the public system, even if it means placing additional strain on the urban environment and infrastructure.

Economic cost: For commuters, the economic cost of congestion is staggering. The hours lost sitting in traffic translate directly into lost productivity for both individuals and businesses. For the millions of commuters in Indian cities who rely on daily wages, the time wasted in traffic is time not spent earning a living. The cumulative effect of millions of people stuck in traffic daily leads to massive productivity losses across sectors, dragging down economic growth.

Adverse impacts on business: Moreover, for businesses, congestion disrupts supply chains and increases operational costs. Delivery delays, increased fuel consumption, and vehicle maintenance costs all rise due to traffic jams. The economic implications of congestion extend to the logistics and manufacturing sectors, which are heavily dependent on the efficient movement of goods. Delays in the transport of goods increase the cost of doing business, which is often passed on to consumers, driving up prices in congested cities.

The opportunity costs of congestion: This is also significant. Beyond the direct loss of productivity, congestion limits opportunities for personal and professional development. The time that could have been spent on more meaningful pursuits—such as further education, social interaction, or relaxation—is wasted on the roads.

The economic impact of congestion is compounded by its influence on urban competitiveness. Cities that are notorious for traffic congestion risk losing their appeal to investors, businesses, and skilled workers. As cities vie for investment and talent in an increasingly globalized economy, the efficiency of their transportation networks becomes a critical factor. Congestion reduces the attractiveness of a city as a destination for both domestic and foreign investment. Investors are less likely to invest in regions where the cost of transporting goods and people is significantly elevated due to chronic traffic delays.

To be in reverse gear for more equitable urban planning. In Indian cities, congestion disproportionately affects the economically disadvantaged, who rely on public transport or non-motorized modes of transport. Buses and auto-rickshaws are frequently caught in the same traffic jams as private vehicles, but with fewer alternatives available, the urban poor bear the brunt of the delays. For many low-income workers, late arrivals due to congestion can mean pay cuts or job loss, further entrenching economic inequalities. On the other hand, the affluent can mitigate some of the effects of congestion by using personal vehicles, ride-hailing services, or even helicopters in extreme cases. This disparity underscores the importance of studying congestion to design urban mobility solutions that are inclusive and benefit all residents, not just the privileged few.

Towards liveable and vibrant cities: Ultimately, addressing congestion in Indian cities is not just about improving traffic flow—it is about creating more livable, sustainable, and economically vibrant cities. The insights gained from studying congestion can inform policies that promote the use of public transport, encourage walking and cycling, and reduce the dependency on private vehicles. Such measures, if implemented effectively, can help reclaim valuable urban space, reduce emissions, and foster a healthier, more productive urban populace.

Key highlights of the assessment

Against this backdrop, the Centre for Science and Environment (CSE) has carried out an assessment of some of the key parameters that reflect the manifestation of the mobility crisis. This includes a quick overview of the national trends in motorization, changing trends in modal share of public transport, walking and cycling, status of electrification, and state of bus and metro transport and their usage.

In addition, a deep dive assessment has been carried out on some of the key parameters based on ground surveys in Delhi to understand how Delhi mirrors the national crisis. This has specially investigated the aspects and consequences of congestion and what it costs to commute in Delhi that have strong bearing on travel choices and behaviour.

The summary highlights of the findings are as follows.

Overview of the national mobility crisis

National trend in motorization: Motorization has been rapid since 2000. New vehicle registrations have doubled every 5-6 years. Even after the COVID slump, the trend bounced back to pre-COVID level within a year. 2023-24 saw about 58,000 registrations per day on an average in the country, of which about 52,000 were private vehicles – cars and two-wheelers.

Modal share in cities is heavily skewed towards private transport. The per capita trip rate and the average trip length in cities have grown substantially in the last decade increasing travel volume and travel distances. Growing dependence on personal vehicles in this context is escalating congestion and pollution.

Electrification of vehicle fleets is still nascent: Electrification has gained pace in the last few years, reaching 6.5 per cent of all new vehicles registered since 2015-16 after the first nationwide incentive programme was launched. In the initial stages small vehicles like e-rickshaw almost entirely dominated the stock. Now electric two-wheelers and three wheelers are gaining ground due to improved total cost of ownership, low charging time, ease of charging due to minimal setup required for residential charging and higher number of two-wheeler charging stations, incentive programme favouring two-wheelers, and industry's interest in the segment leading to more diverse options for consumers, and so on.

Bus transport under pressure: Bus transport in Indian cities have several challenges that include severe bus fleet deficit, financial burdens due to declining ridership, lack of multi-modal integration, and competition with other modes, and neglected private bus sector leading to a disjointed sector. For the country, only 10 buses per lakh population is available on an average. Among the top 19 STUs in the country, between 2014-19, bus fleet increased by only 4.6 per cent, while ridership went down by 5.8 per cent. As a result these STUs have also tripled their losses over this period. The average cost-revenue ratio is 1.6, meaning incurring expenditure compared to revenue by 1.6 times. Out of the 2 million buses operational in India, only 0.4 million are dedicated for urban and non-urban public transport services as stage carriage buses.

Metro services fall short of expectations: The capital intensive metro rails face two challenges - ridership lower than projected target, and poor connectivity. Most systems are not networks but single or at best double corridors. Metro rail systems in Indian cities have only been able to achieve about 25-35 per cent of the projected ridership on average. Delhi is the only metro system in India out of total 16 which has a network of routes. The rest are corridor systems, plying on 1-2 routes. Most of these cities have plans to expand the coverage, and construction is underway, however the timelines for completion are long. Limited corridors and connectivity increased interchanges that also add to the journey costs.

Capital intensive metro systems require financial sustainability: Indian metro systems depend more heavily on passenger fare revenue unlike global systems. Non-farebox contribution to revenue is low (Bengaluru, Mumbai and Chennai seeing 6 per cent, 11 per cent and 16 per cent). Delhi's total revenue recovery ratio is 1.1, meaning that while it is incurring losses it is close to breaking even. On the other hand, other systems have very high losses (total revenue recovery ratio for Mumbai, Bengaluru and Chennai are 1.7, 2.5 and 2.5 respectively).

Active mobility – walking and cycling, is not part of the mainstream policy: Only a few cities in India have recognised the potential of an integrated NMT infrastructure network, and most have incorporated isolated and fragmented walking and cycling projects in their respective city mobility plans, smart city development strategies, master plans, and clean air action initiatives. Moreover, these initiatives mostly have very limited scalability. These are also poorly monitored and maintained that compromises their usage.

Mobility crisis in Delhi

Explosive motorization: With an annual registration of 6.4 lakh vehicles, Delhi registered about 1,750 vehicles every day on an average in 2023-24. Out of this, 1,600 were private vehicles. During the pandemic, while two wheelers registrations declined by 42 per cent, that of cars by only 13 per cent. But the registration made a quick recovery, reaching pre-pandemic levels, within a year

Despite the old vehicle phase out, the crisis prevails: Following the judicial directives, the transport department deregistered 48.7 lakh vehicles in January 2022 including 13 lakh cars and 29 lakh two-wheelers. Even though it is said that old vehicles have been deregistered and that these have stopped operating, it is estimated that about 7 lakh vehicles have taken an NOC for re-registration in other states while 1 lakh vehicles were scrapped.

Sharp drop in modal share of public transport: The available information shows steady drop in public transport modal share since 1994 when the modal share of private vehicles in all motorized trips was 27 per cent. This has increased to 48.2 in 2018. The number of trips in the capital have gone up by 94 per cent since 2008. Average per capita trip rate (PCTR) has increased from 1.38 in 2007 to 1.55 in 2018, a 12 per cent increase. Additionally, the average trip length in Delhi has increased from 6 kms in 2007 to 10.9 kms in 2018 due to the growth of regional centres, and improvement in accessibility of these centres through roads and public transport.

Bus numbers and ridership are very slow to improve: The increase in the bus numbers since 2021 has increased the ridership somewhat but it has not yet recovered to pre pandemic level. While ridership sees an increase, numbers are still lower than pre-COVID levels (25 per cent for DTC buses, 7 per cent for cluster buses). Even though bus ridership is increasing, numbers are still below pre-COVID levels, with DTC buses seeing a 25 per cent reduction in ridership and cluster buses experiencing a 7 per cent drop.

Metro ridership short of projected ridership: Delhi metro's average daily expected ridership in 2019-20 after the completion of the first three phases was 53.47 lakhs. The recorded average daily ridership that year was about half the expectation, merely 27.79 lakhs. Moreover, the average ridership per kilometer has reduced significantly, which means that the network is expanding without a proportional increase in ridership.

Poor connectivity of the metro system: Delhi Metro operated by DMRC is one of the better operating metro systems in the country. However, despite the current coverage of 392.44 kms across 10 routes, it caters to 9.85 per cent of Delhi's population at a 5-minute walking distance or 400 m from a metro station, and 32.08 per cent population at a 5-minute cycling distance or 800 m from a metro station.

Bus and metro ridership comparison reveals that the metro is increasingly becoming the preferred choice for commuters of public transport. Between 2011-2020, bus ridership fell sharply by 24.6 per cent, whereas metro ridership increased by 67.5 per cent. This increase in metro ridership does not reflect the number of trips, but also includes the number interchanges made on routes, due to a change in the ridership calculation formula by DMRC.

Choking congestion: Congestion warps the perception of commuters, due to the delay caused and the extra planning time required for every journey. During weekdays, Delhi sees an average speed reduction of 41 per cent in morning peak hours and 56 per cent during evening peaks. Over weekends, morning traffic is slowed down by 27 per cent and evening traffic by 42 per cent.

Productivity loss: The delay due to congestion also leads to productivity loss. For highly skilled, skilled and unskilled labourers (as per the labour department's standards for minimum wages), an unskilled worker stands to lose between Rs7,200 - Rs19,600 per year due to congestion. Similarly, skilled and highly skilled workers can lose as much as Rs 8,300 - Rs 23,800 and Rs 9,000 - Rs 25,900 a year respectively. This equals to upto 12 per cent of their monthly income.

Perception of congestion and journey delays: The average planning time index for Delhi can go upto 3.64 (average based on 25 selected most congested routes) which means additional 3.64 times the regular travel time during free-flow needs to be considered while planning the time. Evening peaks are observed to have greater variability in travel time prediction. The low traffic reliability leads to commuters being more used to congestion than they should, and congestion becomes part of the routine. Results also show that travel times increased by as much as 4.5 times extra during evening peaks, and up to 2.5 times extra during morning peaks compared to free-flow time.

Cost of journey: Vehicle taxation structure favours personal mobility. Private two-wheelers are taxed the lowest, despite the number of registrations which means higher utilisation of roads and the congestion problem. Similarly, cumulative taxation on cars is lower than cabs and buses over a period of 10 years. Buses are taxed very high despite their low emissions per passenger, considering their role in public transportation. Cumulative taxation per passenger for buses is already more expensive by Year 5 than private cars.

Based on a survey conducted among commuters in Delhi who were asked to describe their journeys by modes, time taken, distance covered and the cost incurred for each mode.

- Private vehicle trips show a lower fuel/fare cost than all other modes – intermediate public transport (IPT), public transport (PT) and mixed modes (compared to the fare cost), while public transport has the highest interchange and transit time costs.
- The factors which increase the journey cost of public transport systems are

interchange mode fare costs for first and last mile, interchange time cost, as well as the increased journey time cost due to congestion (for buses). The median value of income spent on transport based on the journey described by respondents for public transport trips is 18 per cent and for private transport, the median value is 12 per cent.

- Bus trips are more expensive than private vehicle trips due to reduced manoeuvrability and slow speed of buses in congestion compared to private vehicles. Additionally, the interchange time and fare also adds to the total journey cost.
- Metro trips are more expensive than car, two-wheeler or bus transport trips when considering the total journey cost, due to the increased costs of first and last mile connectivity and due to lesser coverage of metro stations compared to bus stations. Additionally, the time taken for boarding and alighting metro trains is also substantial due to factors such as navigating through often crowded platforms, queues for security posts, etc.
- Private transport trip costs are also overestimated by commuters, as per the survey results. It was found that out of the total sample, about 65 per cent private vehicle commuters overestimated their cost of commute. This suggests a systematic bias in how individuals perceive their travel expenses.
- For trips which used multiple transport modes were also much more expensive compared to private vehicles. IPT trips can cost as much as 27 per cent of the annual income for a passenger, whereas mixed trips which include public transport can exceed 50 per cent of the annual income. The maximum limit of private transport trips was 23 per cent.

Congestion and pollution linkage: Congestion also leads to higher pollution as idling can cause emissions that are several times higher than their normal emissions on roads. Studies have shown that emissions can be 3–7 times higher in congested traffic than in free-flowing conditions, with specific pollutants like nitrogen dioxide (NO_2), carbon monoxide (CO), and carbon dioxide (CO_2) experiencing dramatic increases.

Economic cost of congestion: Economic costs due to congestion are also substantial. Projected estimate show that congestion will cost Delhi around USD 14.7 billion by 2030, including pollution and fuel wastage. Daily fuel losses due to idling alone are estimated at millions of dollars.

Way forward

Ambitious technology pathway for energy efficiency and zero emissions target: Ambition technology pathways are needed to cut emissions at source. This will need enablers to accelerate the market at a scale.

Need scalable, integrated, connected and reliable public transport system and services: The technology pathway will have to be complimented and strongly supported by the scalable interventions to build public transport infrastructure.

Create low-emissions zones and scale up a network of walking and cycling infrastructure and efficient last mile connectivity: Every public transport trip begins and ends with a walk trip. Augmentation in public transport ridership will require upscaled holding areas for walking and cycling trips. Low-emissions zones can enable targeted transition in zones and areas for community-wide adoption of sustainable transportation options.

Need restraint and demand management measures to reduce automobility: While sustainable transportation options need to be augmented, it needs to be supported by vehicle restraint measures. A combined strategy of parking area management plan, variable parking pricing, congestion and road pricing, among others need to be adopted to restrain vehicle usage and reduce vehicle miles travelled. Reform taxes to recover the true cost of owning and using personal transport.

Adopt compact urban form to keep jobs and home close: Reduce distances, demand for travel and vehicle usage: India has already adopted transit oriented development policy and urban form based code for urban and transportation planning and integration. This needs targeted and upscaled implementation to promote mixed use and mixed income development, regeneration of urban spaces, within close proximity – about 400-800 sqm radius of transit nodes. This can enable a shift in behaviour. Integrate the needs of urban poor with land-use planning.

Shift budgets from road-building to public transport, active transport and zero-emissions mobility. Also adopt innovative fiscal instruments to mobilise new resources: Considerable resources can be unlocked if the current public expenditure in car centric expenditure can be repurposed and diverted towards public transport infrastructure. Simultaneously, adopt innovative financing including land value capture, polluter pay principle, among others to augment resources. It is also important to explore further augmentation through bilateral and multilateral funding including climate finance.

Adopt measurable and verifiable impact monitoring systems: For each of the intervention detailed strategies need to be designed with clear indicators and committed funding. The strategy design has to draw upon the service level benchmarks of the Ministry of Housing and Urban Affairs, appropriate codes of India Road Congress and the other relevant policy and regulatory norms and guidelines. This needs to be monitored and evaluated every quarter to assess the scope of the progress.

2 NATIONAL CONTEXT OF MOBILITY CRISIS

Rapid motorization and greater reliance on private vehicles are causing more congestion and pollution, driven by low public transport use, higher trip rates, and longer distances.

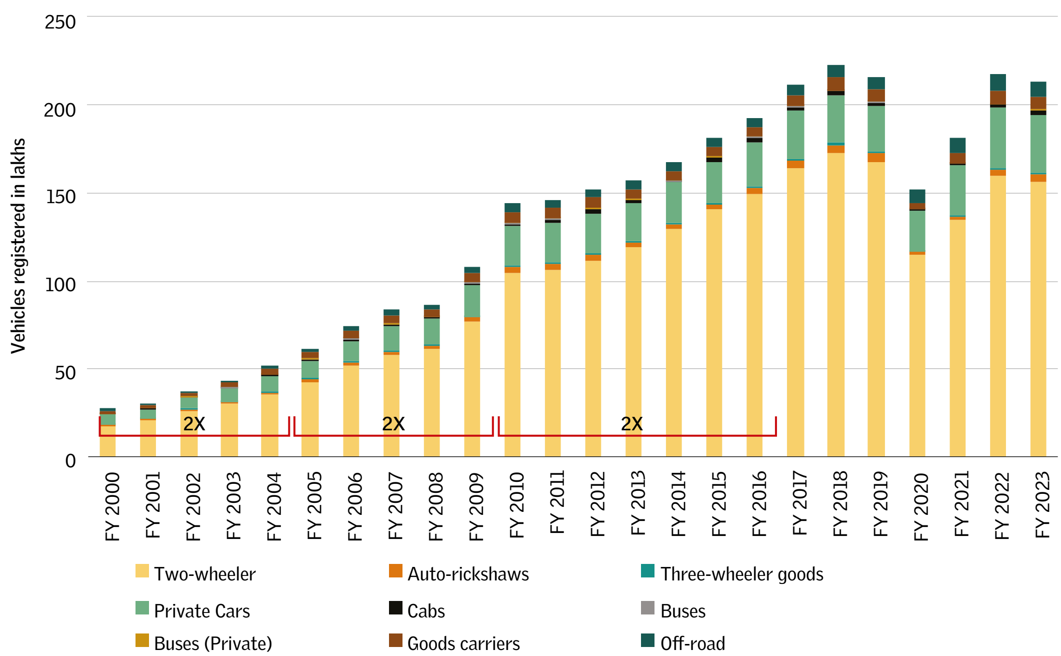
Bus transport suffers from fleet shortages, financial losses, and declining ridership, while most metro systems face connectivity issues, limited ridership, and high operating losses.

Electrification is gaining momentum, especially for two-wheelers, but non-motorized transport infrastructure remains fragmented and poorly maintained, limiting its impact on sustainable mobility.

2.1 Motorization and growing personal vehicle dependence

India's motorization trend and population growth have been exponential and unprecedented. New vehicle registrations have doubled every 5 to 6 years in the country. Compared to FY 2000, nine times more new vehicles were registered in FY 2023-24 *(see Graph 1: India's motorization trend of annual new registrations, 2000-2024).*

Graph 1: India's motorization trend of annual new registrations, 2000–2024



Source: Vahan Database, 2024

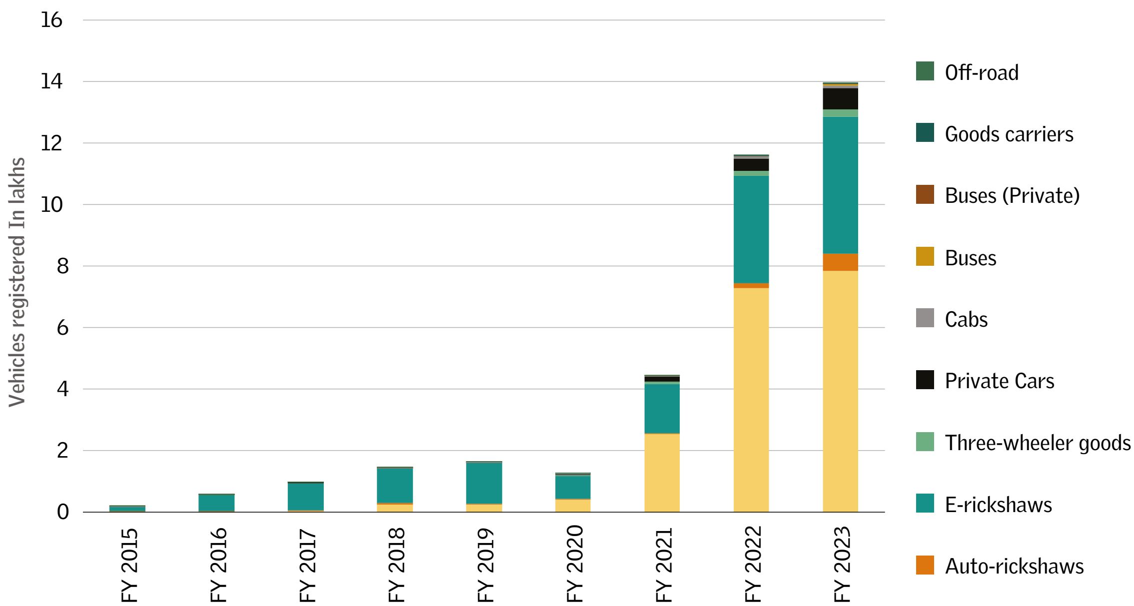
Even after the slow down during the COVID-19 pandemic, the trend bounced back within two years and the numbers climbed back to pre-pandemic levels. The compounded annual growth rate (CAGR) between 2000 and 2024 has been 10.3 per cent for the total vehicles registered in the country.

Personal vehicles have dominated the mix. Over the past 24 years, the average share of two-wheelers has been 72.6 per cent and that of cars 15.3 per cent. The private vehicle share has been in the range of 85-90 per cent throughout.

Nascent beginning of fleet electrification: The electric vehicle (EV) market share has increased from 0.1 per cent in FY 2015-16 to 6.51 per cent in FY 2023-24 *(see Graph 2:India's motor vehicle electrification trend in new annual registrations, 2015-2024).*

This market is growing in stages. During the early phases of the Faster Adoption and Manufacturing of Electric (& Hybrid) Vehicles or FAME scheme, e-rickshaws dominated the market, with a market share of 92 per cent in FY 2017. Most e-rickshaws back then had lead acid batteries because FAME incentives did not distinguish between lithium-ion and lead acid battery systems.

Graph 2: India's motor vehicle electrification trend in new annual registrations, 2015–2024



Source: Vahan Database

After FAME II was launched in 2019, incentives were given only to lithium-ion battery vehicles in all the segments. During this phase, the share of electric two-wheelers increased and since 2019, electric two-wheeler shares has grown rapidly from 15 per cent to 56 per cent in FY 2023.

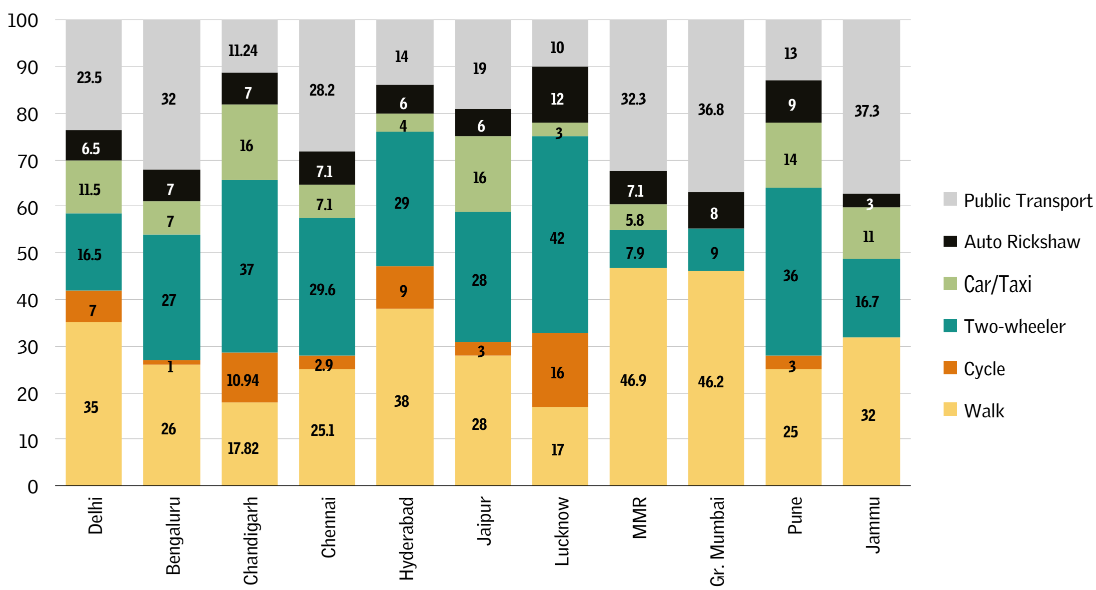
Interestingly, the electric vehicle market did not see a major slump during the pandemic. The private vehicle sector grew throughout the pandemic. Two-wheelers grew 65 per cent between FY 2019 and FY 2020. Cars during the same period quadrupled. Overall, EV registrations dipped by 23 per cent, primarily caused by e-rickshaw registrations halving in FY 2020.

In 2024, FAME was replaced by the Electric Mobility Promotion Scheme (EMPS) as a stopgap measure while the next phase of a demand incentive programme was in the works. During EMPS, two-wheeler sales dropped down to 2021 levels due to reduced incentives. The annual average growth rate of electric two-wheeler registrations in 2024 before the launch of EMPS (Jan-March) was 24.8 per cent. After EMPS till date (Jan-Aug, 2024), the annual average growth rate has dropped to -2.7 per cent.

While the electric vehicles are seen as a beacon of hope for fighting local air pollution and climate change and air pollution, electrification is not going to solve the glaring problem of traffic congestion.

Growing dependence on personal vehicles: A review of the available information on modal share from different sources including city mobility plans and other studies, indicate that on an average the share of personal vehicle usage ranges between 35-45 per cent, that of intermediate public transport (IPT) at about 10 per cent, and public transport modal share a mere 25 per cent in Indian cities. A major share of trips is still non-motorized modes *(see Graph 3 Modal shares in Indian cities show heavy private vehicle dependen).*

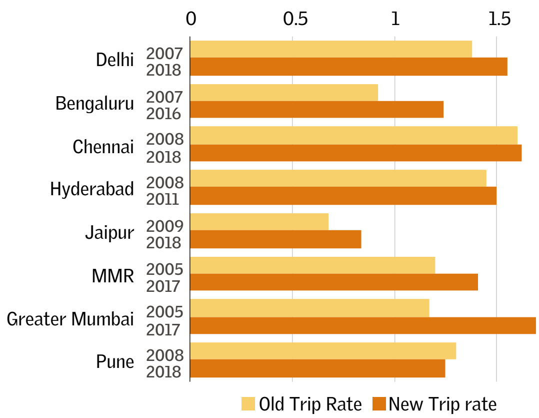
Graph 3: Modal shares in Indian cities show heavy private vehicle dependence



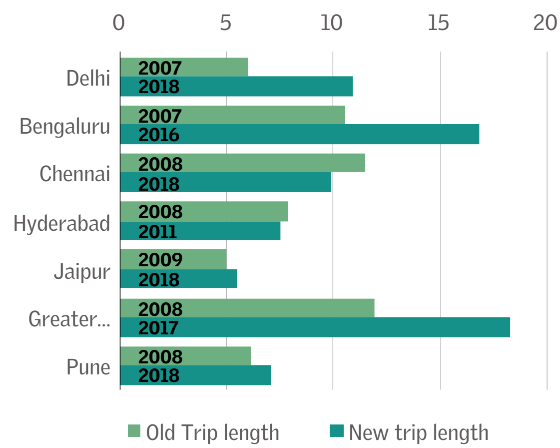
Source: Graph 3 – Respective city CMPs and CTTS studies;

With growing urban population and urban sprawl, cities are witnessing a high number of trips, and increasing trip length. The available data shows that the average per capita trip rate has increased by 17.5 per cent in cities and the average trip length has gone up by 28.6 per cent in the last 10 years *(see Graph 4: Per capita trip rate in the last decade and Graph 5: Average trip length in the last decade).* This implies increase in travel demand and increase in travel distances. In this context if the dependence on personal vehicles continue to grow this will lock in more pollution and carbon.

Graph 4: Per capita trip rate in the last decade



Graph 5: Average trip length in the last decade



Graph 4&5 - Respective city CMPs and CTTS studies, NIUA, IIT-Delhi, Wilbur-Smith Associates

2.2 Bus transport under stress

As of 2019, 56 transport undertakings in Indian cities owned and operated buses. Out of these, 24 are state corporations, 10 are state-owned companies, 8 are government departmental undertakings, 9 are municipal undertakings and 4 are special-purpose vehicles. Delhi Integrated Multi-Modal Transit System (DIMTS) is an associate member of the Delhi government.

These STUs together hold 1.52 lakh buses in India, and out of these 1.31 lakh are operated. For a country with 1.43 billion people and 40 per cent of this being urban population, the urban bus supply is hugely deficient.

Compared to the global front runner cities, Indian cities have on an average three times lower bus fleet numbers per lakh of population. There is roughly 1 operational bus for every 10,916 persons or 10 buses per lakh population see *Table 1: Comparison of public transport supply per lakh of population across global and Indian cities).*

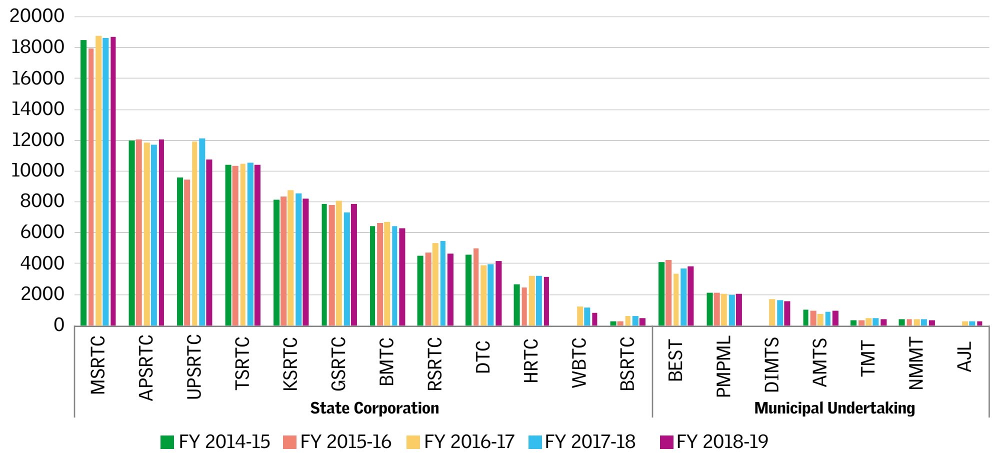
Table 1: Comparison of public transport bus supply per lakh of population in global and Indian cities

City	Metropolitan area Population persons ('000)	Area (km^2)	Bus Fleet size	Bus fleet (per lakh of population)
Global cities				
London	8,302	1,572	7,500	90
Singapore	5,312	716	4,212	79
Hong Kong	7,184	1104	5,743	80
Beijing	20,186	16,411	21,628	107
Shanghai	23,475	6,341	16,235	69
Seoul	10,442	605	7,512	72
Indian cities				
Delhi	19,000	1,483	7,072	35
Mumbai	20,000	603.4	3,410	17
Kolkata	14,900	206.08	1,337	9
Bengaluru	13,193	741	6,677	51
Hyderabad	6,810	625	3,521	52
Ahmedabad	5,578	505	870	16
Kanpur	4,581	403	340	7
Jaipur	4,107	467	250	6
Pune	3,990	516	2,300	58
Lucknow	2,903	631	132	5
Nagpur	2,406	227.36	487	20
Chennai	7,088	1189	3,454	49
Trivandrum	958	214	318	33
Guwahati	957	216	303	32
Mysore	921	155	458	50
Kochi	677	94.88	200	30

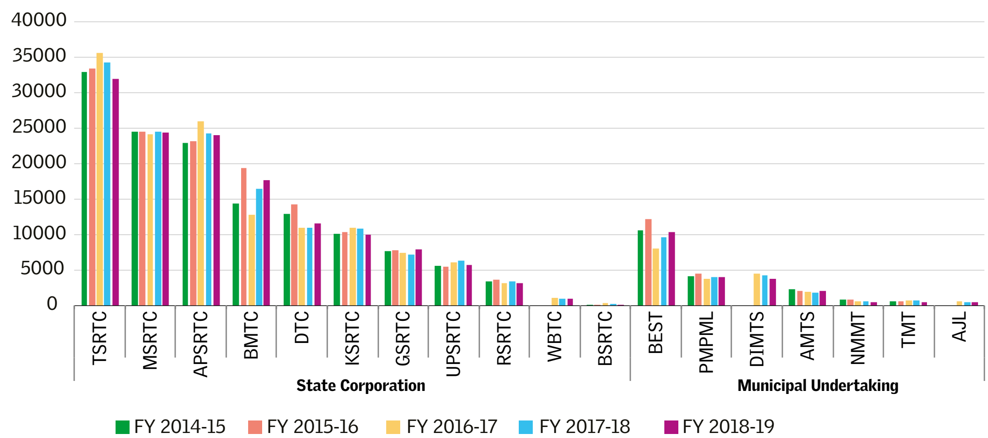
Source: Collated by CSE from official websites, secondary information from respective offices, and news reports (in this order of priority)

The CSE has studied 19 major state transport undertakings (STU), including 12 state corporations and 7 municipal undertakings to understand the girth of the problem. These include the states of Maharashtra, Andhra Pradesh, Uttar Pradesh, Telangana, Karnataka, Gujarat, Delhi, Rajasthan, Himachal Pradesh, West Bengal and Bihar. These state corporations run both intercity and intracity buses in major cities. City undertakings are also available in Mumbai, Pune, Ahmedabad, Thane, and Navi Mumbai. Overall, these 19 STUs represent more than 65 per cent of the bus fleet in India.

Graph 6: Trend of bus fleet numbers in Indian cities, FY 2014–15 to FY 2018–19



Graph 7: Trend of bus ridership in Indian cities, FY 2014–15 to FY 2018–19



Source for graphs: Ministry of Road Transport and Highways, 2023

During the period 2014-2019, these 19 STUs reported a mere 4.6 per cent increase in bus fleet. At the same time, the ridership declined by 5.8 per cent *(see Graph 6: Trend of bus fleet numbers in Indian cities, FY 2014-15 to FY 2018-19 and Graph 7: Trend of bus ridership in Indian cities, FY 2014-15 to FY 2018-19).*

This decline in ridership has led to heavy losses across all STUs. Between FY 2014-15 to FY 2018-19, on an average, the losses have tripled across 19 STUs *(see Table 4: Average and combined revenue recovery of transport undertaking types)*. The combined loss of the 56 SRTUs is Rs17,932 crores. Out of this, the state corporations have the biggest share of 57.39 per cent, followed by state owned companies (23.73 per cent), municipal undertakings (10.33 per cent) and governmental departmental undertakings (6.56 per cent).

Table 4: Average and combined revenue recovery of transport undertaking types

STU type	Combined revenue recovery of the group	Average revenue recovery of an STU
State Corporations	17.60%	16.98%
State-owned companies	26.38%	23.84%
Government department undertakings	39.59%	52.78%
Municipal undertakings	46.19%	46.72%
Associate Members (DIMTS)	48.18%	48.18%
Special purpose vehicles	2.80%	21.39%

Source: Ministry of Road Transport and Highways, 2023

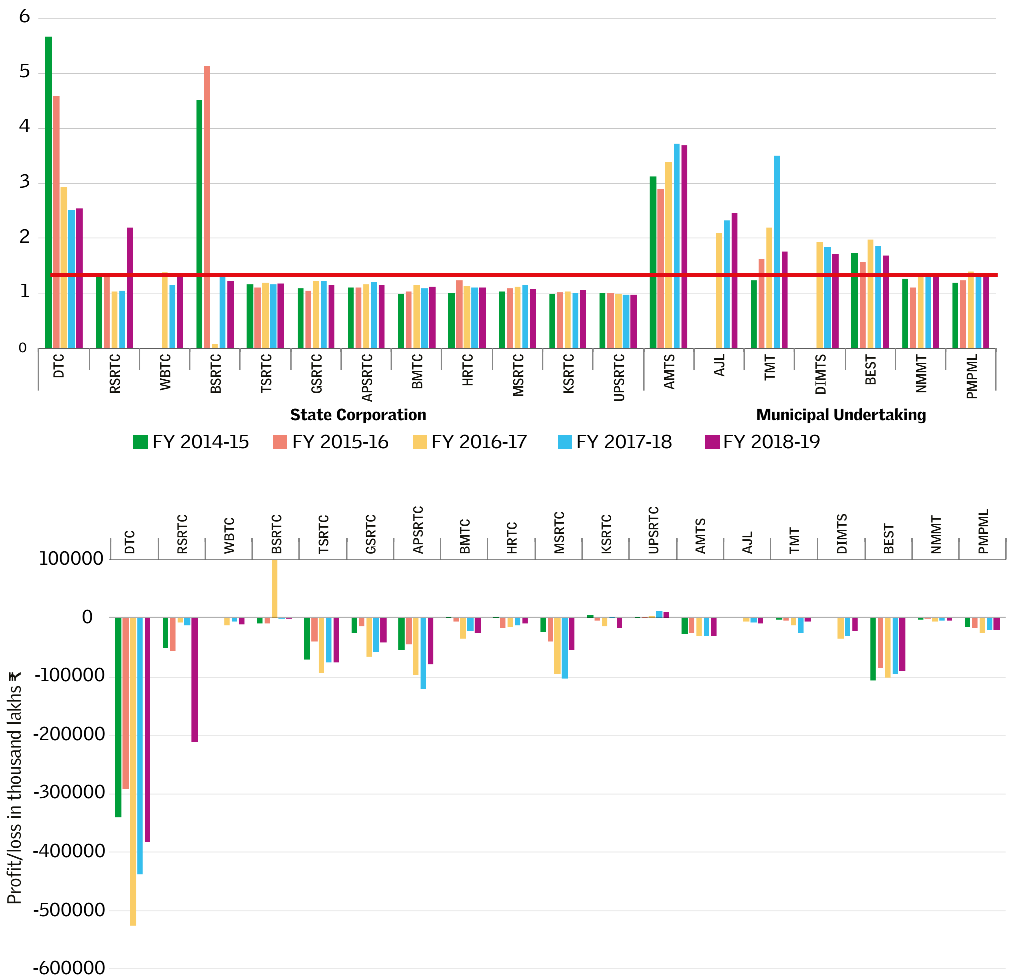
Special purpose vehicles consisting of Agra-Mathura City TSL, Jaipur City TSL, Meerut City TSL, and Kanpur City TSL, have reported the lowest recovery of costs, that is 2.8 per cent in 2018-19.

The leading group of state associate members which consists of only DIMTS reported a 48.18 per cent recovery in the same year. The government department undertakings reported the highest average recovery at 52.78 per cent followed by DIMTS (48.18 per cent), and municipal undertakings (46.72 per cent).

The total revenue recovery ratio is the ratio of total revenue to total operating expenditure. It is the key indicator of financial performance. If it equals 1, the operation as a whole is breaking even; if it exceeds 1 it is earning a surplus, if it is below 1 the operation is losing money. Across the board, STUs have surpassed the break-even point of 1, with the average ratio of 1.6 reported in 2018-19 by the 19 selected STUs studied *(see Graph 8 (A): Cost revenue ratio trend for STUs in Indian cities, FY 2014-15 to FY 2018-19; (B): Profit/loss trend for STUs in Indian cities, FY 2014-15 to FY 2018-19)*.

Due to poor solvency, the STUs principally face two funding challenges. Capital expenditure (CapEx) is required to purchase new rolling stock, creation of bus stops, depots and terminals, and support services such as ITS. Operating expenses (OpEx) funding is required due to the viability gap between cost of operations and revenues received. These challenges must form a basis for meeting any funding needs. Further, it must be remembered that most STUs have limited capacity to manage complex public–private partnerships (PPP) contracts.

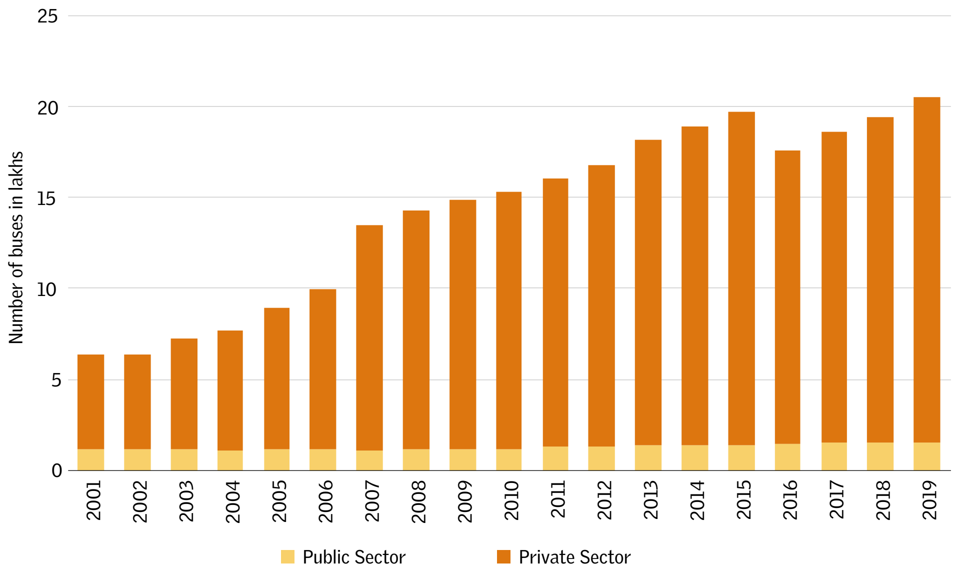
Graph 8 (A): Cost revenue ratio trend for STUs in Indian cities, FY 2014–15 to FY 2018–19; (B): Profit/loss trend for STUs in Indian cities, FY 2014–15 to FY 2018–19



Source: Ministry of Road Transport and Highways, 2023

Domination of private buses: The Indian bus sector is largely dominated by the private bus sector *(see Graph 9 Number of buses in private sector are much higher than public sector)*. While the number of buses has remained almost stagnant in the public sector, private bus numbers are growing rapidly. India has a fleet of nearly 2 million operational buses. Most buses are operated for private institutions (such as schools, offices, and universities) and on contract carriage. A fraction of this fleet, about 0.4 million, is dedicated to (both urban and non-urban) public transport services and these are operated as stage carriage[1].

Graph 9: Number of buses in private sector are much higher than the public sector



Source: Open Government Data Platform

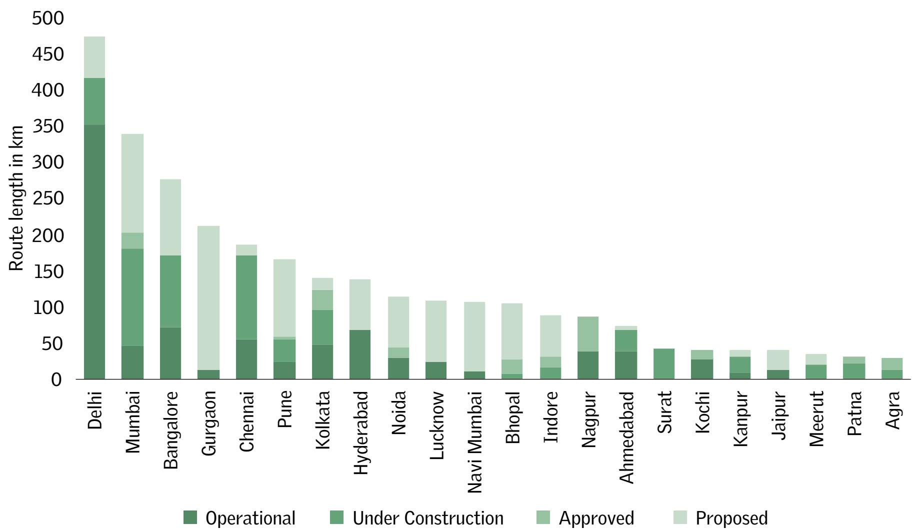
According to CIRT, 64 per cent of passenger kms are catered to by private buses in Indian cities. The growing trend in the number of buses indicates that there is a growing demand for buses in cities. However, the ownership division shows it is still in the unregulated sector.

The implication of this is that the technology transformation in terms of electrification and service level improvement that are needed in the bus sector cannot be pushed adequately in the organised sector. Yet, given the size and growth of these operations, a model is needed to enable changes in the private sector to make it contribute towards sustainable mobility.

2.3 Unique challenges of metro rail

The other big puzzle in the urban transport sector is the Metro rail, the most patronised mass rapid transit system in Indian cities. Sixteen cities in India have an operational metro rail system, with a collective network length of 862 kilometres. Another six metro projects are under-construction *(see Graph 10: Operational metro rail and those corridors under construction, approval and proposed).*

Graph 10: Operational metro rail and those corridors under construction, approved and proposed



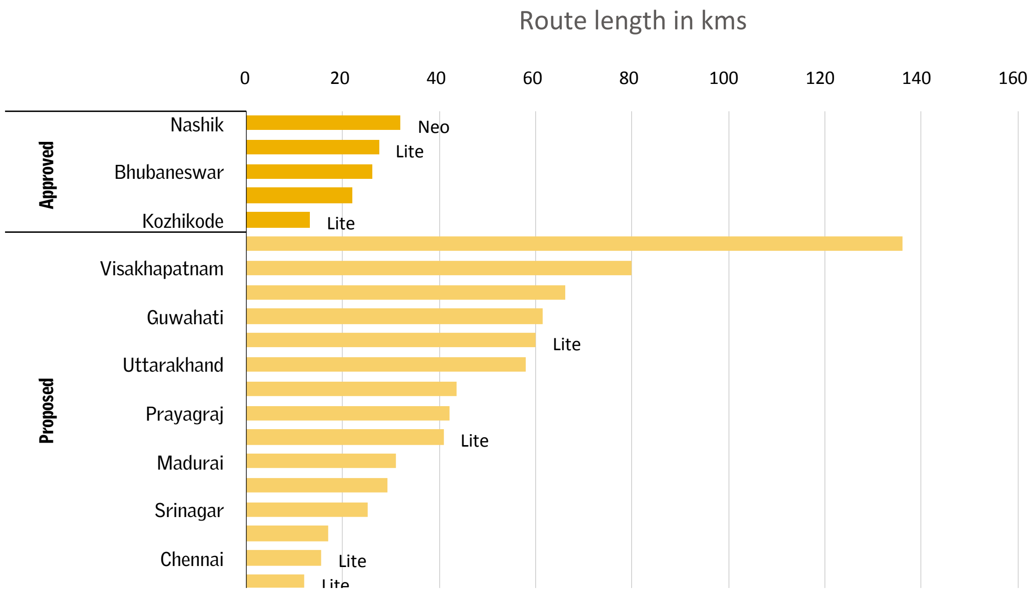
Source: Official city metro websites, DPRs

In addition, to keep the mass rapid system of metro rail affordable to construct, operate and maintain in smaller cities, two new systems were started in 2019, -- Metro Neo and Metrolite. These are "light urban rail transit system", and a "rubber-tyred electric coach powered by overhead traction". Metrolite is almost similar to a tram system, while Metro Neo can be a bus rapid transit network, with multiple coaches similar to the TransMilenio Bus Rapid System in Bogota.

Metro systems are expected to carry a passenger load of more than 15,000 peak hour peak direction traffic (PHPDT). Metrolite is suggested for Tier 2 and 3 cities, where there is a requirement to carry a passenger load of upto 15,000 PHPDT. Metro Neo will be opted on routes which require upto 8,000 PHPDT to be carried via mass transit.

As of March 2024, five cities have a proposed metro/ metrolite/ metro neo project, and fifteen others have proposals pending for approval. Currently there are no operational metrolite and metro neo projects operational in India. If all proposed projects, of metro rail, metrolite and metro-neo go through, the country will have a 3700 km network across cities *(see Graph 11: Approved and proposed metro rail, metrolite and metro neo projects in India).*

Graph 11: Approved and proposed metro rail, metrolite and metro neo projects in India



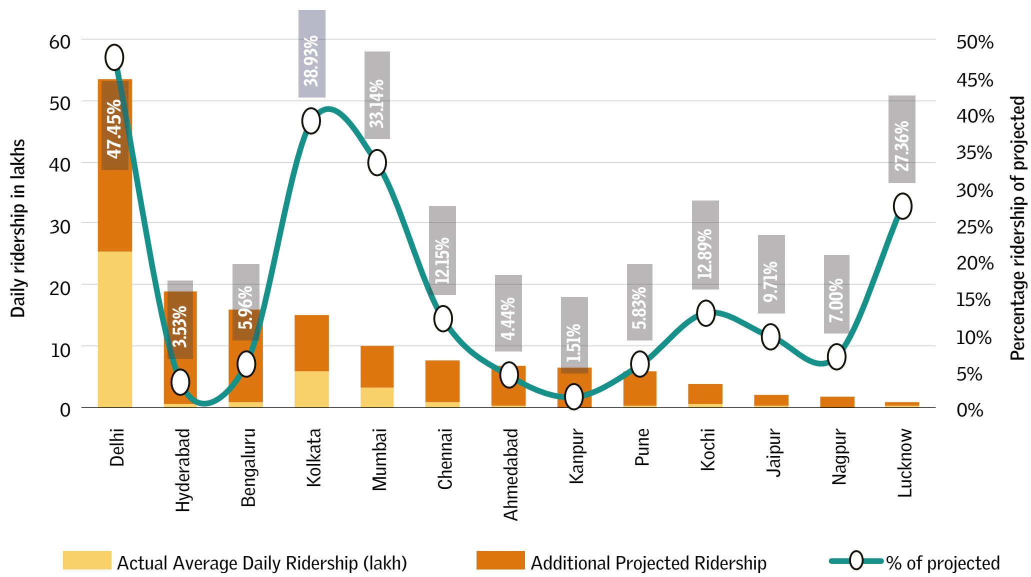
Source: Official city websites, DPRs, media reports

Metro rail systems in India face two major challenges: i) ridership lower than the projected estimates and, ii) lack of integration and poor last mile connectivity. Also most systems are not networks but corridors that increases journey time and interchanges and costs. And iii) financial sustainability.

A study by IIT Delhi in 2023 concludes that metro rail systems in Indian cities have only been able to achieve about 25-35 per cent of the projected ridership. Delhi Metro Rail Corporation (DMRC) has achieved the highest ridership compared to others, and it is less than half of the projected i.e. 47 per cent. This is largely because it has been created as an extensive network as opposed to single corridors in most other cities *(see Graph 12: Actual ridership, projected ridership, and percentage of achieved ridership of metro rail in Indian cities).*

Since benefits and revenue generation are dependent on three actual ridership, none of the systems have achieved the estimated benefits at the time of approval of the project. If a quality public transport system has to be provided to all commuters, an integrated public transport system is required which can serve the differentiated travel demand in different city sizes and land use patterns.

Graph 12: Actual ridership, projected ridership, and percentage of achieved ridership of metro rail in Indian cities

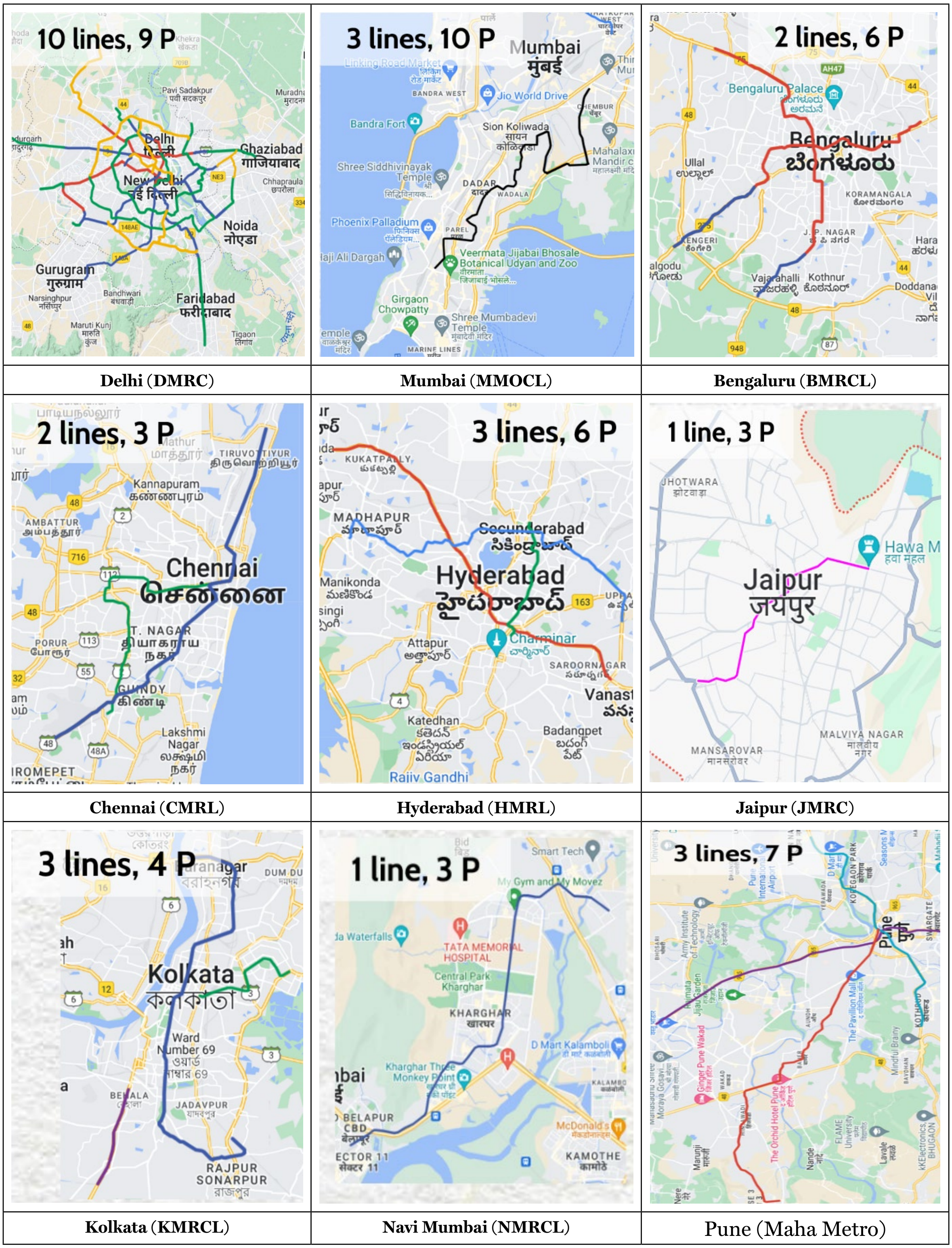


Source: IIT Delhi, Metro annual reports

Network vs corridor approach of the metro also has substantial bearing on travel choices. An important aspect of planning a public transport system is to plan for wider connectivity, and travel flexibility. Therefore, a network approach that is more efficient in connecting destinations is preferred over a corridor approach. Out of the 16 cities with a metro rail system, 15 are corridor based. Delhi is the only city that has an operational network of 10 lines with 254 stations spread over 351 kilometres across the city. *(see Map 1: System design of metro systems in Indian cities)*.

A corridor approach limits the service area, forcing inconvenient and time-consuming interchanges, increasing the overall journey cost while availing the service for commuting. High costs and longer timelines of a network could make a corridor approach more feasible for the initial phases of metro development, with the plan to gradually expand into a network overtime. However, the associated costs and barriers should be handled wisely and quickly. Or loss of confidence in the system among commuters in the initial stages can affect long-term ridership and finances.

Map 1: System design of metro systems in Indian cities



Source: Google Maps; Note: P stands for proposed lines

To assess the financial performance of metro rail networks, three types of recovery ratios have been assessed:

Farebox recovery ratio – ratio of operational expenditure and fare revenue: High dependency on farebox revenue leads to significant losses in the case of service disruptions, such as during the COVID-19 pandemic, and therefore having a higher share of non-operational sources of revenue is important, and metro systems have great potential for leveraging these sources due to their robust ecosystem approach from the get go.

- Operational recovery ratio – ratio of operational expenditure and total operational revenue
- Total revenue recovery ratio – ratio of total expenditure and total revenue

Non-operational revenue can include feeder services, property development income, advertisements, rental services and so on. Other revenue sources would include monetary grants towards capital expenditure, revenue from sale of scraps, interest income from deposits and advances, sale of tender documents among others.

Farebox recovery ratio assesses how much recovery is being made on operating expenditure by farebox revenue. Similarly, operational recovery ratio estimates the recovery made on operational expenditure by operational revenue. And total revenue recovery ratio is the recovery made on total expenditure by total revenue from all sources, therefore is the indicator that establishes whether the operation as a whole is generating profits or not.

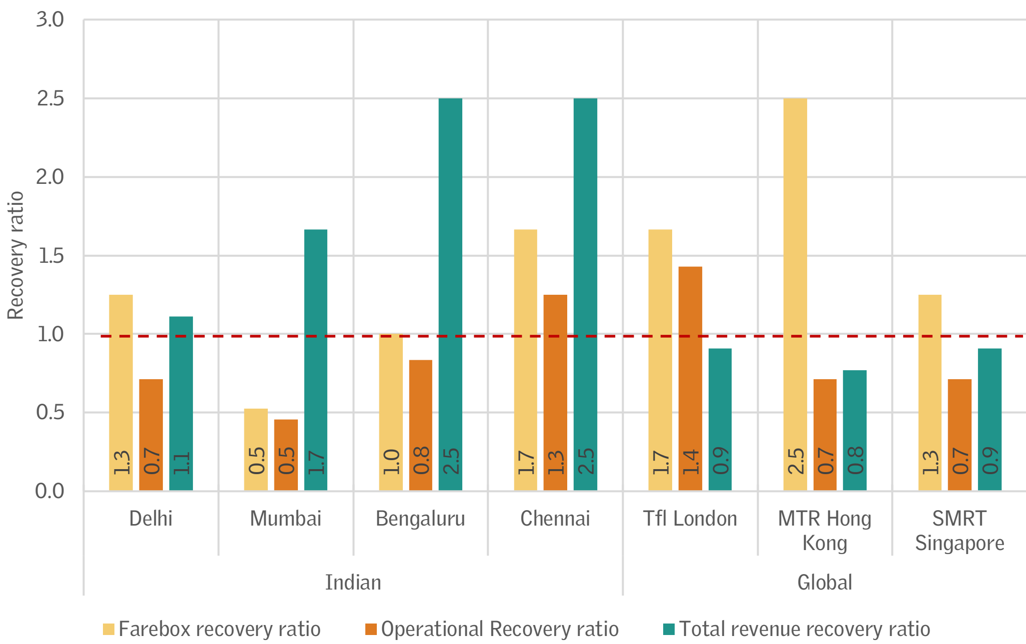
Globally, metro systems have managed to maintain a high share of non-farebox revenue in their total revenue contributions. The Hong Kong MTR and Singapore's SMRT have reported non-farebox contributions as high as 58 per cent and 28 per cent respectively, compared to Bengaluru, Mumbai and Chennai seeing 6 per cent, 11 per cent and 16 per cent[1].

Instead, Indian systems depend more heavily on passenger fare revenue. Mumbai has 89 per cent share of passenger fare, while Bengaluru has 79 per cent in its total revenue. Chennai has a low share of 42 per cent, but that is primarily due to the high share of grants received by Government of India and the state government (worth 26 per cent which is counted as other revenue sources)[2].

Bangalore and Mumbai breakeven on operational expenditure through farebox revenues only, and with addition of non-farebox operational revenue, the total operational revenue becomes favourable for Delhi. Out of the four Indian cities, Delhi has the lowest total revenue recovery ratio of 1.1, which indicates that while the system is incurring losses on total expenditure, it is the closest to breaking even compared to others *(see Graph 13: Recovery ratios compared for Indian and global cities)*.

All three international cities have a total revenue recovery ratio less than 1, which indicates that all of them are profit making projects. This achievement by the systems is accredited to formation of integrated transport authorities which cross-subsidise public transport through revenue from congestion and parking charges, property development and other non-transport operations.

Graph 13: Recovery ratios compared for Indian and global cities



Source: UITP, 2021;

Note: London data for FY 2019-20, Hong Kong for CY 2019, Singapore for FY2015-16, Indian cities for 2020-21

If the ratio equals 1, the operation as a whole is breaking even; if it exceeds 1 it is earning a surplus, while if it is below 1 the operation is losing money.

2.4 Non-motorized networks—victim of neglect

Non-motorized transport (NMT), including walking and cycling, offers significant advantages for urban mobility. It requires less space and infrastructure compared to motorized vehicles, allowing cities to reallocate street space for pedestrians, cyclists, and public spaces, which can enhance active mobility, better health and urban livability.

It also helps reduce traffic congestion by encouraging shorter trips that would otherwise require motor vehicles, leading to fewer emissions and lower fuel consumption. As an affordable and accessible mode of transport, NMT supports equitable mobility, providing travel options to people across different income levels, and fostering healthier lifestyles by integrating physical activity into daily commutes. Additionally, it can play a key role in reducing noise pollution and the heat island effect, contributing to more resilient and climate-adaptive cities.

More importantly, non-motorized transport is vital in extending access to public transport and improving its service quality by bridging the "last-mile" gap between transit stations and final destinations. High-quality NMT infrastructure, such as well-connected bike lanes, pedestrian-friendly streets, and secure bicycle parking near transit stations, enhances user convenience and safety, ultimately improving the overall travel experience.

Walking and cycling are expected to be the most scalable solution to zero-emissions and the carbon-neutral transport trajectory globally. Yet, this is the most neglected strategy in overall transport policies. According to the Census of India, 47 per cent trips are made on foot or using a cycle.

While many Indian cities have incorporated NMT principles into their city mobility plans, smart city development strategies, master plans, and clean air action initiatives, few fully recognise the transformative potential of an integrated NMT infrastructure network *(see Table 6: List of cities and type of NMT project implemented upto February 2024 and Map 2: Cities that have implemented non-motorized transport projects (representative).* To encourage a significant shift toward non-motorized transport, whether for last-mile connectivity or as a primary mode of travel, creating isolated corridors of cycle tracks or pedestrian walkways is insufficient, especially without regulatory measures to ensure unobstructed and encroachment-free pedestrian movement. A more comprehensive approach is necessary to truly embed NMT in urban life.

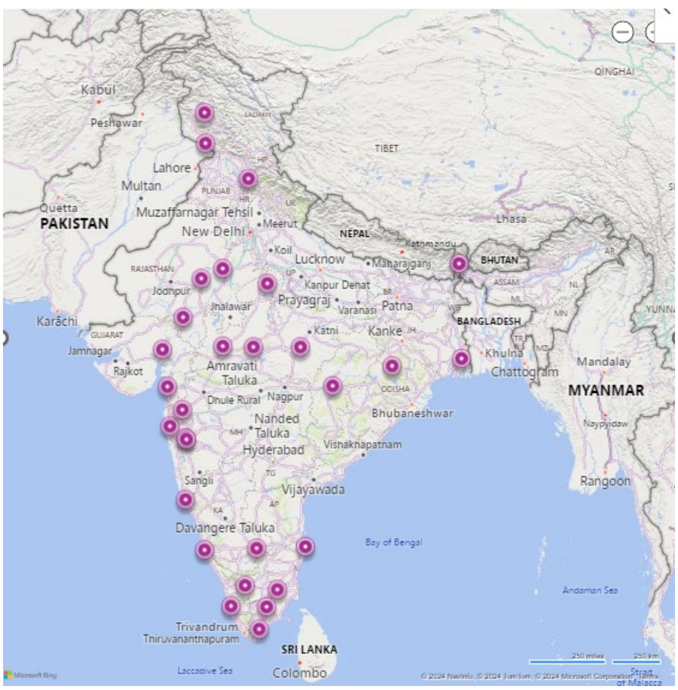
The goal must be to help citizens see NMT as more than just a tool for recreation or personal health, but as a viable and practical choice for everyday commuting. Expanding NMT infrastructure not only supports public transport by improving last-mile connectivity but also lays the groundwork for more advanced mobility systems, such as the implementation of low-emission zones. Moreover, it helps cities meet the growing, often unmet, demand for safe and accessible NMT options.

Table 6: List of cities and type of NMT project implemented upto February 2024

City	Project	City	Project
Delhi	Pedestrianisation	Srinagar	Cycle track
Ahmedabad	Public Bicycle Sharing (PBS)	Nashik	Cycle track
Chennai	NMT network plan	Rourkela	Cycle track
Pune	NMT network plan	Ajmer	Cycle track
Mysuru	PBS	Jaipur	Cycle track
Bhopal	PBS	Udaipur	Cycle track
Gwalior	PBS	Tirunelveli	Cycle track
Pimpri-Chinchwad	Pedestrianisation, PBS	New Town Kolkata	Cycle track and Pedestrian infrastructure
Surat	PBS	Raipur	Cycle track
Bengaluru	Pedestrianisation, PBS	Mangaluru	Pedestrian infrastructure
Ranchi	PBS	Ujjain	Pedestrian infrastructure
Coimbatore	NMT network plan	Thane	Pedestrian infrastructure
Kochi	PBS around metro station	Namchi	Pedestrian infrastructure
Jabalpur	NMT corridor	Madurai	Pedestrian infrastructure

Source: Compiled from media sources, ITDP, GIZ, MoUA, Smart City Mission

Map 2: Cities that have implemented non-motorized transport projects (representative)



Source: Compiled from media sources, ITDP, GIZ, MoUA, Smart City Mission

3 LESSONS FROM DELHI

Introducing the case study

This study tracks key congested corridors in Delhi using congestion indices—speed reduction, travel time, and planning time index—to highlight how peak-hour delays and unpredictable traffic slows daily commutes.

Survey-based journey cost analysis—the second part of the case study—evaluates travel time, fare, and interchange expenses across transport modes to justify consumer preference towards private modes. The hypothesis being tested is that private vehicles enjoy an unfair cost advantage.

Delhi mirrors the national mobility crisis. The problems diagnosed at the national level are clearly demonstrated in Delhi and also brings out the perils of not addressing this crisis. To capture this challenge a deep dive analysis has been created in the city of Delhi to highlight the factors that are consistently undermining the pollution control measures in the city.

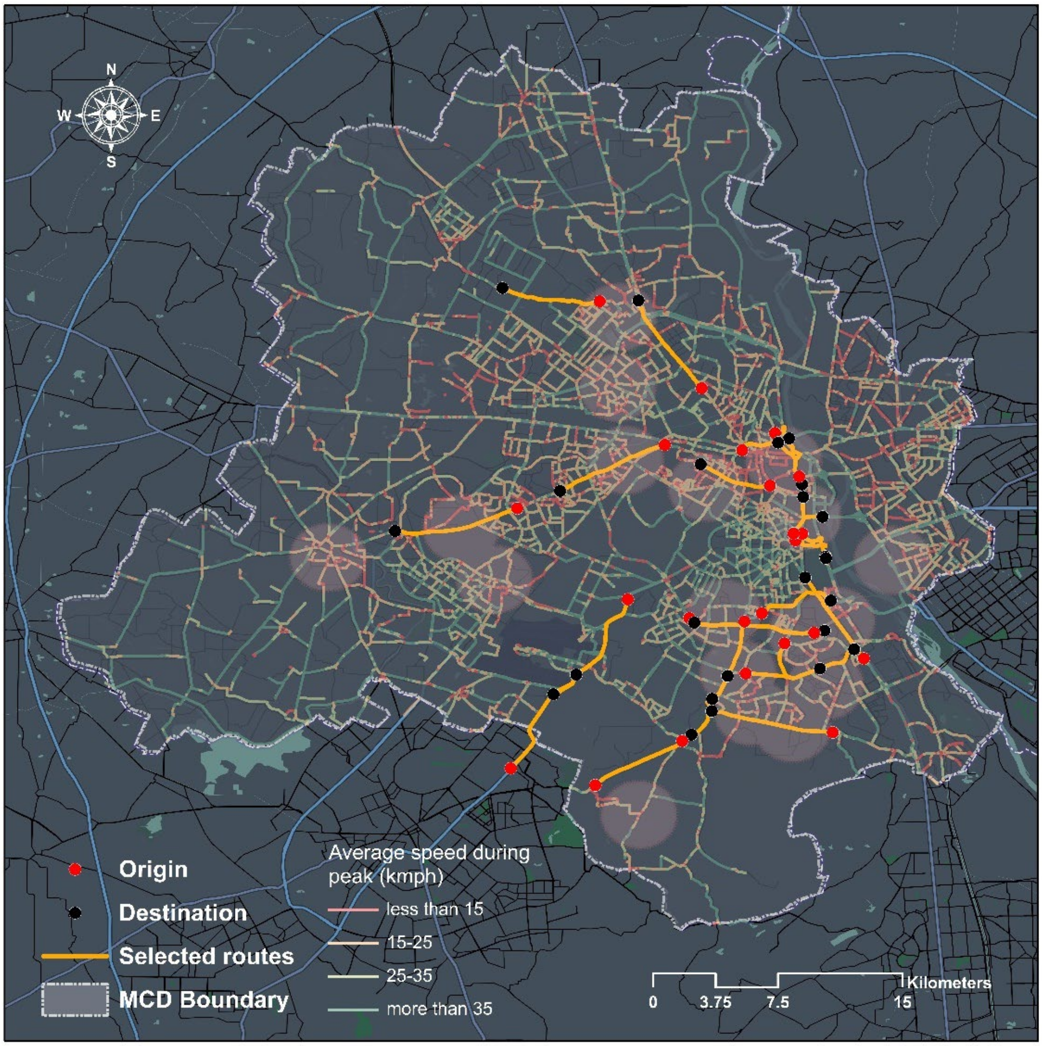
Methodology: This assessment aims to analyse how congestion influences commuting choices, particularly the preference for private vehicles over public transport, increases travel times, imposes hidden economic costs that are often overlooked and not well understood. These costs include wasted fuel, environmental degradation, and productivity losses. This assessment puts a spotlight on these hidden costs, investigates the structure of transportation costs, quantifies journey cost impacts, and how in the absence of congestion and environmental charges for private vehicle users, commuter preferences are distorted. All of these together contribute to the congestion problem.

For this purpose key high traffic corridors have been selected to quantify congestion by using metrics such as the Speed Reduction Index, Travel Time Index, Planning Time Index, and Congestion Index. By using hourly traffic data collected over a week (10th September to 16th September 2024), variations in traffic flow have been captured during peak and off-peak hours, gaining insights into how congestion evolves throughout the day. *(see Map 3: Selected routes in Delhi for congestion data collection; SeeAnnexure 1 for Details of routes.)*

The road stretches studied were chosen after consulting several sources of literature available on the most congested areas in Delhi. Among these, the latest and most frequently referenced were the "Report of High Powered Committee on Decongesting Traffic in Delhi"[3] and the Delhi Traffic Police report on congestion hotspot identification[4]. Specific routes were further refined using a popular web navigation and transportation service, Google Maps, which offers a "traffic layer" displaying live traffic speeds.

The Speed Reduction Index measures the reduction in speed on congested roads compared to free-flowing traffic conditions, offering a clear indicator of how congestion slows down movement. The Travel Time Index highlights the additional time commuters spend travelling during peak hours, while the Planning Time Index reflects the time buffer commuters need to add to ensure timely arrival, given the unpredictability of traffic. Together, these indices will provide a comprehensive picture of congestion in the city, allowing for the quantification of

Map 3: Selected routes in Delhi for congestion data collection



PREPARED BY CSE

its economic costs in terms of fuel consumption, pollution, and lost productivity. *(See Annexure 2 for indices and variables used for analysis).*

Secondly, this assessment also reviewed the survey results gathered from the commuters in Delhi. Respondents were asked to provide detail on their entire commuting experience from origin to destination, identifying the modes of transport they use, the time taken for each mode, the cost incurred, and the distance travelled. This detailed breakdown of journeys allows for a comprehensive analysis of the total cost of commuting, including fare costs, time costs, and the added cost of switching modes, wherever applicable.

The hypothesis being tested is that private vehicle users currently enjoy an economic advantage over public transport users, as these users currently do not pay for the environmental harm they cause (through emissions) or the congestion they contribute to, creating an economic surplus that makes private vehicles disproportionately attractive.

It is argued that this economic surplus enjoyed by private vehicle users comes at the expense of the broader public and the city's environment. Public transport users, who rely on slower, less direct routes, face a cumulative cost burden that includes fare payments, time lost in traffic, and the inconvenience of interchanging between modes. Not to mention, the higher road taxation per passenger designed for public transport. Without accounting for these additional costs in their journey, private vehicles continue to appear economically favourable.

Thus, introducing low-emission zones, congestion pricing or other forms of environmental costs for private transport users could make public transport a more attractive alternative. Public transport could then become more competitive, especially if such revenues are reinvested into improving public transport infrastructure, reducing fares, or enhancing service quality.

By quantifying the true cost of commuting for both private vehicle users and public transport users, this study aims to demonstrate the economic distortions caused by the current pricing structure. It will underscore the need for more equitable policies that account for the social and environmental costs of private vehicle use, thereby encouraging a shift towards public transport and reducing overall congestion in Delhi.

4

DELHI

The state of mobility

Like the national trend, Delhi struggles with persistent congestion due to limited public transport, poor road space use, and policies favoring private vehicles. Rising travel times and unreliable journeys underscore the need for better congestion management.

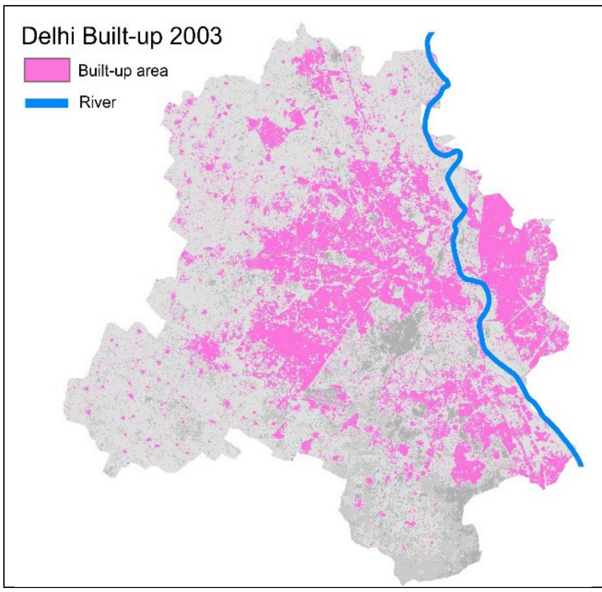
Bus ridership remains below pre-pandemic levels despite increased fleet size, while metro systems face connectivity limitations and a shift in commuter preference toward metro travel despite unfulfilled ridership potential.

Vehicle taxation policies favour private mobility over public transport, creating cost burdens on buses despite their efficiency. Deregistration efforts to reduce pollution highlight systemic challenges in enforcement and sustainable mobility incentives.

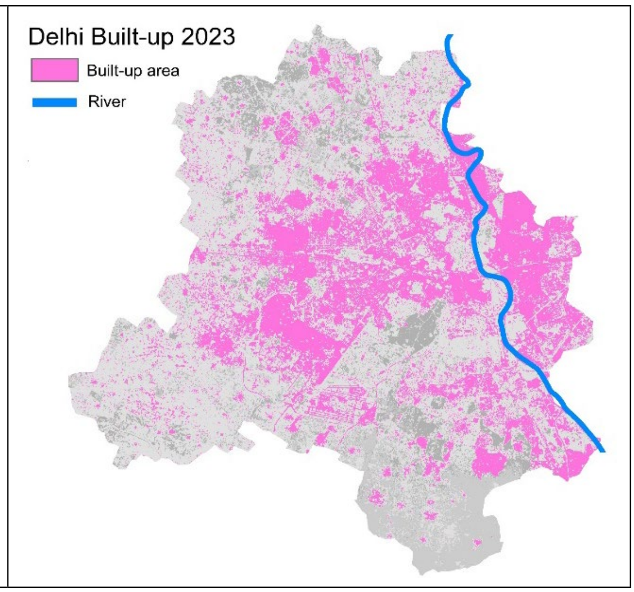
In the last two decades, Delhi's population has increased from 1.39 crore in 2001 to 1.64 crore in 2023, continuing a trend of slow, but steady growth. Landsat 7 and Landsat 8 satellite images used to study the Land Use/Land Cover (LULC) of Delhi, and comparisons made between years 2003 and 2023. Built spaces are highlighted in PINK in the map. The LULC analysis reveals an increase in built spaces in Delhi by 12.43 per cent *(see Map 4: Delhi's built-up area in 2003 and Map 5: Delhi's built-up area in 2023)*.

At the same time, urban green and cropland has decreased by 10.86 per cent, while heavy vegetation and urban forests have increased by 7.29 per cent. Increase in population and urbanisation has impacted the increase in attraction centres, job creation, and travel demand. According to CMIE (Centre for Monitoring Indian Economy Pvt. Ltd.), Delhi has added 64 per cent or roughly 1.65 crore new jobs in just 2022-23.[5]

Map 4: Delhi's built-up area in 2003



Map 5: Delhi's built-up area in 2023

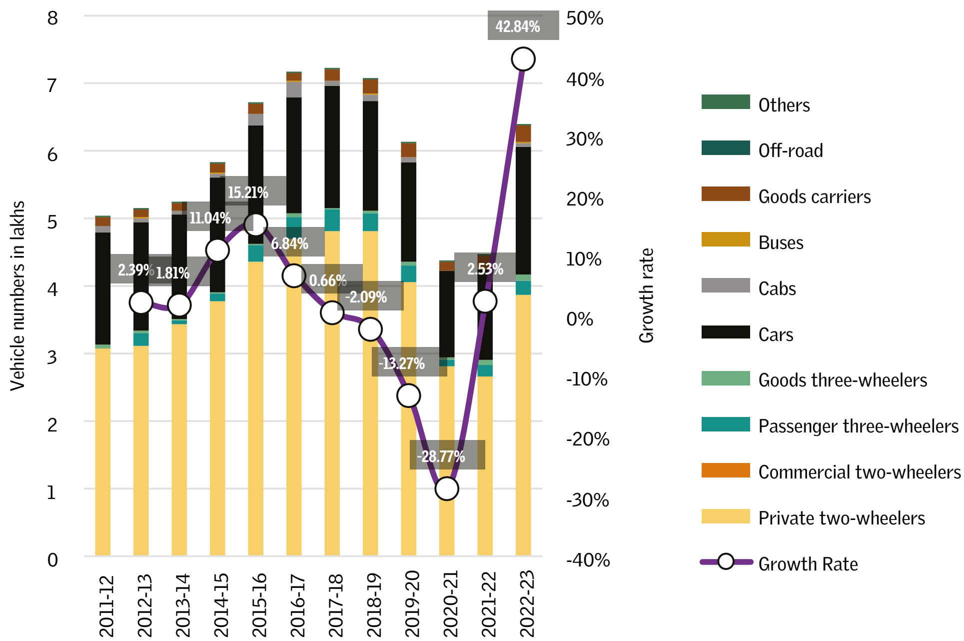


Data Source: NASA EarthData Satellite Images; Landsat 7 for 2003, Landsat 8 for 2023; prepared by CSE

4.1 Motorization

A steady rise in total number of vehicle registrations in Delhi was observed up until 2016, increasing by about 33 per cent compared to 2011-12. Yearly registration started to drop between 2016-2021, by about 35 per cent, due to a combination of slumping automotive sector, and the COVID-19 pandemic. Motorization made a strong recovery in the year 2022-23, when numbers rose by a staggering 47 per cent (see *Graph 14: Trend of new vehicle registrations in Delhi, 2011–2023*).

Graph 14: Trend of new vehicle registrations in Delhi, 2011–2023



Source: Vahan Database

Two-wheelers dominate the numbers. It fell by about 42 per cent during the pandemic in 2020-21, while private cars faced a slight decrease of 13 per cent between 2019-21.

Passenger segments, cabs and auto-rickshaws faced severe decline, going down 90 per cent and 65 per cent respectively, but bounced back to increase by 84 per cent, and 99 per cent respectively and immediately during 2021-22.

During FY 2011 and FY 2023, the mix of vehicle segments remained the same. Two-wheelers continued to dominate with a share greater than 60 per cent a year, followed by cars, claiming a substantial 30 per cent share in the total mix, and losing merely 1.9 percentage points after 10 years.

Cabs form less than 1 per cent share. Goods carriers increased by only 1.8 per cent, and formed a minor share of less than 4 per cent in total. Passenger three-wheelers now have a 3.2 per cent share, 0.5 per cent lower than the last decade.

Other categories (Commercial two-wheelers, Buses, Off-road, Others) collectively comprise less than 1 per cent of the total mix.

Two-wheeler share has never reduced below the 60 per cent mark, peaking at 74.8 per cent in 2018-19. However, the two-wheeler market is heavily hit by the pandemic, reducing to 66.5 per cent in 2021-22.

Cars, however, took a very different trajectory, seeing a relative increase in their share during the pandemic period, peaking for the first time in 11 years in 2021-22 at 33.46 per cent. Coincidentally the same year the two-wheeler sales slumped, indicating a clear shift towards cars among commuters.

Old vehicle phase out: As a soft measure to check rampant increase of on-road vehicles, especially personal vehicles in the state, Delhi's transport department (GNCTD) deregistered 48,77,646 old petrol and diesel vehicles in January 2022. This was done in accordance with the National Green Tribunal's (NGT) direction to ban 10-year-old or older diesel vehicles and 15-year-old or older petrol vehicles to ply on NCT of Delhi's roads.

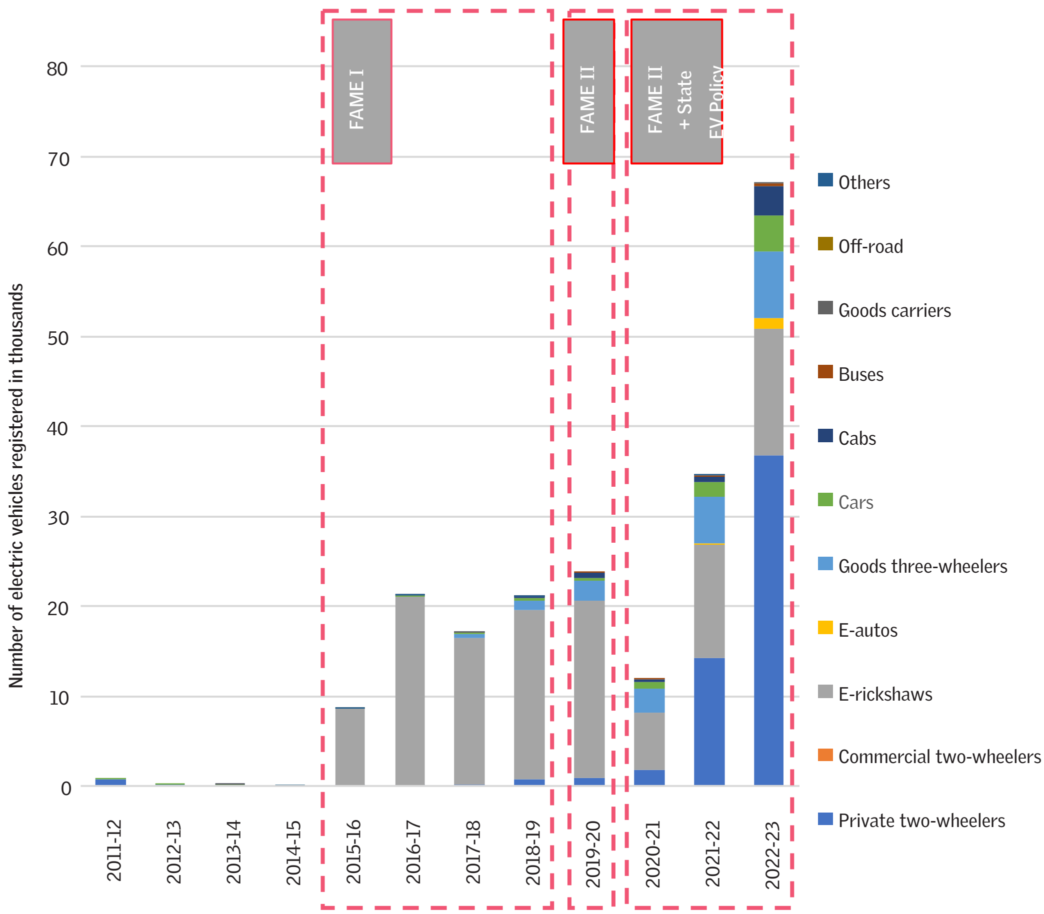
According to the Economic Survey of Delhi 2022-23, as a result of the deregistration drive, the number of registered vehicles in the state dropped by 54.76 per cent, from 79,17,898 to 1,22,53,350. This included 13 lakh cars and 29 lakh two-wheelers.

The transport department notes that although the vehicles have been deregistered, not all of them have stopped operating on the roads. About 7 lakh vehicles at present have taken an NOC for re-registrations in other states, and about 1 lakh have been scrapped. In addition, if the Traffic Police in Delhi spots these deregistered vehicles plying on the roads, they will be impounded and scrapped.

Vehicle electrification: Delhi state's electric vehicle (EV) share stood at 11.78 per cent out of all newly registered vehicles in FY 2023-24, from a non-existent market in 2011-12 with total registrations of just 723. While the state was unable to meet its state EV policy target of 25 per cent electrification by FY 2023-24, Delhi was one of India's first states to cross the 10 per cent mark in FY 2022-23, and it had the highest electric vehicle share by the end of the last financial year (see *Graph 15: Trend of new electric vehicle registrations in Delhi, 2011–2023*).

The state implemented its comprehensive EV policy in 2020 featuring an ambitious target, supported by purchase subsidies and tax rebates for both private

Graph 15: Trend of new electric vehicle registrations in Delhi, 2011–2023



Source: Vahan Datab

and commercial vehicles. It included scrappage incentives for replacing old vehicles with EVs and supported retrofitting companies to convert conventional vehicles.

Notably, Delhi was the first to include battery-swapping station operators in its policy, offering direct financial aid for setting up charging stations and managing battery sales. Its widespread charging network covers over 97 per cent of developed areas in 3km x 3km grids.

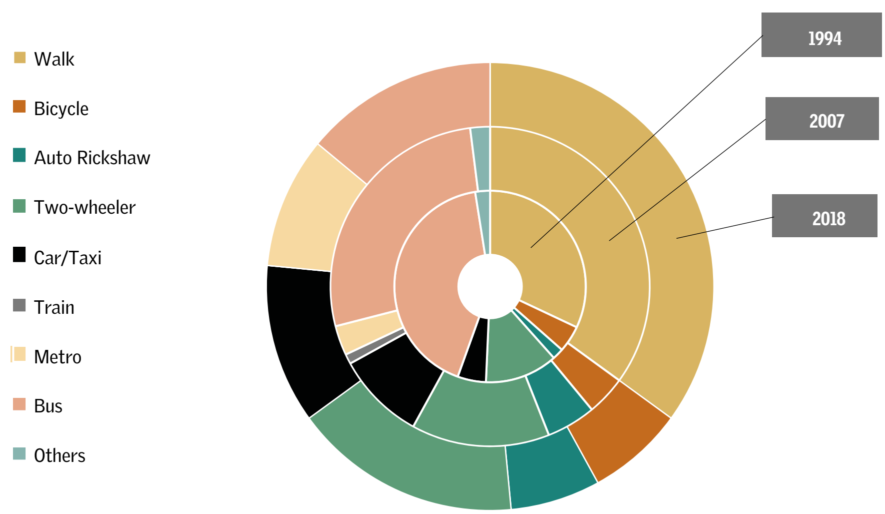
Mandates in the state extend to public transport, para-transit, e-commerce, and delivery fleets to convert into electric. The Switch Delhi website serves as a key resource, providing information on policies, incentives, charging station locations, even an EV savings calculator.

Personal vehicle domination, largely two-wheelers, is seen in the electric vehicle market as well. When considering e-rickshaws in the mix, the two-wheeler share is 55 per cent, and without e-rickshaws the two-wheeler share is 69 per cent.

Given the controversy around e-rickshaws, the unregulated manufacturing, driver licensing, passenger overloading, other safety concerns, and battery issues, it is important to understand which segments represent the majority in the electric vehicle market in Delhi with and without considering e-rickshaws share in the mix.

Growing dependence on personal vehicles: Since 1994, the modal shares have steered more towards private transport. In 1994, private mode (two-wheeler and car) share was 17 per cent, and bus share was 42 per cent. In 2007, the private vehicle share rose to 23 per cent while public transport (bus and metro) share dropped to 30 per cent. In 2018, 29 per cent trips were made on private modes, and 24 per cent using a bus or a metro. *(see Graph 16: Change in modal split in Delhi over 30 years).*

Graph 16: Change in modal split in Delhi over 30 years

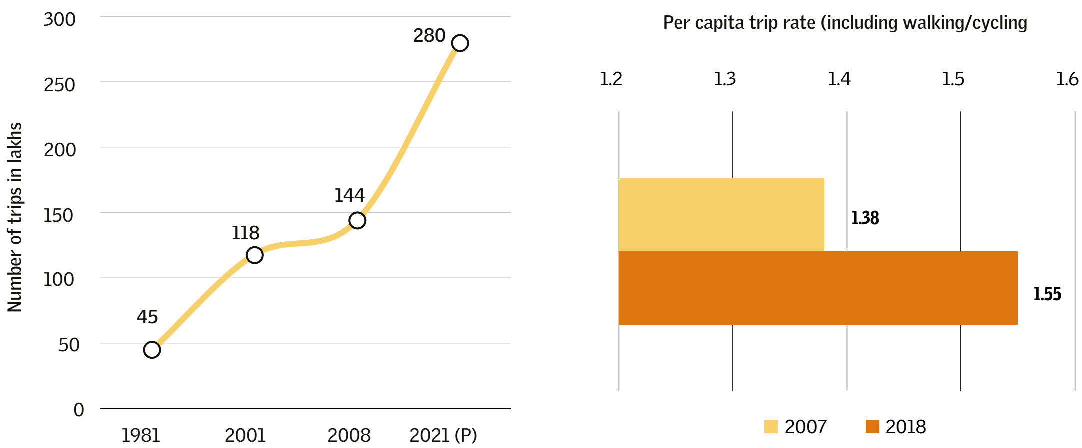


Source: IIT Delhi, GNCTD, DIMTS, NIUA, MPD 2041

More travel: The number of trips in the capital have gone up by 94 per cent since 2008, and more than five times in the last forty years. Average per capita trip rate (PCTR) has increased from 1.38 in 2007 to 1.55 in 2018, a 12 per cent increase. For motorized trips (excluding walking and cycling), PCTR was 0.905 in 2018, up from 0.87 in 2001 and 0.72 in 2018.

Longer travel: Additionally, the average trip length in Delhi has increased from 6 kms in 2007 to 10.9 kms in 2018, as a result of the growth of regional centres, and increase in accessibility of these centres through roads and public transport. This marks an 81 per cent rise in the average trip length in 10 years. *(see Graph 17: (A) Trip generation, 1981-2021; (B) Delhi's change in per capita trip rate in 10 years).*

Graph 17: (A) Trip generation, 1981-2021; (B) Delhi's change in per capita trip rate in 10 years



Source: SPA Delhi, DIMTS, NIUA; Note: P stands for projected by NIUA

n conclusion, commuters in Delhi are travelling more and for longer distances, and the rise has been exponential in the last few years. According to NIUA, 52 per cent of the trips carried out in Delhi are work-related, 15.4 per cent are recreational trips, and 14 per cent are education trips.

Metro has the highest trip length of 16.7 km, defining metro's role in long-distance commute. Two-wheelers, cars, and buses are used for medium-distance commute between 8 km and 14 km. All trips longer than 5 kms are made using motorized modes.

4.2 Skewed taxes favour personal vehicles

Ideally, road tax should be aligned with the emissions of a vehicle segment, road usage, congestion impacts and a range of other externalities. The more the emissions per commuter, the higher should be the tax as per the "polluter pay principle".

In Indian cities, a vehicle owner/operator may need to either pay a lifetime road tax, annual road tax, or both, depending on the vehicle category and the state they are registered in. The lifetime tax is only applicable to personal vehicles; two-wheelers and cars.

There are two types of lifetime taxes in Delhi, one is paid to the central "Vahan" portal operated by the Ministry of Road Transport and Highway. The one is charged by the transport department of Delhi. Commercial vehicle owners need to pay a recurring annual tax charged by the transport department (which can include a lump sum for a period of 2 or more years to Vahan at the time of registration which is compensated later).

Private vehicles: Diesel cars need to pay a higher Vahan tax (25 per cent higher) than petrol cars. Corporate car owners pay 25 per cent higher tax than individual owners for their vehicles for both petrol and diesel variants.

For an individual car owner, the Vahan tax is between 4 per cent-10 per cent for petrol, and 5 per cent-12.5 per cent for diesel depending on the vehicle cost. Corporate car owners between 5 per cent-12.5 per cent for petrol, and 6.25 per cent-15.63 per cent for diesel, depending on vehicle cost. And finally for two-wheelers, Vahan road tax is between 2 per cent and 8 per cent depending on vehicle cost.

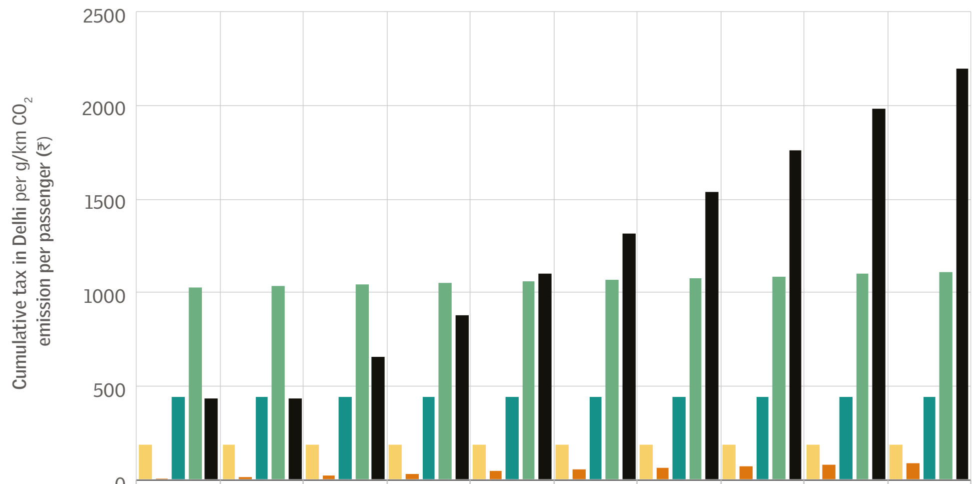
To this is added the lifetime road tax of Delhi transport department. For two-wheelers it can be between Rs 650 and Rs 1,990 depending on the engine capacity, or presence of trailer attachments. For cars, depending on the vehicle curb weight, tax can be between Rs 3,815 and Rs 11,590 + Rs 2,000 (for each tonne over 2) for vehicles over 2 tonnes.

Commercial vehicles: In Delhi, commercial vehicle operators need to pay based on their vehicle's passenger capacity or load capacity, whichever applicable. For passenger vehicles annual tax can range from Rs 305 to Rs 1,915 + Rs 218 per passenger for vehicles with capacity of more than 18 passengers. For goods vehicles, annual tax varies from Rs 665 to Rs 4,245 + Rs 470 per tonne over 10 for vehicles with over 10 tonnes of load capacity. For auto-rickshaws and cabs, an annual flat tax of Rs 305 and Rs 405 is to be paid respectively.

When cumulative tax to be paid is accounted for over an ownership period of 10 years, the disparity between segments based on emissions per passenger becomes stark *(see Graph 18: Cumulative tax (lifetime + annual) for different vehicle segments per g/km of* CO_2 *emission per passenger, Year 1 to Year 10).*

Private two-wheelers are taxed very low, however considering the high utilisation rates, and the sheer number of registrations which adds to the congestion problem, due to heavy two-wheeler dependence in India, two-wheelers should be taxed higher than other sustainable modes.

Graph 18: Cumulative tax (lifetime + annual) for different vehicle segments per g/km of CO_2 emission per passenger, Year 1 to Year 10



	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Two-wheeler	189	189	189	189	189	189	189	189	189	189
Auto Rickshaw	9	19	28	38	47	56	66	75	85	94
Car	443	443	443	443	443	443	443	443	443	443
Cab	1028	1037	1046	1055	1063	1072	1081	1090	1099	1107
Bus	440	440	660	880	1100	1320	1540	1760	1980	2199

Two-wheeler Auto Rickshaw Car Cab Bus

Source: Delhi Transport Department (GNCTD), ICCT (reports 2021-23), CSIR-NIT, TRB-NASEM, ICCT's Fuel Economy conversion tool
Note: Assumptions and variables for calculating are mentioned in Annexure 3.

Taxation of cabs is higher compared to personal cars and rightly so, since cabs have a higher vehicle utilisation. However, the per passenger emission of a cab is lower when compared to a private car running on single occupancy. Taxation on private cars needs to increase since the economics of a journey favour private vehicles more, and road taxation is a one of the measures to promote a modal shift to sustainable modes.

Buses are taxed very high despite their low emissions per passenger, considering their role in public transportation. Cumulative taxation per passenger for buses is already more expensive by Year 5 than private cars. In a state of financially burdened bus operators, lower taxation will be a much-needed relief. The move indirectly will also lead to encouraging more buses used over private vehicles.

4.3 Public transport under pressure

4.3.1 Systematic challenges in Delhi metro

Rail-based networks offer significant advantages over buses when it comes to public transport, primarily due to their higher capacity, reliability, and efficiency. Trains can move a much larger number of passengers in a single trip compared to buses, making them ideal for cities with dense populations and high travel demand. Rail systems operate on dedicated tracks, free from road traffic congestion, ensuring more predictable and consistent travel times, especially during peak hours. They are also more energy-efficient, often powered by electricity, which reduces carbon emissions and contributes to cleaner urban environments. Additionally, rail networks are scalable, capable of handling growing passenger volumes without the challenges of road space limitations that buses face. In terms of passenger comfort, rail systems generally offer smoother rides and greater frequency, enhancing the overall quality and appeal of public transport.

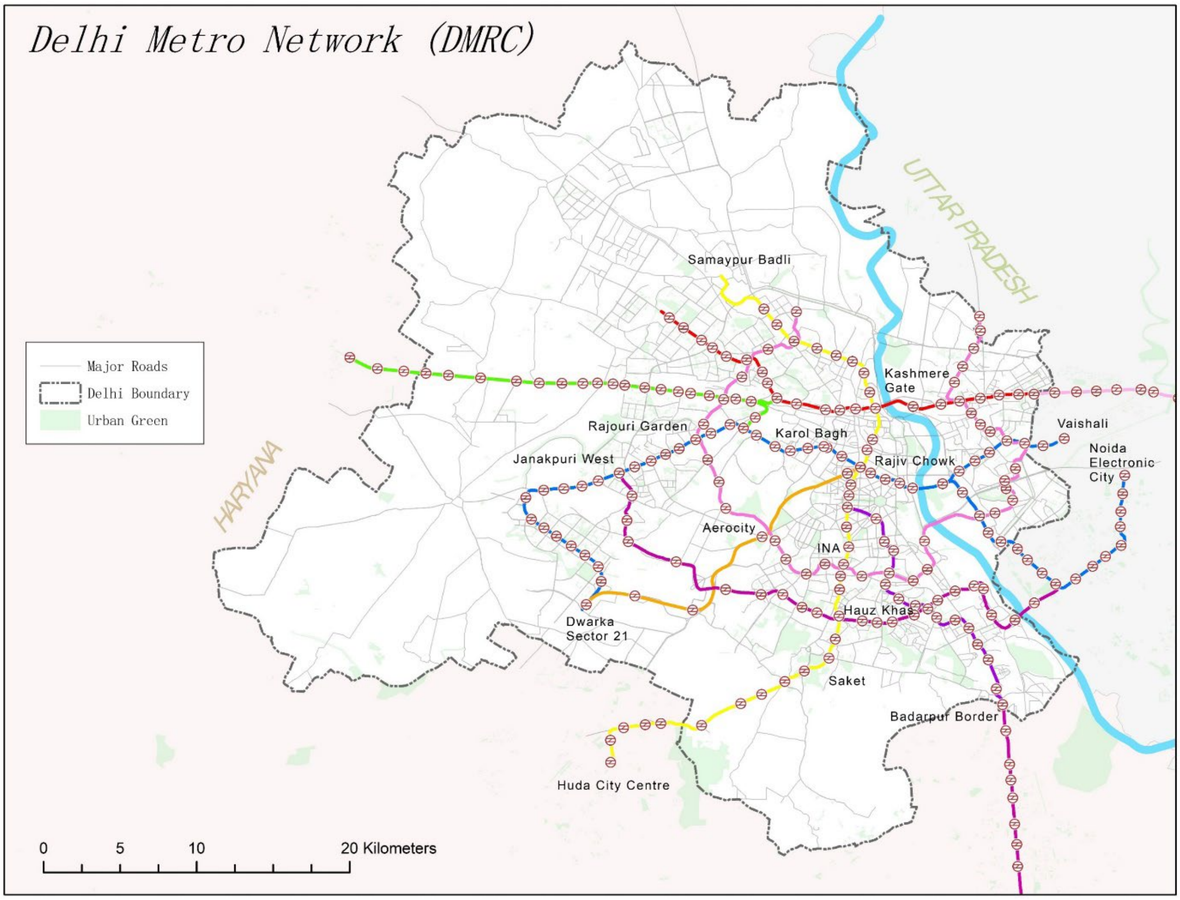
Delhi's Mass Rapid Transit System (MRTS) is an ongoing ambitious project to offer its commuters with a non-polluting efficient rail-based transport system, integrated with its road-based transport network.

Delhi Metro Rail Corporation (DMRC), an equal equity participation of the Delhi government and Government of India was registered in 1995 to construct an elaborate MRTS network in Delhi.

There are currently four phases in the network, Phase 1 to Phase IV. Phase I-III have been constructed and are operational, spanning across Delhi with a network of 392.44 kms, including 58.5 kms in the National Capital Region (NCR). The metro network has 288 operational stations, and is divided into 10 colour coded lines.(see *Map 6: Delhi's metro rail network, 2024)*

The project's first phase, Phase I was constructed between 2002-06, creating 64.751kms and 59 stations. Phase II started in 2005, ended in 2012, adding 123.3 kms, including 22.91 kms High Speed Airport Metro Express Line and 16.315 kms

Map 6: Delhi's metro rail network, 2024



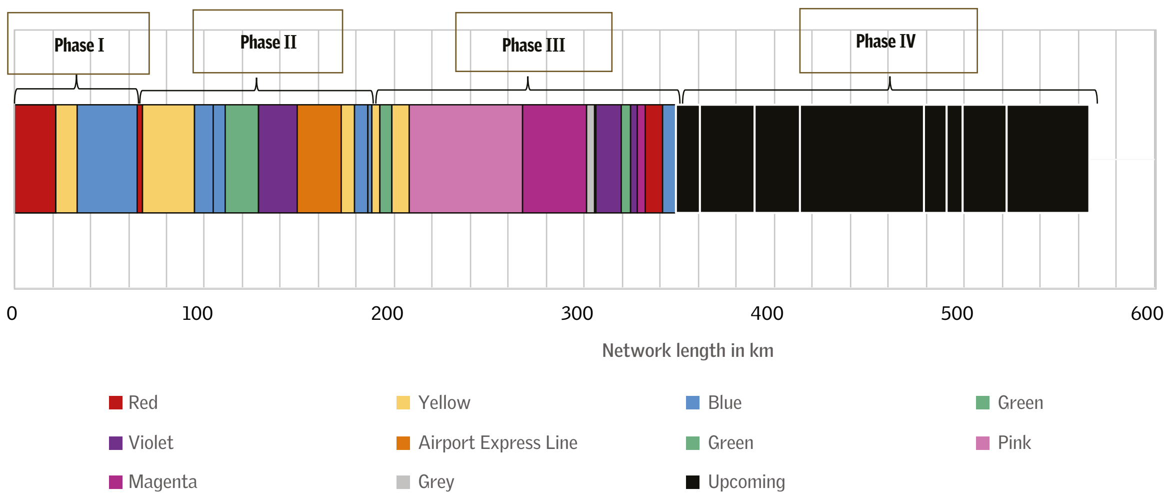
PREPARED BY CSE

of NCR lines with 86 total stations (of which 13 are in NCR). Phase III lasted between 2012-21, creating 160.07 kms and 109 stations, of which 42.18 kms with 20 stations are in NCR.

After Phase IV of the metro's network is constructed, the total metro network will span 565.8 kms across Delhi, increasing the total network length by 44 per cent.

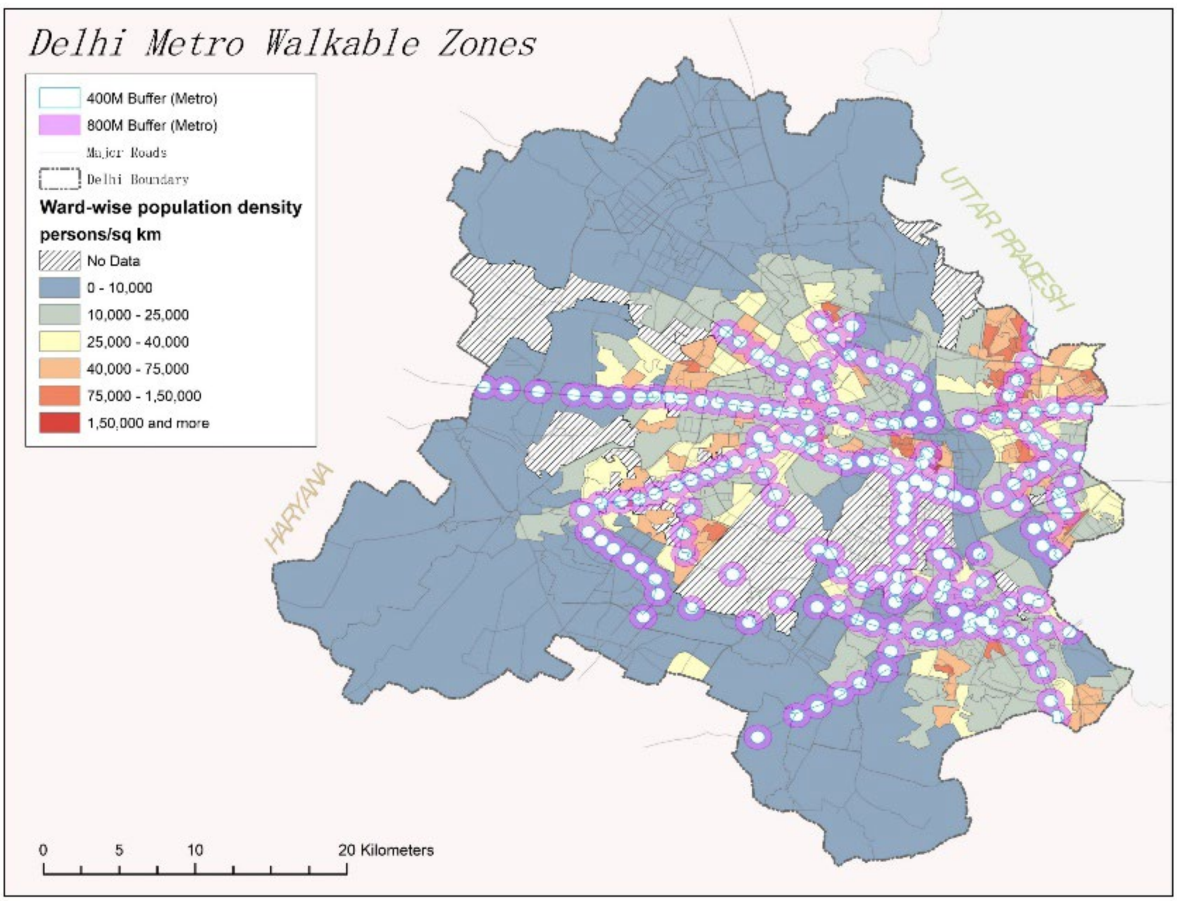
Phase IV has two parts of three-corridors each, the first three priority corridors being constructed first. DMRC started constructing Phase IV in 2021-22, and plans to start its operations in 2026. *(See Graph 19: Addition of new metro lines in Delhi, Phase I (2002) – Phase IV (2026P).*

Graph 19: Addition of new metro lines in Delhi, Phase I (2002) – Phase IV (2026P)



Source: Economic Survey of Delhi, 2022-23

Map 7: NMT zones (400m and 800m buffers) around metro stations



Analysis by CSE using DMRC and State Election Commission data (ward-level population)

A spatial analysis by CSE reveals that the current metro network caters to 9.85 per cent of Delhi's population at a 5-minute walking distance or 400 m from a metro station, and 32.08 per cent population at a 5-minute cycling distance or 800 m from a metro station (see *Map 7: NMT zones (400m and 800m buffers) around metro stations)*.

In Delhi, metro trains run from 6:00 AM in the morning till about 11:00 PM in the night. The planned train frequency varies from 2 minutes 44 seconds during peak hours to upto 10 minutes during non-peak hours. The frequency is different for weekdays, Saturdays and Sundays and may reduce to upto 12 minutes per train during Sunday off-peaks on some low ridership routes.

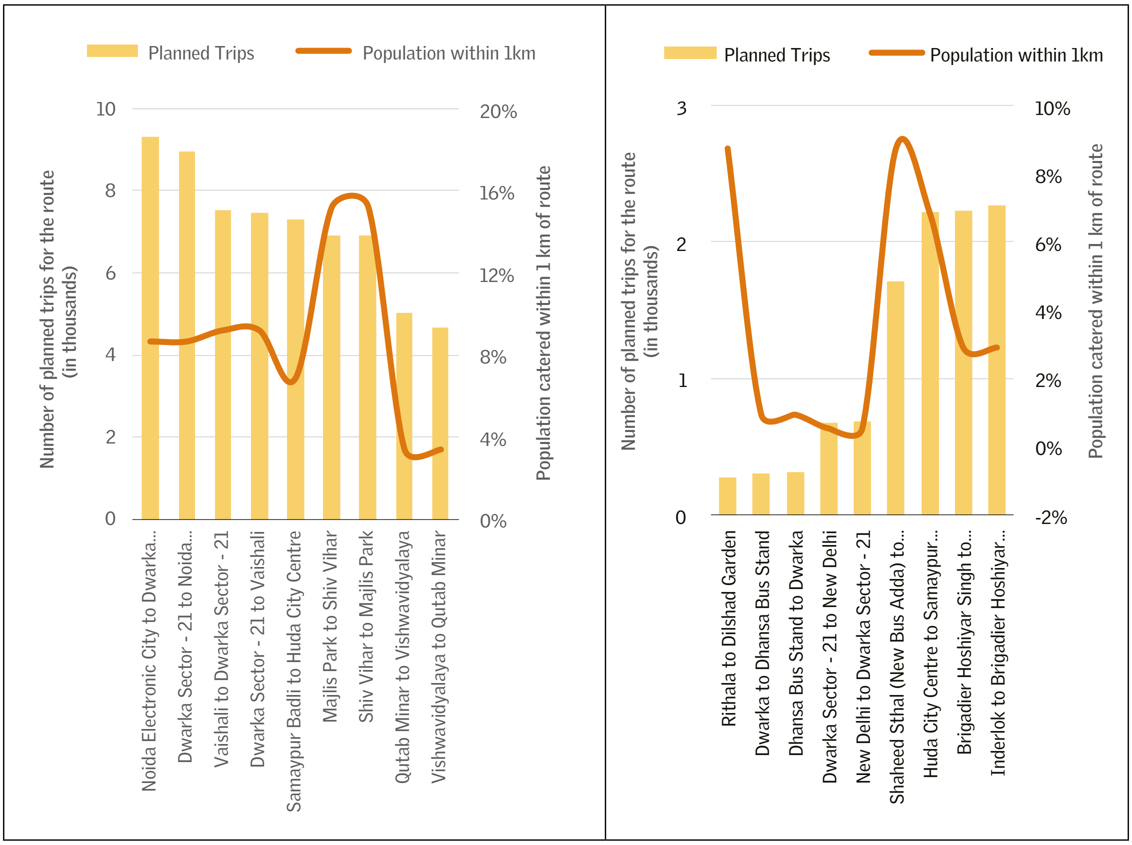
Route-wise analysis of planned frequency and ridership suggests that the average frequency on highest ridership lines do not exceed 5.5 minutes during peak hours on weekdays, and 7 minutes during off-peak hours. Moderate ridership lines have weekday peak hour frequency range of 3.35 to 6.8 minutes, and off-peak hour frequency range is 3.8 to 9.5 minutes. Commuters on low ridership routes may need to wait upto 10 minutes during weekday peak hours, and during off-peak hours the frequency can go upto 12 minutes.

Planning routes for metro rail is generally easier than for buses because metro systems operate on dedicated tracks, independent of road traffic and congestion. This allows for fixed, well-defined routes with fewer variables to consider, such as changing traffic patterns or road conditions, which buses must navigate. Metro routes are typically planned around key hubs and high-density areas, ensuring direct, efficient travel with minimal disruption. In contrast, buses require more flexible routing to accommodate shifting demand, road infrastructure limitations, and frequent changes in urban layouts, making route planning more complex and less predictable.

In an analysis of highest and lowest planned number of trips in the DMRC system, it was observed that the planned number of trips is not always synonymous with the extent of population catered to by the route within 1 km, which is roughly a 5-minute cycling distance *(see Graph 20: (A) Routes with highest number of planned trips and population catered; (B) Routes with lowest number of planned trips and population catered).*

This may be due to varying commuter patterns, varying peak travel times, and connectivity to key areas such as business districts, educational institutions, or other transit hubs.

Graph 20: (A) Routes with highest number of planned trips and population catered; (B) Routes with lowest number of planned trips and population catered



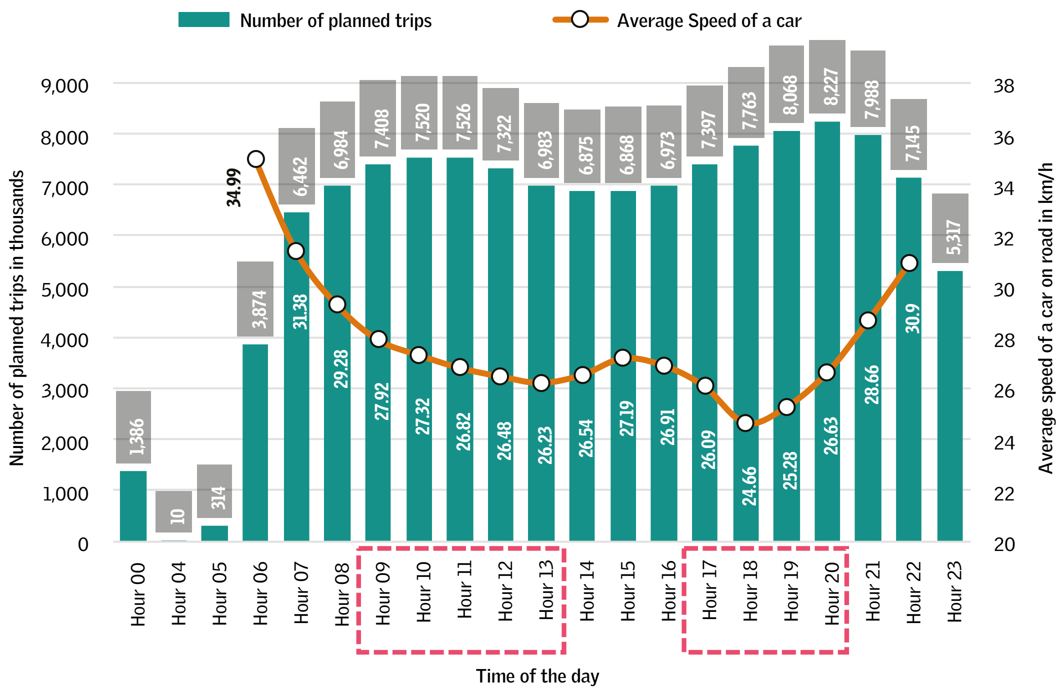
Open Transit Data by GNCTD-IIT Delhi

For example, the pink line route of Majlis Park-Shiv Vihar and return have the 6th and 7th highest number of planned trips respectively, however the 1-km radius population around it is almost twice (15.19 per cent) than that of Noida Electronic City-Dwarka Sector 1 on the blue line (8.64 per cent), the route with the highest planned number of trips.

Similarly, the lowest trips planned for any route is for the red line Rithala-Dilshad Garden route, although it caters to a significant 8.74 per cent of Delhi's population in a 1-km radius.

With respect to the overall trips planned for the system, Delhi metro's peak (higher number of trips) matches precisely with the peak travel times on the roads (lower travel speeds), that is 9 AM to 12 PM during morning, and 5 PM to 8 PM in the evening. This offers the perfect opportunity for commuters choosing a private

Graph 21: Analysing Delhi metro's capacity to cater to on-road peak times



Source: Open Transit Data by GNCTD-IIT Delhi, Google Maps API

mode for commuting to shift to metro services *(See Graph 21: Analysing Delhi metro's capacity to cater to on-road peak times).*

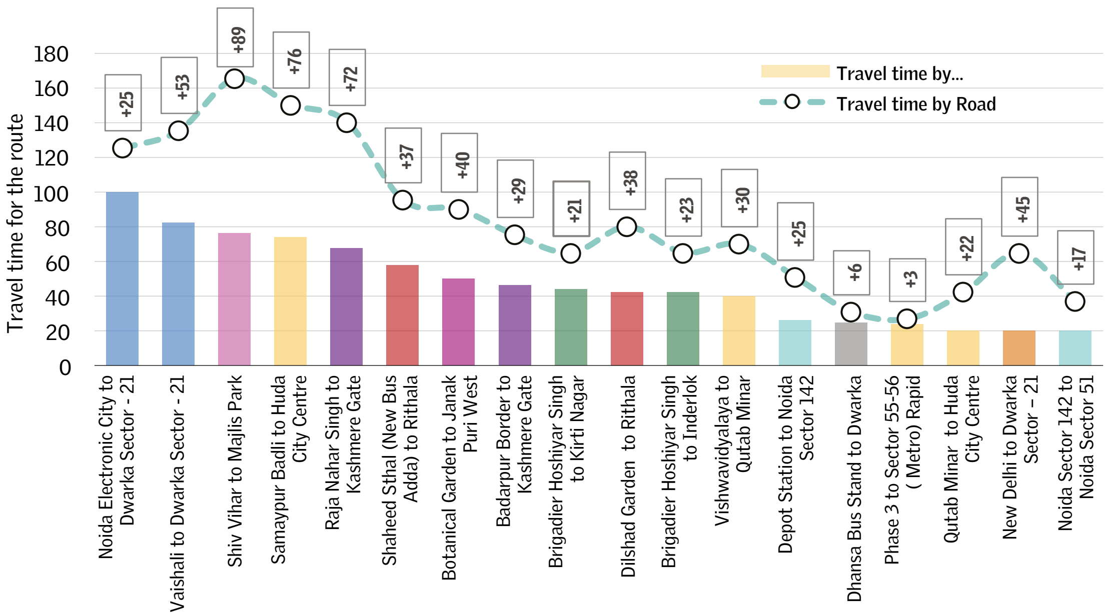
Another factor which makes mass transit rail-based networks attractive for commuters is the lower travel times compared to road transport modes. If a commuter takes the same route on the road as the metro routes, it takes them an average of 80 per cent more time during peak hours.

The airport line (orange line) on Delhi metro saves the most time relative to taking a cab from its origin in New Delhi (railway station area) to Dwarka Sector 25, since upto 225 per cent more time is consumed on the roads during peak hours.

Pink line (Shiv Vihar to Majlis Park), and violet line (Raja Nahar Singh to Kashmere Gate) save the second and third most time compared to roads on their respective routes (see *Graph 22: Comparing travel time at different metro routes, and travel time by road*).

However, despite the advantage of a dedicated corridor and a decently organised system, Delhi's rail based public transport is not free of challenges.

Graph 22: Comparing travel time at different metro routes, and travel time by road



Data Source: Open Transit Data by GNCTD-IIT Delhi, Google Maps API

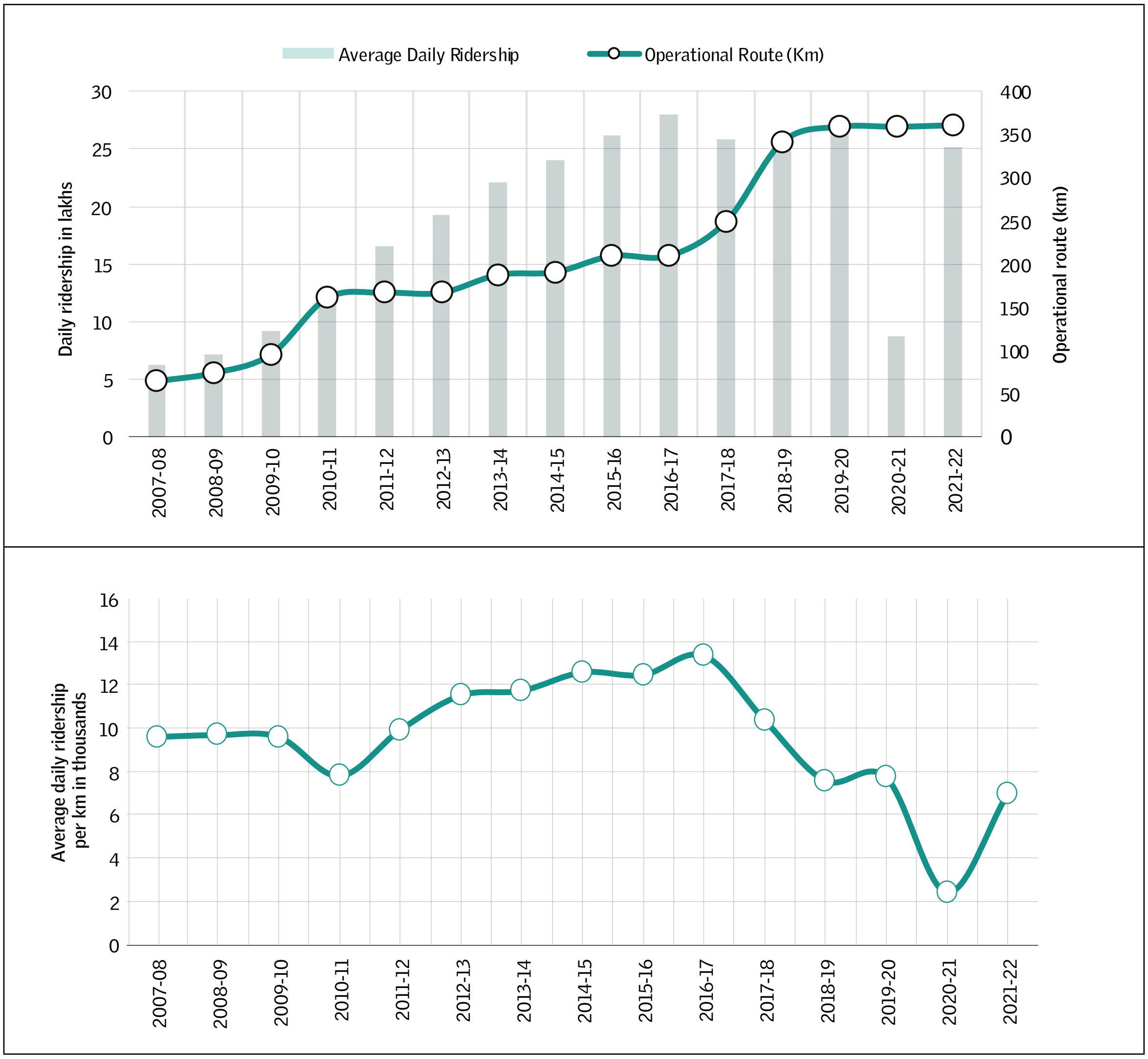
Delhi metro's average daily projected ridership in 2019-20 after the completion of the first three phases was 53.47 lakhs. The recorded average daily ridership that year was about half the expectation, merely 27.79 lakhs.

While the system has managed to maintain, and even increase its daily average ridership over the years, its ridership efficiency, or the average ridership per km of the network has reduced significantly, from its peak in 2016-17 recording 13,339 passengers per km per day, to 6,970 passengers per km per day. This suggests that the network is expanding without a proportional increase in ridership.

Ridership augmentation can be achieved by improving accessibility to already built metro stations, physical multi-modal integration between transit stations/ stops, improved last-mile connectivity, and planning dense development over long corridors to capture adequate land value and population (see *Graph 23: (A) Trend in operational routes and ridership, 2007-2023; (B) Trend in ridership per km, 2007-23*).

Frequency of metro rail: Moreover, as per the planned arrival and departure times provided in the GTFS data, the wait times at Delhi metro stops were analysed to understand the frequency of trains, and the standard deviation from

Graph 23: (A) Trend in operational routes and ridership, 2007-2023; (B) Trend in ridership per km, 2007-23



Source: Economic Survey of Delhi, 2021-22 and 2022-23

Note: - Data since 2013 iincludes Airport Line. DMRC has taken over the operation from the close of business operating hours of 30.06.2013.

- Data since 2019 includes Rapid Metro. DMRC has taken over the operation on 22.10.2019

- Since 2019-20 Passenger Journey is calculated in terms of the number of corridors used by a passenger

the average waiting times at respective stations. Standard deviation here defines the consistency and predictability of the wait time. A low deviation would mean the frequency is more consistent and predictable.

Based on this, four categories were made to categorise stations under specific parameters of waiting times (WT) and wait time standard deviations (SD): Low SD-Low WT, Low WT-High SD, High WT-Low SD, and High WT-High SD:

- Low Standard Deviation (SD): SD is less than 25 per cent of the Average Wait Time
- High Standard Deviation (SD): SD is greater 50 per cent of the Average Wait Time
- Low Wait Time (WT): Average Wait Time is less than 5 minutes
- High Wait Time (WT): Average Wait Time is greater than 8 minutes

The goal was to find what share of stations fall into each of the categories, separately for onward and return journeys. The result is as follows (see *Graph 24: Planned average waiting times and standard deviations at metro stations during onward/ return journeys, 2024 (example of each category in red* and *Table 5: Summary of results - frequency and its predictability at metro stations*).

Graph 24: Planned average waiting times and standard deviations at metro stations during onward/return journeys, 2024 (example of each category in red

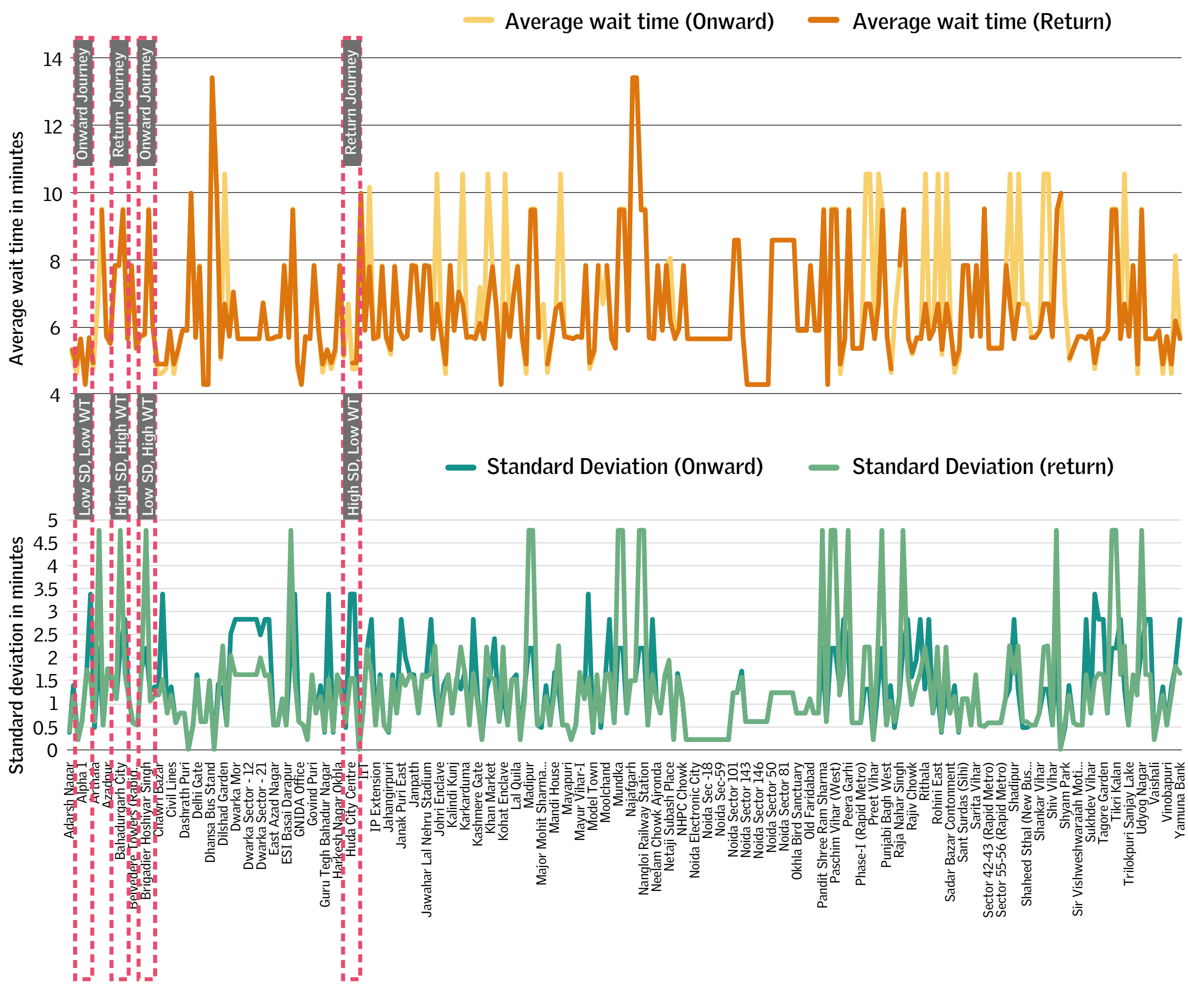


Table 5: Summary of results - frequency and its predictability at metro stations

	Onward journey stations	Return journey stations	Onward Journey Station Examples	Return Journey Station Examples
Low SD, Low WT	4.6 per cent	9.9 per cent	Alpha 1, Delta 1, Depot Station, GNIDA station, Knowledge Park II, Noida Sector 143	AIIMS, Alpha 1, Chandni Chowk, Chawri Bazaar, Civil Lines, Dwarka Mor
Low SD, High WT	21.3 per cent	6.1 per cent	Ashok Park Main, Bahadurgarh City, Brigadier Hoshiyar Singh, Delhi Aerocity	Delhi Aerocity, Dhaula Kuan, Dhansa Bus Stand, Inderlok
High SD, Low WT	3.1 per cent	0 per cent	Arjan Garh, Chhatarpur, Huda City Centre, IFFCO Chowk	--
High SD, High WT	0 per cent	7.6 per cent	--	Ashok Park Main, Bahadurgarh City, Dilshad Garden

CSE analysis results

Low SD – Low WT: 4.6 per cent stations of onward journey and 9.9 per cent stations of return journey presented an ideal scenario in which the wait times are consistently low on the stops.

Low SD – High WT: For 21.3 per cent of onward and 6.1 per cent of return journey stations, wait times are long but consistent, hence planning is easier for travelling, but the service is poor due to high wait times.

High SD – Low WT: For 3.1 per cent onward journey stations, getting a train is quick on an average day, but unpredictability of waiting times makes it challenging for commuters to plan their travel. Inconsistencies and operational disruptions should be checked in these stops.

High SD – High WT: At 7.6 per cent return journey stations, not only is the wait time long, it is also inconsistent. This indicates poor metro service quality in these stations.

Yet the potential of augmenting metro ridership is considerable. Spatial analysis reveals that the current metro network caters to 57.95 per cent of Delhi's population at a 5-minute walking distance or 400 m from a metro station, and 83.15 per cent population at a 5-minute cycling distance or 800 m from a metro station.

4.3.2 What ails Delhi's bus system

Buses are the prime mover of people. These can penetrate very deep into neighbourhoods, their services can be organised flexibly to meet the changing pattern of travel demand, and are more fuel efficient in terms of moving people. A bus occupies twice the size of a car but carries 25-40 times the number of passengers. Buses offer enormous fuel and pollution savings. But the bus system and ridership are under tremendous pressure.

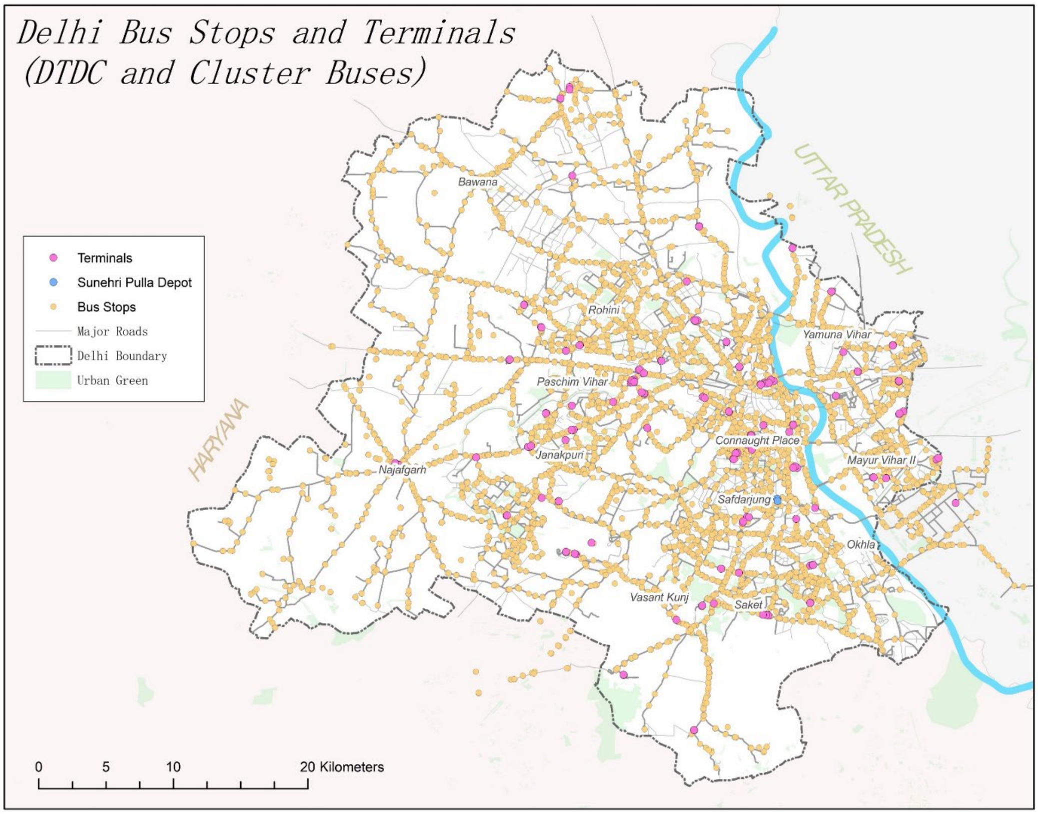
Delhi has two public entity bus services. The Delhi Transport Corporation (DTC) bus service, and the cluster bus service by DIMTS.

DTC was handed over to the Delhi government by the Government of India in 1996. Cluster bus service started in 2011, by the Delhi government, modelled after the Paris public transport system. The idea is to cluster bus routes together (it was launched by clustering 657 routes into 17 clusters), to leverage network synergies.

By 2021-22, Delhi Transport Corporation (DTC) had a fleet of 3,762 buses, and cluster bus fleet was 3,310 buses.

The entire bus network in Delhi spans across the state to every major arterial, sub arterial and collector road. According to the Open Transit Data portal of Delhi, as on August 2023, there are in total 3,464 bus stops and 543 bus routes (including both DTC and cluster buses) across Delhi. (see *Map 8: Delhi's network of bus stops and terminals for DTC and Cluster buses (DIMTS), 2024*)

Map 8: Delhi's network of bus stops and terminals for DTC and Cluster buses (DIMTS), 2024

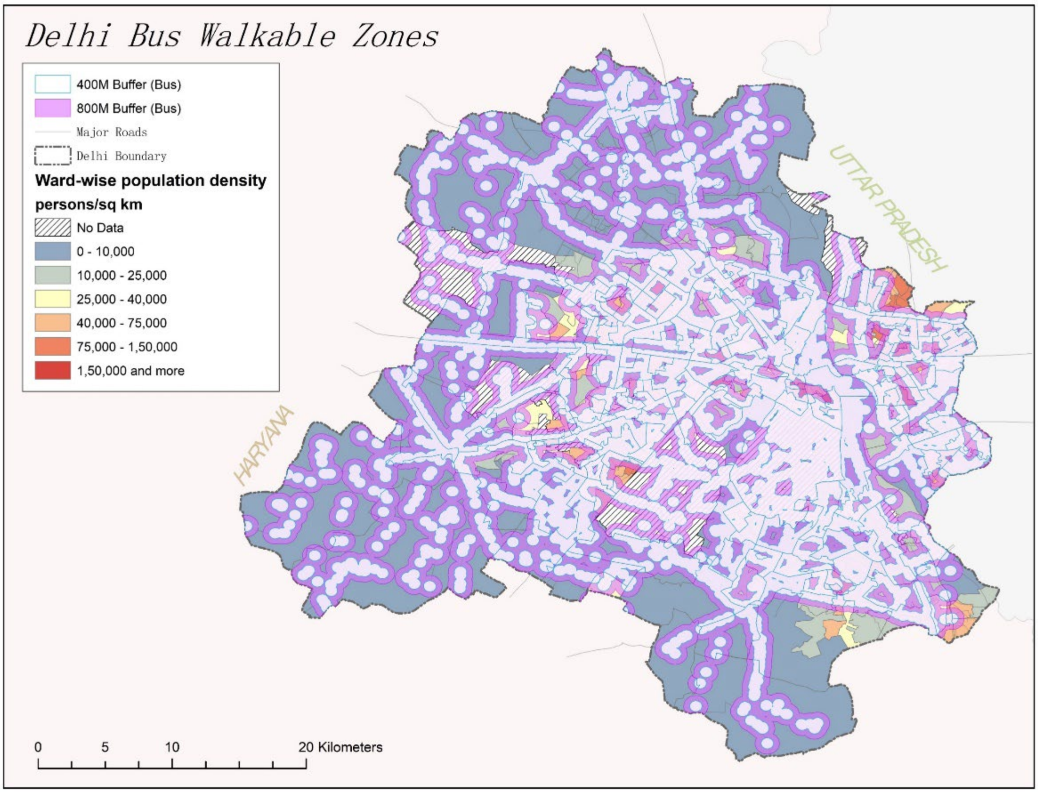


Data Source: Open Transit Data by GNCTD-IIT Delhi

Delhi has 23 clusters of bus depots and 40 DTC bus depots. Apart from that, there are 17 bus terminals in Delhi out of which 16 are operational.

Delhi also has 3 Inter State Bus Terminals (ISBT) at Kashmere Gate, Sarai Kale Khan, and Anand Vihar. The latter two are up for redevelopment for their integration with Regional Rapid Transit System (RRTS) projects. (*see Map 9: NMT zones (400m and 800m buffers) around metro stations*).

Map 9: NMT zones (400m and 800m buffers) around metro stations



Analysis by CSE using GTFS and State Election Commission data (ward-level population)

In 2021-22, for every 1,000 people, Delhi had less than half a bus: 0.43 bus per 1,000 population. In other words, the state has one bus for every 2,321 people in the city.

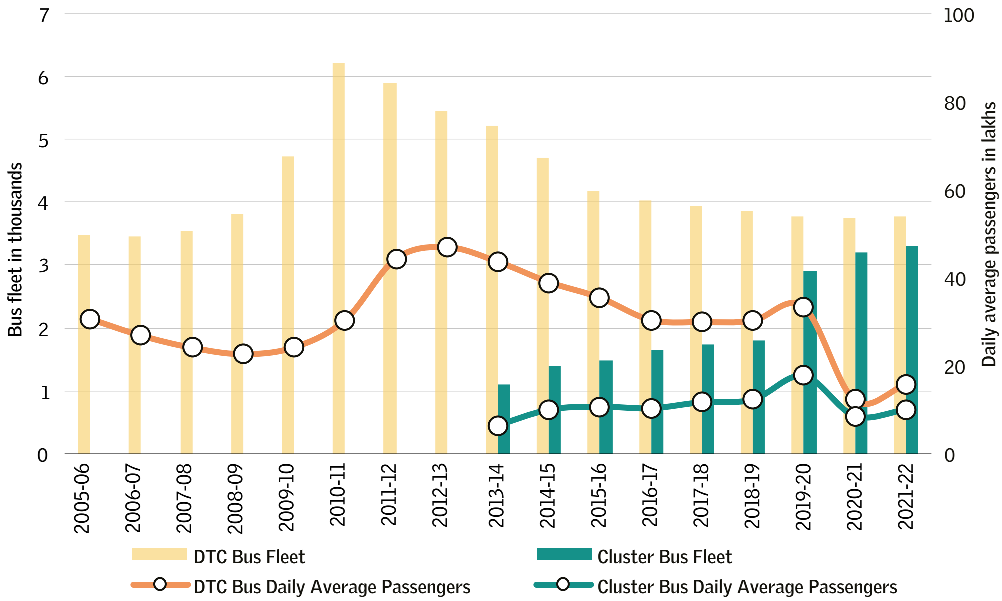
Countries with robust bus systems, such as Mexico and Brazil, have 3 and 5 buses per 1000 population respectively.

The DTC bus fleet has been on the decline consistently since 2010-11, reducing by 40 per cent by 2021-22, whereas the cluster bus fleet has more than tripled, as the government has focused more on the cluster bus system.

The daily ridership for DTC buses has been on a downward trend since FY 2012, dropping by 30 per cent until right before the pandemic, and then further dropped by 63 per cent the next year with COVID restrictions. Cluster buses on the other hand saw an increase in ridership, which tripled by FY 2019 since FY 2013. Cluster buses also did feel the blow of the pandemic, albeit softer, dropping ridership by

50 per cent between FY 2019 and FY 2020. (see *Graph 25: Bus fleet vs ridership, 2005-2022*).

Graph 25: Bus fleet vs ridership, 2005-2022



Source: Economic Survey of Delhi, 2021-22 and 2022-23

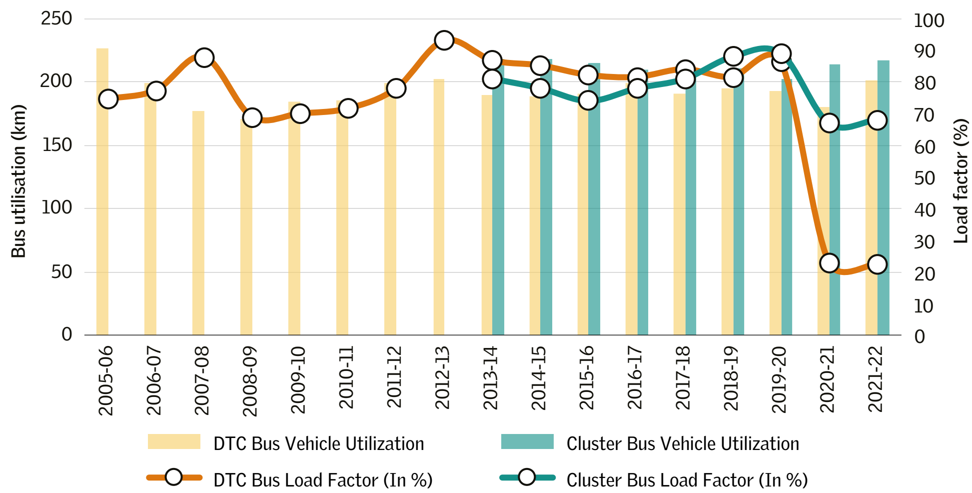
Utilisation and load factors through the years reflects the bus supply and demand for the region.

In Delhi, during 2013-2020, the DTC bus load factors dropped whereas the bus utilisation increased. This suggests that during that period, bus supply was not matched efficiently with the demand, leading to inefficient deployment. (see *Graph 26: Bus utilisation VS load factor, 2005–2022*).

This could be a symptom of inefficient route planning, lower than projected demand on bus routes, and commuters switching over to other modes of transport. Later during the pandemic, the bus utilisation stayed high, while the load factors dropped significantly since the buses were deployed for essential services to aid the pandemic, with very low ridership.

In the case of cluster buses, quite an opposite trend was seen. Bus load factors increased during 2015-20. However, there was a slight dip in the bus utilisation, suggesting that there was a shortage of bus numbers on cluster routes, leading to overcrowding and a need to augment the number of buses on the routes.

Graph 26: Bus utilization VS load factor, 2005–2022



Source: Economic Survey of Delhi, 2021-22 and 2022-23

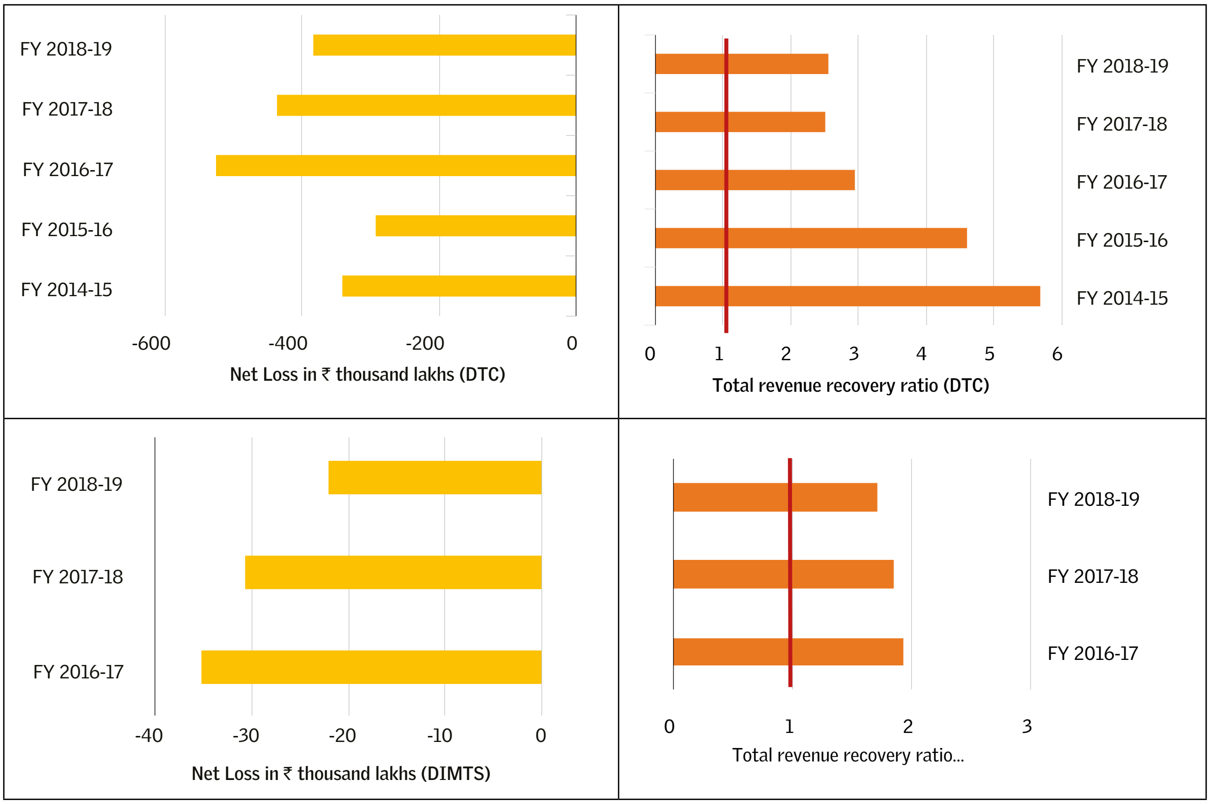
In the latest edition of the annual report, "Review of performance of state road transport undertakings (SRTU)," released in 2023 by the Ministry of Roads Transport and Highways (MoRTH), DTC is the highest loss making SRTU in India, reporting a loss of over Rs 380 thousand lakh in FY 2018-19, albeit an improvement of 12.4 per cent year-on-year (YoY).

The total revenue recovery ratio of DTC that year was 2.55. The total revenue recovery ratio is the ratio of total operating expenditure to total revenue, and is a key indicator of financial performance. If it equals 1, the operation as a whole is breaking even; if it exceeds 1 it is losing money, while if it is below 1 the operation is earning a surplus (see *Graph 27: (A) Net loss incurred by DTC, 2014-19; (B) Trend in total revenue recovery ratio by DTC, 2014-19; (C) Net loss incurred by DIMTS, 2014-19; (D) Trend in total revenue recovery ratio by DIMTS, 2014-1*).

DIMTS reported a net loss of Rs 22 thousand lakh, showing an improvement of 27.7 per cent compared to the previous year. The total revenue recovery ratio for DIMTS was 1.72 for the same year (see *Graph 28: Comparing ridership trend of metros and buses in Delhi, 2007-2022*).

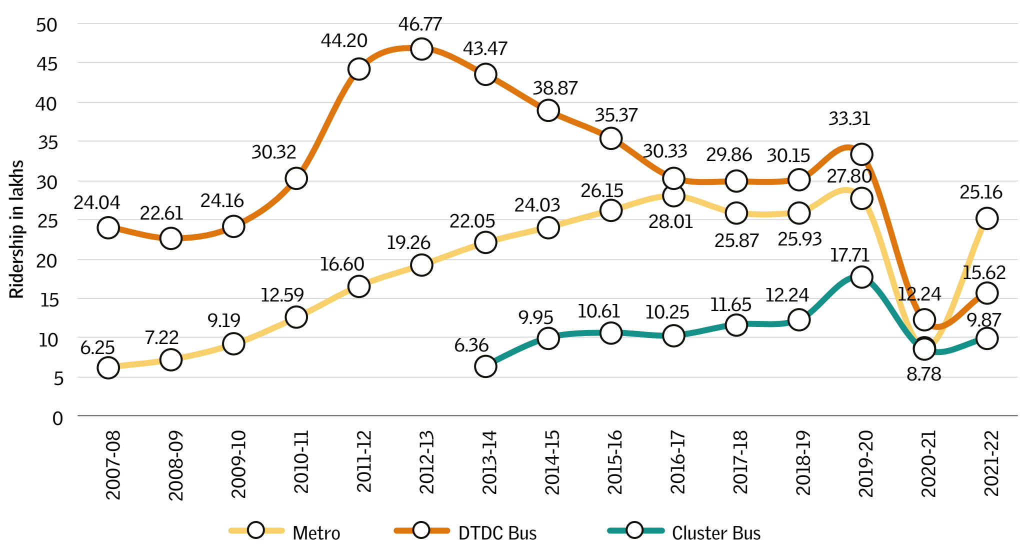
Bus and metro ridership comparison reveals that the metro is increasingly becoming the preferred choice for commuters of public transport. Between 2011-2020, bus ridership fell sharply by 24.6 per cent, whereas metro ridership increased by 67.5 per cent.

Graph 27: (A) Net loss incurred by DTC, 2014-19; (B) Trend in total revenue recovery ratio by DTC, 2014-19; (C) Net loss incurred by DIMTS, 2014-19; (D) Trend in total revenue recovery ratio by DIMTS, 2014-19



Source: MoRTH

Graph 28: Comparing ridership trend of metros and buses in Delhi, 2007-2022



Source: Economic Survey of Delhi, 2021-22 and 2022-23

After the pandemic restrictions were lifted, metro was quick to rebound reaching 90 per cent of its pre-pandemic levels only in 2021-22, while DTC buses and cluster buses could only recover 46.8 per cent and 55.7 per cent of their pre-pandemic level ridership respectively.

This recovery made metro ridership surpass the combined ridership of DTC and cluster buses for the first time in 2021-22 since its inauguration.

As done for DMRC, CSE analysed the wait times at Delhi bus stops, for both DTC and cluster buses to understand the frequency shortfall of buses, and the standard deviation or consistency/predictability of the frequency at respective stops.

Based on this, four categories were made to categorise stops under specific parameters of waiting times (WT) and wait time standard deviations (SD): Low SD-Low WT, Low WT-High SD, High WT-Low SD, and High WT-High SD:

- Low Standard Deviation (SD): SD < 50 per cent of the Average Wait Time
- High Standard Deviation (SD): SD > 100 per cent of the Average Wait Time
- Low Wait Time (WT): Average Wait Time < 10 minutes
- High Wait Time (WT): Average Wait Time > 15 minutes

The goal was to find what share of stations fall into each of the categories, separately for onward and return journeys. (see *Table 6: Summary of results - frequency and its predictability at bus stops* and *Graph 29: (A) Low wait time/WT, low standard deviation/SD stops; (B) High WT, Low SD; (C) Low WT, High SD; (D) High WT, High SD (values in minutes)*).

Table 6: Summary of results - frequency and its predictability at bus stops

	Share	Station Examples
Low SD, Low WT	0.09 per cent	Arya Samaj Road, Sardar Patel Marg, Okhla Crossing
Low SD, High WT	50.06 per cent	18-Block Lodhi Colony, AIIMS Ring Road, Adarsh Nagar / Bharola Village, DDA Market Kalkaji, Inderlok
High SD, Low WT	2.34 per cent	Vipassana Bhawan, Majlis Park Metro Station, ISBT, Defence Colony, Kali Bari Mandir, Mayur Vihar Phase-2
High SD, High WT	1.11 per cent	Laxmi Bai College, CRPF Jharoda Crossing, Hyatt Hotel, Sukhdev Vihar, Tagore Garden Gurudwara / Holy Child School, Samaypur School

CSE analysis results

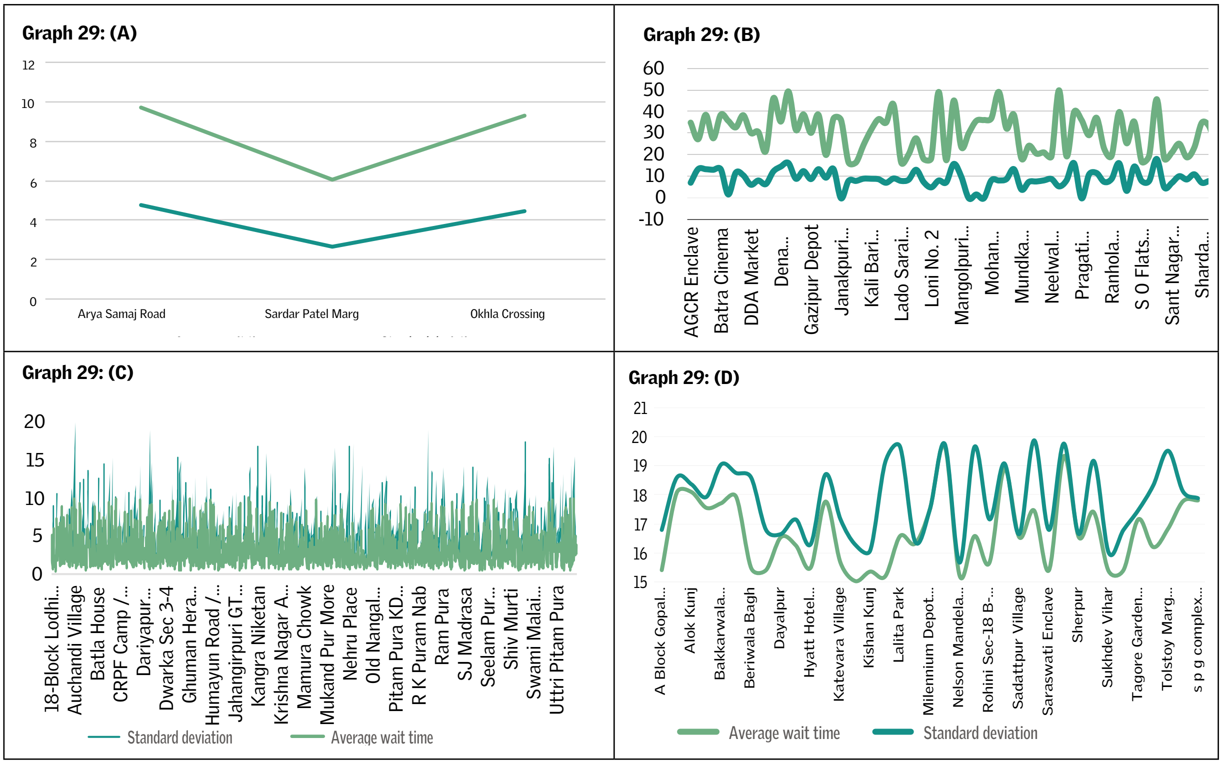
Low SD – Low WT: Only 0.09 percent stops presented an ideal scenario in which the wait times are consistently low on the stops.

Low SD – High WT: More than 50 per cent bus stops have long but consistent and predictable wait times, hence planning is easier for travelling, but the service is poor due to high wait times.

High SD – Low WT: For 2.34 per cent bus stops, getting a bus is quick on an average day, but unpredictability of waiting times makes it challenging for commuters to plan their travel. Inconsistencies and operational disruptions should be checked on these stops.

High SD – High WT: For 1.11 per cent stops, not only is the wait time long, but it is also inconsistent. This indicates poor bus service quality in these stations

Graph 29: (A) Low wait time/WT, low standard deviation/SD stops; (B) High WT, Low SD; (C) Low WT, High SD; (D) High WT, High SD (values in minutes)



5 DELHI'S CONGESTION

What travelling in Delhi feels like

Chronic congestion warps commuter perceptions, normalizing delays and excessive planning time for daily travel. Travel time reliability is poor, with evening peaks showing the highest variability, causing significant productivity losses across all income groups.

Public transport incurs higher costs due to interchange times, last-mile connectivity, and congestion. In contrast, private vehicle trips seem cheaper despite hidden costs. Survey data shows biases in cost estimation, influencing mode choice preferences.

Congestion worsens pollution, with idling vehicles emitting significantly higher pollutant levels. The economic burden includes major losses from fuel wastage and pollution, projected to cost billions by the next decade.

As more people choose personal vehicles, the road space becomes increasingly congested, further straining public transport systems like buses. Buses, already suffering economic losses and inadequate service quality, face the brunt of congestion, making them slower, less reliable, and more unattractive to potential users. This vicious cycle of private vehicle preference exacerbates congestion, which in turn worsens public transport performance, making it even less competitive against personal vehicles.

Congestion, thus, becomes more than just a symptom of personal vehicle dependency—it actively tips the scales in favour of private transport. As public transport vehicles are stuck in traffic, journey times lengthen, reliability decreases, and the overall cost of public transport, both in terms of time and money, rises.

The result is that public transport becomes less viable for commuters who can afford to switch to personal vehicles, perpetuating a cycle of private vehicle growth. This chapter will explore how congestion directly impacts journey costs and productivity, disproportionately affecting public transport users and reinforcing the reliance on personal vehicles, which only serves to worsen the situation further.

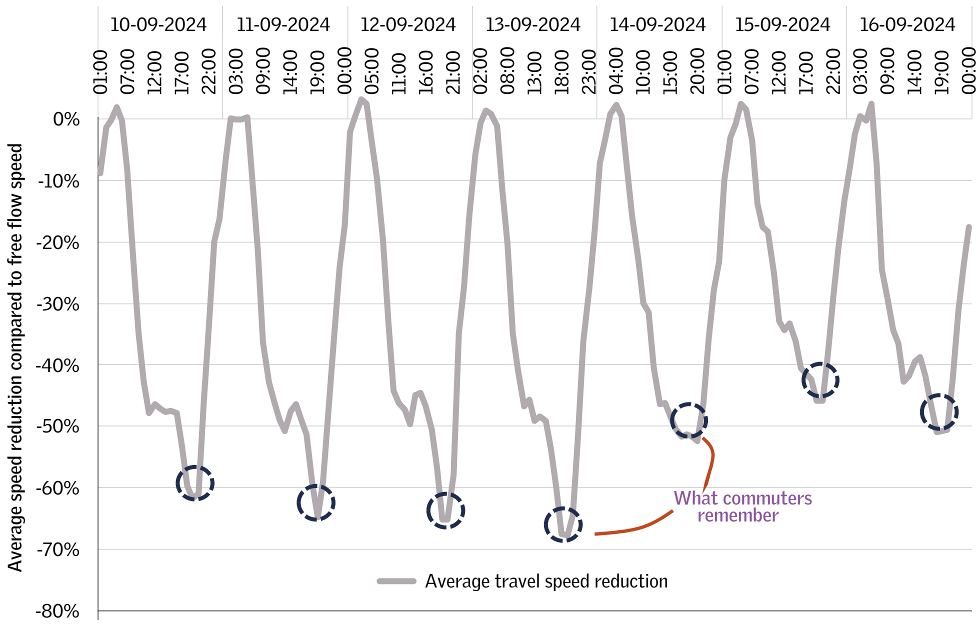
5.1 Reliability of journey

In congested cities, the perception of travel is shaped more by the experience of delays than by average travel times. Drivers, especially in urban areas, become accustomed to the reality of congestion and expect delays as part of their routine, particularly during peak hours. They offset this by adjusting their schedules or allocate extra time for their journeys. Rather than thinking in terms of how long a trip should take under optimal conditions, plans are made for the worst-case scenario.

This creates a disconnect between actual travel time and perceived travel time. The perception becomes skewed, with most travellers recalling their journeys as longer and more tiresome than a simple average would suggest.

Literature to study congestion has evolved to measure this gap in perception and experience of traveling. Statistical tools such as the Planning Time Index (PTI) and Travel Time Index (TTI) have been developed to quantify not just the average travel time but the variability and reliability of journeys. The PTI reflects how much extra time travellers need to allocate to ensure they reach their destination on time, especially during peak congestion periods, while the TTI compares travel

Graph 30: Speed change during different times of day in Delhi, 10th-16th September



Data source: Google Maps API

times in congested conditions to optimal or free-flow conditions. These indices capture the reality that commuters often experience, where the unpredictability of travel due to congestion makes planning more difficult.

During weekdays, Delhi sees an average speed reduction of 41 per cent in morning peak hours and 56 per cent during evening peaks. Over weekends, morning traffic is slowed down by 27 per cent and evening traffic by 42 per cent (see *Graph 30: Speed change during different times of day in Delhi, 10th-16th September*). Speed reduction has been calculated with respect to free-flow speed. Peak hours can be defined as the time zones when speed reduction approaches the "mode" value, which was found to be between 10 AM and 1 PM in the morning, and 6 PM to 9 PM in the evening. Free flow hours were considered between 2AM to 5 AM.

A more sinister consequence of congestion other than a skewed perception of travel is the productivity loss. This loss has economic implications on both individuals and businesses. Time stuck in traffic can be utilised for professional services or personal commitments.

According to the International Labour Organisation, 30 per cent of workers in India are employed as daily wage workers[6]. This population is directly impacted economically by phenomenon such as congestion.

"Delay" is defined as the increase in travel time compared to free-flow hours. Using delay and the daily income earned by "very skilled", "skilled" and "unskilled" workers, the yearly opportunity loss can be estimated, if time spent on roads was utilised for their professional services.

According to the state Labour Department, the minimum daily wage of an unskilled worker should be Rs 695 per day, for a skilled worker should be Rs 843 per day, and for a highly skilled worker should be Rs 917 per day[7]. The number of working days in a year were considered to be 250 days, and the average day of work was assumed to be 8 hours long.

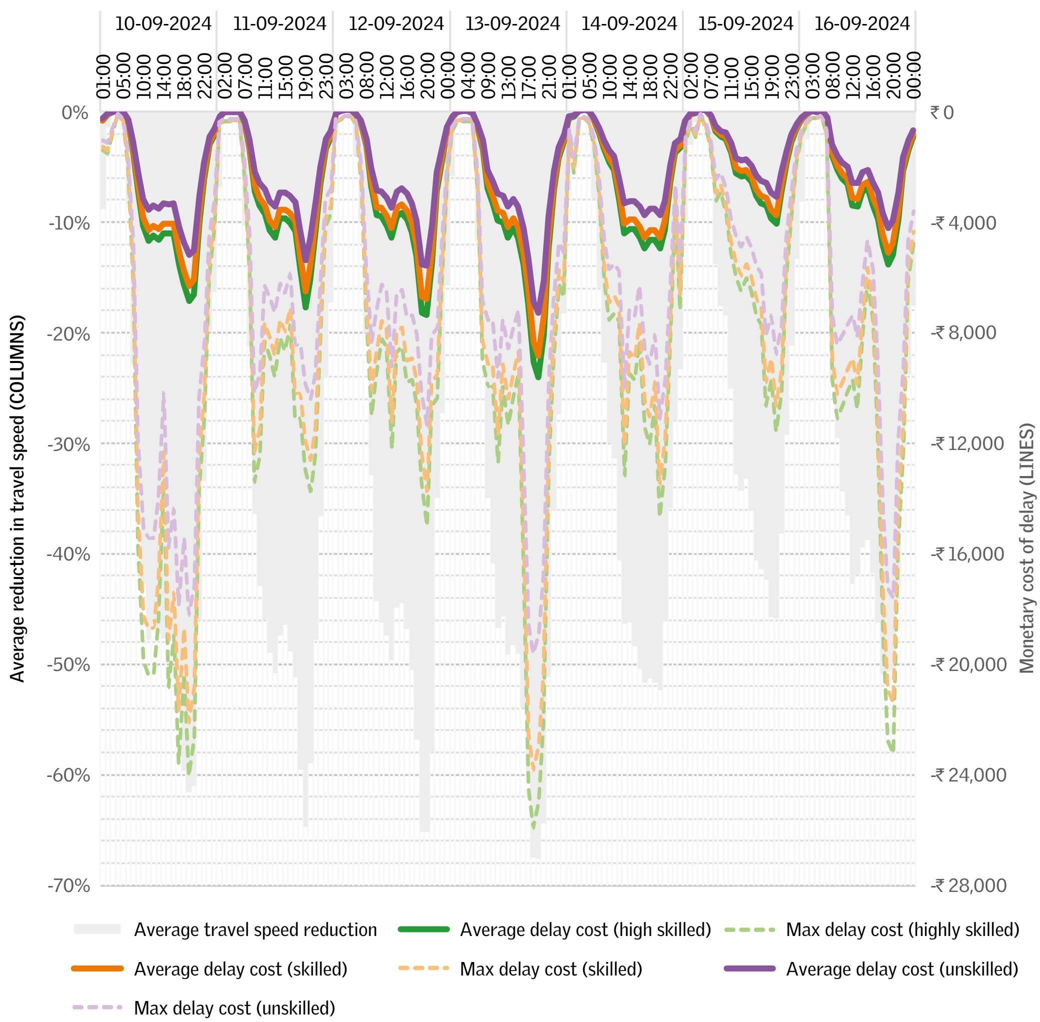
The results show that in a year an unskilled worker stands to lose between Rs 7,500 - Rs 20,100 in a year due to congestion. Similarly, skilled and highly skilled workers can lose Rs 9,100 - Rs 24,400 and Rs 9,900 - Rs 26,600 in a year respectively (see *Graph 31: Speed change versus yearly economic loss among different worker categories*). This amounts to 4 to 12 per cent of their annual income, depending on the extent of congestion, and the time of travel.

Furthermore, plotting Time Travel Index and Planning Time Index explains the extent of congestion by quantifying the required extra planning time. TTI equal to 1.5, for instance, means that a trip will take 50 per cent longer during peak hours than in free-flow conditions. PTI uses the 95^{th} percentile speed on a route at any given day, to ensure on-time arrival 95 per cent of the time. For example, if PTI is equal to 2, commuters need to plan for double the free-flow travel time to avoid being late 95 per cent of the time.

Among the selected stretches in Delhi, PTI can go as high as 7.7 during evening peaks (see Grah 32), which means travelling on those stretches will require a time buffer seven times higher than the free flow. The buffer region between travel time index and planning time index is the "Reliability Buffer", that is the buffer required to ensure reliable time compared to average travel time. The following instance from the results in Graph 32 explain this theory better:

"Travelling on Route 10 (Refer to Annexure 1 – Delhi-Ajmer Express way in the direction of Gurugram to I.G.I. Airport) at 1 PM for a distance that usually takes

Graph 31: Speed change versus yearly economic loss among different worker categories



Data Source: Google Maps API, Delhi Labour Department

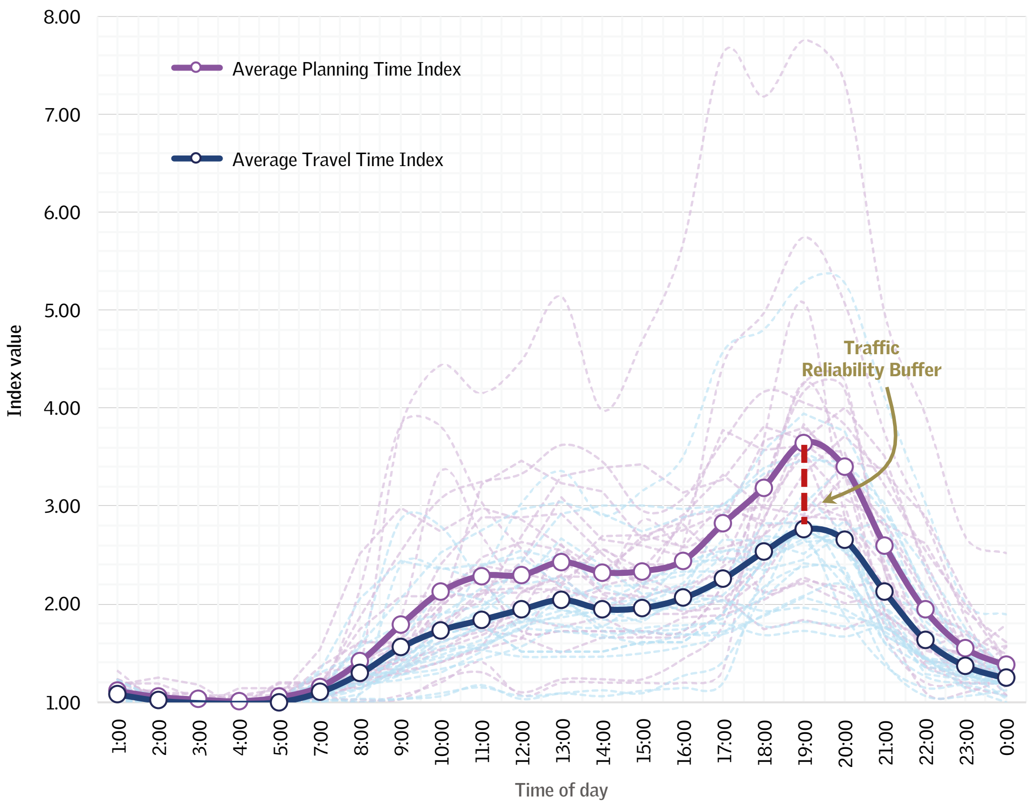
8 minutes during no congestion, and took an average of 26 minutes (TTI = 3.3) at 1 PM at any given day, will require a buffer of 15 minutes (PTI = 5.14) to travel anyway at 1 PM for any given day.”

PTI and TTI are always greater than or equal to 1. The value of TTI equal to 1 means that the average travel time is equal to the mean free speed and there is no delay, and PTI equal to 1 indicates than there is no variability and no planning time is required to start the trip.

Evening peaks are observed to have greater variability in travel time prediction. In the morning, travel is often more spread out as people start their commutes at slightly different times depending on their personal schedules but most people finish around the same time in the evening.

Additionally, evening trips are not only limited to primary trips. Secondary trips such as running errands, shopping, social visits, and so on add on to the trip load. Further, evening trips can be shorter, which can lead to commuters preferring personal modes more than public transport (see *Graph 32: Average planning time index and travel time index during different times of day in Delhi*).

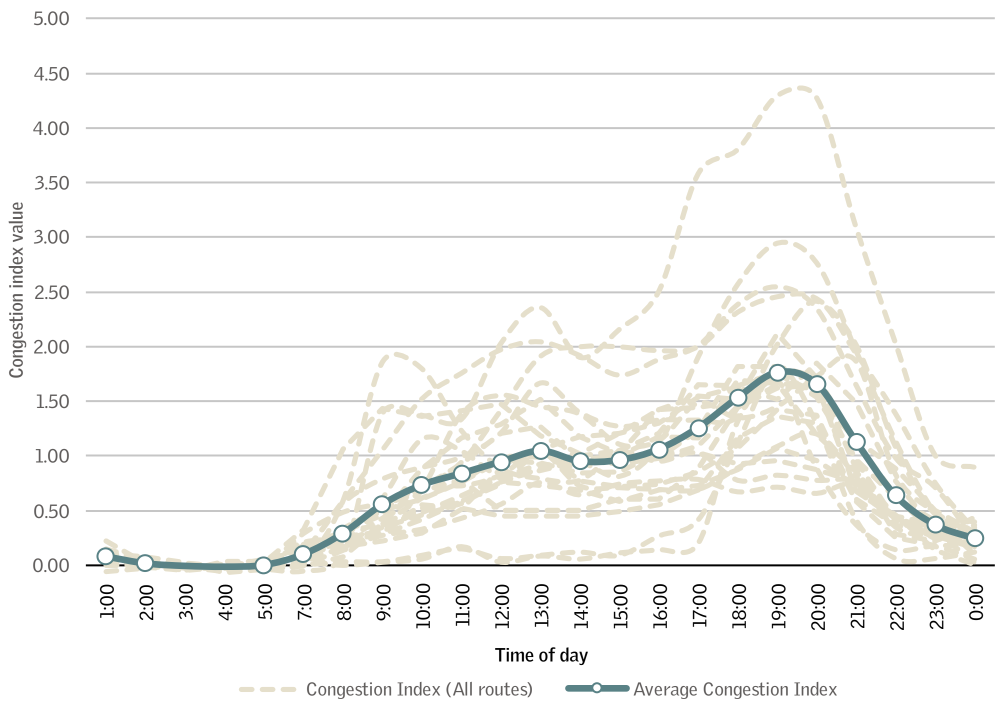
Graph 32: Average planning time index and travel time index during different times of day in Delhi



Data Source: Google Maps API

Travel time congestion index denotes the increase in travel time compared to the free-flow time at any time of day. It is the ratio of delay to free-flow time. Results show that travel times increased by as much as 4.5 times extra during evening peaks, and up to 2.5 times extra during morning peaks compared to free-flow

Graph 33: Average congestion index (using travel time) for different times of days in Delhi



Data Source: Google Maps API

time. (*Graph 33: Average congestion index (using travel time) for different times of days in Delhi*)

In summary, congestion significantly distorts the perception of travel time and delays. Commuters experience unpredictability, where actual travel time often exceeds the average due to traffic, particularly during peak hours. This creates a skewed perception, as travellers recall journeys to be more prolonged and exhausting than they actually are.

As congestion worsens, commuters are forced to allocate extra planning time, which ultimately leads to a loss of productivity, especially for daily wage workers who suffer economic impacts from time lost in traffic.

This study hypotheses that congestion is leading to increased costs for using public transport. The limited connectivity of public transit, with commuters relying on para-transit or long walks to access metro stations, is further strained by heavy traffic, increasing the opportunity cost of commuting. As a result, private transport becomes relatively more affordable despite fuel and maintenance costs.

To investigate this, a survey was conducted among commuters in Delhi to record the travel pattern for their primary trips.

5.2 Journey cost survey results—anatomy of commute

Respondents were asked to provide a step-by-step account of their daily journeys, listing each mode of transport used. This included all segments of the trip, such as walking to the bus stop, taking the bus, taking an intermediate paratransit mode, and walking again to reach their destination.

In addition to mode selection, respondents were asked to indicate their annual income levels, categorized into predefined income ranges. The survey also collected data on journey times for each mode of transport, including waiting times at interchanges. For those using personal vehicles, additional information such as vehicle mileage and fuel type was gathered. To assess their perceived cost of commuting, respondents were asked to provide details on travel fares or fuel costs associated with each leg of their journey.

In cases where public transport was used, respondents were asked to specify their origin and destination stations for both bus and metro travel.

5.2.1 Commute profile

The sample comprises 36 per cent males, 62 per cent females and 2 per cent non-binary groups. The sample was well spread among all income categories, with a marginally higher representation of income class earning 6 to 12 lakhs per annum *(Graph 34: Distribution of income categories)*.

Graph 34: Distribution of income categories

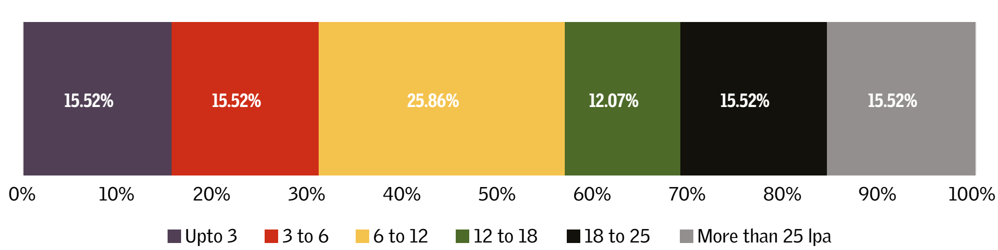
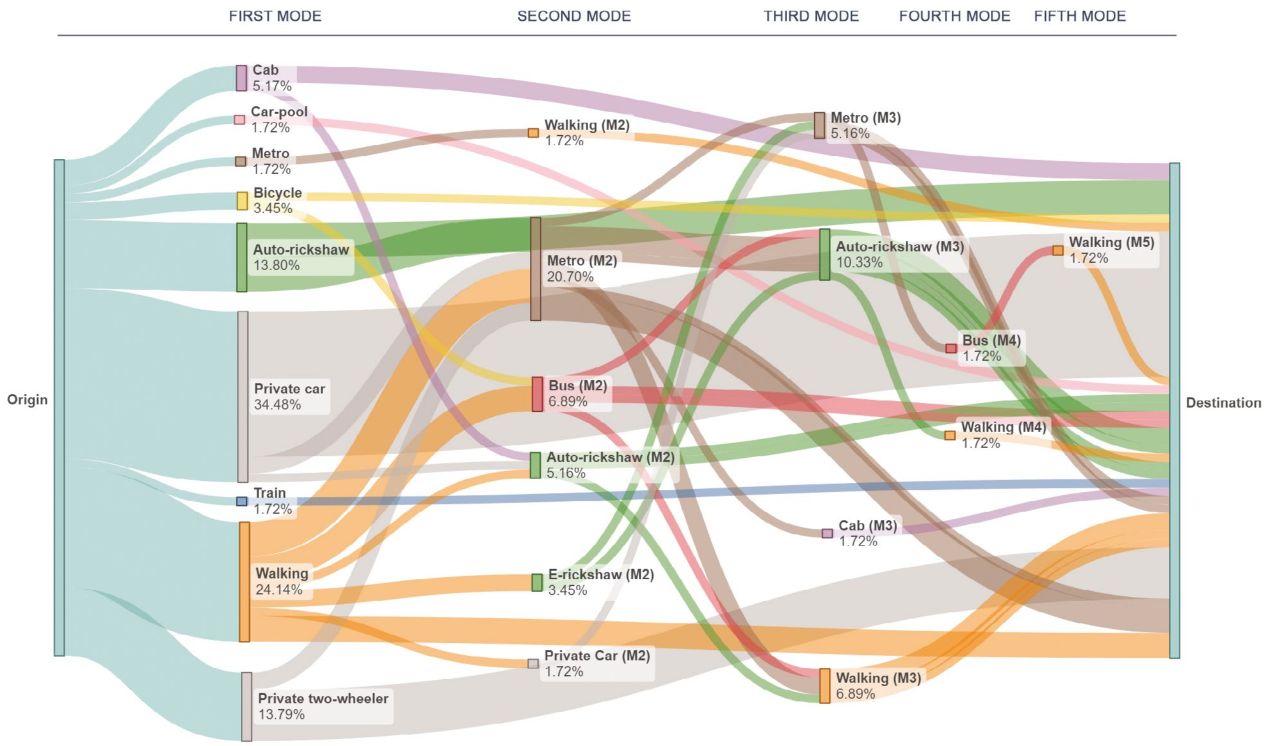


Figure 1: Sankey diagram visualising sample commuters' travel patterns



Results from survey

Results of primary survey

A Sankey diagram was used to visualise the spread of sample size among various transport modes used for travel. There are 165 distinct flows between 80 different nodes, each node representing various modes of transportation and interchanges. The diagram captures commuters' intricate journey paths, showcasing a diverse range of travel modes, including walking, intermediate para transit (auto-rickshaw and cabs), public transport (bus and metro), private vehicles, and others. Each flow in the diagram corresponds to a segment of the commuter's journey (*Figure 1: Sankey diagram visualising sample commuters' travel patterns).*

These patterns reveal several interesting aspects of commuter behaviour. Majority of people use private transport to commute (about 49 per cent). Out of these just about 2 per cent parked their cars or two-wheelers at a distance which required a walk of upto 500 meters, which suggests that most commuters park their vehicles either in their residential complex or nearby.

Among private car users, 10 per cent take their vehicles to the metro and then catch a train to commute, whereas 60 per cent take their cars to the destination directly. Similarly, 75 per cent two-wheeler users travel directly to the destination, while the rest take the metro.

Out of all commuters, metro is accessed as the second mode by 20 per cent (7 per cent walk to the station, 7 per cent use their private vehicle to get to the station, and the rest take an auto-rickshaw). Close to 5 per cent use the metro as the third mode, which is either accessed by a private vehicle, or an e-rickshaw or is an interchange between two connecting metro journeys. For 3.5 per cent of all commuters, metro is the third mode, accessed by walking to their private vehicle or walking to take an auto-rickshaw.

All cab commuters were using the vehicle for the entire journey, except one peculiar case where an interchange was made for a shared auto-rickshaw to reach the destination, possibly or due to limited coverage of a cab service (e.g. BluSmart only operates only within Delhi. A commuter living in NCR but close to the Delhi border may book a cab upto an auto-rickshaw stand in Delhi).

Buses were used between the second mode to the fourth mode. About 9 per cent of all commuters used buses in some part of their journey. About 7 per cent used it as the second mode (4.5 per cent walked to the stop, and the rest cycled upto 5 kms to access a stop), and the other 2 per cent used it as the third mode as last mile after metro.

To summarise, the data highlights a strong dependence on personal vehicles among commuters as their primary mode of travel. This high reliance on private vehicles, particularly cars and two-wheelers, and a preference for convenience and direct travel to destinations reflects a trend where many commuters prioritize the ease of private vehicle use over public transport, which could be attributed to the lack of efficient or convenient alternatives for these journeys.

The share of car users and two-wheeler users combining their vehicle use with metro is a commentary on either the lack of reliable and affordable intermediate paratransit for first and last mile. Furthermore, only a small fraction of commuters park their vehicles at a distance that requires walking up to 500 meters, which reinforces an ecosystem built for dependence on private vehicles.

The data also reveals that bus usage is relatively low, much lower than metro. The fact that bus users cycle up to 5 kilometers to reach a stop is notable, suggesting that access to bus services might not be as convenient or widespread.

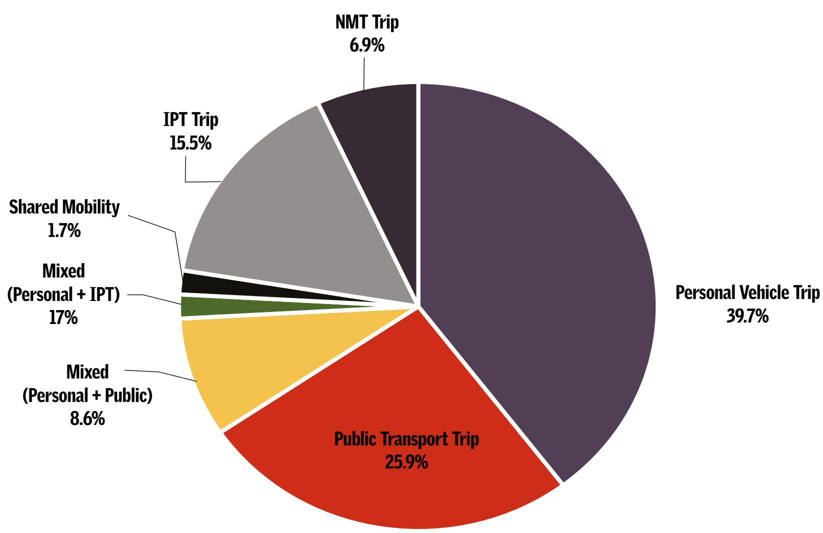
5.2.2 Journey cost assessment methodology

Based on the mode chosen to cover the majority of the trip length, the journeys can be categorised into:

- personal mode trips (from origin to destination),
- public transport trips (predominantly public transport with first and last mile),
- intermediate paratransit trips (includes first and last mile walking/cycling),
- non-motorized trips (only walking or cycling),
- shared mobility trips (using shared autos, car-pools, etc)
- and mixed trips (further classified into personal + public modes, and person + IPT modes)

As discussed, the majority of the trips are personal mode only trips (close to 40 per cent), and public transport mode trips are 26 per cent of the trips. Intermediate paratransit trips are also significant, about 15.5 per cent of the total mix (see *Graph 35: Distribution of journey types across sample).*

Graph 35: Distribution of journey types across sample



Results from survey

This categorisation is important to understand the significance of cost components while calculating the journey cost for each trip type. For example, while fare cost in public transport modes such as buses might cost less compared to the fuel cost of vehicles, the interchange time along with the last mile fare cost, and the extra journey time cost might increase the total journey cost significantly. The journey cost for each type can be broken down into components as per (see *Table 7: Cost components of different categories of trips*).

Table 7: Cost components of different categories of trips

Journey Type	Cost Components	Sample share (per cent)
Personal mode	Fuel cost, Journey time cost	39.7
Public transport	Fare cost, Interchange time cost, Journey time cost, Last/First mile time cost, Last/First mile fare cost	25.9
Intermediate para-transit (IPT)	Fare cost, Interchange time cost, Journey time cost	15.5
Mixed (personal + public transit)	Fuel cost, Fare cost, Interchange time cost, Journey time cost, Last/First mile time cost, Last/First mile fare cost	8.6
Mixed (personal + para transit)	Fuel cost, Fare cost, Interchange time cost, Journey time cost	1.7
Shared mobility	Fare cost, Journey time cost	1.7
Non-motorized transport (NMT)	Journey time cost	6.9

Prepared by CSE

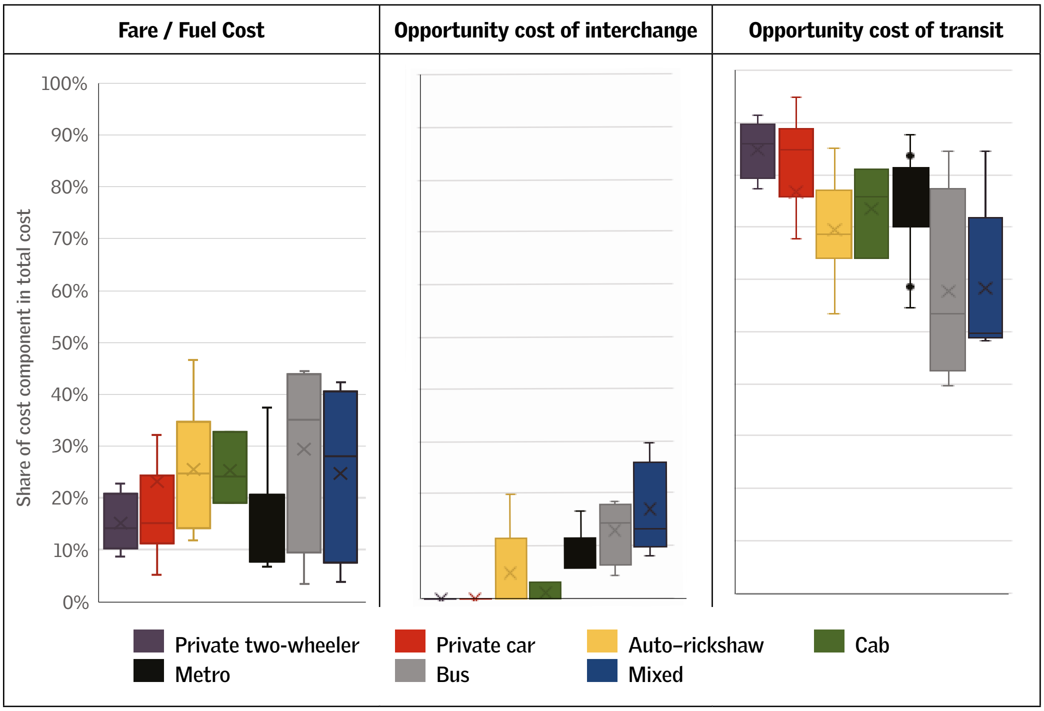
Before comparing total journey costs among segments, the analysis captures a comparison of the weight of different cost components for each vehicle segment graphically using the box and whisker charts.

The three key cost components analyzed were fuel/fare costs, interchange time costs, and travel time costs (transit time cost). By visually representing these costs, the goal was to identify patterns and disparities in how different modes of transport perform in terms of cost efficiency across these dimensions.

This analysis provides critical insights into the cost burdens for each mode. Private vehicles show a lower fuel cost than all other modes (compared to the fare cost), while public transport has the highest interchange and transit time costs (*Graph 36: Fare/fuel cost, interchange time cost, and transit time cost of public and private transport journeys respectively)*.

It becomes easier to pinpoint where inefficiencies lie. The results allow us to identify where interventions are necessary to reduce costs or waiting times for specific modes, such as improving first/last-mile connectivity for public transport users or reducing time spent during interchanges.

Graph 36: Fare / fuel cost, interchange time cost, and transit time cost of public and private transport journeys respectively



Results from survey

5.2.3 Comparative usage costs of modes—public and private transport

On face value, when only fuel and fare costs are included for journey costs, public transport is cheaper. In fact, one of the basic principles of designing a public transport system is affordable fares for sections of the society, aiming to make transportation accessible to the majority. Additionally, public transport systems are often subsidized by the government to keep fares low, further enhancing their affordability compared to the high operational and ownership costs of private vehicles, such as fuel, maintenance, insurance, and parking fees.

To observe and compare the distribution of fuel cost / fare cost for public and private transport journeys to see a visible trend, a box and whisker graph was created for both datasets from the sample of the study.

Box and whisker graph is a graphical representation that shows the distribution of a dataset. It provides a visual summary of the data's central tendency, variability, and any potential outliers.

The box represents the interquartile range (IQR) or the middle 50 per cent of the share of annual income spent on their primary trips (one way journey). The bottom edge of the box is the first quartile (25^{th} percentile), and the top edge is the third quartile (75^{th} percentile).

The line dividing the box into two is the median (50^{th} percentile). Whiskers are the lines protruding outside the box; they show the range of the data, excluding outliers. The whiskers typically extend to the smallest and largest data points within 1.5 times the (IQR). Any values plotted beyond the whiskers are outlier values.

Among the sample for the study, when considering "private transport only" and "public transport only" trips, it Is observed that the median value of public transport fare is ₹2.97 per km, significantly lower than the median of fuel cost for private transport journey is ₹6.36.

Conversely, the IQR for private transport is much wider (₹2.5-₹8.5), showing more variation in expenses. The whiskers further reveal that while public transport fare costs do not exceed ₹4 per km, private transport costs can reach up to ₹10.5 per km.

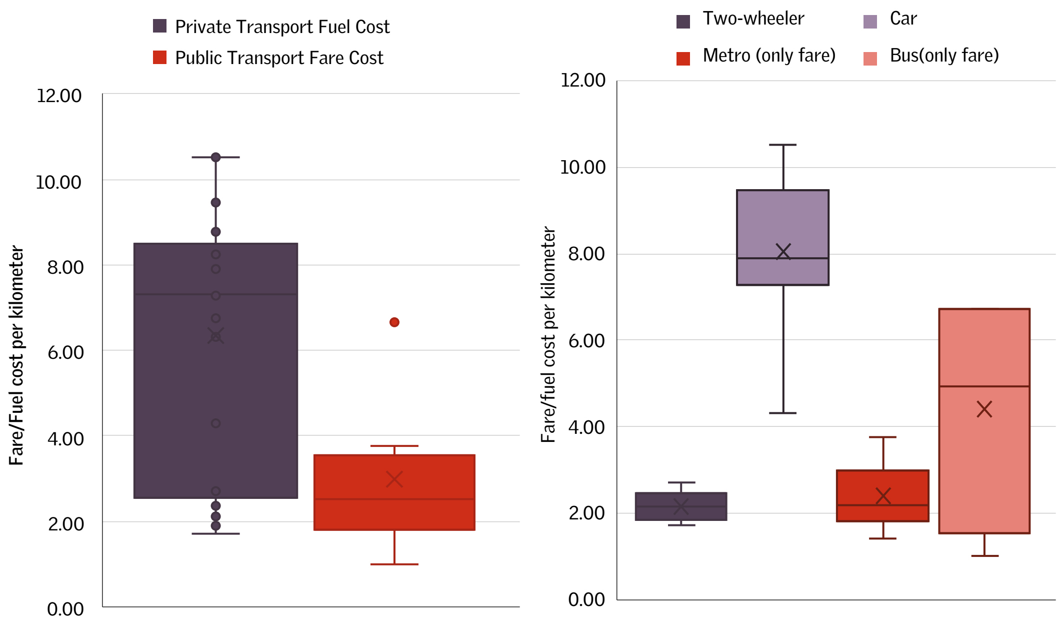
Breaking up journeys into segments, it was observed that car trips are the most expensive out of all, due to the lower mileage, whereas two-wheeler fuel on an average cost less than ₹2.5 per km.

Bus trip fares were more expensive than metro and two-wheeler trips, due to the presence of commuters in the sample (2 per cent of all samples) who take an office shuttle bus service, which costs them substantially higher than public buses (see *Graph 37: Fare and fuel cost of public and private transport journeys respectively*).

However, the factors which increase the journey cost of public transport systems are interchange mode fare costs for first and last mile, interchange time cost, as well as the increased journey time cost due to congestion (for buses). Time costs are also called "opportunity costs" in the cost of urban mobility because the time spent travelling could have been used in other productive ways.

Adding these cost components to the fare cost changes the dynamics entirely. The hypothesis that this study aims to test is that when opportunity costs are included, private transport journeys are cheaper than public transport. To test the hypothesis, the "One tailed t-test" will be used.

Graph 37: Fare and fuel cost of public and private transport journeys respectively



Results from survey; Note: Public transport journey fare cost does not include intermediate para-transit fare costs

A one-tailed t-test is a simple statistical test that helps us compare two groups to see if one is greater or lesser than the other, rather than just looking for any difference. In simpler terms, the test compares the average costs from both groups. It looks at whether the average public transport cost is statistically higher than the private transport cost.

The test gives a number called a "p-value". This number predicts whether the difference is meaningful or just happened by chance.

This starts by assuming the null hypothesis (H_0), which is typically a statement that says there is no effect or no difference. The alternative hypothesis (H_1) represents the specific claim the study aims to test, and hoping to prove is true.

Hypothesis	*Null Hypothesis (H_0): Public transport costs are less than or equal to private transport costs.*
	Alternate Hypothesis (H_1): Public transport costs are greater than private transport costs.

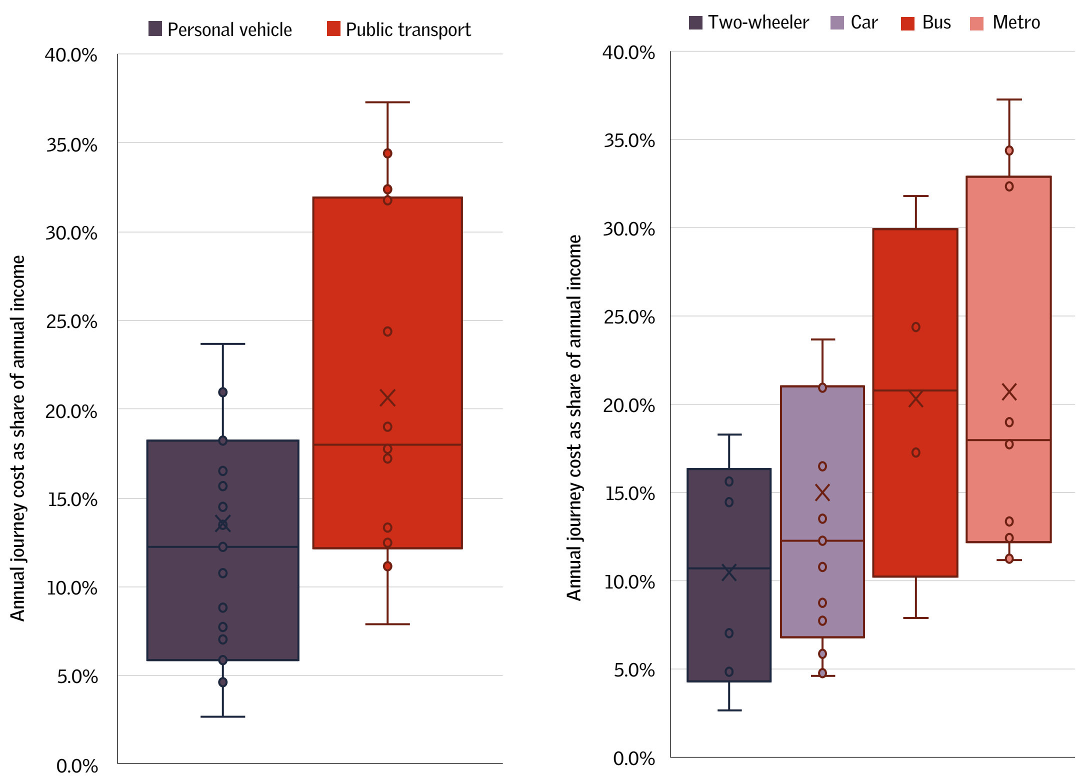
The p-value derived from the data sets of total annual journey cost as share of annual income (to normalise trend among different income groups and affordability) is 0.024.

In this study, a commonly accepted significance level of 0.05 (or 5 per cent) was used. The significance level is the threshold below which the null hypothesis can be rejected in favour of the alternative hypothesis. Since p-value is less than this threshold, it means the observed data provides strong evidence against the null hypothesis, and the alternative hypothesis holds.

Therefore, it can be concluded that the data provides statistically significant evidence that "public transport is indeed more expensive than private transport when considering additional costs such as time lost during interchanges, the fare for alternative modes (e.g., auto-rickshaws), and opportunity costs".

The median value increases substantially for public transport, compared to private transport costs while considering the total journey cost. The median value for public transport is 18 per cent, with the interquartile range between 12 and 32 per cent. For private transport, the median value is 12 per cent, while the IQR is 6 to 18 per cent. As mentioned previously, these shares are the share of income spent on daily one day journey cost (see *Graph 38: Total journey cost of public and private transport journeys respectively*).

Graph 38: Total journey cost of public and private transport journeys respectively



Results from survey

Interestingly, metro trips are more expensive when considering the total journey cost, due to the increased costs of first and last mile due to lesser coverage of metro stations compared to bus stations. Additionally, the time taken for boarding and alighting metro trains is also substantial due to factors such as navigating through often crowded platforms, queues for security posts, etc.

This increases the journey time, and hence the opportunity cost. Commuters often claimed that metro trips are more feasible for longer trips, as road congestion balances out the extra time spent manoeuvring around in the metro station before catching the train. For shorter trips, commuters prefer personal modes or intermediate para-transit.

Perceived costs of journey: Another interesting finding was the difference in perceived cost and the actual cost of commute for personal vehicle users. Private vehicle users evaluated their journey costs to be much more expensive than they actually were.

To quantify and compare this difference, a Bland-Altman plot was created, which helps assess the agreement between two variables—in this case, perceived cost and actual cost. In this context, "agreement" refers to how accurately commuters perceive the real expenses they incur, and whether these perceptions significantly differ from the true costs.

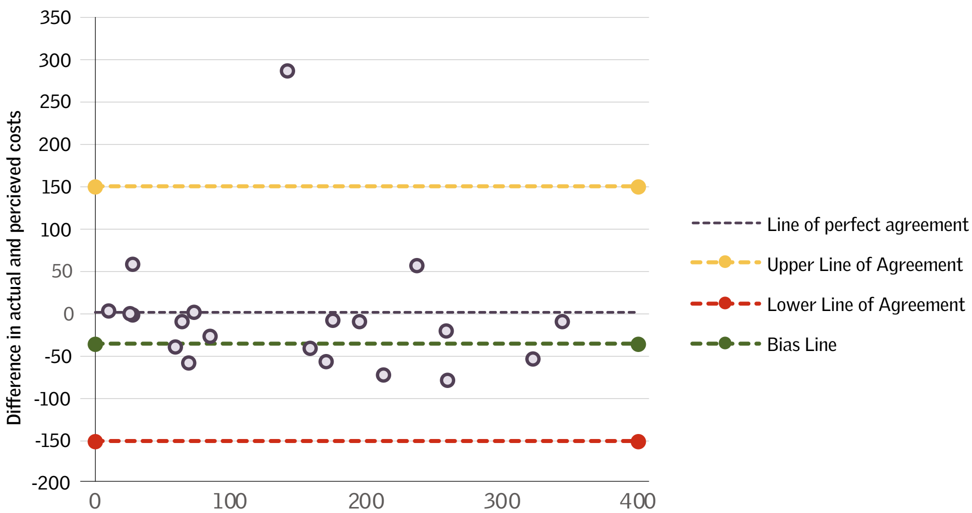
The axes in a Bland-Altman plot are the mean of the two costs (X-axis), and the difference of the two variables (Y-axis). The horizontal line at zero represents the line of perfect agreement or in other words, the line at which actual costs are most accurately perceived. The Upper and Lower Lines of Agreement (LoA) capture 95 per cent of the perception values' range.

Since the difference captured was *Actual Cost – Perceived Cost*, values approaching the Upper LoA are commuters who underestimated their costs, and the values approaching the Lower LoA are commuters who overestimated their costs. Any points outside this range suggest significant deviations in the perception of cost (in other words, outliers).

The Bias Line represents the mean difference between the two variables being compared—in your case, the difference between actual cost and perceived cost. It is essentially a horizontal line that shows the average bias across all data points.

In this particular case, the Bias Line is below zero (value ₹-36.67), which means that on average, the **actual cost is lower than the perceived cost**, showing a **tendency for overestimation**: people are overestimating their travel costs (*Graph 39: Bland-Altman plot showing perception of travel cost among private vehicle commuters).*

Graph 39: Bland-Altman plot showing perception of travel cost among private vehicle commuters



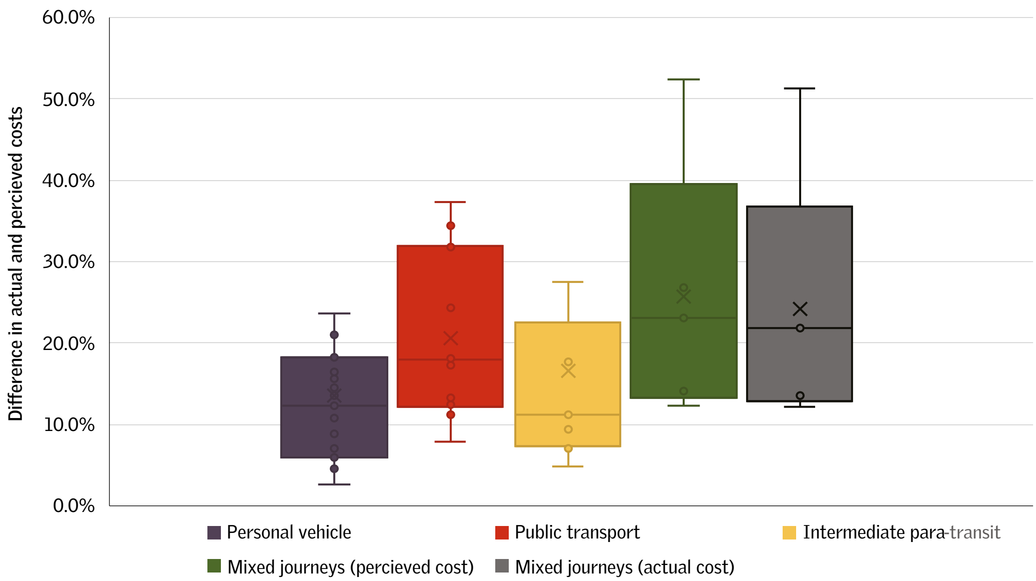
Results from survey; Note: The calculations were done for fuel costs only, since opportunity costs are not usually perceived by commuters while self-evaluating their journey costs

In fact, out of the total sample, about 65 per cent private vehicle commuters overestimated their cost of commute. This suggests a systematic bias in how individuals perceive their travel expenses, which could be attributed to a perceived sense of entitlement associated with private vehicle ownership. This bias in perception might be influenced by the convenience, status, or perceived comfort associated with private vehicles, leading to inflated cost expectations compared to the actual figures.

5.2.4 Cost of intermediate public transport (IPT) trips and mixed mode journeys

When journey costs for IPT-only trips (Intermediate Public Transport such as auto-rickshaws or e-rickshaws) and mixed trips (which include both private and public transport, as well as IPT for last-mile connectivity when necessary) were calculated and compared with private transport-only and public transport-only trips, an interesting pattern emerged. IPT-only trips were found to be more expensive than private transport-only trips, but less costly than public transport-only and mixed trips. Private transport remains the cheapest of them all.

Graph 40: Total journey cost of intermediate para-transit and mixed public-private transit trips compared with private transport trip costs



Results from survey; Note: Mixed journeys include trips made using both private transport and public transport, along with IPT last/mile when needed.

This analysis highlights that public transport trips, despite their intended affordability, can result in significantly higher overall expenses. IPT trips can cost as much as 27 per cent of the annual income for a passenger, whereas mixed trips which include public transport can exceed 50 per cent of the annual income (*Graph 40: Total journey cost of intermediate paratransit and mixed public-private transit trips compared with private transport trip costs*).

This is proof again that elevated costs are primarily driven by high opportunity costs, such as journey and waiting time, particularly for bus trips, which often involve extended durations and multiple interchanges. These factors can make public transport trips unexpectedly expensive for commuters, even when direct fare costs appear lower.

As seen in the previous segment, whenever private transport is involved in a journey, commuters' perception of the total cost (fuel only) starts skewing. In the case of mixed transport journeys as well, the perceived costs are slightly higher than actual costs of commuting (albeit only 2 per cent in this case).

5.2.5 Pollution linked to congestion and vehicle idling

Traffic congestion and prolonged vehicle idling are significant contributors to urban air pollution, emitting various harmful pollutants such as nitrogen oxides (NOx), carbon monoxide (CO), particulate matter (PM), and volatile organic compounds (VOCs).

The mechanics of internal combustion engines under idle or stop-and-go conditions are less efficient, leading to incomplete fuel combustion, which directly results in higher levels of these emissions compared to free-flowing traffic. Additionally, pollutants from idling are released close to the ground, exacerbating ground-level ozone formation, which can severely impact respiratory health, especially in densely populated urban centres.

Emissions from vehicles idling in traffic also contribute significantly to secondary organic aerosols (SOAs), which have been associated with cardiovascular and respiratory conditions. The composition of these SOAs often includes ultrafine particles (UFPs) that are small enough to penetrate lung tissue and enter the bloodstream, compounding the health risks associated with prolonged exposure to urban traffic emissions.

In high-congestion scenarios, the cumulative effect of multitude of vehicles idling or accelerating intermittently generates "hot spots" of pollution, particularly in enclosed spaces such as the "tunnel like effect" caused by tall construction on both sides of road segments or near intersections.

Scientific evidence around emission rates of pollutants during idling suggests manyfold increase compared to when the vehicle operates at optimal speeds (which is said to be 40-60 kmph).

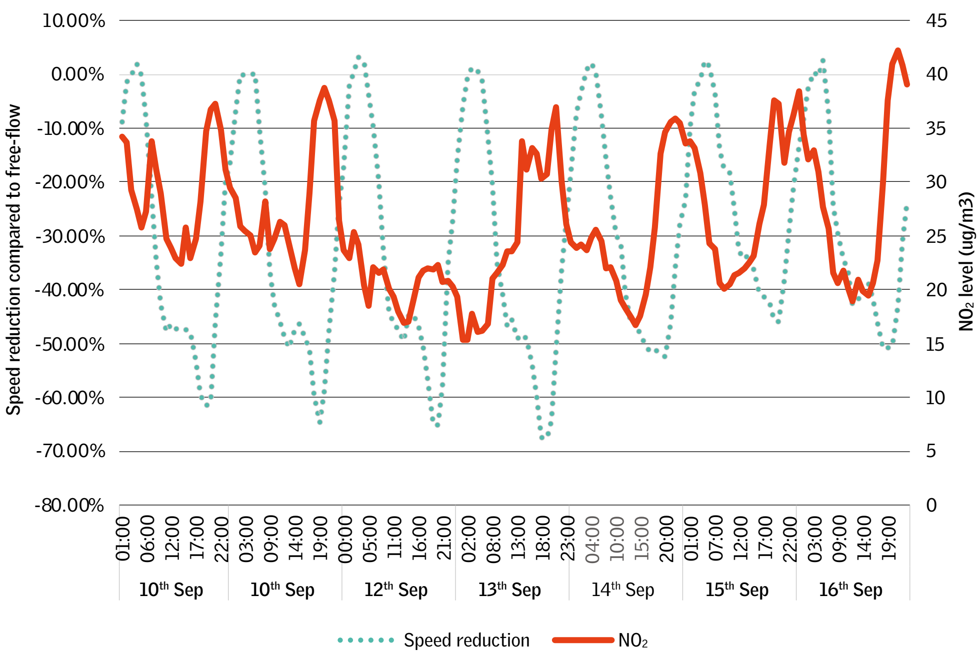
Literature review shows emissions to be 3–7 times higher in congested traffic than in free-flowing conditions, with specific pollutants like NO_2, CO, and CO_2 experiencing dramatic increases. A 2024 study shows that during congestion emissions are 3–7 times higher than in free-flow conditions.[8] Another 2023 study shows that due to congestion, $PM_{2.5}$ increases by 3.5 µg/m*, O_3 increases by 1.1 parts per billion.[9] Yet another 2016 study shows that the percentage increase in pollutant in three sets of runs between delay and non-delay: NO_2 (166 per cent), HC (100 per cent), CO (180 per cent), CO_2 (71 per cent).[10]

Economic costs due to congestion are also substantial. Projections estimate congestion will cost Delhi around USD14.7 billion by 2030, including pollution and fuel wastage. Daily fuel losses due to idling alone are estimated at millions of dollars. A 2017 study shows that the projected traffic congestion costs (includes pollution + fuel) 14658 million USD/yr for the year 2030.[11]

Vehicles caught in congestion and idling can spew emissions several times higher than their normal emissions on roads. Since vehicles are the dominant sources of nitrogen oxide levels, there is a strong correlation between vehicles and hourly changes in NOx levels.

The data for 7 days in Delhi (10th September- 16th September 2024) presents the correlation between NO_2 and speed reduction compared to free-flow speed. The data indicates that during peak hours on working days (27th - 30th), when travel speeds drop, NO_2 levels were found to be notably high. The correlation coefficient for speed reduction and NO_2 levels for peak hours is -0.534 which indicates a moderate negative relationship between the two with a variance of -0.28. This means that when speed decreases, NO_2 levels increase, and for the data recorded during the week about 28 per cent of the variance in NO_2 can be explained by the changes in the speed. (see *Graph 41: Correlation between average speed reduction and average NO_2 levels, 10-16 September 2024).*

Graph 41: Correlation between average speed reduction and average NO_2 levels, 10-16 September 2024



Data source: Google Maps API, CPCB

6. Way forward

Ambitious technology pathway for energy efficiency and zero emissions target: Ambition technology pathways are needed to cut emissions at source. This will need enablers to accelerate the market at a scale.

Need scalable, integrated, connected and reliable public transport system and services: The technology pathway will have to be complimented and strongly supported by the scalable interventions to build public transport infrastructure.

Create low-emissions zones and scale up a network of walking and cycling infrastructure and efficient last mile connectivity: Every public transport trip begins and ends with a walk trip. Augmentation in public transport ridership will require upscaled holding areas for walking and cycling trips. Low-missions zones can enable targeted transition in zones and areas for community-wide adoption of sustainable transportation options.

Need restraint and demand management measures to reduce automobility: While sustainable transportation options need to be augmented, it needs to be supported by vehicle restraint measures. A combined strategy of parking area management plan, variable parking pricing, congestion and road pricing, among others need to be adopted to restrain vehicle usage and reduce vehicle miles travelled. Reform taxes to recover the true cost of owning and using personal transport.

Adopt compact urban form to keep jobs and home close: Reduce distances, demand for travel and vehicle usage: India has already adopted transit oriented development policy and urban form based code for urban and transportation planning and integration. This needs targeted and upscaled implementation to promote mixed use and mixed income development, regeneration of urban spaces, within close proximity – about 400-800 sqm radius of transit nodes. This can enable a shift in behaviour. Integrate the needs of urban poor with land-use planning.

Shift budgets from road-building to public transport, active transport and zero-emissions mobility. Also adopt innovative fiscal instruments to mobilise new resources: Considerable resources can be unlocked if the current public expenditure in car centric expenditure can be repurposed and diverted towards public transport infrastructure. Simultaneously, adopt innovative financing including land value capture, polluter pay principle, among others to augment resources. It is also important to explore further augmentation through bilateral and multilateral funding including climate finance.

Adopt measurable and verifiable impact monitoring systems: For each of the intervention detailed strategies need to be designed with clear indicators and committed funding. The strategy design has to draw upon the service level benchmarks of the Ministry of Housing and Urban Affairs, appropriate codes of India Road Congress and the other relevant policy and regulatory norms and guidelines. This needs to be monitored and evaluated every quarter to assess the scope of the progress.

Annexure 1: Selected routes for congestion analysis, Delhi

Route Number	Road Name	Towards direction	KM	Short Link
Route 1	Baba Banda Singh Bahadur Setu	Sarai Kale Khan	4.4	https://maps.app.goo.gl/PDAzJX3KsrQUbZ9J9
Route 2	Jangpura Rd	Delhi Golf Club	5.8	https://maps.app.goo.gl/hPx3tC4M3gubyrjaA
Route 3	Mahatma Gandhi Rd	Ashram	7.5	https://maps.app.goo.gl/vm3xxqf4NRXVmc568
Route 4	Mahatma Gandhi Rd	Moti Bagh	6.4	https://maps.app.goo.gl/CeAEi44vFNpBWp7W9
Route 5	Sri Aurobindo Marg	Mehrauli	5.1	https://maps.app.goo.gl/HJMAjfiAfVE9qwv69
Route 6	Outer Ring Rd	Okhla	6.5	https://maps.app.goo.gl/D12gjR5DyjN3V6VN7
Route 7	Outer Ring Rd	Greater Kailash to Kakaji Mandir	4.0	https://maps.app.goo.gl/W8eQwdFmzzXpV6ry8
Route 8	Acharya Shree Tulsi Marg	Qutab Minar	6.0	https://maps.app.goo.gl/7S9r2FFZje9Pni5o6
Route 9	Acharya Shree Tulsi Marg	Hauz Khas	5.0	https://maps.app.goo.gl/XyZW1AErrf2UowRj9
Route 10	Delhi Ajmer Expressway	Gurugram to Delhi I.G.I. Airport	7.0	https://maps.app.goo.gl/bvja6PiByUpmxRvz5
Route 11	Delhi Ajmer Expressway	Dhaula Kuan to Delhi I.G.I. Airport	7.5	https://maps.app.goo.gl/rCyHo82VtbhopuuBA
Route 12	Vikas Marg	ITO	2.1	https://maps.app.goo.gl/s1rXvzdpdPnrm5M86
Route 13	India Gate Circle (C Hexagon) - Purana Qila Rd	Pragati Maidan	2.1	https://maps.app.goo.gl/jhnVoDZH9UWUsmZYA
Route 14	Pragati Maidan Tunnel Rd	Sant Nagar	2.7	https://maps.app.goo.gl/DTf7iZiZSKkCTUcJ7
Route 15	Mathura Rd - Bhairon Marg	Supreme Court to Sant Nagar	2.8	https://maps.app.goo.gl/mFGxhGQtzcQHvFas6
Route 16	GT Karnal Rd	Shastri Park	2.8	https://maps.app.goo.gl/LB2KivqEqQxDrvFk9
Route 17	Lothian Rd - Netaji Subash Marg	Delhi Gate	5.9	https://maps.app.goo.gl/ns7Fib9v1p6qzGY3A

Route 18	Desh Bandhu Gupta Rd	Sarai Rohilla Station	4.0	https://maps.app.goo.gl/eBHD7uDNbPVNZvuu7
Route 19	Lothian Rd - Netaji Subash Marg	Jama Masjid	2.5	https://maps.app.goo.gl/5rP8NRTc1T9G7eVM8
Route 20	Bahadur Shah Zafar Marg	Delhi Gate	2.4	https://maps.app.goo.gl/55BNdAbvZnADWXu37
Route 21	Shivaji Marg	Najafgarh	6.8	https://maps.app.goo.gl/TMZu4Ei5MUUzb1f7A
Route 22	Shivaji Marg	Subhash Nagar Metro	6.2	https://maps.app.goo.gl/dHRL62CffJqFRJqt9
Route 23	Samaypur Badli Metro Rd	Rohini	5.4	https://maps.app.goo.gl/zKXvYGUPQLc5M46q9
Route 24	GT Karnal Rd	Libas Pur	6.3	https://maps.app.goo.gl/GK1e7Y1LSz6Ua6yD9
Route 25	Mehrauli Badarpur Rd	Lado Sarai	6.6	https://maps.app.goo.gl/v5Tx4D5jgnP4JKHT7

Prepared by CSE

Annexure 2: Variables and measures used in the study to quantify congestion

General Variables	Definition
Free flow speed/time	The average speed/time that a motorist would travel if there were no congestion and no other adverse conditions (such as weather).
Peak hour	The busiest time of the day (highest traffic).
Off-peak hour	Times of day other than peak hours.
95th percentile time	Represent the near-worst travel time (in the 95th percentile during the day).

Measure	Description	Formula
Delay	Delay is defined as extra travel time taken during a journey against expectations (against free-flow time).	*Travel time (at any given time of day) – Free flow time*
Travel Time Index	TTI is the ratio between average travel time and free-flow travel time. It represents how much longer on average a commuter travels on average on a route compared to free-flow hours.	$\frac{\text{Average travel time}}{\text{Free flow time}}$
Planning Time Index	PTI is the ratio between 95th percentile travel time and free-flow travel time. It represents how much extra time buffer a commuter needs to consider given their perception of travel time.	$\frac{\text{95th percentile travel time}}{\text{Free flow time}}$
Congestion Index (travel time based)	It represents the increase in travel time compared to the free-flow time at any time of day. It is the ratio of delay to free-flow time.	$\frac{\text{Travel time (at any time of day) – Free flow time}}{\text{Free flow time}}$
Congestion Index (travel speed based)	It represents the decrease in travel speed compared to the free-flow speed at any time of day.	$\frac{\text{Travel time (at any time of day) – Free flow time}}{\text{Free flow time}}$

Compiled by CSE; Source: M. Kumar et al. 2021; Federation Highway Association (US), 2023

Annexure 3: Assumptions for calculating cumulative vehicle tax over a period of 10 years for vehicles registered in Delhi

Vehicle segment	Fuel type	Assumption to calculate state tax	CO_2 emissions in g/km
Two-wheeler (2W)	Petrol	125 cc variant; Cost: ₹70,000	36.01
Auto Rickshaw (3W)	CNG	-	64.91
Car (4W)	Petrol	Gross weight: 1400 kg; Cost: ₹8 lakhs	137.35
Cab	Petrol	Cost: ₹8 lakhs	137.35
Light Goods (LCV)	CNG	Load Capacity: 1300 kg	154.9
Heavy Goods (HCV)	Diesel	Load Capacity: 12 tonnes	445
Bus	CNG	Passenger capacity: 35	1062.2

Source: Data Source: Delhi Transport Department (GNCTD), ICCT (reports 2021-23), CSIR-NIT, TRB-NASEM, ICCT's Fuel Economy conversion tool

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The immediate sign of the mobility crisis is paralysing congestion in cities. As cities struggle to sustain a healthy growth in public transport, cycling and walking for the urban masses, explosive growth in personal cars and two-wheelers lock-in enormous pollution, energy intensity, and wasteful use of land. Mobility becomes so inefficient that people cannot reach destinations with ease, incur high journey costs, suffer unpredictable commuting time, and lose productive time.

All of these add up to high health costs and welfare losses. Choking congestion not only slows down revival and reinvention of public transport and active mobility, it also defeats the purpose of increasing investments in mass transport and vehicle electrification. It is a paradox that even as electric buses are increasing, their usage and ridership are declining.

Even though this crisis is part of the lived reality of the urban masses, cities do not make the effort to generate on-ground evidence on the factors contributing to this problem to recalibrate the solutions. This assessment therefore decodes the elements of Delhi's congestion in the real-world in terms of travel patterns, travel costs, bus service level, commuters experience with congestion and commuting, to provide the basis for enhancement of public transport efficiency, improve reliability, and promote sustainable mobility through better planning and integrated infrastructure solutions.

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