LOW-EMISSION ZONES

OPPORTUNITIES AND IMPACTS

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Why this spotlight on low-emission zones?

Several policy mandates have converged in states and cities to address the problems of health threatening air pollution and carbon intensive urban growth with a special focus on transportation trajectory. Currently, the states and cities are required to frame and implement clean air action plans as well as climate change mitigation plans for a combined co-benefit of clean air, low-carbon pathways and liveability.

These multi-sector strategies and multi-prong approaches are accelerating the technology roadmap, urban planning and design strategies, infrastructure and system planning. There has been substantial progress in sectoral policies, regulations and standards to drive this change. But these are at varying degree of progress. India is at that cusp of change that requires urgent and scalable solutions.

Central to this transition is the community-wide adoption of new-generation technologies, acceptance of new design and urban planning approaches in the local neighbourhoods or municipal zones, and lifestyle adjustments to enable a paradigm shift. This absorptive capacity of the community has to scale up and get stronger even as the implementing agencies upscale the level of services at neighbourhood scale and industry advances and transforms clean and low carbon technologies across sectors. This requires strategic enablers.

This recognition of community as a propeller of change has shifted the policy focus towards an area-based approach to implementation for aligned, synergistic and integrated cross-sector strategies in a targeted area to influence the local communities. Traditionally, area- based approaches to planning and zoning regulations have been the key focus of city master plans. This is now gaining credence for connecting and bridging the gap between policies and implementation for scalable change.

This area-based approach to pollution control and low-carbon pathways is evolving in stages.

The zoning approach to pollution control efforts was first catalysed in Delhi when the Supreme Court directives of 2017–18, in the ongoing public interest litigation,

had directed implementation of hot spot action plans in the most polluted parts of the city. About 13 areas were identified as pollution hotspots and hyper-local action plans were developed based on local survey of pollution sources for implementation. An analysis by the Centre for Science and Environment showed at that time that while the city-wide average level of particulate matter less than 2.5-micron size (PM2.5) was much higher than the National Ambient Air Quality Standard, the levels in some hotspots were higher even than the city average.

This hotspot planning approach in Delhi led to the adoption of similar approaches in other cities under the National Clean Air programme (NCAP) to address local sources of pollution including road dust, burning of garbage and industrial waste, construction activities and traffic congestion. While hotspot plans may have helped to control some of the dispersed sources like waste burning, construction and road dust, this has not been effective in addressing vehicular pollution in a local area. Limited approaches of re-engineering of roads or traffic realignment are not the solutions for vehicular pollution. This requires deeper systemic approaches even at a neighbourhood scale.

Clean air action in Delhi has catalysed area-based approach to controlling vehicular pollution. Some of the earlier directives from the Supreme Court had mandated the National Capital Territory of Delhi to allow only compressed natural gas powered public transport and local commercial transport.[1] This led to ring fencing of Delhi as a special zone for controlling diesel emissions. A series of directives followed, including restricting entry of heavy duty diesel trucks by imposing environment compensation charge (ECC) on each truck entry daily, and disallowing entry of ten-year-old trucks in Delhi.[2] Other ring-fenced measures included imposition of pollution cess on each big diesel car and SUV sold, each litre of diesel fuel sold and ban on ten-year-old diesel vehicles.[3] This strategic focus helped to accelerate fleet renewal in Delhi.

More matured area-based strategy emerged when the Supreme Court directed implementation of the parking policy and rules, 2019, that were notified by the government National Capital Territory of Delhi.[4] This has provided for municipal ward-wise parking management area plans (PMAP) as a demand management measure to restrain personal vehicle usage. This required demarcation of legal parking areas after providing for all road users in the street design, protection of green areas and footpaths from parking, implementation of variable parking pricing to reduce parking demand, integration of parking facilities with the charging network, and use of parking revenue for local area improvement among

others. This cohesive framing can act as a vehicle-restraint measure to reduce congestion and pollution.

In fact, the Supreme Court has further directed implementation of PMAPs in Delhi and the National Capital Region (NCR).[5] This has now been taken forward by the Commission on Air Quality for NCR and beyond seeking its implementation by October 2024. In fact, the Delhi Master Plan 2040 has taken this approach on board along with public transport accessibility index to enable implementation.

While such area-based approaches to pollution control have evolved in Delhi, several other cities have moved forward to reorganise streets to pedestrianize targeted spaces. The national government programmes and schemes, including Smart City, AMRUT and Challenge programmes, have promoted pedestrianisation of streets, walking and cycling infrastructure in targeted areas.

The most significant area-based planning approach and policy adopted for nation-wide implementation is the Transit Oriented Development (TOD) Policy, which has been issued by the Ministry of Housing and Urban Affairs (MoHUA).[6] This requires cities to leverage the transit systems to regenerate and redevelop about a 400–800-square-metre area around the transit nodes and stations for mixed-use and mixed-income development. This area needs to be regenerated and redeveloped for safe and convenient access to the transit nodes through walking and cycling infrastructure, improved last-mile connectivity and restraints on parking. This area-based planning is expected to reduce dependence on personal vehicles and increase the use of transit.

Complementary to this development is the compact urban form-based code that allows small block sizes, and high street density. In fact, the railways have adopted this for development and redevelopment of their station areas.

Though policy precedents have been established for area-based approaches, this requires a more cohesive framing for convergence of action at a neighbourhood scale for strategic adoption of clean and zero-emission vehicles and increased usage of public transport, walking and cycling options by the local communities.

The ultimate beneficiary and the driver of the change at the local level are the communities. Thus, the urban-planning approach has to combine a range of complementary strategies for cohesive infrastructure planning to enable community adoption of clean technologies and mobility solutions in targeted zones. Such aligned and mutually reinforcing interventions can reduce toxic

exposures, carbon intensity of transport and commuting and healthcare costs, and increase productivity and improve overall wellbeing.

Towards low-emission zones

Implementation of Low Emission Zones (LEZs) is the direction of change in several global cities of Europe, UK, US and other regions. But there is no uniform definition or harmonised of application of LEZ.

The most classical application of LEZs is in London, where it has grown in stages over the decades – from parking management and pricing to congestion pricing to emissions pricing in the central London – to develop as an LEZ.[7] In other European cities like Berlin, it works more like reclamation of streets in neighbourhoods for walkers and cyclists while restricting vehicular movement to improve liveability.[8] Stockholm, Barcelona and other cities may have relatively broader applications of pricing entry of polluting vehicles into the zones. The LEZ strategy targets polluted and congested areas to catalyse city-wide changes in air quality.

LEZ implementation is based on the assumption that area-based regulation for weeding out old and polluting vehicles from the zone, accelerated adoption of clean and zero-emission battery-powered vehicles by the local community, and increased usage of public transport, walking and cycling can reduce vehicular emissions in the targeted zone can help to meet air-quality targets, reduce public-health risk, and improve local welfare. This is guided and facilitated by local-level strategy, detailing of operational parameters, and citizen engagement.

As noted previously, Indian cities have the opportunity to adopt a cohesive framing of low-emission zones for integrated implementation of enhanced public transport services, walking cycling strategies, fleet renewal, phase-out of old vehicles, adoption of clean and zero-emission vehicles in a targeted area to complement ongoing pollution-control efforts in that area.

In fact, under the NCAP programme, a few states are inclined to include low-emission zones in their city action plans. The city of Bhubaneswar has taken the lead to create such zones and have also come up with a detailed plan based on multi-stakeholder consultation.[9] The municipal corporation of Pimpri Chinchwad is proposing to take such an area-based approach for pollution control under their graded response action plan.[10] Chennai has created a guidance framework based on global good practices.

Several studies are being initiated by different stakeholders to understand the potential application of area-based approach for pollution control. This growing interest has generated several questions with respect to the nature and scope of its implementation and design.

Highlight of the CSE assessment

The Centre for Science and Environment (CSE) has assessed the potential application of LEZs in Delhi. Currently, there is no legally defined programme on LEZ in India. Therefore, its potential application needs to be assumed and approximated based on the emerging global good practices and aligned with the relevant principles of the existing regulations and policies, to build the scenarios for implementation.

Any potential LEZ policy framing has to consider and assess the possible impact of LEZ restrictions on the local and affected communities especially belonging to different income classes as the success of the policy will be determined largely by the adaptive capacity of the communities. It is particularly important to understand what is needed to minimise any disproportionate impact of the proposed measures and restrictions for the LEZ in term of replacement of old vehicles with new, reducing usage of personal vehicles etc. on different commuting groups and income classes. This will help to design the safeguards and orient the programme accordingly.

This is primarily because implementation of LEZ rules will involve additional costs for the individuals in the community even though the health and welfare benefits are significant. This is particularly so for the poorer households in the zone. They will be required to either upgrade their vehicles to align with the latest emissions standards, adopt zero-emission vehicles or switch to public transport. Policies may have to mitigate the financial burden on the targeted sections with the help of exemptions, discount, concessional loans, buy-back and vehicle-replacement schemes etc.

One of the reasons for taking this perspective is the global experience that has shown that implementation of such community-oriented strategies requires strong public support. That is possible only if there is an advanced strategy is in place to prevent and mitigate disruptive impacts on communities with well-designed interventions and strategic support. In fact, when after the initial success with the low-emission zones in Central London it was planned expand ultra-low emissions zone (ULEZ) there was strong public backlash. There were concerns around additional new expense, increased cost of living, inflation, higher levels

of car ownership in new areas, and less public transit than the city centre. These required more nuanced planning.

Towards LEZ in Delhi

To understand the impact of a possible LEZ programme in Delhi, a framework for its implementation has been assumed to indicate the scope of its operations and operational parameters, zonal restrictions on polluting vehicles, fiscal strategy to act as incentive and disincentive for dirty and clean vehicles, fleet renewal strategies, and mobility options to enable behaviour change within the zone.

The overall objective is to understand how LEZ implementation can influence vehicle owners (personal vehicles) and vehicle operators (commercial vehicles) to replace older vehicles with cleaner vehicles and zero-emission vehicles. Can LEZ implementation accelerate electrification among vehicle owners/operators? Can LEZ implementation influence commuting preferences and shift commuters to sustainable modes? What will be the differentiated impact of LEZ implementation on different income classes and what is needed to mitigate the impact?

About the location and zonal boundary of the study: For the purpose of this study, New Delhi Municipal Council (NDMC) area has been selected to assess potential implementation. This area is known for its diverse land-use patterns and prominent institutional, public and semi-public places including Rashtrapati Bhavan, Parliament House, ministries and administrative offices etc. It also includes key commercial and activity areas, including Connaught Place, Gole Market, Sarojini Market, Janpath Market and Khan Market among others. The residential complexes include exclusive communities such as government officials and politicians as well as prominent citizens in addition to a few mixed communities. This zone is an important employment centre that draws large numbers of commuters from within the zone and outside.

Locational advantages: NDMC has an extensive road network of 1,450 kilometres, which is around 35 per cent of the total developed space. In fact, as per the service-level benchmark (SLB) for urban transport prepared of MoHUA, any area with more than 15 per cent road space in comparison to the developed space of that area is considered as level 1 or the highest level of service. From that perspective it is very well endowed. More than 60 per cent of arterial, sub-arterial and collector road has footpath facilities. About 38 per cent of the footpath have more than 2.5 m width.

Good public-transport connectivity: What adds to its locational advantage is that as much as 62 per cent of the developed area is located within 400-metre and almost all the developed area within an 800-metre distance from the transit nodes or the metro stations. In addition, it is well served by the buses, including electric buses.

Perception survey to assess public response to LEZ implementation: This assessment has applied survey techniques to generate data and responses from a wide spectrum of road users, vehicle users and owners, public-transport providers, and public-transport users. This addresses both polluters and beneficiaries.

To understand the potential impact of the LEZ implementation on the community, a wide spectrum of target groups were covered, including private two-wheeler and car owners, auto operators and users, cab operators and users, and freight service providers.

For perception analysis a specific focus was on auto, cab, bus, and metro users, private e-two-wheeler and e-car user, commercial e-two-wheelers and e-car operators and e-auto operators.

Understanding the commuting pattern and the profile of the communities: To relate the user responses and perception to the reality of their commuting needs, the survey has included travel-related factors, including origin and destination, trip purpose, trip frequency, primary and secondary trips, choice of modes, vehicle ownership etc.; socioeconomic and demographic factors (i.e., sex, age, employment status, education level, income level etc.); psychological factors (i.e., concern about environment related issues, political orientation and perception of the stringency of the intervention, in this case LEZs) of various social group/s who on daily basis access the study area; and the perception of public/semi-public and electric vehicle users to under the reason behind choosing these modes and existing challenges of these modes.

The samples are well-distributed across the targeted geography. Around 77 per cent of the respondents are male and 23 per cent are female. About 79 per cent are from active working population groups (i.e., 26–55 years). Only 19 per cent have education levels below the tenth grade. More than 50 per cent of respondents are either graduate or post graduate.

Understanding the legal pre-requisite for LEZ implementation: Enabling legal framework for LEZ implementation already exists. There is a plethora of

zonal regulations, fleet renewal requirements lined with emission standards for vehicles, fleet electrification targets, TOD policy, mandate for PMAPs, and street design guidelines that provide a cohesive legal basis for establishing LEZs.

The main interest has been to understand how LEZs accelerate usage and adoption of clean vehicles and zero-emission electric vehicles in the targeted zone. Also of interest has been how LEZs can influence commuting choices of the commuters and shift towards use of public transport, walking and cycling, and use clean vehicles.

The possible strategy for LEZ implementation to assess public perception: For the purpose of assessment of potential implementation and public perception of the change, the following two policy scenarios have been proposed for implementation in Delhi.

Policy scenario 1: A complete ban on polluting vehicles

- What if pre-BS-VI emission standards and non-electric vehicles are not allowed to enter a designated LEZ area – a complete ban.
- A heavy penalty is imposed on the defaulters – penalty amount can be high to ensure compliance.

Policy scenario 2: Fee-based entry for polluting and older vehicles

- Pre-BS-VI emission standards and non-electric vehicles are allowed to enter, but only after paying access charge.
- This fee-based approach is expected to gradually incentivize vehicle owners to switch to cleaner alternatives.
- The entry fees can be substantially lower than the penalty suggested for the scenario one.

This assessment brings out the differential opinion across vehicle segments and income classes.

Impact on personal vehicle segments

The overall interest in the personal vehicle segments – 2W and cars – is to understand to what extent the LEZ implementation will drive commuters to shift to a new clean vehicle, opt for electric vehicles, shift to public transport and how much are they willing to pay to enter the LEZ zone without changing their old vehicles if the restrictions kick in. Moreover, how these choices will play out in different income categories and for primary and recreational/secondary trips.

Private 2W users: Around 65 per cent of the 2W primary trip users are reluctant to shift to any other mode in the case of a complete ban, and will buy a new 2W. As many as 38 per cent of secondary/recreational trip users have shown interest in purchasing new 2Ws; almost an equal number of respondents (35 per cent) are interested in using public transport.

Irrespective of primary or secondary usage, lower-income groups (earning up to Rs 6 lakh) will prefer to buy 2W (BS-6 or electric) if the restrictions are harsher. However, higher income groups (earning Rs 6–18 lakh) have shown interest to shift to cars/cabs/public transport. This brings out the price sensitivity of the lower income group for whom the per kilometre cost of operating a two-wheeler is cheaper than the basic fare of a bus.

Around 55 per cent of the primary trip users are willing to pay some kind of charges to enter the proposed LEZ, if they fail to upgrade their 2Ws to meet the requirements of the LEZ. But more recreational trip users – around 78 per cent – are interested in paying access charge to enter the LEZ zone.

The willingness to pay survey shows that about 90 per cent compliance is expected if the entry charge is pegged around Rs79 and more for frequent two-wheeler users and Rs 131 and more for non-frequent commuters.

However, a substantial shift to public transport – to buses and metro – is possible in different income categories – 24 per cent in the income bracket of Rs 3–6 lakh, 44 per cent in Rs 6–12 lakh, 43 per cent in Rs 12–18 lakh. This brings out the potential for modal shift if LEZ is in place.

Private car users: Usage of personal vehicles is more inelastic and shows even with harsh restrictions most of them will continue to use cars.

In fact, the majority – almost 75 per cent – in the lowest income group of up to Rs 3 lakh have opted for shifting to two-wheelers. A sizeable share in the higher income groups have opted to move to new cars if there is a ban on entry of older vehicles.

Preference for public transport is higher among the middle-income groups with stronger preference for metro than buses. For example, in the Rs 6-12 lakh category while 33.3 per cent have opted for metro only 3.5 per cent have opted for buses.

If there is an entry-charge-based LEZ, then irrespective of primary or secondary trip users almost 91–92 per cent respondents are ready to pay access charge to continue to use their existing vehicles.

The willingness to pay survey shows that the frequent car owners/users may show close to 90 per cent compliance with the LEZ requirements if the entry charge is expected to be fixed at Rs 120. Non-frequent recreational users may even go up to Rs 163 for 90 per cent compliance.

Overall, it thus appears that primary car users are more willing to pay to keep using their private mode. In fact, both car owners and two-wheeler owners show high levels of willingness to pay. Clearly, there is higher inelasticity among higher income groups and higher willingness to pay and lower preference for mode shift. However, for two-wheeler owners, elasticity levels are similar across categories.

Potential electrification of 2Ws and cars with LEZ implementation: Even though the preference for buying BSVI compliant cars is higher among the car owners, the preference for electric cars is also quite substantial – 20 per cent in the Rs 12–18 lakh income category, and 11–13 per cent in lower income groups have preferred to opt for electric cars.

Among the two-wheeler owners there is a stronger preference for electric two-wheelers among the lower income categories – 27 per cent in up to Rs 3 lakh category and 31 per cent in Rs 3–6 lakh category. Interestingly, in the higher-income category there is a stronger preference to migrate to a car.

Impact on commercial and public transport segments

The potential impact of the LEZ strategy on para-transit vehicles – autos and cabs, and good vehicles – is expected to play out differently. The imperatives are different.

The LEZ implementation will require these segments to also move to clean technologies or electric vehicles. They will also be governed by the two possible scenarios of either a ban on older technologies or entry by paying an access charge.

These segments need an assessment of the potential impact not only on the service operator but also the user of the services.

Among intermediate public transport operators, auto operators are more vulnerable than cab operators in both the scenarios. Cab users are more reluctant

to use cabs or compromise on their trip. Cab drivers are less willing to shift to a compliant mode, compared to auto drivers as their area of service is more flexible.

Auto operators: If there is a ban on entry of old technologies of pre-BSIV vehicles, around 65 per cent of drivers claim they will upgrade their vehicles to compliant modes. But 35 per cent have claimed that they will stick to their present vehicles and stop their services within LEZ area.

Among those willing to shift to compliant modes, 69 per cent prefer to buy a BS-6 auto, and 31 per cent prefer electric autos.

Among those not willing to shift, 74 per cent have stressed upon additional financial burden to buy new vehicle and need support.

If access charge-based entry is allowed for older vehicles instead of outright ban, they do not expect any direct financial implication as they will pass on the cost to the users as journey cost.

However, almost 74 per cent have agreed that it will increase their operational cost and create a dent in their profit.

Auto users: If all pre-BSIV vehicles are banned, the users do not expect direct financial implications except that such measures may reduce the availability of autos in the zone.

However, in the case of access charge-based entry, about 44 per cent of the respondents may prefer to use autos, and 28 per cent to use public transport or NMT modes. About 15 per cent have said they may reduce their number of trips.

The willingness to pay survey shows that about 90 per cent compliance is possible if the entry fee is about Rs78 for auto users.

Cab operators: Around 50 per cent of drivers claim they will upgrade their vehicles to compliant modes, while the other half will stick to their current vehicles and simply stop their services within the LEZ zone.

Among those willing to shift to complaint modes, their preference is equally divided between BS-6 and electric cabs.

Among those who are not willing to shift, 66 per cent are reluctant to shift. This is largely because their vehicles are fairly new and their services are not dependent on the LEZ area to maximise their earnings.

Moreover, if access charges are enforced this will not have any direct financial implication on the cab drivers as they will pass on the cost to users as journey cost. However, around 78 per cent of them have agreed that it will increase their operational cost and create a dent on their profit.

Cab users: If there is a complete ban on older vehicles, cab users do not expect any additional direct financial implications, except that it may reduce the availability of cabs.

In the case of entry charges, about 55 per cent of the respondents prefer to use cabs only, about 18 per cent may opt for public transport and NMT modes, and another 18 per cent may prefer personal vehicles. Only 2 per cent respondent said that they would reduce their number of trips.

The willingness to pay survey shows that 90 per cent compliance is possible if Rs 100 is fixed as entry charge.

Overall, it appears that most intermediate public transport users are willing to pay to enter the LEZs. Those who are not willing to pay expect that LEZ-compliant cabs are available. The majority of auto users are expected to use a private vehicle or public transport.

Good service providers: This category is more forthright about discontinuing services in the LEZ area if a ban or hard restrictions are imposed. However, in the case of ban there is some willingness to shift to new vehicles, even electric vehicles.

In the case of entry charges, the willingness to pay survey shows that for LDVs, MDVs and HDVs, 90 per cent compliance with LEZ requirement is possible at the entry fee level of Rs 550–600, Rs 377 and Rs 430 respectively.

Enablers and barriers to implementation of LEZ

While a perception survey and field assessment may indicate a positive trend in effecting the technology choices for clean and zero-emission vehicles as well as preference for a modal shift, this potential impact needs to be understood in relation to the larger mobility ecosystem in the city and the mobility choices that the people may have. LEZ implementation will require addressing these issues.

Therefore, to understand the larger operative conditions that will influence and determine commuting and technology choices, an additional assessment has been carried out to understand those challenges.

The assessment specifically asked the respondents about the public transport, intermediate public transport usage and electric vehicle usage. This helped to assess the nature of improvement needed to enable implementation of LEZ.

Perception of the public transport users: The majority of respondents – 94 per cent bus users and 63 per cent metro users – said that the "cost effectiveness" is the prime reason for their mode choice. Moreover, overcrowding of public transport and low frequency of services and unreliability are their major concerns.

They ranked several factors that are currently making public transport unattractive. These factors include lack of access/availability, overcrowding, safety concerns, inadequate frequency, inconvenient scheduling, lack of direct route, and longer travel times. Lack of availability, overcrowding and long journey time were ranked high among 2W and cars users.

In fact, CSE's analysis of the arrival and departure schedule of each bus stop as available in the open transit data of the Delhi government shows that less than 1 per cent of bus stops have a less than a 10-minute waiting time and 50 per cent of bus stops have a high waiting time – more than 15 minutes. Moreover, additional CSE's analysis shows that traffic speeds go down by as much as 32 per cent during morning peaks (7 AM to 12 PM) and up to 37 per cent during evening peaks (5 PM to 8 PM) in Delhi. All these factors make buses unattractive.

LEZ implementation will require addressing these challenges to improve the overall public transport services ad safe access. Even though Delhi has the highest number of electric buses, overall bus ridership has declined. The reforms based on service level benchmark will become critical.

Similarly, while demand for IPT is substantial, there are concerns around ad hoc pricing (high/unfair fare), high waiting time and low reliability – particularly for cab services – and these are key areas of concern. Commuters have listed unfair fares, high waiting time for cabs, personal safety, low integration of modes, limited coverage and issues with the drivers as key challenges.

Potential electrification of 2Ws and cars with LEZ implementation: Even though the preference for buying BSVI compliant cars is higher among the car

owners, the preference for electric cars is also quite substantial – 20 per cent in the Rs 12–18 lakh income category, and 11–13 per cent in lower income groups have preferred to opt for electric cars.

Among two-wheeler owners, there is a stronger preference for electric two-wheelers among the lower income categories – 27 per cent in up to Rs 3 lakh category and 31 per cent in Rs 3–6 lakh category. Interestingly, in the higher-income category there is a stronger preference to migrate to a car.

The 2W users list lack of charging infrastructure, range anxiety, poor maintenance of available charging infra, charging cost, and difficulty in finding as some of the key areas of concern in this transition. Similarly, potential electric commercial vehicle users (auto, 2W, cars) highlight the key challenges as range anxiety, poor maintenance of charging infra, inconsistent power supply, high charging costs in some areas, difficulty in finding fast charging, limited availability of charging as the key impediments.

The way forward

LEZ is an important enabler to connect policies with ground implementation of mobility and electrification strategies. Several policies on fleet renewal, fleet electrification and mobility management have evolved. But these require an integrated and aligned approach to transform the urban spaces. The LEZ strategy has direct bearing on the commuters and communities in targeted zones.

While solutions related to technology, transportation and design are possible, their adoption within given the socioeconomic context is challenging. As its effectiveness depend on the wider acceptance by the community, it is necessary to understand the disproportionate impacts on different socioeconomic groups to identify the appropriate mitigation and support action.

The assessment brings out that potentially LEZ can influence technology and commuting choices – but this will have to be enabled at the individual and community level by improving the overall service level of public transport services and also cushioning the cost of makeover for a section of the community.

Harsher restrictions including outright ban on entry of older vehicle technologies can have stronger impacts on choices as such measures do not provide options. But this may be more politically difficult to push through. This may also be the cause of public resistance jeopardizing the entire strategy.

There is also a sizeable inelastic section among the personal vehicle users who despite the harsher measures on entry and exit from the LEZ may continue to stay on with their personal vehicle usage and also resist change. This requires community oriented inclusive strategies.

Take steps

Expand the scope of the pollution hotspot plans to create low emissions zones for co-control of vehicular pollution: While the ongoing hotspot clean air plans are addressing the dispersed sources of pollution like dust and open burning, it is necessary to build on that to create a cohesive LEZ to address specifically the vehicular pollution and toxic exposures to reduce health risks for communities.

Delineate zones for creation of LEZ: Municipal corporations may be mandated to identify the potential zones for implementation of LEZ. The New Delhi Municipal Council and the Municipal Corporation of Delhi may identify the ward-wise zones that can implement LEZ. To lead the process, it is possible to identify the NDMC area that has several locational advantages to start the LEZ programme.

Notify LEZ policy and regulatory framework for implementation: It is necessary to frame and notify the LEZ policy along with the strategy for implementation. This needs to outline the guidance framework for the implementing agencies.

Phase in LEZ implementation for the targeted zone:

- **Phase 1**: All area management plans need to converge for implementation in specified zones. Combine implementation of the parking management area plans (PMAP) along with variable parking pricing policy across all neighbourhoods of the zone; initiate pedestrianisation of key commercial areas; introduce access-based charges for entry of vehicle with higher charges for pre-BS IV vehicles; make entry of electric vehicles free, charge a nominal entry fee for BSVI vehicles and that may increase after the introduction of BSVII vehicles. Eliminate end-of-life vehicles from the zone and begin with time restricted movement for targeted vehicles. Simultaneously, enhance public transport services and accessibility of the zone.

- **Phase 2**: In the second phase while all the provisions of the phase one will continue, the strategy will be ramped up by restricting pre-BS-IV vehicles. Introduce more direct fiscal and non-fiscal incentives for promoting electric vehicles and apply polluter pay principle. Scale up electric vehicle charging infrastructure in the zone.

Addressing differentiated impacts on income groups: Moderate to high economic impacts on different income groups are expected in personal vehicle segments. This is particularly so in the policy scenario one that aims to ban entry of pre-BSIV vehicles, scale up electric vehicle requirements to be in the zone and encourage use of public transport.

It is evident from the survey that economically vulnerable groups such as old people and small-income self-employed categories may require some fiscal support for the shifts to cleaner technology.

The overall assumption for the general category of owners of personal vehicles is that they need to move to public transport for primary trips and mobilise their own investments if purchase of new vehicles is required. However, a targeted and purposeful fiscal incentive can be considered if old vehicles are encouraged to be replaced with electric vehicles.

Commercial vehicles needs fiscal and non-fiscal incentives to shift to electric vehicles. Moreover, the LEZ policy should be aligned with the city-wide scrappage policy and scrappage incentives and also incentive programmes for fleet electrification to help absorb the cost of transition in the zone. Under the current scrappage policy, state governments are required provide tax incentives for scrappage of targeted vehicles. This can be further expanded in scope for one-time support to lower income households and small businesses.

Creation of dedicated funds from entry fees and parking fees implementation of LEZ and infrastructure development: Dedicated fund from parking management area plans and the access fees to enter LEZs can help to fund the cost of transition, and the fiscal strategy to help people to tide over to adjust to the LEZ requirements. Revenue should be earmarked for local area improvement and to regenerate infrastructure, connectivity and improve the service levels. Municipalities need to plan the enforcement infrastructure, including the gantry, cameras and IT system for access fee collection, staffing for enforcement, and other support systems. A dedicated fund can help to meet its costs as well as that of incentives for replacement of vehicles and improvement in public transport services.

Augment public transport accessibility and service level of LEZ: Restrictions in LEZ need to be supported by enhanced public transport services as per the MoHUA benchmarks and safe walking and cycling access in the targeted zone.

This can help to reduce traffic load, improve quality of transit and experience of commuting, EV charging network, among others.

Leverage LEZ to accelerate fleet electrification: The perception survey has brought out that even though the preference for BS6 compliant cars is high among the car owners, the preference for electric cars is also quite substantial – 20 per cent in the higher income category, and 11–13 per cent in relatively lower income groups. Among the two-wheeler owners there is a stronger preference for electric two-wheelers in nearly all income categories. Fee entry into LEZs and supported by charging infrastructure, free and preferential parking and higher charges for internal combustion vehicles can encourage more rapid shift towards electric vehicles.

Upgrade on-road emissions monitoring with the help of remote sensing measurements for efficient identification of grossly polluting vehicles. Real-world data on on-road emissions performance can help to inform strategy development and also enable implementation. Such evidences can also help to build public support for the LEZ initiative.

Design enforcement and compliance strategy: This will be a combination of regulatory and fiscal action with a legal back up.

Public campaigns and awareness on the benefits of LEZ will be a critical entry point. Engagement with communities and the small business will be crucial to build public support. It is necessary to demonstrate the benefits of the initiative for each of these groups and how the cost of change can be tide over.

LEZ implementation requires strong interface with city-wide strategy for public transport improvement and fleet electrification: LEZ implementation will have cascading effect on the larger communities beyond the LEZ that will be accessing the zone from outside. Moreover, transportation options and multi-modal integration need a scalable infrastructure across the city to connect origin and destination of masses efficiently. This requires a serious attention.

The advantage of the LEZ approach is that it can integrate multiple strategies to achieve both vehicle technology transformation and mobility transition. This can combine fleet renewal for quicker adoption of clean, energy efficient, and zero emissions electric vehicles. At the same time it can enable scalable, integrated, connected and reliable public transport system and services; upscaled network

of walking and cycling infrastructure and efficient last mile connectivity; reduce automobility; promote compact urban form to keep jobs and home close; reduce distances, reduce demand for travel and vehicle usage; improve infrastructure for sustainable mobility; integrate the needs of urban poor and vulnerable groups and improve liveability of neighbourhoods.

SECTION 1: Towards low-emission zones in Delhi

In view of the growing interest in implementing low emissions zones (LEZ) to accelerate quicker adoption of clean and zero emissions vehicles community-wide in cities, as well as, scale up usage of public transport, walking and cycling with effective vehicle restraints measures in targeted zones, the potential application of LEZ and the impact on the targeted communities have been undertaken.

Going forward this will be a critical strategy to reduce emissions from vehicles and scale up sustainable mobility options at the community scale.

As the LEZ approach and its operation requires restrictions on use of old and polluting vehicles in the targeted zones and promotion of public transport accessibility, there is always a risk of public backlash and pushback. The initiation of LEZ policies must be approached with sensitivity and foresight. It is crucial that the initial endeavours in LEZ implementation need to show the positive impacts and demonstrable benefits. Otherwise, failure to achieve positive outcomes can lead to adverse public discourse and significantly hinder the willingness of policymakers to pursue further implementations or expansions of LEZ initiatives.

It is imperative to initiate LEZ implementation in such an area that not only fulfils certain prerequisites conducive to success but also demonstrates a palpable need for such measures. An ideal LEZ pilot area should be a locale where existing conditions favour the establishment of an LEZ, thereby enhancing the probability of its effectiveness.

Rationale for identifying NDMC for LEZ impact assessment

In view of these, New Delhi Municipal Council (NDMC) area has been chosen as a potential LEZ implementation area for the purpose of assessing the potential applications and its impact on the communities.

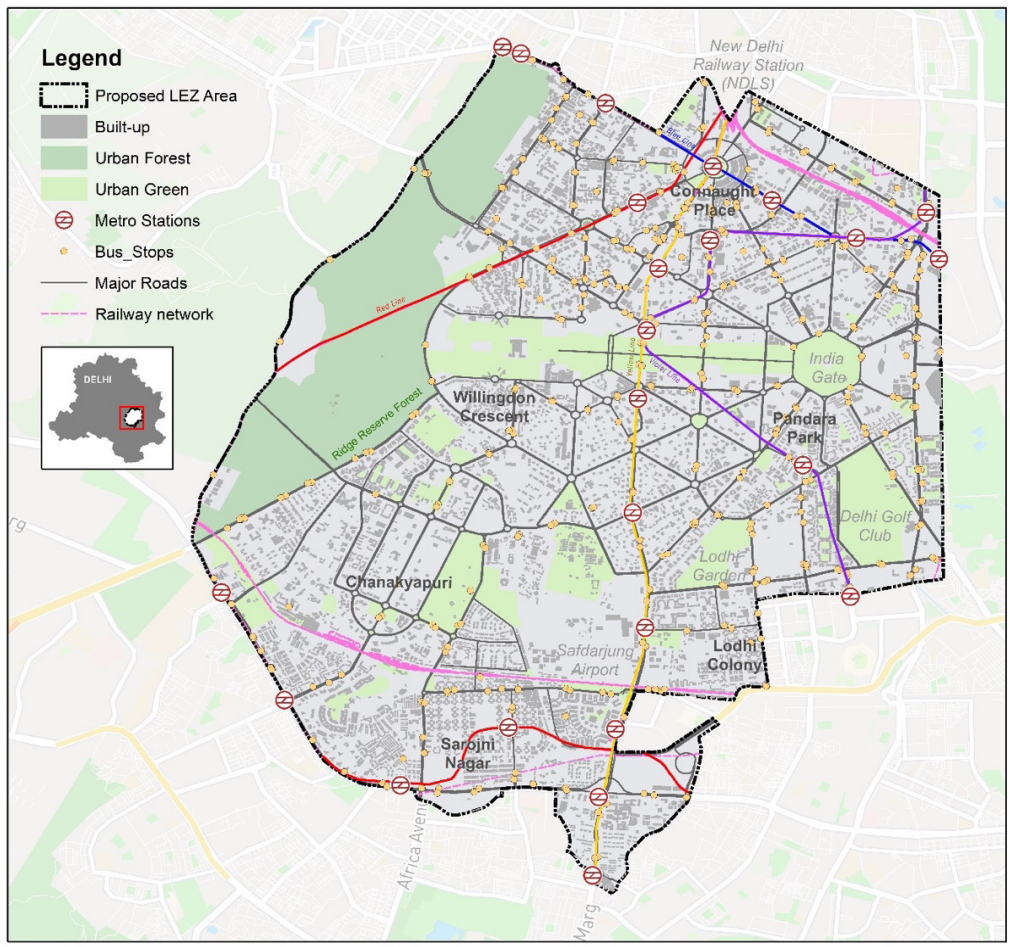
The Transport Department, GNCTD is actively considering to develop LEZ in NDMC area, thus choosing NDMC for impact assessment shall greatly benefiting the efforts and study outcomes will also assist the decision makers to identify the right option and key interventions areas more effectively.

Understanding the study (NDMC) area

Entire administrative area of NDMC is considered as the study area for LEZ impact assessment, as data collection, implementation and even enforcement (when LEZ in operation) in single administrative jurisdiction is comparatively much easier (see *Map 1: Study (NDMC) area for assessing the impact of LEZ implementation, for details*.

The selected (NDMC) area is well connected through both metro and public bus services. Almost 30 per cent area is under institutional and public and semi-public category. Prominent places include Rashtrapati Bhavan, Parliament House, and various ministries and administrative offices. There are key cultural institutions like the National Museum, National Gallery of Modern Art and community

Map 1: Study (NDMC) area for assessing the impact of LEZ implementation

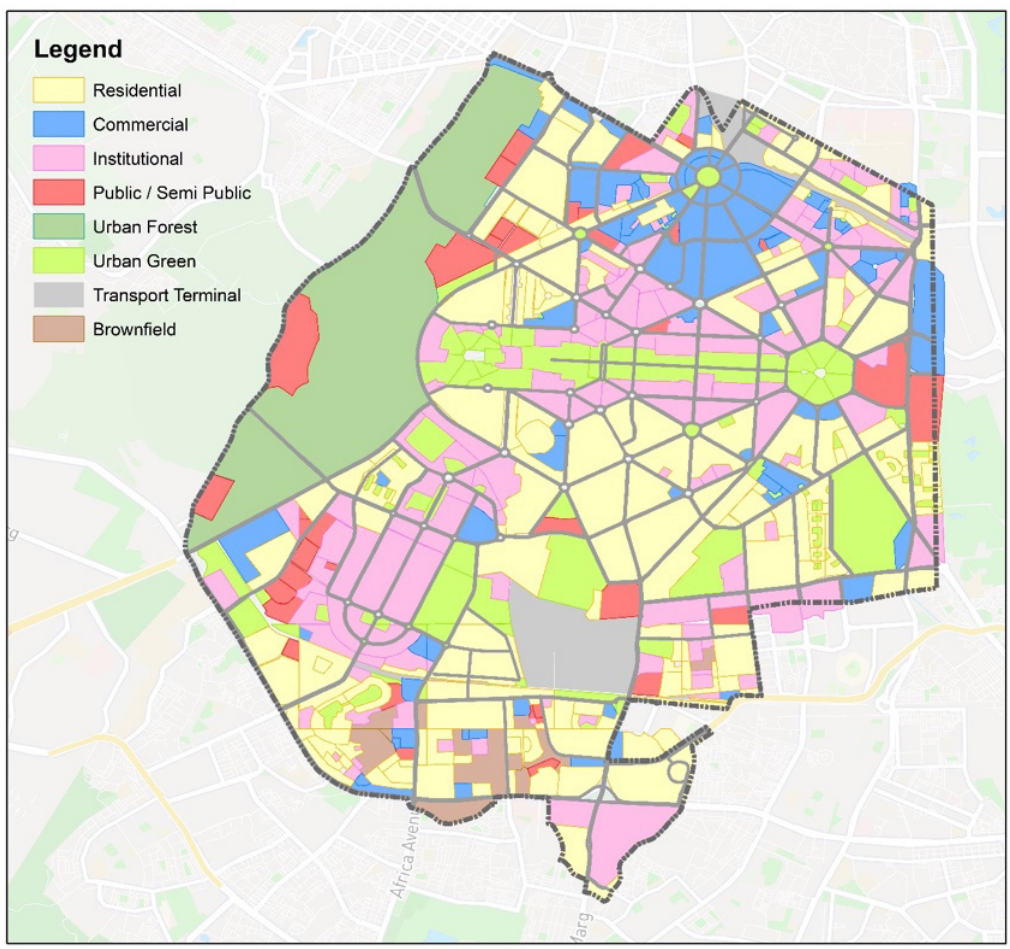


Prepared by CSE; Data Source: DMRC, Delhi Open Data Portal, OpenStreetMap

support institutions such as India Habitat Centre; research and development centres like the Indian Council of Medical Research (ICMR) among others are also falls within this zone (see *Map 1: Distribution of existing landuse and land cover pattern in NDMC area)*.

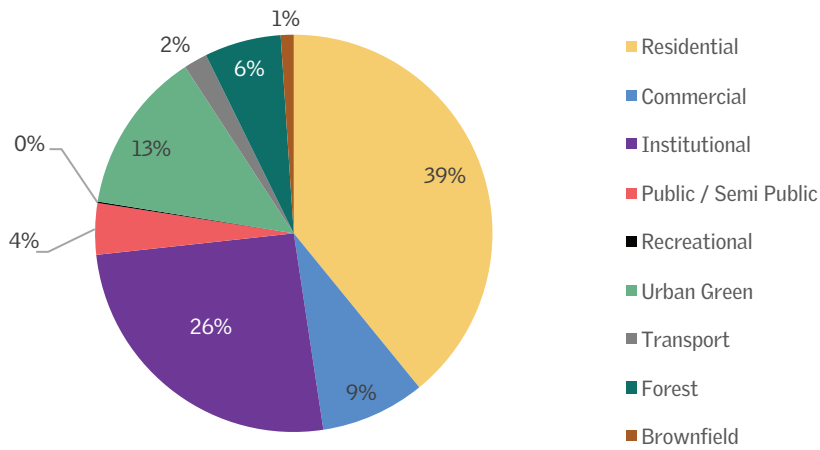
Apart from that this area also houses critical commercial areas of Delhi such as Cannaught Place, Gole Market, Sarojini Market, Janpath Market, Khan Market and so on, which cover around 9 per cent of the total area. See Graph 1: Percentage share of landuse and land cover in NDMC area.

Map 2: Distribution of existing land use and land cover pattern in the NDMC area



Prepared by CSE based on ground survey

Graph 1: Percentage share of land use and land cover in NDMC area



Prepared by CSE based on ground survey

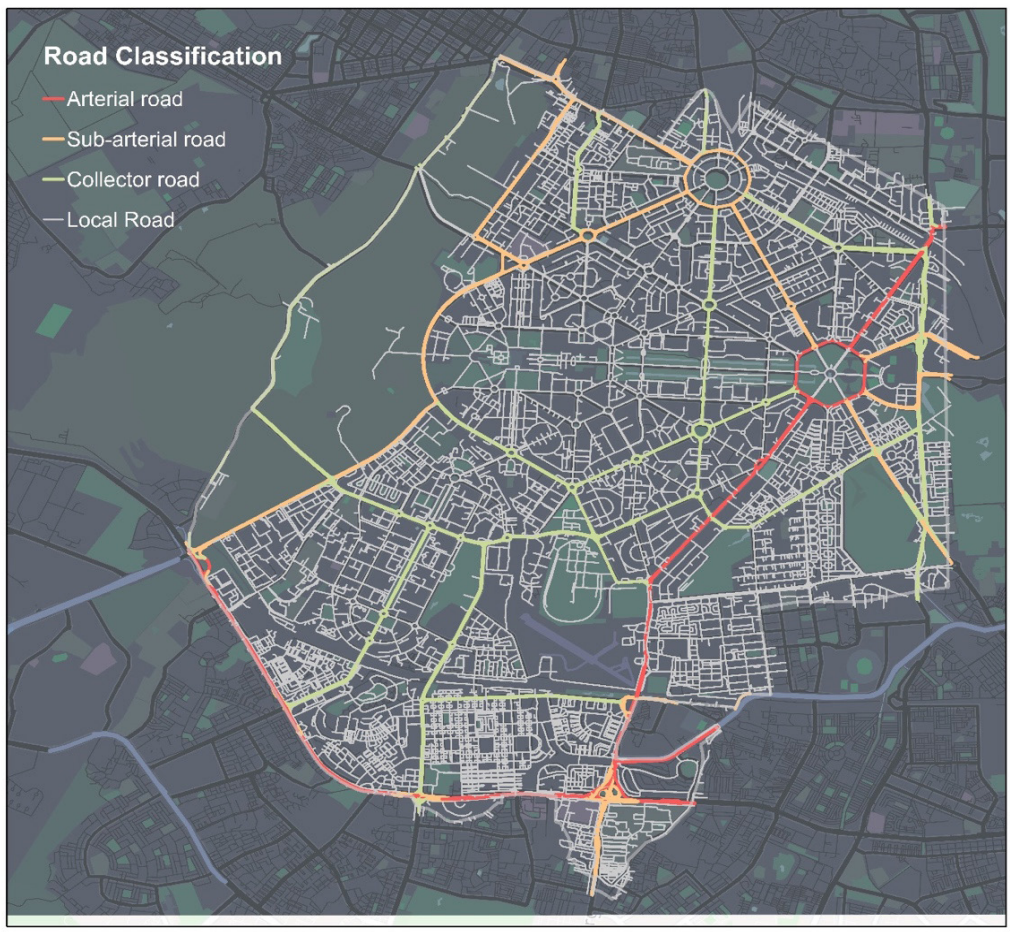
Around 13 per cent area is under 'Urban green spaces'. Some of the key recreational spaces in Delhi such as Children's Park at India Gate, Kartavya Path, The Delhi Golf Club, Lodhi Garden, Nehru Park, Delhi's race club, Safdarjung Tomb etc. Key educational institutions such as St. Columba's School and St. Stephen's College; medical institutions such as AIIMS Delhi and Ram Manohar Lohia Hospital etc. also located within NDMC's jurisdiction.

As a result of all of these, a wide range of commuters, be it ministers, officials from the central ministries and other government offices, businessmen, students, patient, tourists etc. access this area on day-to-day basis.

Study area has a total road network of 1,447.36 kilometres (see *Map 3: Distribution of road network within study area*). Around 6 per cent of total road is wider than 45m and above and thus categorised as Arterial and sub-arterial roads. While around 89 per cent road network is either 12 m or less (see *Table 1: Details of roads network existed within in study area*).

Road consumes around 35 per cent of the total developed space in the study area. It is interesting to note that according to service level benchmark (SLB) for urban transport prepared by Ministry of Housing and Urban Affairs (MoHUA), any area with more than 15 per cent road space in comparison to the developed space of that area, should be considered as level one (highest). Thus, higher road space in the study area suggests that the area is well connected with its surroundings.

Map 3: Classification of road network within study area



Prepared by CSE; Data Source: TomTom

Table 1: Details of road network within in study area

Road Classification	Total Length (km)	Share in total roads	Max right-of-way (m)	Total Area (sq. km)
Arterial	31.84	2.20%	60	1.91
Sub-arterial	50.66	3.50%	45	2.28
Collector	78.16	5.40%	30	2.34
Local	1286.7	88.90%	7 to 12	9.56
Total Road Area in sq. km				16.10
Total Developed Area (LEZ) in sq. km				45.57
Share of roads in LEZ in sq km				35.32%

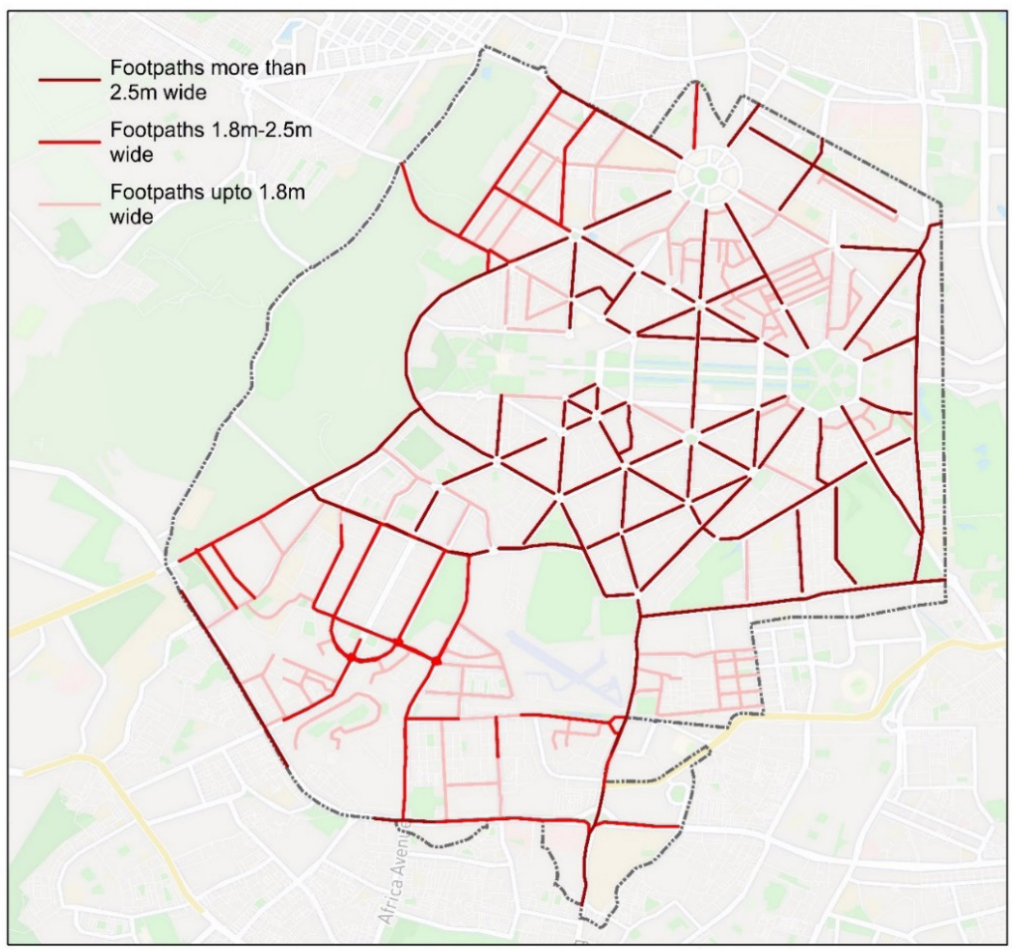
Prepared by CSE; Data Source: TomTom

Note: The ROW considered is maximum observed. The total area calculation is therefore also maximum.

A deeper ground level assessment of pedestrian facilities in this area revealed that around 168 km of pedestrian walking facilities or footpath existed in this area which is merely 12 per cent of the total area. Thus, according to the service-level benchmark (SLB) indicator, this area comes under level 4. SLBs can be level 1 to level 4, with level 4 being the lowest. The low SLB level is mainly due to the predominant share of local road network which is 12 m or less wide.

Even though footpath facilities are less prominent in the local and neighbourhood roads, but more optimistic results are seen for major roads in the area, because around 60 per cent of the arterials, sub arterials, collector roads with more than 30 m width have footpath facilities. See Table 2: Share of footpath according to road category, for details.

Map 4: Distribution of footpath network in the study area



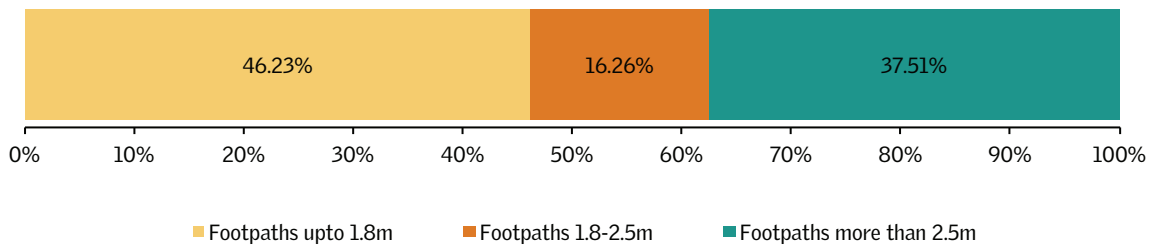
Source: Prepared by CSE based on ground survey

Table 2: Share of footpath according to road category

Road type	Max right-of-way (m)	Share of footpath total
Arterial roads	60	57.16%
Sub-arterial roads	45	66.92%
Collector roads	30	57.93%
Total footpath /Total roads	11.59%	

Prepared by CSE based on ground survey and TomTom data

Graph 2: Percentage distribution of footpath facilities within the study area



Prepared by CSE based on ground survey

Around 54 per cent of all the footpaths are quite wide i.e., 1.8 m and above. And 38 per cent footpath is wider than 2.5 m. According to the Indian Roads Congress (IRC) guidelines, footpaths should be atleast 1.8 m wide (see *Graph 2: Percentage distribution of footpath facilities within the study area*).

Majority of the footpath network is continuous and more or less constant in terms of width. However, in certain locations like Sarojini Nagar market area, near Connaught place and other similar market area and other activity places, footpaths are largely occupied by the street vendors and vehicle parking (see *Map 4: Distribution of footpath network in the study area*).

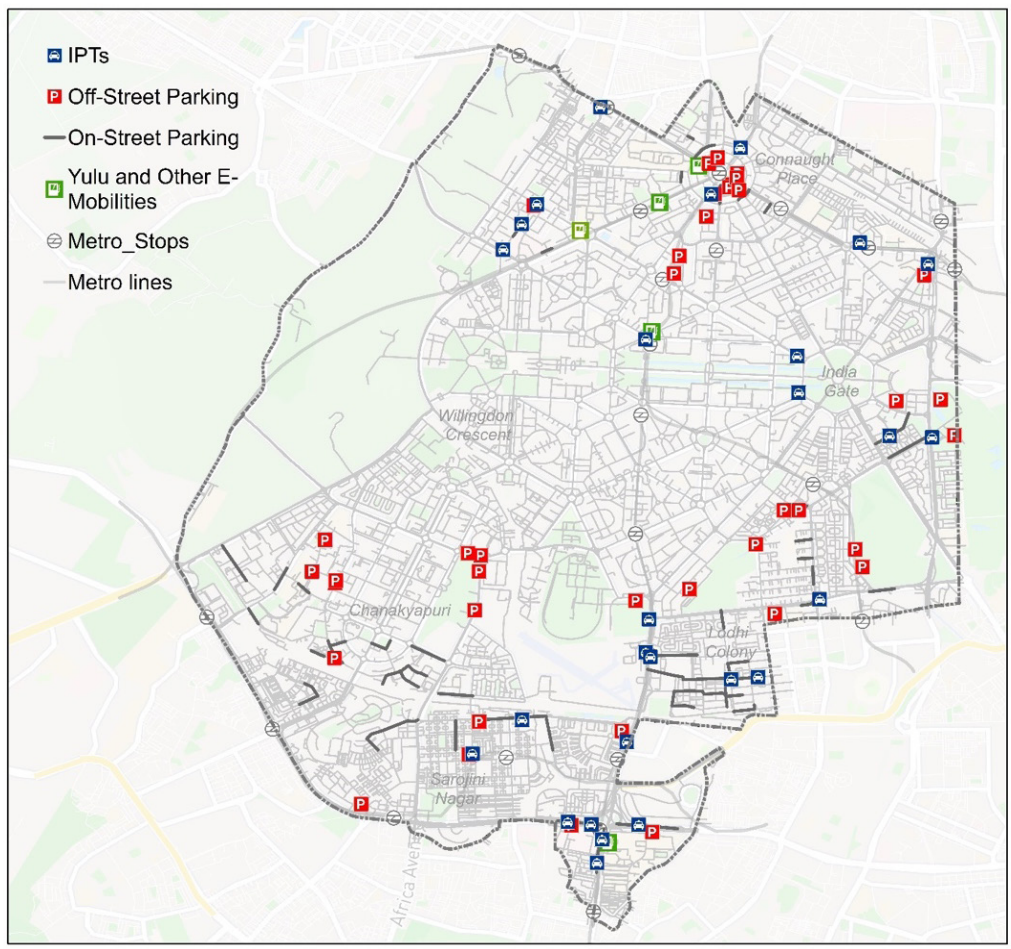
Currently, the study area has around 32 intermediate para-transit stops or auto stands as auto-rickshaws are the predominant IPT services in this area. Majority of the auto stands are informal and unregulated. Apart from auto services, ride hailing services like ola and uber are also quite popular among commuters. Micromobility services like cycles or e-cycles stations are also available adjacent to eight metro stations.

In terms of parking facilities, the area has around 62 off-street parking facilities. These off-street parking locations consist of multi-level car parking (MLCP),

municipal corporation regulated car parking and private public parking area. Apart from that, around 17 kilometers of road sections are being used for on-street parking activities, which include both paid and unpaid parking facilities.

These on-street parking locations were highly prevalent in the southern and eastern region of the LEZ. Some prominent locations on which on-street parking activity was high are: Satya Marg and Chanakya Marg in Chanakyapuri; Brigadier Hoshiyar Singh Marg and Rajmata Vijayraje Scindia Marg, and Maharaja Agrasen Marg in Sarojini Nagar; and most internal roads in Civil Colony between Sri Aurobindo Marg and Second Ave (Lodi Colony) (see *Map 5: Locations of various transport facilities [including IPT stops, on-street and off-street parking] within study area, for details).*

Map 5: Locations of various transport facilities (including IPT stops, on-street and off-street parking) within study area



Prepared by CSE based on ground survey

Almost all the big offices and large institutional spaces have their own private parking spaces.

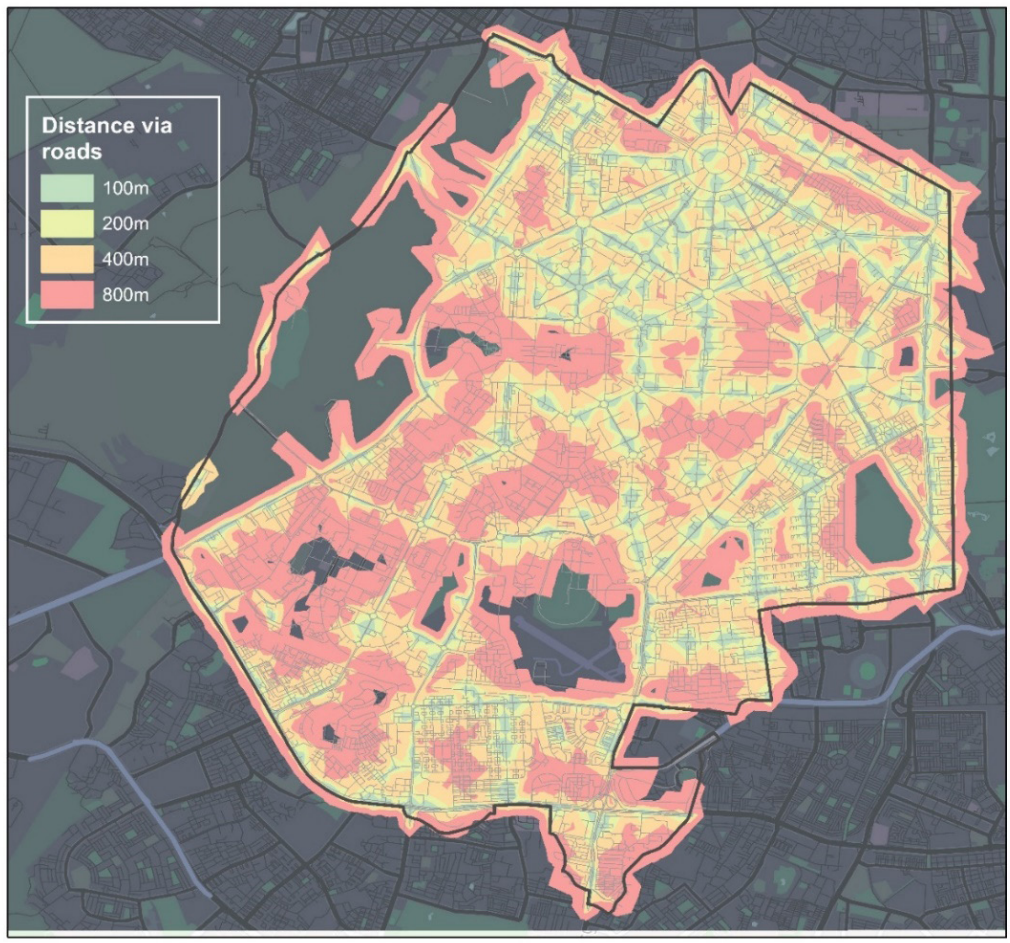
The area is also well connected through public transport facilities including metro and bus services. There are 24 metro stations and around 400 bus stops located within the study area (see *Map 6: Locations of bus stops and metro stations within the study area*).

A deeper analysis to determine the coverage of the public transport (PT) services within the area reveal that around 62 per cent of the developed area is located just 400-meter buffer from the transit nodes whereas almost all the developed area reside well within 800-meter distance from the transit nodes. (See Map 7: Public transport coverage (via roads) within the study area).

Map 6: Locations of bus stops and metro stations within the study area

Prepared by CSE; Data Source: Delhi Open Data Portal

Map 7: Public transport coverage (via roads) within the study area



Prepared by CSE; Data Source: TomTom, Delhi Open Data Portal

SECTION 2: Methodology for impact assessment

Assessing the true impacts of a mobility intervention, require a comprehensive understanding of various factors which govern the individual mode choice. In this regard, it is quite important to understand the travel-related factors (i.e., Origin-destination, trip purpose, trip frequency, choice of modes, vehicle ownership etc.); socio-economic and demographic factors (i.e., sex, age, employment status, education level, income level etc.) and psychological factors (i.e., moral obligation towards environment related issues, political orientation and perception on the stringency of the intervention - in this case LEZ) of various social group/s who on daily basis access the study area.

As LEZ interventions are primarily considered to restrict the usage of polluting vehicles thus, it is assumed that all the electric vehicle and Bharat Stage-6 (BS-6) vehicle user and operator will not be affected by the LEZ interventions. All non-compliant vehicle users or operators operating within the study area shall be impacted due to LEZ. Thus, Survey questionnaire was drafted for all kinds of user/operator groups including two-wheeler, car, auto, goods carrier among others to capture their perception about the LEZ intervention.

Additionally, user perception surveys were also conducted to include those social groups who use public transport (PT) or intermediate public transport (IPT) services for daily commute and those who operate electric vehicles including two-wheeler, car and autos, within proposed LEZ area. These surveys were conducted to understand the present challenges and opportunities of these modes and what more can be done to make these more attractive options.

Developing scenarios for the assessment

Impact assessment was carried out on the basis of two scenarios, firstly, complete ban on the non-compliant vehicles to enter the study (LEZ) area and secondly, limited access of non-compliant vehicles within the LEZ area with penalty provision. Survey questionnaire was framed for each scenario to test and capture the response of different user or operator groups through providing a comprehensive insight into the potential effectiveness and repercussions of LEZ. Brief summary of both the scenarios are provided below:

Policy scenario 1: This scenario assumes non-compliant vehicles are those, which do not meet the BS-VI emission standards or are not electric vehicles. These need to be completely prohibited from entering the proposed LEZ area. In a case of non-compliance, a heavy penalty need to be imposed on the defaulters. The penalty amount will be kept higher to ensure absolute compliance.

This scenario will test the readiness of the vehicle owners or operators (in case of auto and goods carriage) to switch to LEZ compliant vehicles or opt for alternative modes of transport and evaluate the economic and operational impact on those who rely on non-compliant vehicles for their daily operations or commute.

Policy scenario 2 – access charge to enter LEZ with non-compliant vehicles: Under this scenario, non-compliant vehicles are allowed entry into the LEZ, but at a financial cost or by paying access charge. This fee-based approach is designed to gradually incentivize vehicle owners to transition to cleaner alternatives. The fee to enter the LEZ will be substantially lower than the penalty in case of scenario 1.

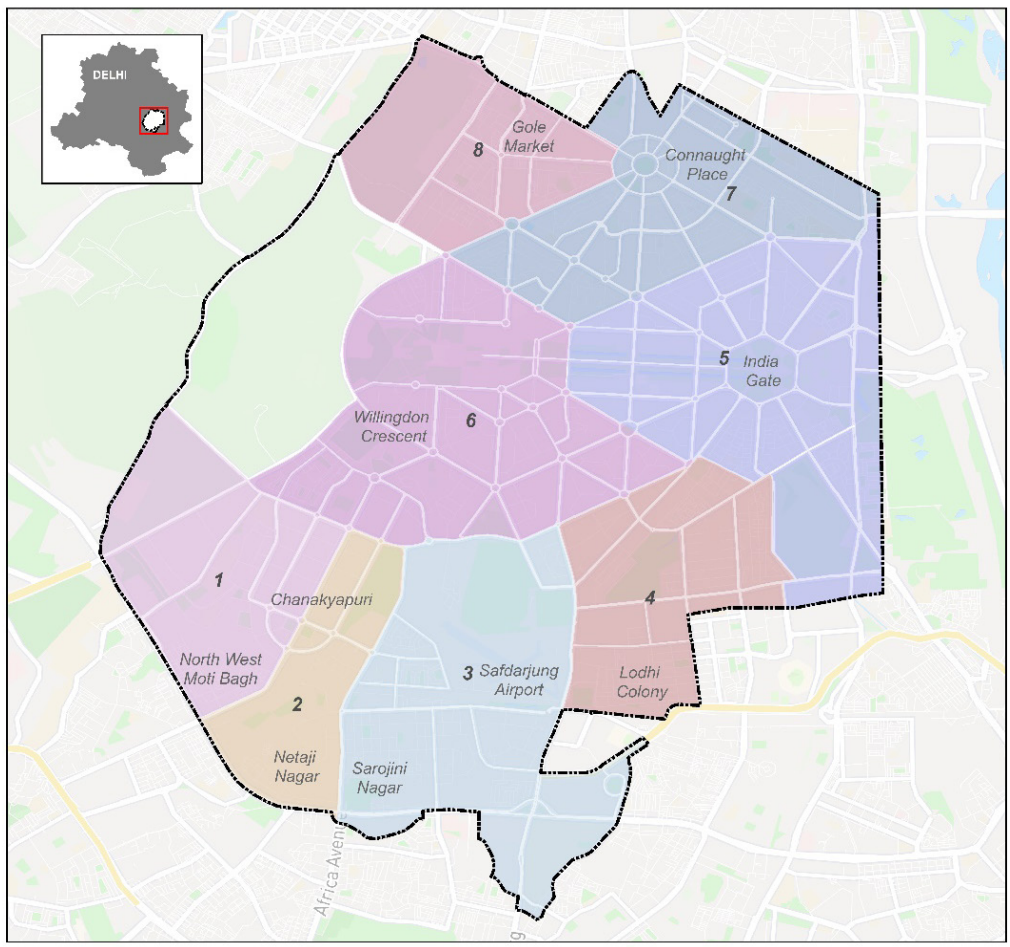
This scenario will help gauge the elasticity of demand for entry into the LEZ and identify a critical cost threshold, which could inform the optimal pricing strategies for LEZ implementation without causing undue hardship to the stakeholders, and ensuring policy justice to all groups.

Surveys and data collection

Impact assessment is done based on the results received from primary surveys. All the surveys were conducted through questionnaire survey method where responses of all the stakeholders were captured on a set of previously decided questions. The samples were collected using Stratified Random Sampling method, where the samples were divided into some selected stakeholder groups or strata and then random sampling technique was used to collected the required number of samples from each group. To ensure geographical spread, NDMC area was divided into eight zones, based on neighbourhood boundaries and almost equal number of survey samples were collected from each zone.

Broadly two types of surveys were conducted; firstly, to understand the potential impact of LEZ interventions on non-compliant vehicle user or operators. Second types of surveys were conducted to capture the perception of existing PT/ IPT users, and also electric vehicle users (both private and commercial two-wheeler and car user and auto user).

Map 8: Zonal map for collecting data within study (NDMC) area



Prepared by CSE

Non-compliant vehicle owner/ operator survey: Under this category five different stakeholder groups were identified which includes private two-wheelers, private cars, auto operators, cab operators and freight service providers and views were captured to understand and assess the impact of both LEZ scenarios. The main aim of this group of surveys was to analyse the maximum amount (critical cost) people who will be willing to pay to enter the LEZ after which they will shift to a cleaner mode of transport.

Around 630 samples were collected from different stakeholder groups. Details of the samples collected according to stakeholder groups are provided in *Table X of Annexure 1*. In all of these surveys, data was collected on the socioeconomic profile of the individual stakeholder to understand their age, gender, income, vehicle ownership details, daily trip dairy, daily cost of travel and what will be

their potential behavioural change (according to both scenarios) in case LEZ is introduced and what is that critical cost point above which they will consider shifting from existing mode or altering their travel habits.

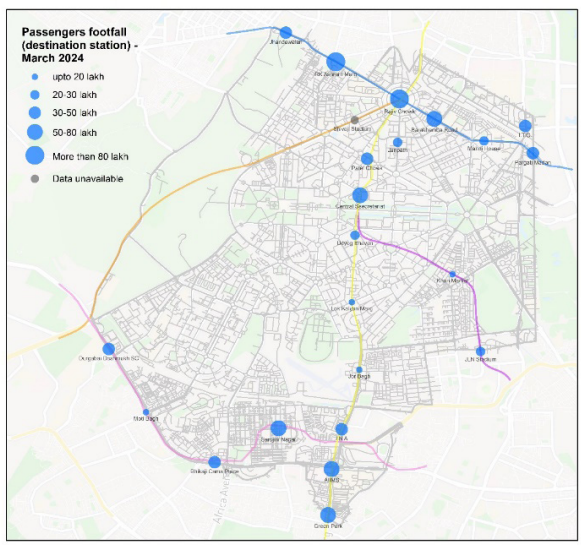
To analyse the willingness to pay among different groups, the Gabor-Granger method was used. The Gabor-Granger method is a market research technique used to assess the price sensitivity of consumers and determine the optimal price point for products or services. In the context of LEZ, the service is access to the low-emission zone. In other words, this method enables gauging the different levels of compliance for entering the LEZ area that can be expected at different fee price points.

User perception survey: In addition to understand the impacts of LEZ intervention/s on the prospective stakeholders, user perception was also captured to find out the existing challenges of using some of the complied modes (i.e., public and intermediate public transport users and electric vehicle users) and what kind of support is required for smooth transition to both users and operators of those modes. Perceptions was captured from nine different stakeholder groups (i.e., four public and intermediate public transport user groups including auto, cab, bus and metro; and five electric vehicle user groups including both private and commercial e-two-wheeler and e-car user and e-auto user).

Around 419 samples were used for the assessment. Stakeholder-wise details of the

Map 9: Transit ridership analysis within NDMC area

A. Monthly footfall of metro stations



B. Major bus routes with high commuters

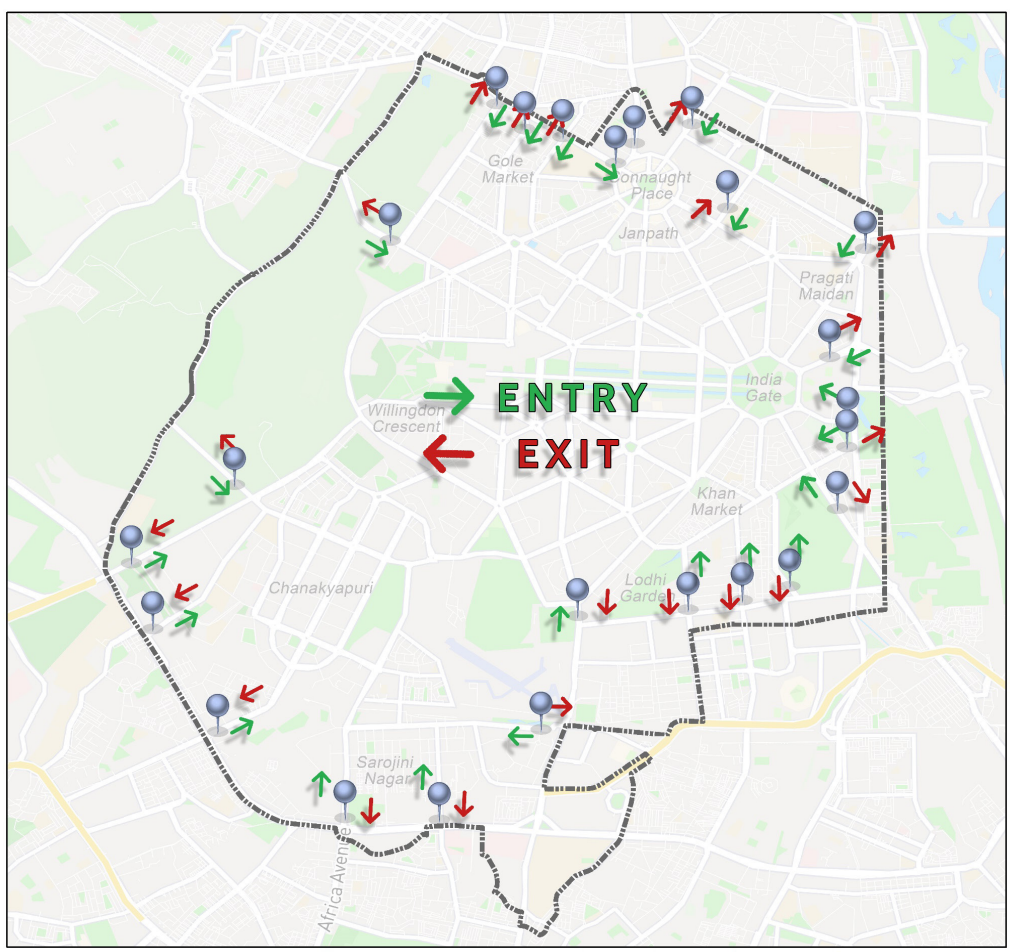
Prepared by CSE; Data Source: DMRC

surveys were provided in **Annexure-1**. In addition to the core questions, all the surveys capture the basis profile of the stakeholders; their age, income, daily trip dairy etc. for detailed analysis.

It is interesting to note that ridership analysis of both metro and bus services helped in identifying some of the key transit access points and routes which further assist in collecting the user survey data.

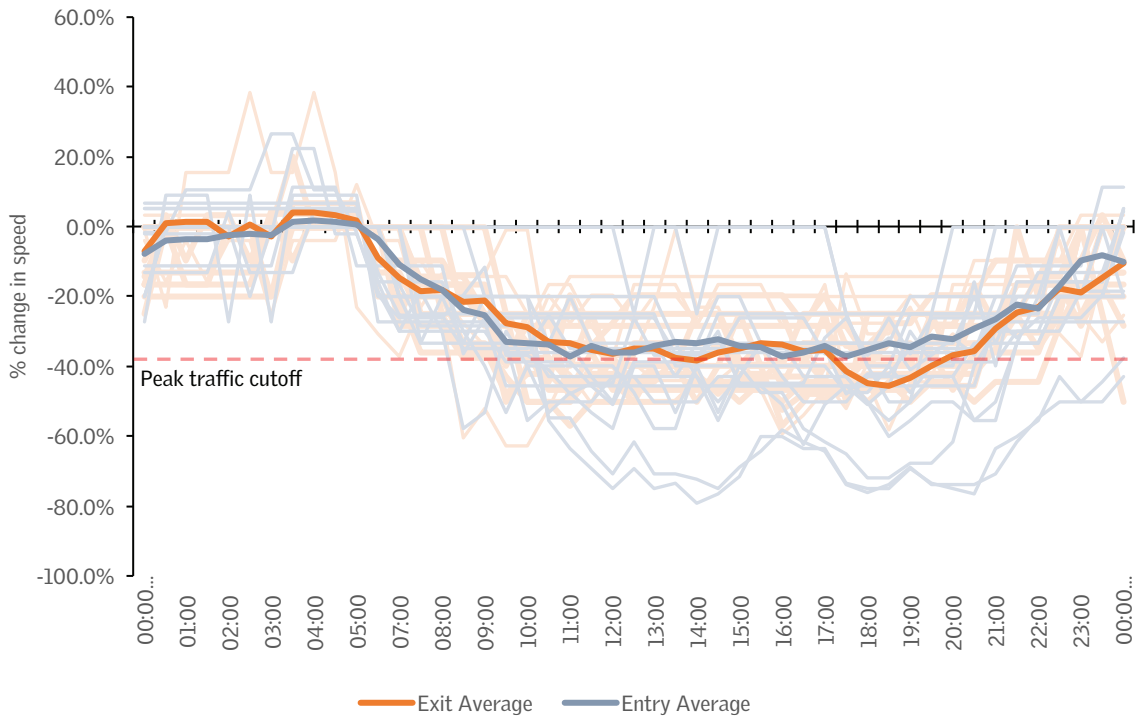
In addition to the questionnaire surveys, traffic volume counts survey was also conducted at 24 locations in the proposed LEZ are to understand the volume of traffic entering and existing the area during the peak hours. All the entry and exit locations were strategically selected to capture almost all the vehicle entry/ exist with minimum data collection points. See Map 8: Locations of traffic volume count (TVC) survey in NDMC area, for details.

Map 10: Locations of traffic volume count (TVC) survey in NDMC area



Prepared by CSE

Graph 3: Percentage change in traffic speed on major arterial and sub-arterial roads in NDMC area



Prepared by CSE; Data Source: Google Maps API

To identify the peak hours, google map directions API data was used to understand the percentage changes in traffic flow occurred at each cordon point, both for vehicles exiting and entering the LEZ area (see *Graph 3: Percentage change in traffic speed on major arterial and sub-arterial roads in NDMC area).*

Graph 3 indicates that morning peak hours commence around 9 AM and extend until approximately 12 PM, after which traffic speeds show a slight increase. Evening peak hours start at 5:30 PM and conclude at 8:30 PM. These peak periods were identified based on a threshold of a 30 per cent reduction in traffic speed from early morning free-flow speed. Realistically, traffic speeds do not recover beyond this threshold from 9 AM until 8:30 PM. However, slight improvements in speed were used to mark the end of the peak hours. It must be noted that exit speeds have been seen decreasing by up to 48 per cent during evening peak, and by 40 per cent during off-peaks (1:30 PM-2:00 PM), which is during the lunch break hour for several institutions in the area.

The underlying assumption for this assessment was that the periods of maximum traffic flow correspond to the times when travel speeds are at their lowest. Analysing the travel speed data, helped to identify the peak periods of the day to schedule the volume count surveys during these critical periods.

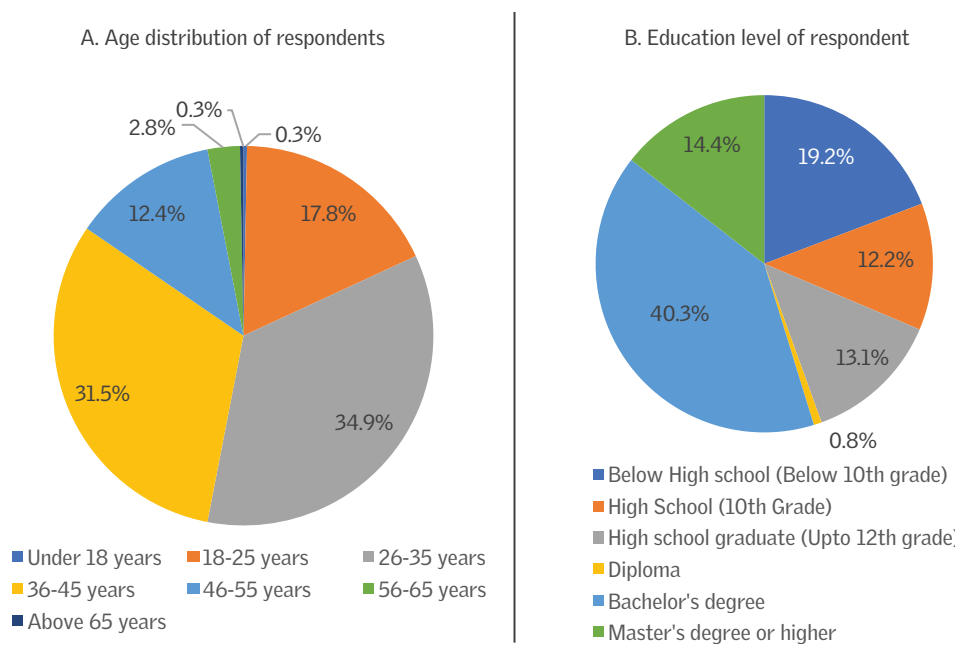
Study limitations: Due to lack of data related to actual number of vehicles which enters/ exists the study area on daily basis and their emission standards, actual emission benefits of both the LEZ scenarios were left unaddressed.

SECTION 3: Findings from the survey

All the surveys were administered within the NDMC jurisdiction. A total of 1049 survey samples were collected including 630 samples of non-compliant vehicle user/ operator and rest 419 samples to capture the perception of compliant vehicle users/ operators. Both the survey samples were collected across eight identified sub-zones to ensure geographical coverage. Details of survey sample distribution across the zones are provided in *Annexure 2*.

Among respondent around 77 per cent are male and 23 per cent female. Though respondents are coming from a wide range of age groups, about 79 per cent of them are from active working population groups (i.e., 26 to 55 years). This reflects the demographics of the NDMC area (see *Graph 4: Age and education profile of the respondents*).

Graph 4: Age and education profile of the respondents



Prepared by CSE based on primary data

Stakeholder-wise impact assessment on non-compliant vehicle user/ owner: The main objective of this study is to understand the stakeholder-wise impacts of LEZ implementation. How non-compliant vehicle user/ owner will adapt or not adapt to the new change.

Two-wheelers

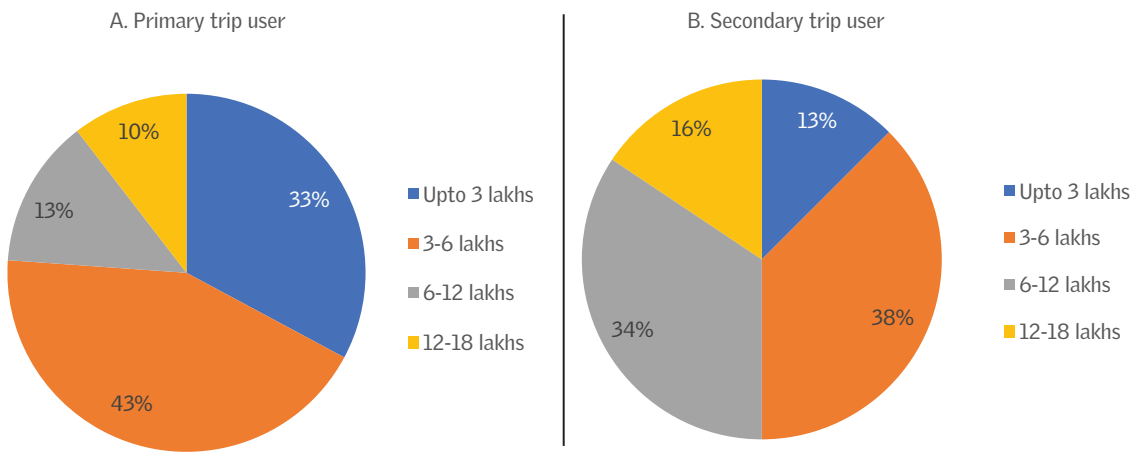
Owner/user profile: 68 per cent of the respondents of this stakeholder group uses the two-wheelers (2Ws) for their primary trips which is predominantly work trips (i.e., 95 per cent of all primary trips). Respondents those who are using the 2Ws for their secondary trips are mainly using it for recreational and shopping activity (i.e., 97 per cent of all secondary trips).

It is interesting to note that almost 79 per cent of the primary trips occur on daily basis. Whereas, 75 per cent of all the secondary trips happen either once in a month or very rarely.

Income distribution pattern reveal that almost 76 per cent of these primary trip users are having annual income range up to 6 lakhs; whereas for secondary trip users almost 72 per cent fall within the income range of 3 to 12 lakhs. See Graph 5: Income distribution pattern of two-wheeler users, for details.

Similarly, analysis of emission profile of non-complaint two-wheeler user reveals that around 54 per cent and 45 per cent of primary and secondary trip users uses BS-3 or older two-wheelers, respectively.

Graph 5: Income distribution pattern of two-wheeler users



Prepared by CSE based on primary data

Table 3: Ranking of major reasons for not preferring public transport facilities

List of reasons	Short trips of less than 5 kms	Medium trips of 5 to 15 kms	Long trips of more than 15 kms
Lack of access/availability*	Rank 7	Rank 1	Rank 7
Overcrowding	Rank 6	Rank 2	Rank 6
Safety concerns	Rank 5	Rank 5	Rank 5
Inadequate frequency	Rank 4	Rank 4	Rank 4
Inconvenient scheduling / timing	Rank 3	Rank 5	Rank 3
Lack of direct routes	Rank 2	Rank 6	Rank 2
Longer travel times**	Rank 1	Rank 1	Rank 1

Prepared by CSE based on primary data
Note: The percentages indicate the proportion of votes each reason received, determining its rank relative to other reasons. The rank for each reason is based on the majority share of votes it received.
* Lack of access/availability of transit stations from origins and destinations; ** Longer travel times compared to private mode of transport

Interestingly, 85 per cent of the primary trip user and 81 per cent of secondary trip user of private two-wheeler group don't pay a single penny for 2W parking.

While asking for their preference to use personal two-wheeler over existing public transport facilities, a mixed responses is received depending upon their travel or commuting distance, and these responses are more or less similar for both primary or secondary trip users (see *Table 1: Ranking of major reasons for not preferring public transport facilities for daily commuting).*

Although responses of both short (less than 5 kms) and long (more than 15 km) distance commuters are identical – for them travel time, unavailability of direct services and lack of service delivery becomes the main reasons for not using public transport facilities be it bus or metro. Whereas, medium (5 to 15 km) distance traveller highlights – longer travel time, lack of service accessibility and overcrowding as the main reasons for not using public transport.

Ranking longer travel time as the top reasons for not taking public transport, irrespective of their commuting distance, clearly indicates peoples' preference over value of time over safety. It is interesting to mentioned that providing dedicated services (particularly for buses); reducing transfer time through integrating the services and waiting time at stops by increasing service frequency can significantly improve the travel time of public transport.

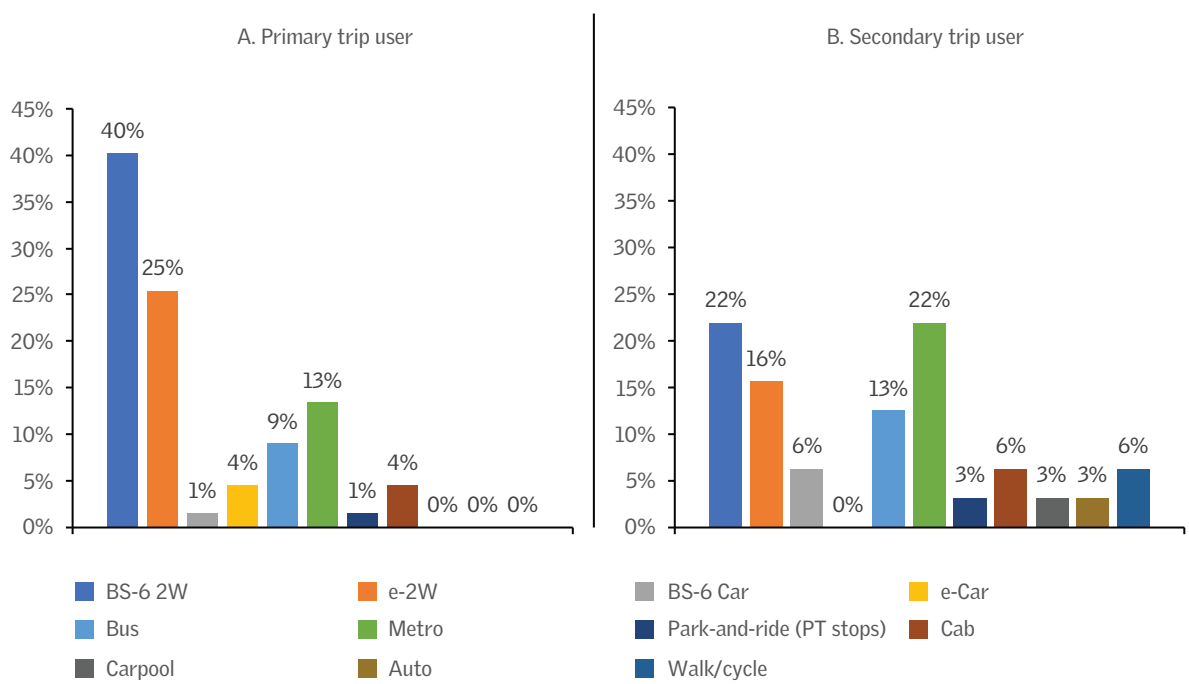
Two-wheelers: Impact of policy scenario 1: Complete Ban on BS-IV and older two-wheelers

Analysing the response on how the scenario-1 situation, in which a complete ban shall be imposed on all non-compliant 2Ws (i.e., BS-4 and older vehicles) from entering the LEZ zone, may impact on their travel pattern (assuming a heavy penalty will be levied in case of non-compliance), reveals some interesting facts about their choices.

Around 65 per cent of the primary trip user has shown they reluctancy to shift to any other mode than two-wheeler and in case of complete ban they will buy a new two-wheeler. Only 21 per cent has stated that they will shift to public transport mode for commuting. Whereas, even though majority of secondary trip users, i.e., 38 per cent has shown their interest in purchasing new two-wheelers, but almost equal number of respondent (35 per cent), has shown their interest in using public transport. See Graph 6: Preferred mode/ vehicle choice for travel in scenario-1, for details.

A deeper income class wise mode/ vehicle choice reveals that irrespective of primary or secondary trip user, it is the income group with an annual income up to

Graph 6: Preferred mode/ vehicle choice for travel in scenario-1



Prepared by CSE based on primary data

Table 4: Income class-wise mode/ vehicle choice in scenario 1

Mode/ vehicle category	Primary trip user				Secondary trip user			
	Up to 3 lakh	3-6 lakhs	6-12 lakhs	12-18 lakhs	Up to 3 lakhs	3-6 lakhs	6-12 lakhs	12-18 lakhs
BS-6 2W	68%	38%	11%		50%	33%	9%	
e-2W	27%	31%	11%	14%		25%	9%	20%
BS-6 Car			11%				9%	20%
e-Car		3%	11%	14%			0%	
Bus	5%	7%	11%	29%		17%	9%	20%
Metro		17%	33%	14%		17%	45%	
Park-and-ride* (PT stops)			11%			8%		
Cab		3%		29%			9%	20%
Carpool								20%
Auto					25%			
Walk / cycle					25%		9%	

Prepared by CSE based on primary data

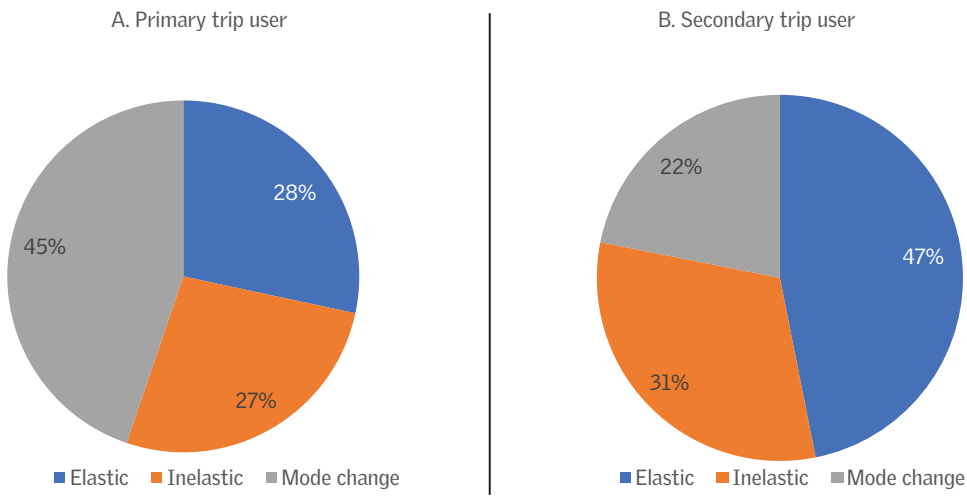
1) *'Park and Ride' stands for parking private vehicles on the outskirts of the LEZ and using a compliant vehicle / service to enter the LEZ; 2) Percentages are representing the share within each subgroup.

6 lakhs are preferring to stick to two-wheeler as main mode even after scenario-1 is implemented. And among two-wheelers preference is more towards now emission norm (BS-6 and above) over electric. Some of the secondary trip user with lower- and middle-income category with shorter trip distance i.e., less than 5 kms., have shown their interest in taking auto or just walk to the destination. Whereas, slightly higher income class respondent has shown interest in shifting to public transport (more than 40 per cent). Some even shown to do cab or carpool services to reach their destination. See Table 1: Income class-wise mode/ vehicle choice in scenario-1, for details.

Two-wheelers: Impact of policy scenario 2: Access charge to enter LEZ

In the second scenario in which commuters need to pay a fee to enter the LEZ area, we begin by dividing respondents into three groups. Those with an 'elastic demand' who have indicated a maximum fee to enter the LEZ exceeding which will result in them shifting to another mode; those with 'inelastic demand' who will continue to use their current non-compliant private vehicle irrespective of the LEZ charge which they are willing to pay irrespective of the cost; and those who are not willing to pay any charge, and will shift to an LEZ compliant mode as soon as the fee comes into effect.

Graph 7: Impact of scenario 2 on private two-wheeler owner/user



Prepared by CSE based on primary data

In response, almost 27 per cent primary trip users show they may continue to use their vehicles irrespective of the increase in cost of journey. Another 28 per cent have replied that they are willing to pay an additional charge and incur a cost within a range and maximum up to 5.5 times their journey cost. The remaining 45 per cent prefer to shift to LEZ compliant modes.

In case of secondary trip user, only 22 per cent have expressed their desire to shift their modes. Otherwise, 47 per cent of them are ready to pay a charge. About 31 per cent are unaffected by the increase in the cost of access. (See Graph 7: Impacts of scenario 2 on private two-wheeler user).

A deeper analysis of income class reveals that for primary trip users, lower and lower middle -income groups with an income up to 6 lakhs will prefer to shift in case price escalate beyond their accepted range. Higher income groups are ready to pay more (i.e., more than 50 per cent of their journey cost). Secondary trip users make lesser number of trips within LEZ area.

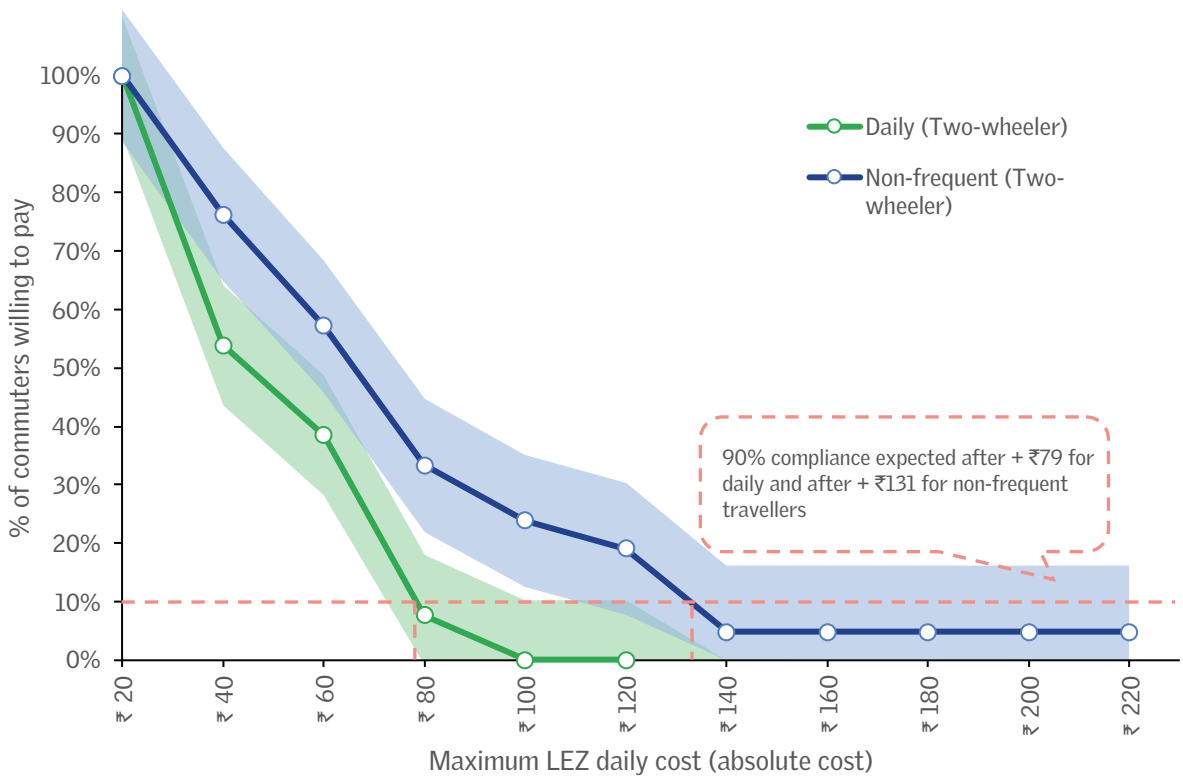
The sample population with elastic demand, that was willing to pay a fee to enter the LEZ were asked their maximum price to enter exceeding which will make them shift away from their private mode of transport, or the 'critical cost'. To understand the price elasticity curve of demand for critical cost indicated by private two-wheelers users, Gabor-Granger method was used. The demand curve plots the maximum price amount against the share of willing commuters.

Table 5: Income class-wise response of private two-wheeler owner/user in Scenario 2

Particulars	Primary trip user				Secondary trip user			
	Up to 3 lakhs	3-6 lakhs	6-12 lakhs	12-18 lakhs	Up to 3 lakhs	3-6 lakhs	6-12 lakhs	12-18 lakhs
Inelastic	18%	21%	44%	57%	25%	33%	27%	40%
Elastic	5%	38%	56%	29%	50%	42%	55%	40%
Mode shift	77%	41%		14%	25%	25%	18%	20%

Prepared by CSE based on primary data

Graph 8: Willingness to pay curve for frequent and non-frequent trips among two-wheeler owners



Prepared by CSE based on primary data

1) Shaded areas are 95% confidence intervals;
2) It must be noted that these prices are over and above the current daily journey costs of commuters which needs to be paid every time to enter the LEZ.
3) In the context of low-emission zone pricing, compliance in Gabor-Granger method can be read as the percentage of population not agreeing with a particular price point, since it is expected that the share not willing to pay more than that amount. As an example, if only 10 per cent of the sample population agree with a particular fee amount, 90 per cent reduction in number of vehicles is likely entering the LEZ area, meaning a 90 per cent compliance.

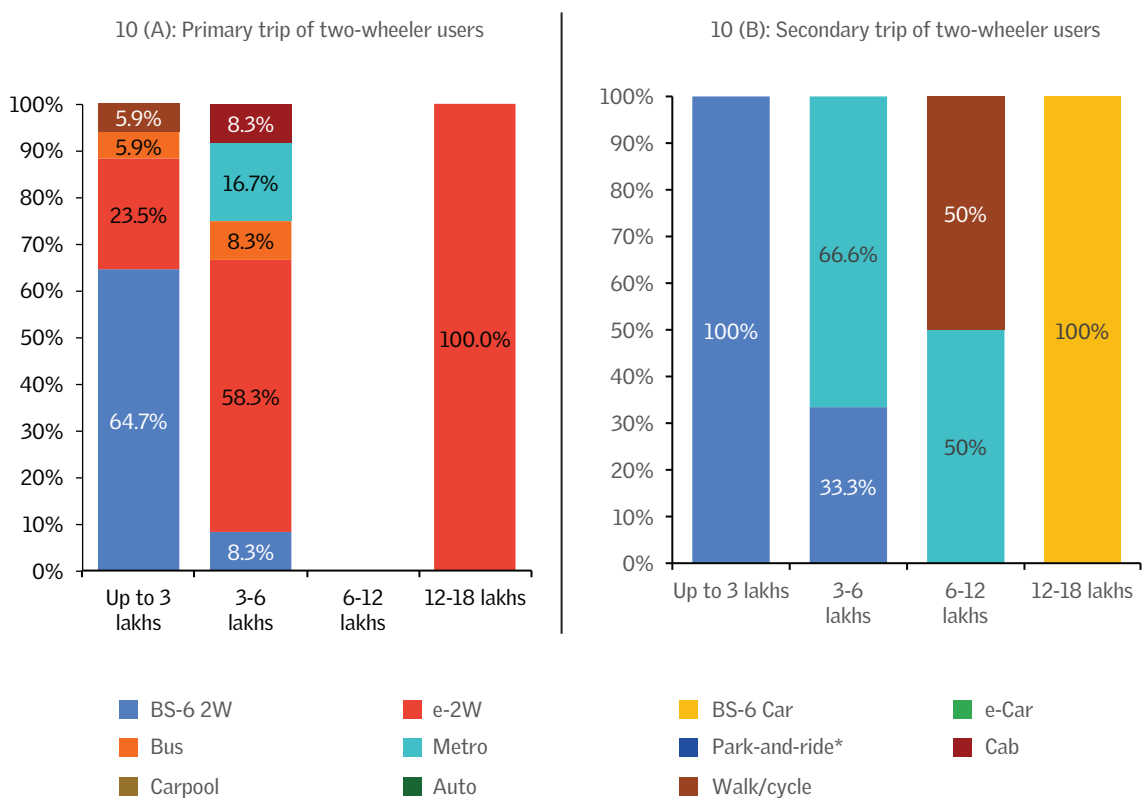
The results from the curve plotted suggests that among daily two-wheeler commuters, 90 per cent compliance is expected after ₹₹ 79, whereas for non-daily commuters, the same level of compliance can be achieved after ₹₹131.

The average cost daily two-wheeler users indicated that they can pay is ₹₹ 32 to enter the LEZ, while non-daily two-wheeler users average is ₹₹ 63. The compliance for both groups at their average indicated costs are 25 per cent. It can be inferred from this that the average indicated critical cost is much lower than the cost required for a more stringent implementation (90 per cent compliance).

The sample that was not willing to pay any fee and was readily willing to shift to another compliant vehicle were asked their preferred compliant mode of shift.

Among primary trip commuters, lower income groups tend to prefer BS-6 two-wheelers more, and as the income increases, the sample leaned more towards cars and electric vehicles. Among secondary trip commuters, no preference was given to electric vehicles. Income groups leaned more towards metro, lower income groups showed preference for BS-6 two-wheelers and higher income group towards BS-6 cars.

Graph 9: Preferred mode/ vehicle choice for travel in scenario 2



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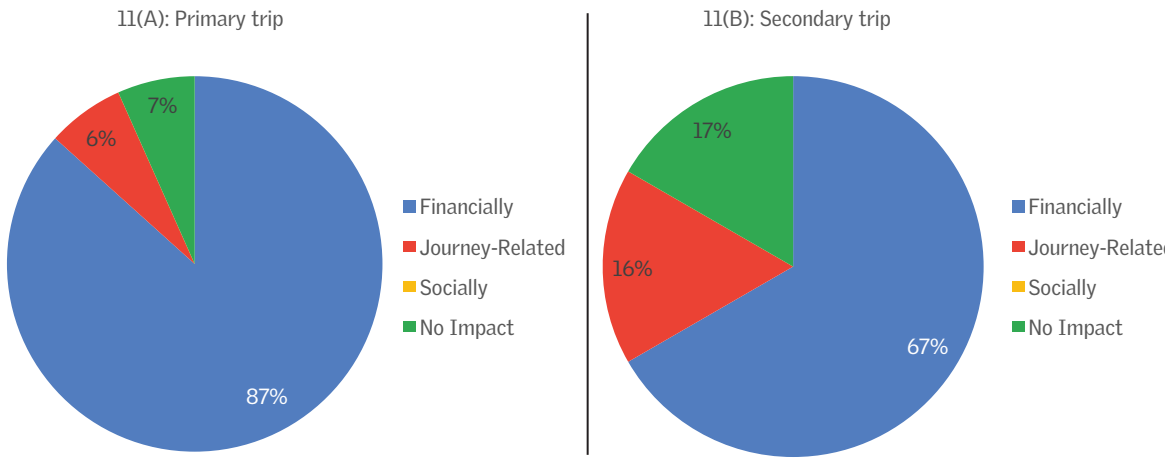
Graph 10: Type of impact on two-wheeler users in scenario 2



Prepared by CSE based on primary data

Secondary trip makers will not be as financially impacted by the change, as primary trip makers. However, higher share of secondary trip makers has indicated a journey-related impact which includes increase in travel time, reduced comfort and so on. About 16 per cent commuters making secondary trips to the LEZ area will not have any impact due to the mode change.

Private cars

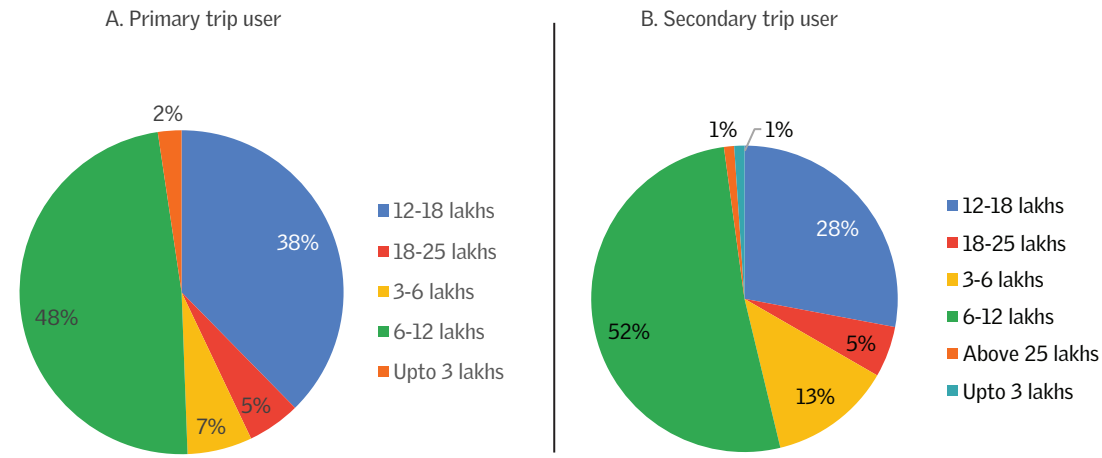
Owner/user Profile: 64.6 per cent of car users use their vehicle for their primary trips which is predominantly work trips (83.6 per cent of all primary trips). Those using cars for their secondary trips are using them primarily for recreational activities and adhoc errands (15.2 per cent of all secondary trips).

Majority of the primary trips (72 per cent) are made daily, whereas majority of all the secondary trips (82 per cent) happen occasionally.

Income distribution pattern reveals that almost 86 per cent of the primary trip users earn between 6 and 18 lakhs per annum. Almost 80 per cent of the secondary trip users fall in the same income range. The four-wheeler owners therefore belong largely to the higher middle to higher income class, unlike two-wheeler users. (See Graph 12: Income distribution pattern of two-wheeler users).

Analysis of emission profile of non-complaint car user reveals that around 75 per cent and 82 per cent of primary and secondary trip users respectively use vehicles

Graph 11: Income distribution pattern of car owner/ users



Prepared by CSE based on primary data

with a BS-4 engine type. Between 10 to 11 per cent of the sample population were unsure about their engine type when asked.

It was also found that 69 per cent of the primary trip users and 63 per cent of secondary trip car users do not pay anything for parking.

While asked for their preference to use personal car over existing public transport facilities, mixed responses were received based on their commuting distances. These responses are more or less similar for primary or secondary trip users (see *Graph 7: Ranking of major reasons for not preferring public transport facilities for daily commuting*).

For short distance commuters (less than 5 kms), travel time in public transport, and concerns around safety and expectation of comfort are the primary reasons for not using public transport facilities. For both medium (5-15 km) and long (more than 15 km) distance commuters, lack of access, longer travel times and comfort are the primary reasons.

Ranking longer travel time as the top reasons for not taking public transport, irrespective of their commuting distances, indicates priority attached to value of time. Providing dedicated services (particularly for buses); reducing transfer time by integrating multiple transport services and increasing service frequency can significantly can improve the travel time of public transport.

Graph 12: Ranking of major reasons for not preferring public transport facilities

	Short trips of less than 5 kms	Medium trips of 5 to 15 kms	Long trips of more than 15 kms
Lack of access/availability*	Rank 7	Rank 1	Rank 1
Overcrowding	Rank 1	Rank 2	Rank 2
Safety concerns	Rank 2	Rank 3	Rank 7
Inadequate frequency	Rank 4	Rank 4	Rank 4
Inconvenient scheduling / timing	Rank 3	Rank 5	Rank 5
Lack of direct routes	Rank 4	Rank 6	Rank 6
Longer travel times**	Rank 1	Rank 1	Rank 1

Prepared by CSE based on primary data
Note: The percentages indicate the proportion of votes each reason received, determining its rank relative to other reasons. The rank for each reason is based on the majority share of votes it received.
*Lack of access/availability of transit stations from origins and destinations; ** Longer travel times compared to private mode of transport

Private cars: Impacts of Policy scenario 1: Complete Ban on BS-IV and older cars

In the complete ban scenario, in which non-compliant vehicles will be banned from entering the LEZ against a heavy penalty, owners of BS-4 or older cars were asked which mode they would prefer.

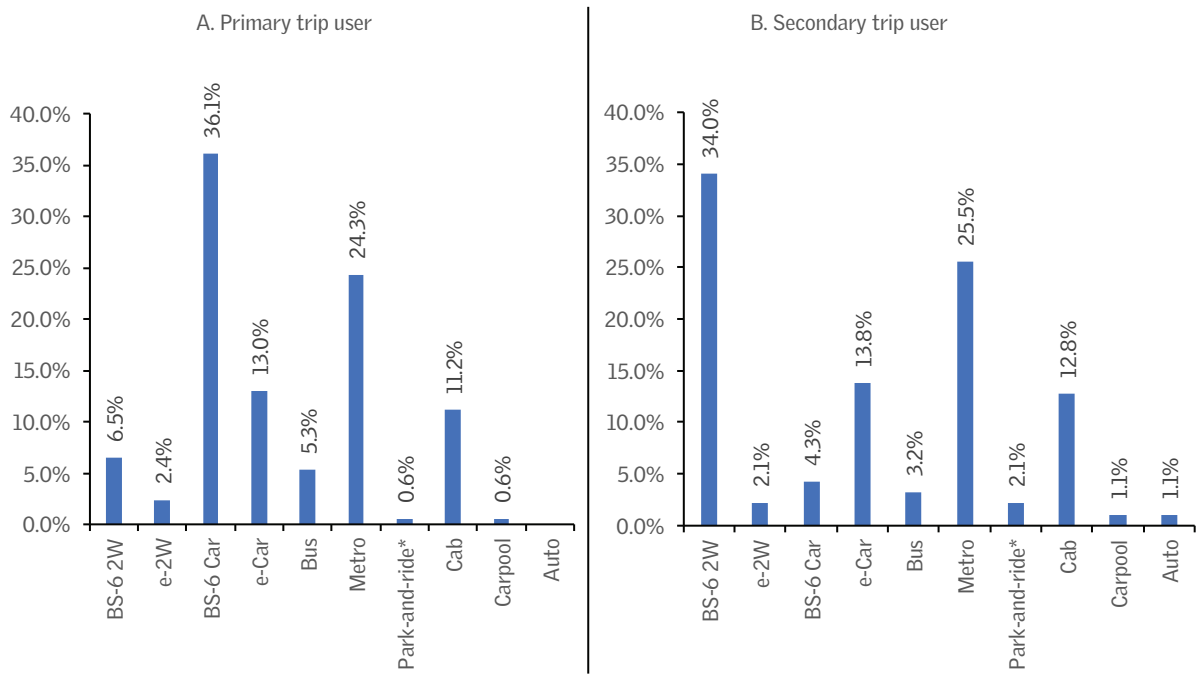
About 49 per cent of the primary trip car users will stick to a car after the ban, with 36 per cent indicating a preference for BS-6 cars and 13 per cent for an electric car. Close to 30 per cent car owners are willing to shift to public transport modes, bus and metro. Preference for a cab is considerable at 11 per cent.

Secondary trip car users have a high preference for a BS-6 two-wheeler rather than a car (34 per cent and 25 per cent respectively), as less frequent trips to the area make them reluctant to invest in a compliant car. About 29 per cent have shown interest in taking a public transport mode to the LEZ, while 13 per cent say they will take a cab for their trips to the area.

Further analysing of these choices based on the income levels reveals that across all income groups in primary and secondary trips, car owners want to stick with cars, more likely a BS-6 car than an electric.

Low-income groups among them are more likely to shift to a BS-6 two-wheeler for making primary trips. To make secondary trips, most car commuters will take the metro. Preferences towards electric vehicles still lie with mid-high to high income groups (12 lpa or more), although mid-low-income groups did show considerable inclination towards electric cars for their primary trips.

Graph 13: Preferred mode/vehicle choice for travel in scenario 1



Prepared by CSE based on primary data

Table 6: Income class-wise mode/ vehicle choice in Scenario-1

Group	Primary Trip					Secondary Trip					
Subgroup	Up to 3 lakhs	3-6 lakhs	6-12 lakhs	12-18 lakhs	18-25 lakhs	Up to 3 lakhs	3-6 lakhs	6-12 lakhs	12-18 lakhs	18-25 lakhs	Above 25 lakhs
BS-6 2W	75.0%		4.9%	6.5%				6.3%	3.8%		
e-2W			1.2%	4.8%			8.3%	2.1%			
BS-6 Car	25.0%	54.5%	33.3%	40.3%	40.0%		41.7%	35.4%	30.8%	40.0%	
e-Car		27.3%	13.6%	11.3%	20.0%		8.3%	8.3%	26.9%		100.0%
Bus		18.2%	3.7%	6.5%			16.7%	2.1%			
Metro			33.3%	22.6%		100.0%	16.7%	27.1%	26.9%	20.0%	
Park-and-ride*			1.2%					2.1%			
Cab			8.6%	6.5%	40.0%		8.3%	12.5%	11.5%	40.0%	
Carpool				1.6%				2.1%			
Auto								2.1%			
Walk / Cycle											

Prepared by CSE based on primary data
1) *'Park and Ride' stands for parking private vehicles on the outskirts of the LEZ and using a compliant vehicle / service to enter the LEZ; 2) Percentages are representing the share within each subgroup.

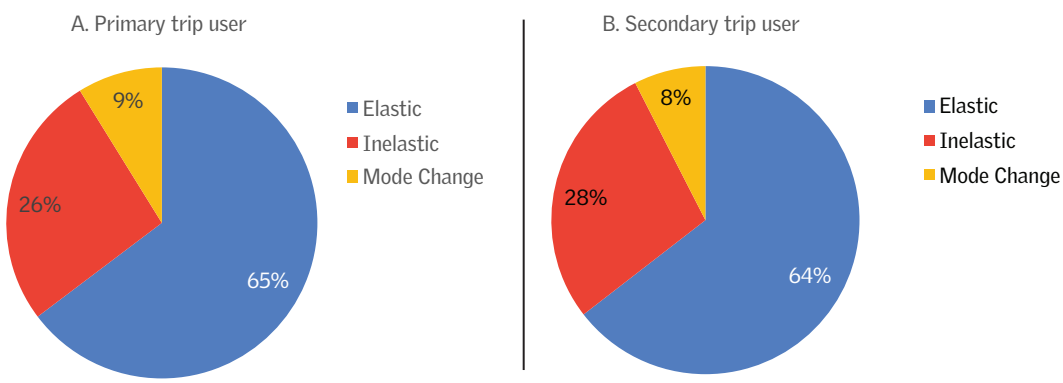
Private cars: Impact of policy scenario-2: Access Charge to enter LEZ

Similar to two-wheeler samples, car owners in the second scenario are divided into three groups. Those with an 'elastic demand' have indicated the maximum range of fee that they are willing to pay to enter the LEZ exceeding which they will shift to other modes. Those with "inelastic demand" will continue to use their current non-compliant private vehicle irrespective of the LEZ charge which they are willing to pay irrespective of the cost. Those who are not willing to pay any charge will shift to an LEZ compliant mode as soon as the fee comes into effect.

Among frequent commuters (primary trip), 28 per cent have shown elastic demand whereas 27 per cent have shown inelastic demand. Among non-frequent commuters (secondary trips), 47 per cent have shown an elastic demand, and 31 per cent have shown an inelastic demand. Rest of the commuters will opt for a change in their mode.

To understand willingness to pay across income classes, the three groups were divided based on their income. Interestingly, unlike in the case of two-wheelers, car owners have a greater affinity to their private vehicle, evident from the low share of mode change preference indicated across the board. Among frequent travellers (primary trips), both low- and high-income groups indicate a particularly strong resistance towards a mode change as they both form the majority of inelastic demand among primary trips. Among non-frequent travellers (secondary trips), elastic demand forms the majority across most income classes. Since a significant number of lower-income and highest income users are inelastic, pricing strategies must be carefully considered to effectively influence travel behaviour.

Graph 14: Impacts of scenario 2 on private two-wheeler owner/ user



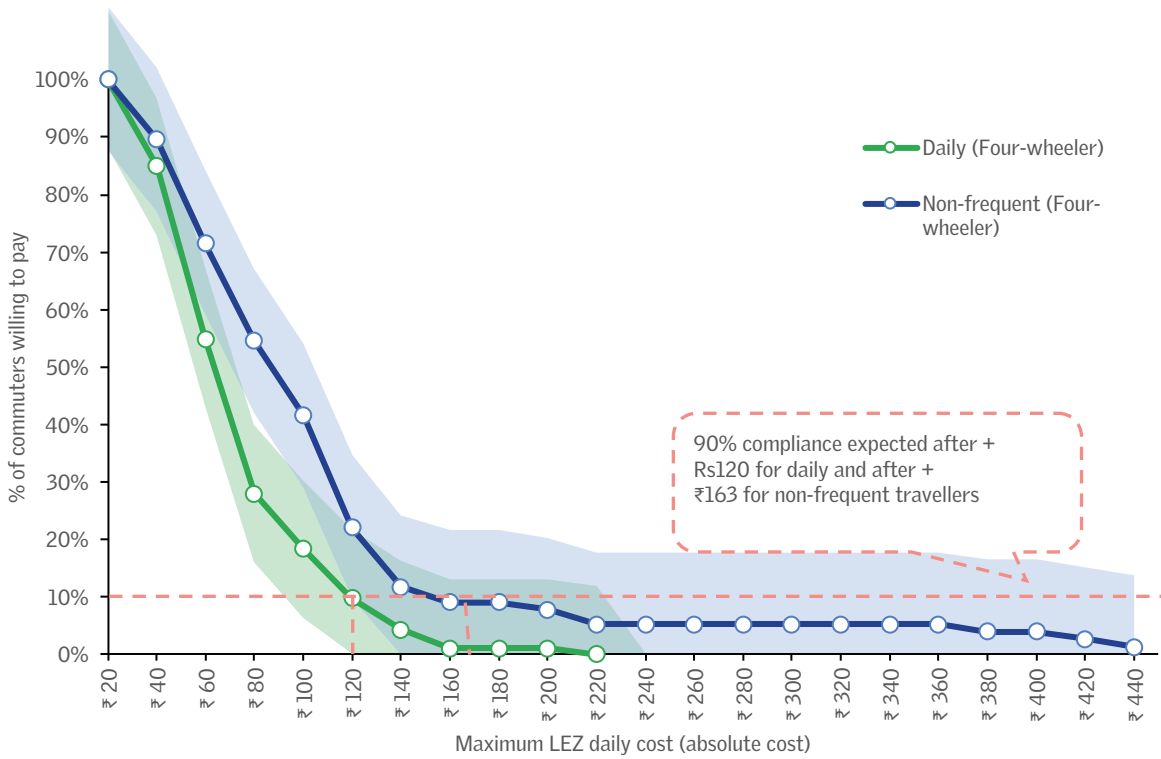
Prepared by CSE based on primary data

Table 7: Income class-wise response of private two-wheeler owner/ user in scenario 2

Particulars	Primary Trip					Secondary Trip					
	Up to 3 lakhs	3-6 lakhs	6-12 lakhs	12-18 lakhs	18-25 lakhs	Up to 3 lakhs	3-6 lakhs	6-12 lakhs	12-18 lakhs	18-25 lakhs	Above 25 lakhs
Elastic		27%	77%	64%	33%	100%	67%	65%	73%		100%
Inelastic	75%	46%	17%	27%	67%		8%	27%	27%	100%	
Mode Change	25%	27%	6%	9%			25%	8%			

Prepared by CSE based on primary data

Graph 15: Willingness-to-pay curve for frequent and non-frequent trips among private car owners



Prepared by CSE based on primary data

1) Shaded areas are 95 per cent confidence intervals;
2) It must be noted that these prices are over and above the current daily journey costs of commuters which needs to be paid every time to enter the LEZ.
3) In the context of low-emission zone pricing, compliance in Gabor-Granger method can be read as the percentage of population not agreeing with a particular price point, since it is expected that the share not willing to pay more than that amount. As an example, if only 10 per cent of the sample population agree with a particular fee amount, 90 per cent reduction in number of vehicles is likely entering the LEZ area, meaning a 90 per cent compliance

Similar to private two-wheelers, car owners with elastic demand indicated the maximum price they are willing to pay to enter the LEZ area, exceeding which they will shift from their private mode of transport. To understand the price elasticity

curve of demand for critical cost indicated, Gabor-Granger method was used. The demand curve plots the maximum price amount against the share of willing commuters.

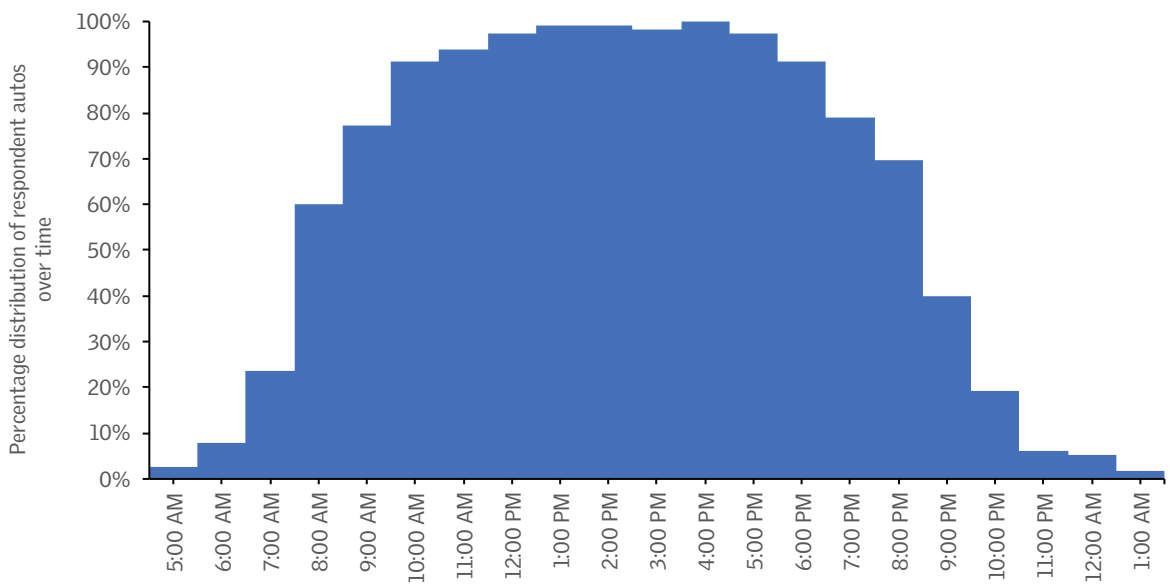
The results from the curve plotted suggests that among daily car commuters, 90 per cent compliance is expected at Rs 120. For occasional commuters the same level of compliance can be achieved at Rs 163. While two-wheeler users have indicated around Rs 52 as acceptable to enter the LEZ, the occasional users have indicated Rs 84.

Auto drivers

Driver profile: Around 61 per cent auto drivers operates their own vehicle, whereas, rest 39 per cent operate hired autos on rent. 40 per cent respondents were operating BS-3 or older autos and around 61 of all the surveyed autos were found more than 8 years old.

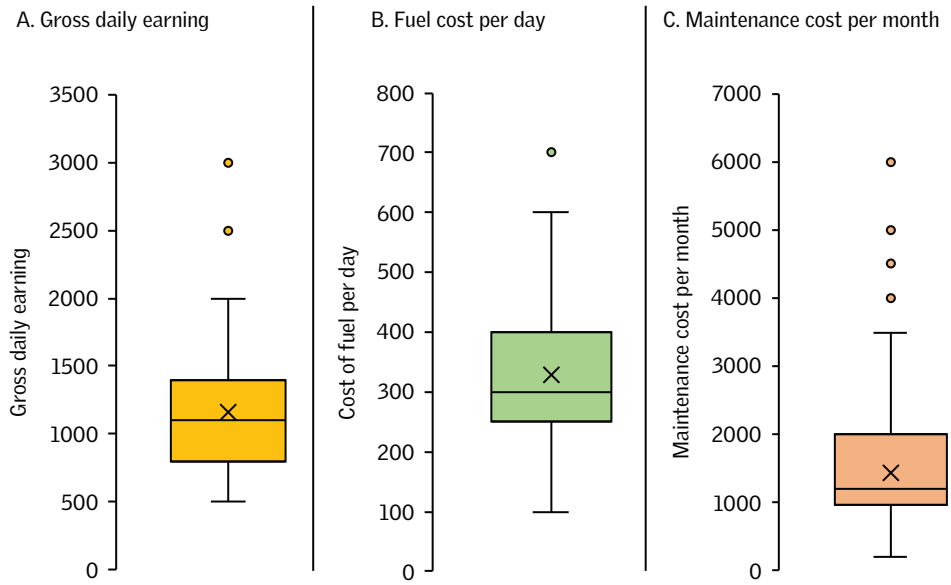
Around 67 per cent auto drivers are involved in this profession for more than six (6) years. Auto drivers are operating these vehicles throughout the day. Around 79 per cent drivers agreed that they operate these autos for minimum 5 to 10 trips or more in a day. Though auto operations hour extends from early morning (5 AM)

Graph 16: Observed auto operations within LEZ area



Prepared by CSE based on primary data

Graph 17: Details of auto operations



Prepared by CSE based on primary data

to late night (1 AM), actual peak starts from 8 AM in the morning to 8 AM in the evening (see *Graph 10: Observed auto operations hour within LEZ area*).

Gross daily earnings of each auto driver range between Rs 800 to Rs 1400 (interquartile range) with a median value of Rs 1100. Whereas, their daily fuel cost ranges between Rs 250 to Rs 400 with a median value of Rs 300.

Autos drivers: Impact of policy scenario 1: Complete ban on BS-IV and older autos

When faced with the option of complete ban on BSIV and pre BSIV vehicles, around 65 per cent of the respondents have indicated that they will upgrade their vehicles to LEZ compliant modes. About 35 per cent will continue with their present autos and stop providing services within LEZ area as upgrading the vehicles will add tho their financial burden.

Autos drivers: Impact of policy scenario 2: Access charge to enter LEZ

Additional access charge to enter the LEZ area, will not have any direct financial implication for the auto drivers. They are expected to pass on the additional cost to the users as journey cost. However, almost 80 per cent of them have agreed that it may dent their ridership number and their daily earning. About 18 per cent drivers

have not agreed with access charge and would like to restrict their services and operate outside the LEZ zone.

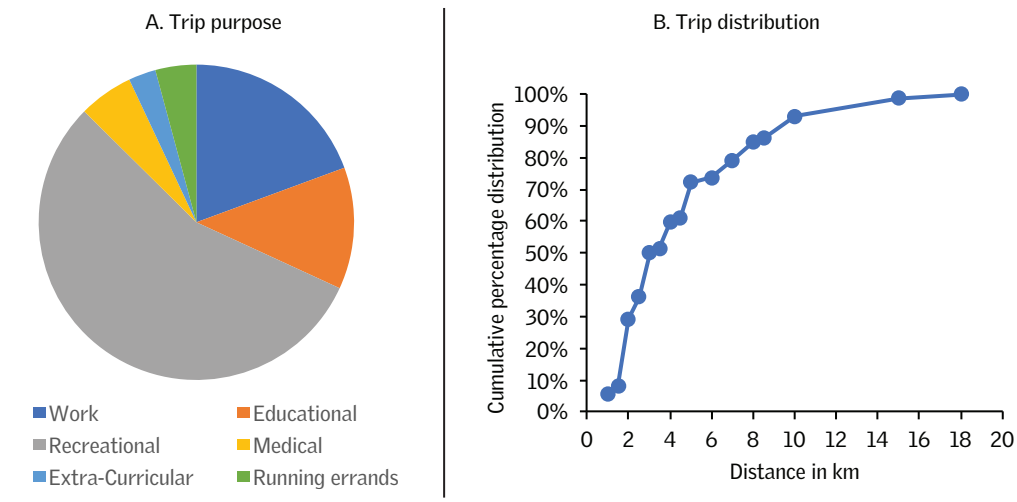
Around 67 per cent of the auto drivers have shown interest in upgrading the vehicles to LEZ compliant BS-6 and Electric autos. However, they would need fiscal subsidy from the government including low interest loans, financial subsidy to procure e-autos and also improved charging infrastructure.

Auto users

User profile: Female user ratio of the auto segment is quite high - almost 47 per cent. Around 55 per cent of the users are taking autos for recreational purposes, followed by work and educational trips which is 19 and 13 per cent, respectively. It is quite expected as this NDMC area has concentration of recreational areas, prominent commercial areas such as Connaught Place, Khan Market, Janpath Market, Sarojini Nagar, to name a few. Also heritage sites like India Gate, and Jantar Mantar. As a result, only 22 per cent trips are regular. Almost 70 to 75 per cent trips are happening within 6 km of the distance requiring 15 to 20 minutes of journey time.

Auto users: Impact of scenario 1: Complete Ban on BS-IV and

Graph 18: Trip purpose and trip distribution of three-wheeler users



Prepared by CSE based on primary data

Table 8: Indirect impact of ban on three-wheeler user

Type of impact	Percentage of Auto user
No significant impact	5.6%
Use compliant IPT vehicles	44.4%
Reduce number of trips to LEZ	15.3%
Shift to private modes (compliant)	6.9%
Switch to sustainable modes	27.8%

Prepared by CSE based on primary data

older autos

Although, ban on non-compliant autos will not impact the users directly as they will shift to other compliant modes. Almost 79 per cent auto users have said that they will shift to complaint modes and about 15 per cent have said they will reduce their trip numbers.

Auto users: impact of scenario 2: Access charge to enter LEZ

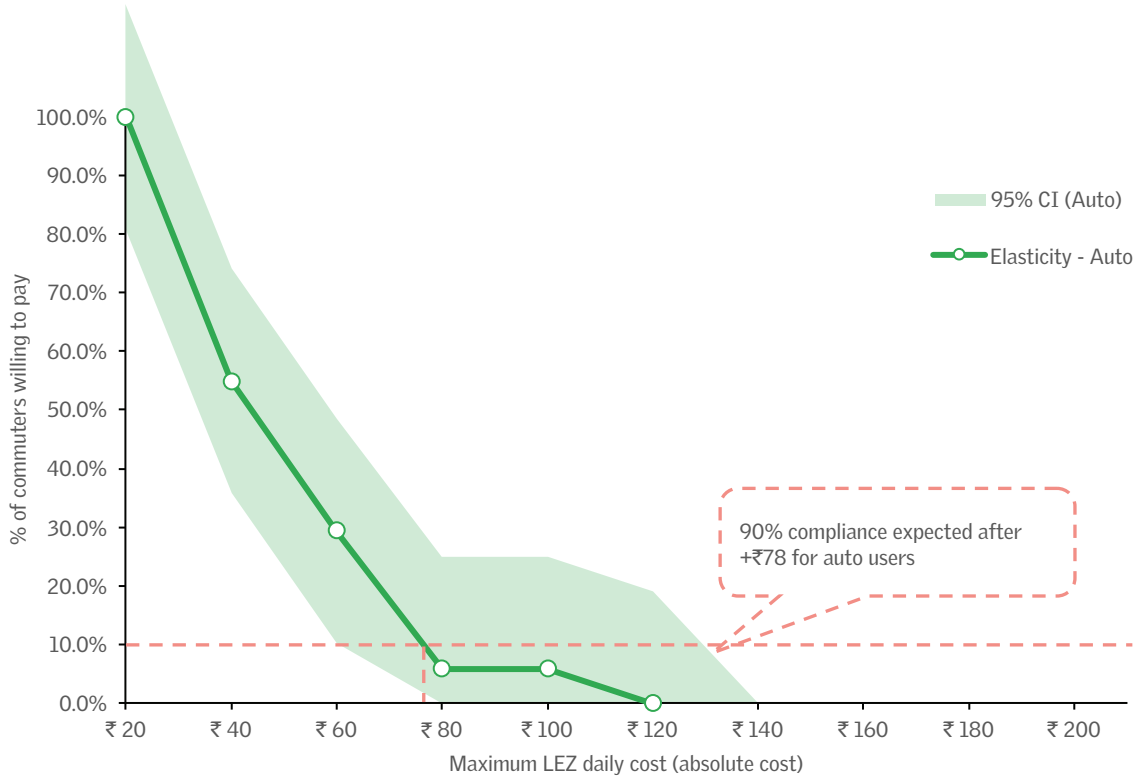
Assuming any additional charges on non-compliant auto to enter the LEZ area will be passed on to the commuters or users as journey cost, it is quite important to understand the impact of the policy scenario 2 or access charge to enter the LEZ.

In view of the above, the auto users have been asked to share their views on the critical cost of shift in terms of share of fare they are willing to pay over the existing fare to enter the area.

A price elasticity curve of demand was created for auto and cab users visiting the LEZ area using the Gabor-Granger method. The demand curve plots the maximum price amount (in the context of LEZ, the maximum price commuters are willing to pay to enter) against the share of commuters willing to pay a certain price.

The results show that 90 per cent compliance can be expected after ₹₹ 78 for auto

Graph 19: Willingness to pay curve among auto users



Prepared by CSE based on primary data

1) Shaded areas are 95 per cent confidence intervals;
2) It must be noted that these prices are over and above the current daily journey costs of commuters which needs to be paid every time to enter the LEZ.
3) In the context of low-emission zone pricing, compliance in Gabor-Granger method can be read as the percentage of population not agreeing with a particular price point, since it is expected that the share not willing to pay more than that amount. As an example, if only 10 per cent of the sample population agree with a particular fee amount, 90 per cent reduction in number of vehicles is likely entering the LEZ area, meaning a 90 per cent compliance

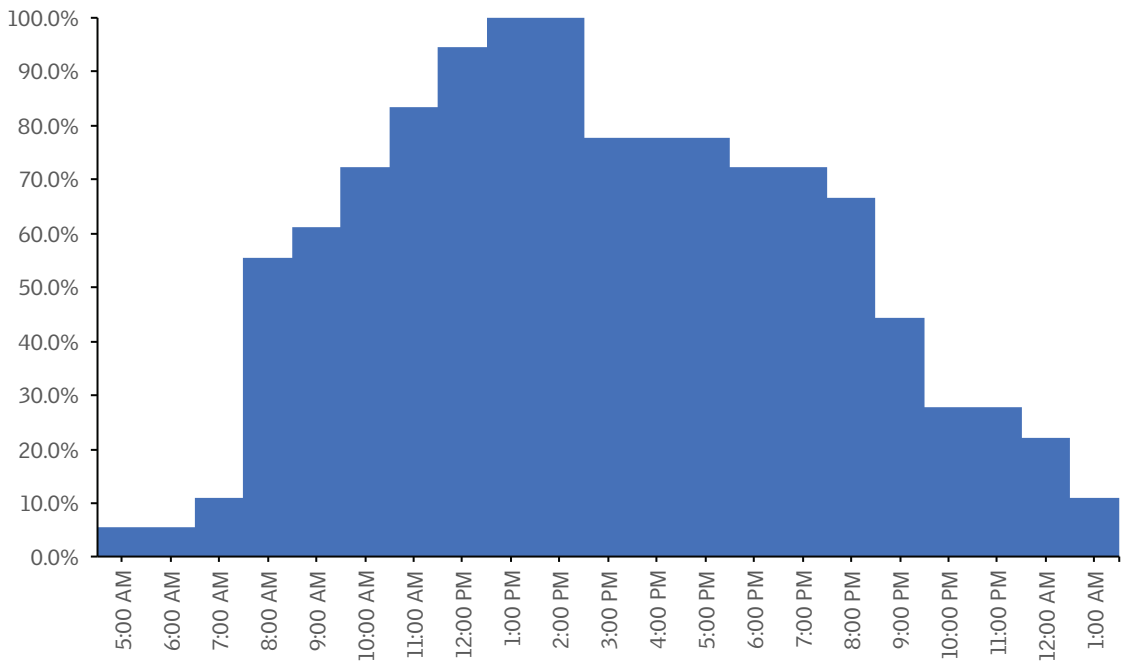
users. The average auto user can pay a maximum fee of ₹₹ 33, at which 36 per cent compliance can be expected.

Cab drivers

Driver Profile: Around 94 per cent cab drivers own their vehicle, and the rest operate rented cabs. Majority of the sample (77 per cent) are currently driving BS-4 cabs and around 55 per cent of the sample are operating vehicles older than eight (8) years.

The majority (72 per cent of auto drivers) have been driving cabs for more than six (6) years. About 79 per cent cab drivers can more than 5 trips in a day.

Graph 20: Observed cab operations within LEZ area

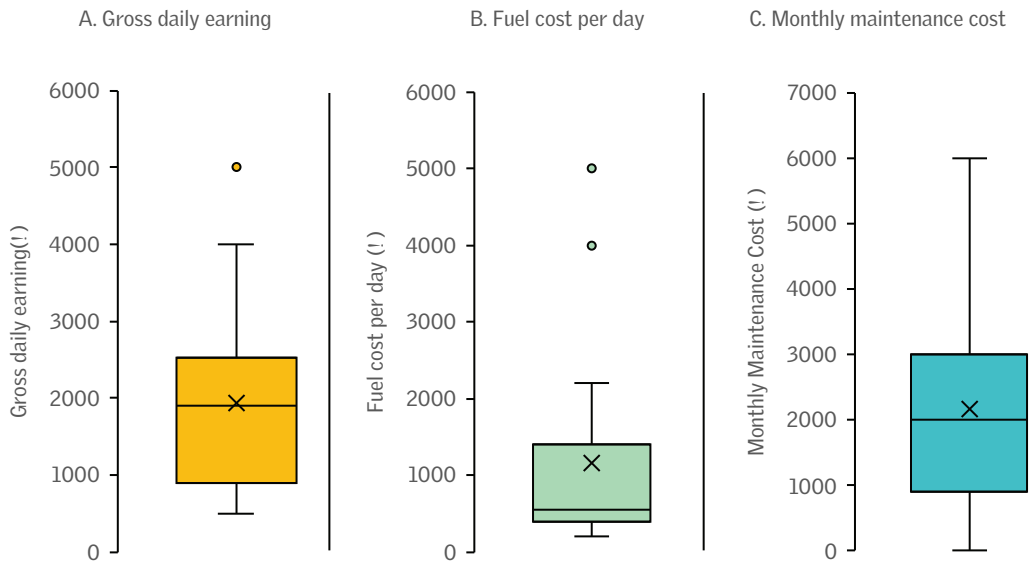


Prepared by CSE based on primary data

Across the sample, the operational hours extend between early morning (5 AM) until late night (1 AM), however the peak operational hours in which most of the sample operate their vehicles falls between 9 AM in the morning and 8 PM in the evening. See Graph 10: Observed auto operations hour within LEZ area, for details.

Gross daily earnings of most drivers range between Rs 850 to Rs 2,600 with a median value of Rs 1,900. Whereas, the daily fuel cost of most cab drivers ranges

Graph 21: Financials of cab drivers



Prepared by CSE based on primary data

Note: The above representation are box and whisker plots. Box and whisker graph is used to see the spread of the data. The line splitting the box in two is the median; the dots are outliers in the data; the cross marks the mean value of the data; the vertical lines above and below the box represent the upper and lower limits of the data; and the lines and the box together with the median line divide the data into four quartiles.

between Rs 400 to Rs 1,400 with a median value of Rs 600. The maintenance cost can be anywhere between Rs 900 to Rs 3,000 per month.

Cab driver: Impact due to scenario 1: Complete Ban on BS-IV and older cabs

In an event when BS-4 or older vehicles are banned, around 50 per cent cabbies claim they will upgrade their vehicles to compliant modes, while the other 50 per cent will stick to their present vehicle and simply stop their services within LEZ area.

Like auto drivers, for a significant share of cab drivers the decision to not make a shift was due to financial constraints, however this share did not form the majority among reasons to not shift. 66 per cent cab drivers are reluctant to shift either because their vehicle is not of retiring age or because they are not strictly required to operate in the LEZ area at all to maximise their earnings. The only cab services running in Delhi are cab aggregator services such as Ola and Uber. Cab drivers are required to cater to any area the passengers are destined for, however they get to pick rides they want to take. Therefore, it is much more convenient for cab drivers to maintain their gross income levels while choosing to change their area of service entirely.

Among the 50 per cent drivers willing to get a complaint vehicles, drivers were divided equally between a BS-6 and electric vehicle choice. The higher preference towards electric compared to auto drivers is because to work with cab aggregator services such as BluSmart and Uber Green, the drivers are not required to own their vehicles, nor are they required to maintain the vehicle or worry about factors such as battery replacement costs and degradation costs. Therefore, it is much easier for cab drivers to shift to an electric cab.

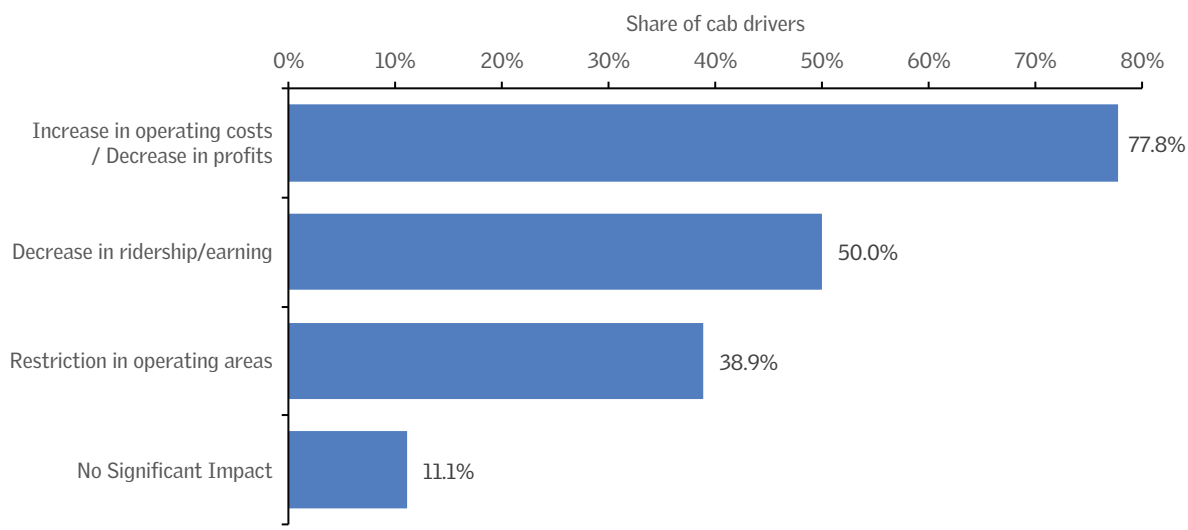
At the same time, majority of drivers willing to opt a BS-6 vehicle (80 per cent) have claimed that they are going for BS-6 because according to them electric cars currently have challenges such as range anxiety, EV vehicle performance, and ambiguous charging facilities in their area.

Majority drivers opting for an electric cab have indicated that their choice is due to the lower operational costs of the vehicle, which increases their profits, as well as due to the prevailing subsidies for commercial vehicles in Delhi state EV policy which reduces the cost substantially. Some drivers also stated that consumers are increasingly shifting to electric cab services, and not driving an electric cab will be a missed opportunity.

Cab driver: Impact due to scenario 2: Access charge to enter LEZ

For the purpose of this study, it was assumed that taxation on IPT vehicles will result in a "Cost Pass Through", or in other words, any charged levied on the drivers will be paid by the consumers. Therefore, the IPT users and not drivers have been

Graph 22: Concerns regarding implementation of LEZ



Prepared by CSE based on primary data

asked their critical cost of shift in terms of share of fare they are willing to pay over the existing fare to enter.

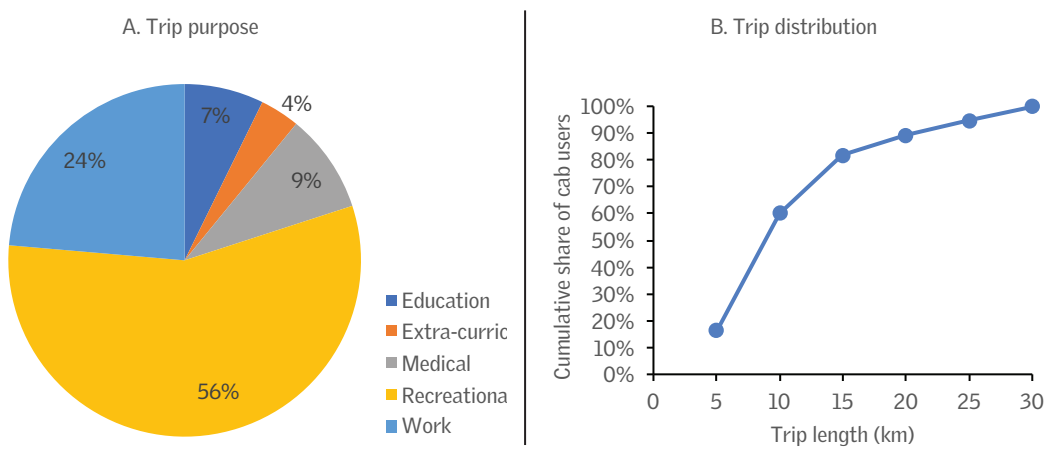
Despite the confidence among cab drivers regarding no change in the number of trips they make due to the LEZ implementation, about 78 per cent of them feel that the LEZ will have an impact on their profits. And 50 per cent have concerns regarding a decrease in their regular ridership due to the additional costs attached for the passengers.

Around 50 per cent of the auto drivers have shown to upgrade their vehicles to complaint vehicles in case their vehicles get taxed to enter the LEZ.

Cab users

User Profile: Majority of the trips made by the sample population in the region are recreational trips (56 per cent). About a quarter are work trips. Most trips

Graph 23: Trip purpose and trip distribution of cab users



Prepared by CSE based on primary data

taken on a cab are medium to long distance trips with about 60 per cent trips ending before 15 km.

Cab User: Impact due to scenario-1: Complete Ban on BS-IV and older cabs

If BS-4 or older auto-rickshaws are banned in the LEZ area, most users have

Table 9: Indirect impact of ban on cab user

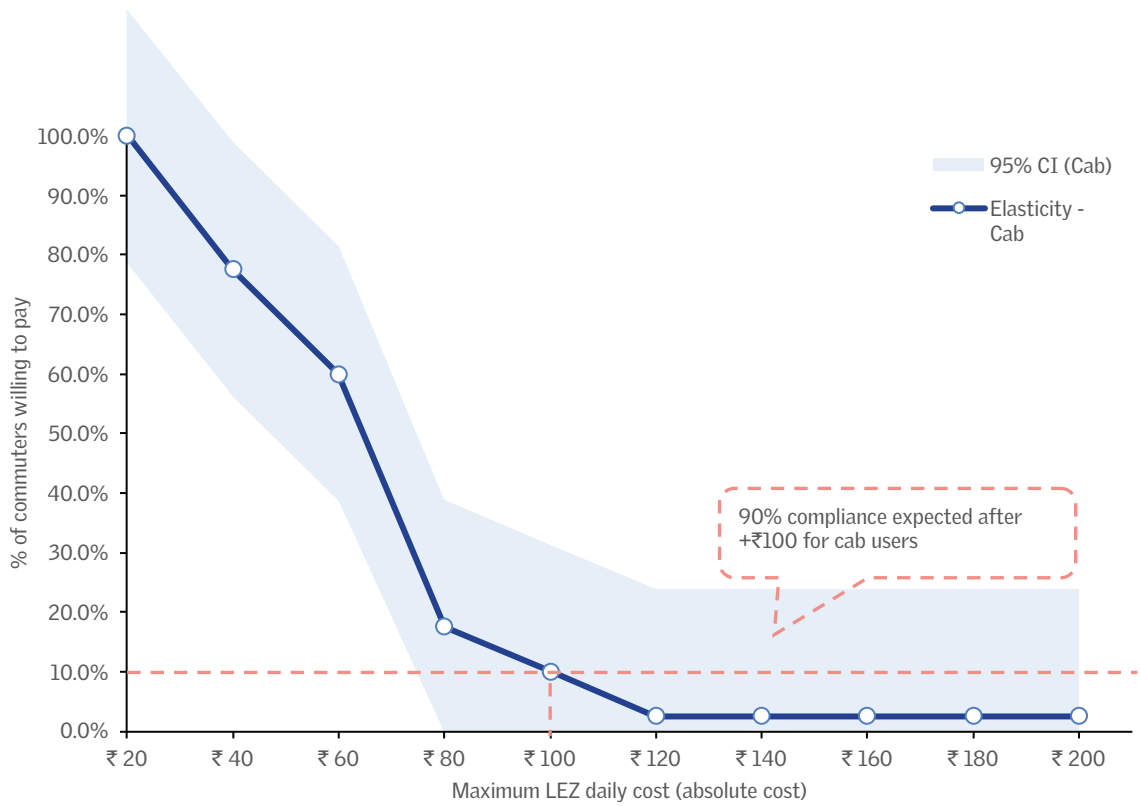
Type of impact	Percentage of cab user
No significant impact	7.3%
Use compliant IPT vehicles	54.5%
Reduce number of trips to LEZ	1.8%
Shift to private modes (compliant)	18.2%
Switch to sustainable modes	18.2%

Prepared by CSE based on primary data

claimed to simple shift to either a compliant cab (54.5 per cent), or use other compliant modes (36.4 per cent). About 7.3 per cent of users will have no impact.

Cab user: Impact due to scenario 2: Access charge to enter LEZ

Graph 24: Willingness-to-pay curve among auto users



Prepared by CSE based on primary data

1) Shaded areas are 95% confidence intervals;

2) It must be noted that these prices are over and above the current daily journey costs of commuters which needs to be paid every time to enter the LEZ.

3) In the context of low-emission zone pricing, compliance in Gabor-Granger method can be read as the percentage of population not agreeing with a particular price point, since it is expected that the share not willing to pay more than that amount. As an example, if only 10 per cent of the sample population agree with a particular fee amount, 90 per cent reduction in number of vehicles is likely entering the LEZ area, meaning a 90 per cent compliance

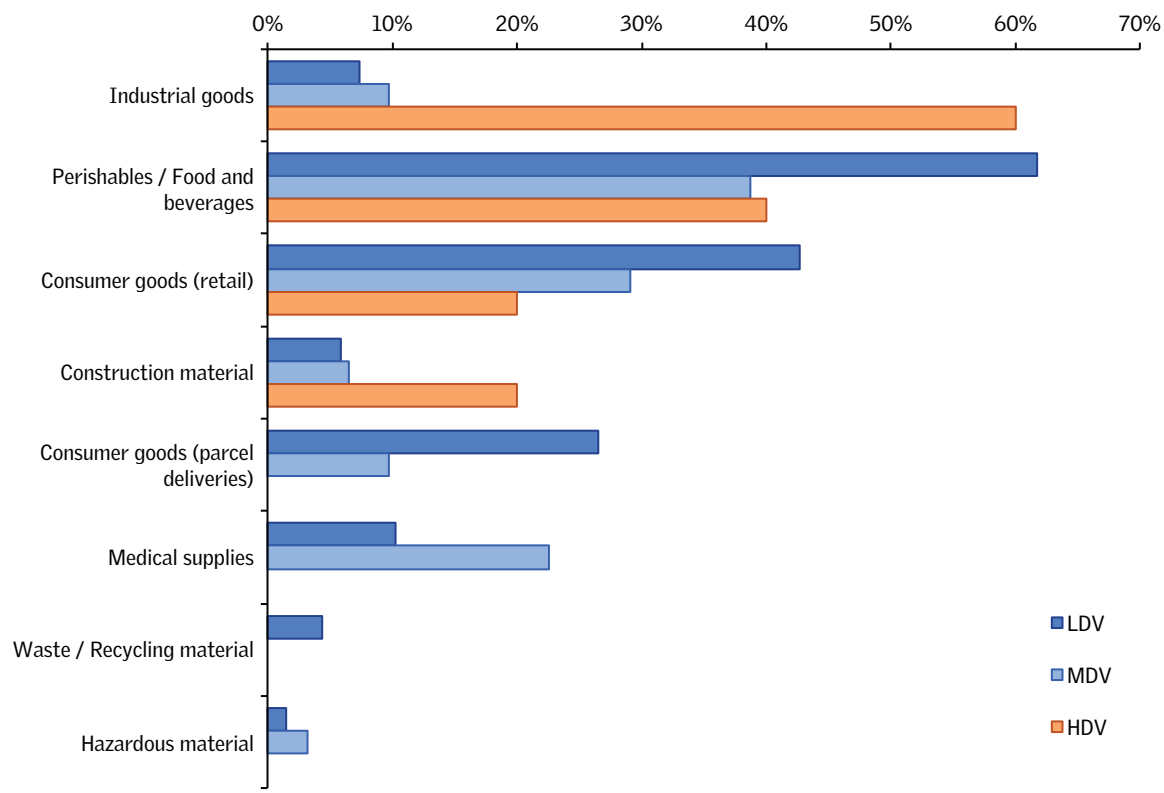
Since it has been assumed that taxation on IPT vehicles will be passed on to the consumer in its entirety, a price elasticity curve of demand was created for auto users visiting the LEZ area using the Gabor-Granger method. The demand curve plots the maximum price amount (in the context of LEZ, the maximum price commuters are willing to pay to enter) against the share of commuters.

The results show that 90 per cent compliance can be expected after Rs 100 for auto users. The average auto user can pay a maximum fee of Rs 49, at which 30 per cent compliance can be expected.

Goods services providers

Profile of goods services providers: Around 65 per cent respondents operate

Graph 25: Type of goods delivered within the study (LEZ) area by goods vehicles category



Prepared by CSE based on primary data
Note: Perishables / Food and beverages = vegetables, fruits, meet, dairy products, grocery etc; Consumer goods = RETAIL - clothing, furniture, electronics, etc; Medical supplies = pharmaceuticals, hospital supplies, etc; Industrial goods = machinery, raw materials for factories, components etc; Construction material = sand, gravel, cement, steel etc; Hazardous material = chemicals, fuels, etc.

light-duty commercial vehicles (LDVs), followed by 30 per cent medium-duty commercial vehicles (MDVs), and 5 per cent heavy-duty vehicles (HDVs).

Light duty vehicles visit the LEZ area much more frequently than medium and heavy vehicles; 20.6 per cent LDVs visit more than 10 times a day, and 67.6 per cent visit 5-10 times a day. Majority (71 per cent) of MDVs enter the anywhere between 5-10 times a day. And about 40 per cent HDVs only visit every other day to once a day.

Diesel vehicle share is the highest among HDVs (40 per cent), and lowest among LDVs (1.5 per cent).

Most businesses (53.8 per cent) own one to five vehicles in their fleet. A sizeable share (32.7 per cent) of the respondents is constituted by single vehicle owners.

Most commercial vehicles in the sample were seen carrying perishables such as food products and/or groceries to commercial areas. The second largest segment was consumer retail goods carrying vehicles such as clothes, furniture, electronics, and so on. Most HDVs were seen carrying industrial goods which includes industrial machinery, raw materials for factories, components etc. Whereas LDVs and MDVs were mostly seen carrying perishables.

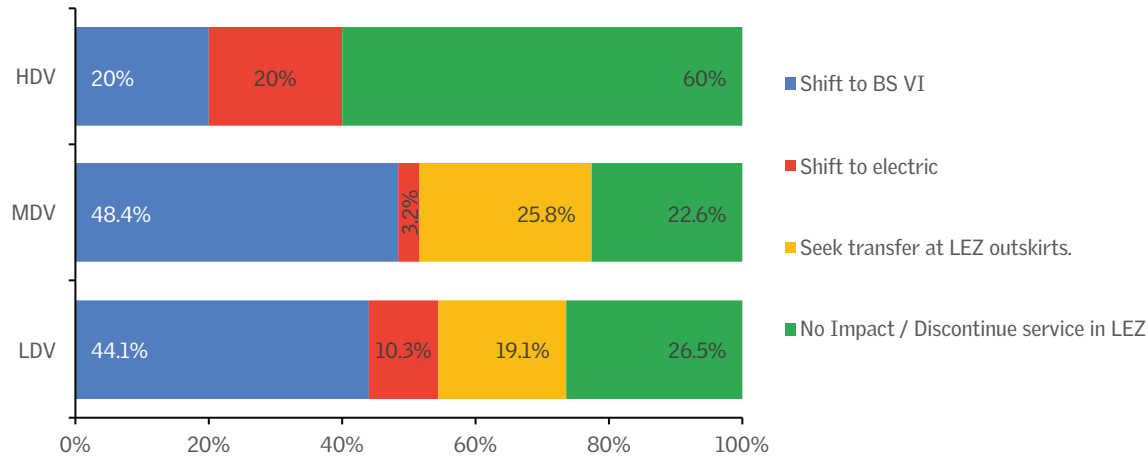
Good service providers – Impact of policy scenario 1: Complete ban on BS-IV and older goods vehicles

Restrictions on all BS IV and older vehicles will lead to goods vehicles operators consider three options: 1) either switch to a LEZ compliant vehicle, 2) discontinue service in the LEZ area and work in other areas, or 3) utilise consolidation centres where goods are transferred from high-emission vehicles to compliant vehicles for final delivery.

MDV and LDV operators have shown interest in taking up the transfer option from a consolidation centre. About a quarter of MDV operators will seek transfer at LEZ outskirts, along with 19 per cent LDV operators.

Close to half of the MDV and LDV operators have stated that they will switch to a BS-VI vehicle while another 3 to 10 per cent have said they will switch to clean and electric vehicles.

Graph 26: Willingness to shift among different goods vehicle segments under policy scenario 1



Prepared by CSE based on primary data

Interestingly, HDV operators have also shown interest in switching to electric vehicles (if possible). However, 60 per cent of them have said that a complete ban on older vehicle will not impact them severely. They will discontinue their services in the LEZ area.

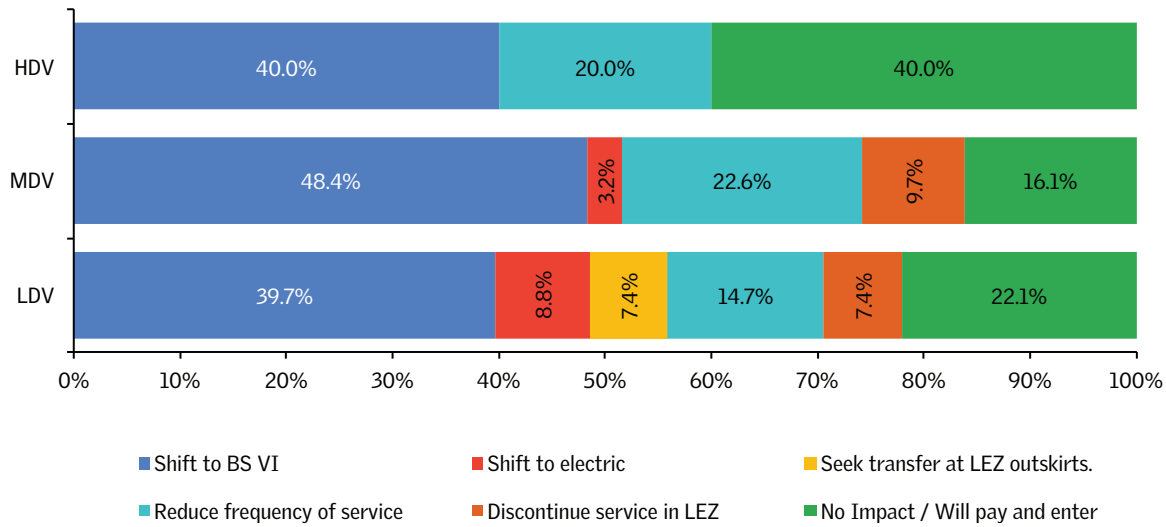
Goods service providers – Impact of scenario 2: Access charge to enter LEZ

With respect to the access charges, irrespective of vehicle category, around 40 to 48 per cent goods operators including LDV, MDV and HDV, want to shift to LEZ compliant modes (preferably BS-VI or EV). Although around 15 to 23 per cent operators agreed that access charge will impact their business in terms of reduced business leads to reduced number of entries. A dominant share (i.e., 40 per cent) of HDV operators have shown the rigidness of not changing the vehicles and ready to pay the entry price.

Only 16 per cent MDV operators and 22 per cent LDV operators have said this development will not have any impact on them and they are ready to pay charges.

In this scenario, the need for transfer stations also goes down significantly. The recurring cost of the entry fee is perceived as more manageable compared to the logistical and operational challenges of transferring goods.

Graph 27: Willingness to shift among different goods vehicle segments under policy scenario-2



Prepared by CSE based on primary data

While asking about their absolute maximum cost within which they will be willing to pay to enter the LEZ area, following responses were observed: (see Graph: Good services: willingness to pay access change).

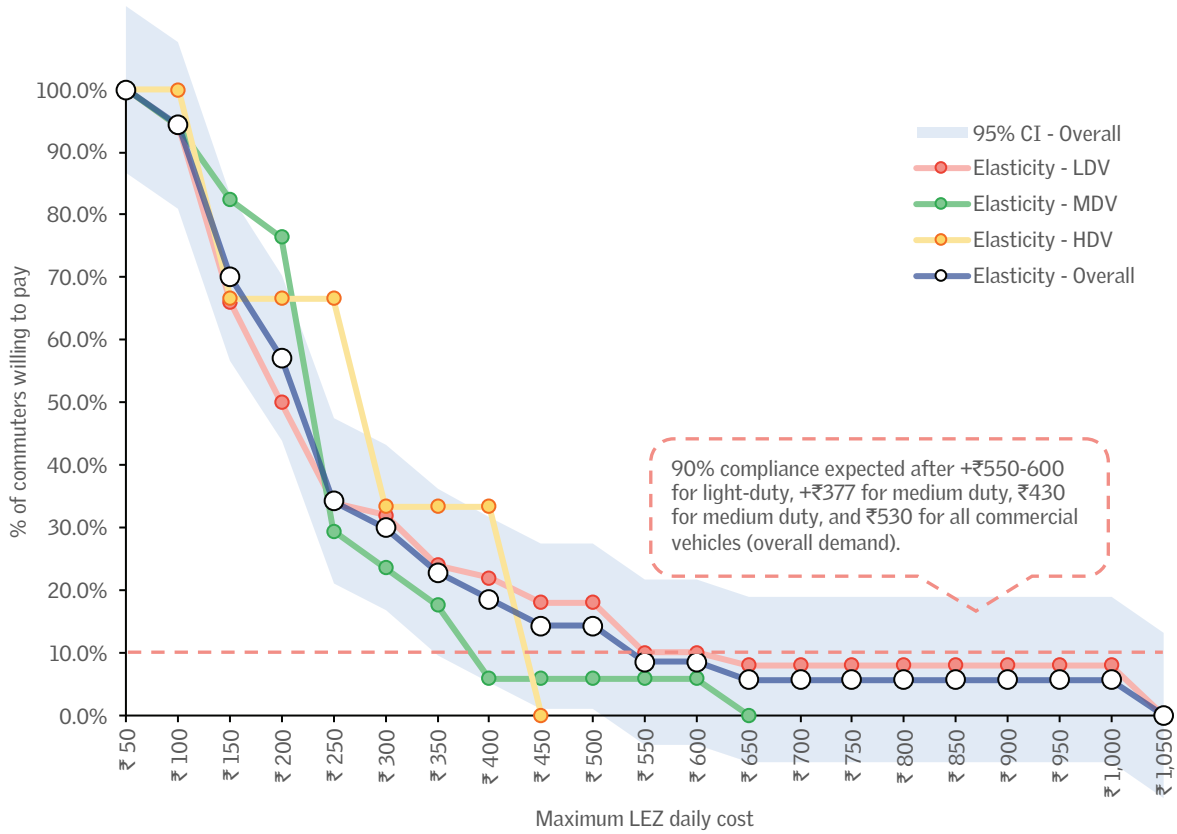
- Average critical cost the LDV operators can pay is Rs 267, at which 66 per cent compliance is expected. HDV users can pay the average critical cost of Rs 222, with an expected compliance rate of 36 per cent. HDVs can pay Rs 250 and compliance expected is 33 per cent.

- Overall, representing all commercial vehicles, the average critical cost is Rs 252 and compliance expected is 68 per cent. The 95 per cent confidence interval at this price is 54.8 to 81.3 per cent.

- For LDVs, MDVs and HDVs, 90 per cent compliance can be expected after Rs 550-600, Rs 377 and Rs 430 respectively. The "overall" curve, gives a 90 per cent compliance expectation after Rs 530.

The current business of most operators is not yet ready for an LEZ, as most operators claimed they do not have any plans to upgrade their vehicles yet. Most others either have plans to procure a BS VI vehicle, or are in the process of adding BS VI vehicles to their fleet. No HDV operator claimed they have plans to upgrade to electric or already have an electric fleet.

Graph 28: Willingness-to-pay curve among different goods vehicle segments



Prepared by CSE based on primary data

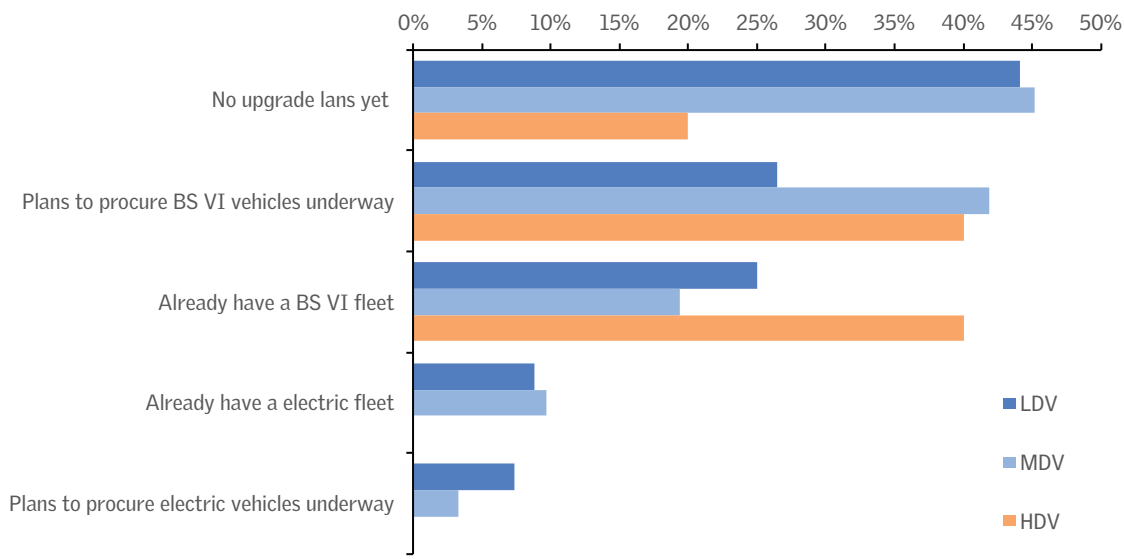
1) Shaded areas are 95 per cent confidence intervals;
2) It must be noted that these prices are over and above the current daily journey costs of commuters which needs to be paid every time to enter the LEZ.
3) In the context of low-emission zone pricing, compliance in Gabor-Granger method can be read as the percentage of population not agreeing with a particular price point, since it is expected that the share not willing to pay more than that amount. As an example, if only 10 per cent of the sample population agree with a particular fee amount, 90 per cent reduction in number of vehicles is likely entering the LEZ area, meaning a 90 per cent compliance

Most operators demand financial incentives, such as subsidies, tax breaks, and low-interest loans to help upgrade to complaint vehicles. As the vehicle load capacity increases from LDVs to HDVs, the share of operators asking for financial support also increases.

Another important support measure highly requested was exemptions for small businesses and phased implementation of the LEZ restrictions, with ample grace period to either switch their vehicles, or for choosing new business areas.

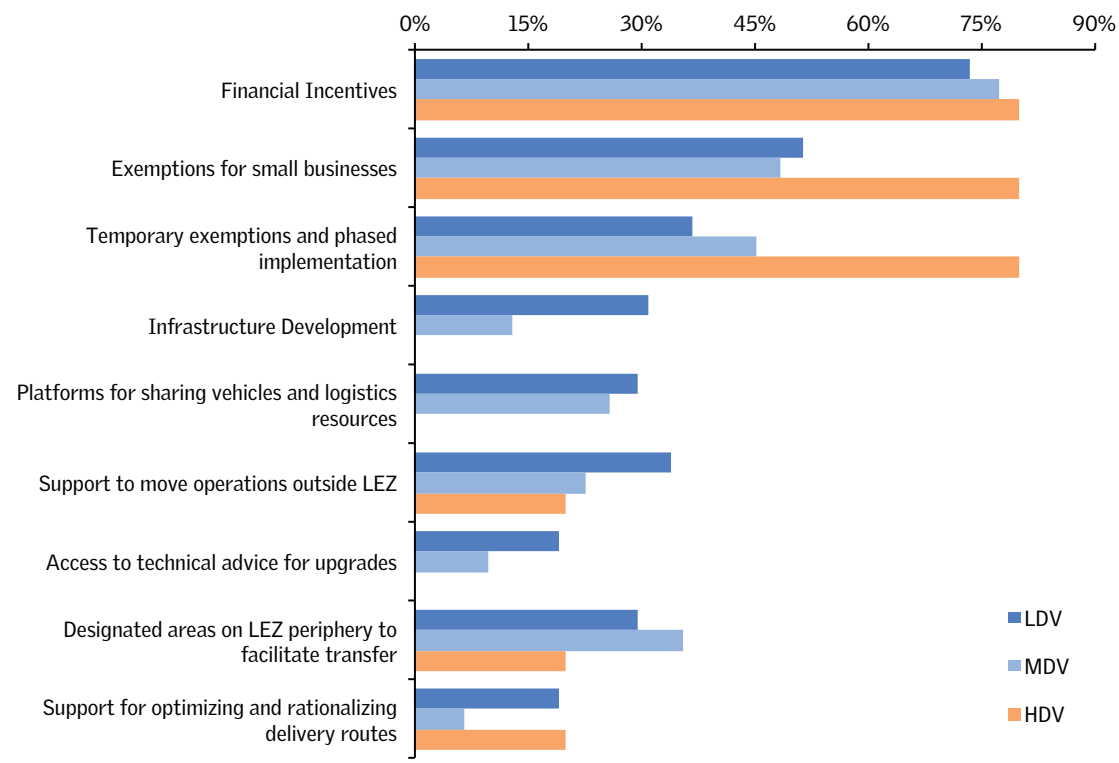
Infrastructure development was highlighted as a priority, although mainly by

Graph 29: Future plans regardless of LEZ among different goods vehicle segments



Prepared by CSE based on primary data

Graph 30: Support required to transition among different goods vehicle segments

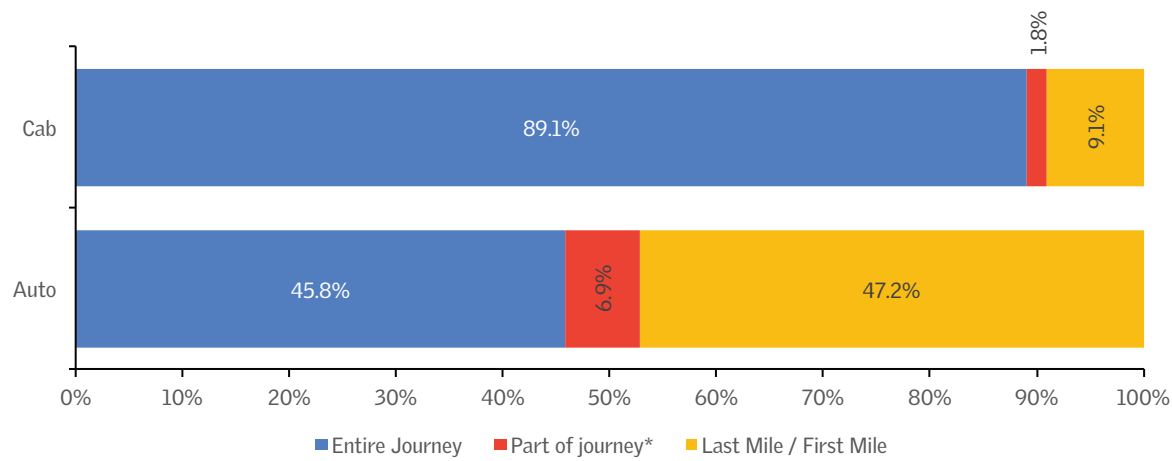


Prepared by CSE based on primary data

light-duty vehicle operators. Other requests included platforms for sharing vehicles and logistics resources, support to move operations outside the Low Emission Zone (LEZ), and designated areas on the LEZ periphery to facilitate transfer, with varying levels of support across vehicle types. Access to technical advice for upgrades and support for optimizing and rationalizing delivery routes were less emphasized overall.

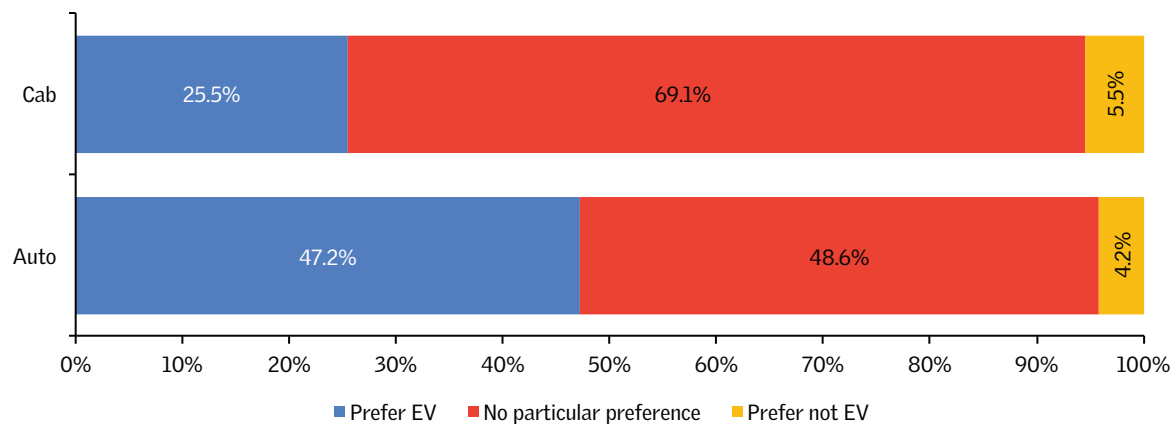
Perception analysis

Graph 31: Portion of journey covered using para-transit by commuters



Prepared by CSE based on primary data; *Part of journey does not include first / last mile.

Graph 32: Preference for electric vehicle among commuters using para-transit



Prepared by CSE based on primary data
Prefer EV: If option given, will prefer EV; Prefer not EV: If option given, will not prefer EV; No particular preference: Do not have a preference as long as need is met

Intermediate public transport (auto and cab) user

Around half of the respondents claimed that they mainly use auto as their first and last mile journey.

A very small fraction of commuters uses cabs as first/last mile modes, whereas almost half of the auto users use it as their first/last mile mode. This can be attributed to the lower prices and lower waiting times for auto-rickshaws during peak hours. Most cab users use it for the entire journey. Both para-transit mode had poor representation in terms of mid-journey usage.

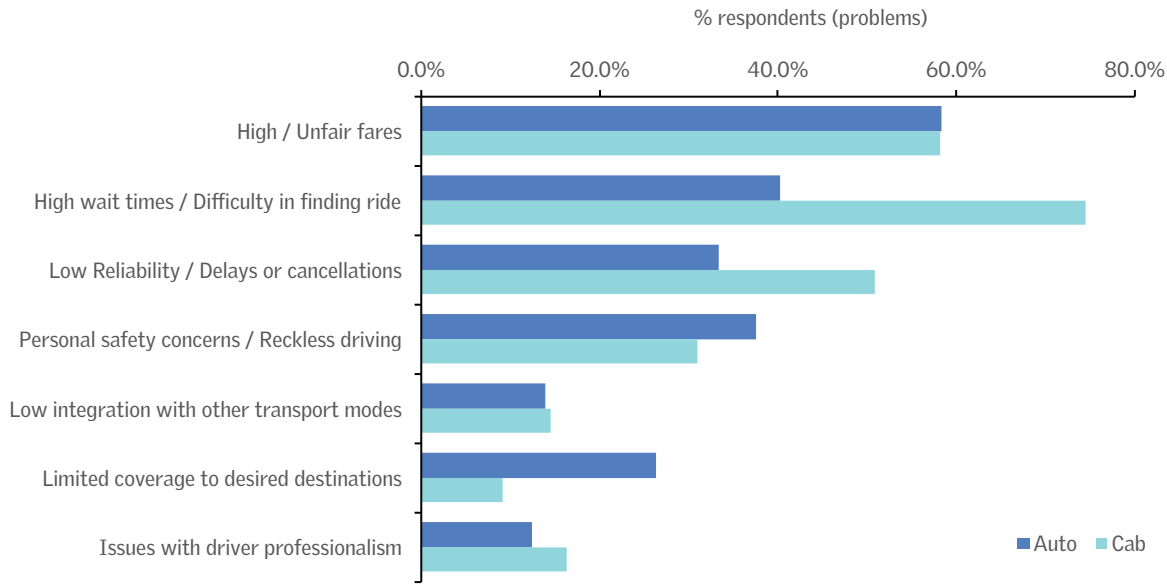
Among auto users, 47.2 per cent prefer using an electric auto if an option is given to use, and 48.6 per cent say there are no such preferences as long as the need is being met. A higher number of cab users are neutral towards the choice, with 69.1 per cent having no preference.

Auto-rickshaw users emphasized that electric auto-rickshaws are a significantly superior option in the market compared to CNG variants, citing their larger legroom and the absence of vibrations and noise from CNG engines, which contributes to a much smoother ride experience. For cab users, the difference in preference is less pronounced, because as far as cars go, the passenger experience for both a CNG car and an EV car is roughly the same. Hence the greater preference for electric vehicles in the auto-rickshaw segment.

The primary challenge reported by auto-rickshaw drivers is the issue of high or unfair fares, largely due to the absence of a standardized fare system which allows drivers to charge arbitrary rates for trips. Additional challenges identified by most auto-rickshaw users include high wait times or difficulty in finding rides during peak hours, safety concerns, and refusals by drivers to take passengers.

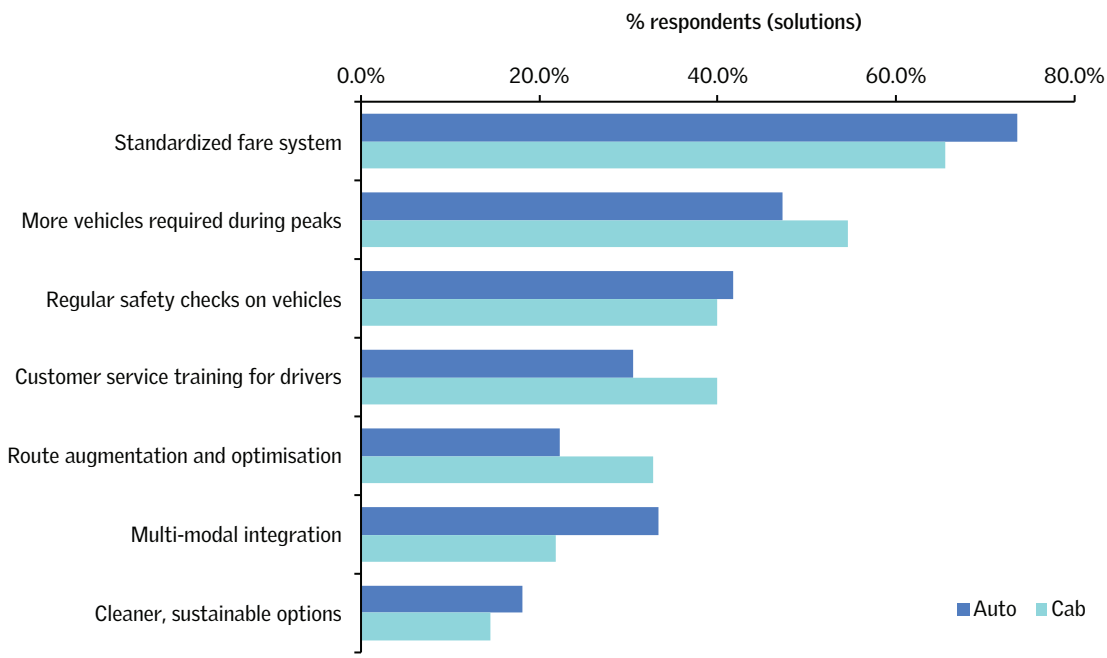
For cab users, the most significant problem is high wait times or difficulty in finding rides, particularly during peak hours. Almost all cab users surveyed were using app-based cab rental services and reported that high wait times, along with refusals and cancellations, were common issues during peak times. Additionally, cab users highlighted surge pricing during peak hours as a major challenge.

Graph 33: Challenges in the current para-transit regime



Prepared by CSE based on primary data

Graph 34: Solutions to improve para-transit according to commuters



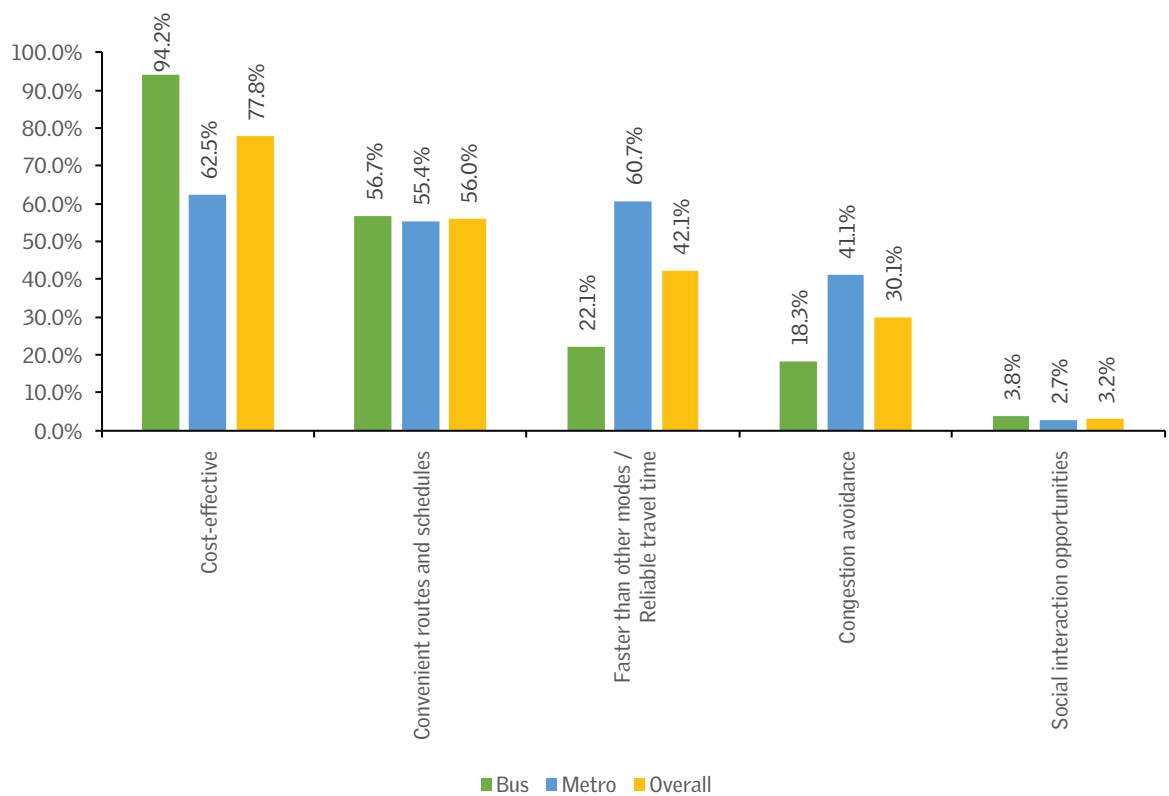
Prepared by CSE based on primary data

There is a strong demand for the implementation of a standardized fare system, with 74 per cent of auto-rickshaw users and 66 per cent of cab users supporting this measure. Both groups expressed an urgent need for more vehicles to be available during peak hours to reduce wait times and delays. There is also a clear call for regular safety and maintenance checks of vehicles to address safety concerns and improve service reliability.

Public transport (Metro and bus) users

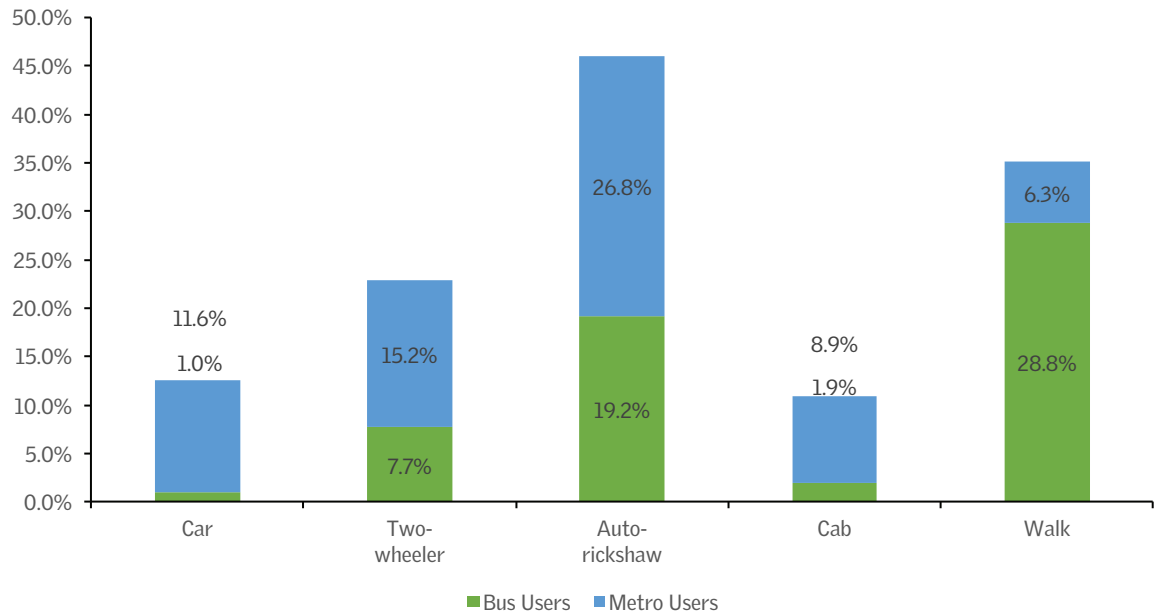
The largest share of the public transport user sample, at 44 per cent, is for office/ business/ work/ service purposes, indicating that nearly half of the PT trips are work-related. Social/recreational trips comprise 31.5 per cent, showing significant use of PT for leisure activities as well. It is important to note that majority of the trips (except recreational and others) are regular trips to the NDMC area that is about 63.4 per cent of the trips overall.

Graph 35: Reasons to prefer public transport over other modes



Prepared by CSE based on primary data

Graph 36: Modes used by public transport users other than bus or metro to commute to study area



Prepared by CSE based on primary data

that 37 per cent of public transport users travel daily. 26.4 per cent use it several times a week, while 15.7 per cent travel monthly. Weekly users account for 6.5 per cent, and 14.4 per cent use public transport rarely. This indicates a high daily and frequent usage among PT users at 69.9 per cent. Most of these frequent users are entering NDMC for non-discretionary trips like employment, education or medical purposes.

A significant portion of both bus (94.2 per cent) and metro (62.5 per cent) users consider cost-effectiveness a major factor for using public transport. Hence, implementing an LEZ might push more people to use public transport due to potential restrictions or increased costs associated with private vehicle usage in the zone. With more people likely to opt for public transport, there could be an increased demand for buses and metro services that are perceived as convenient and offer extensive route coverage.

Metro's speed and reliability are highlighted by 60.7 per cent of its users. An LEZ could further enhance metro usage as private vehicles face restrictions, leading to an increase in demand for faster and reliable transport options like the metro. Since 41 per cent of metro users appreciate its ability to avoid congestion, these

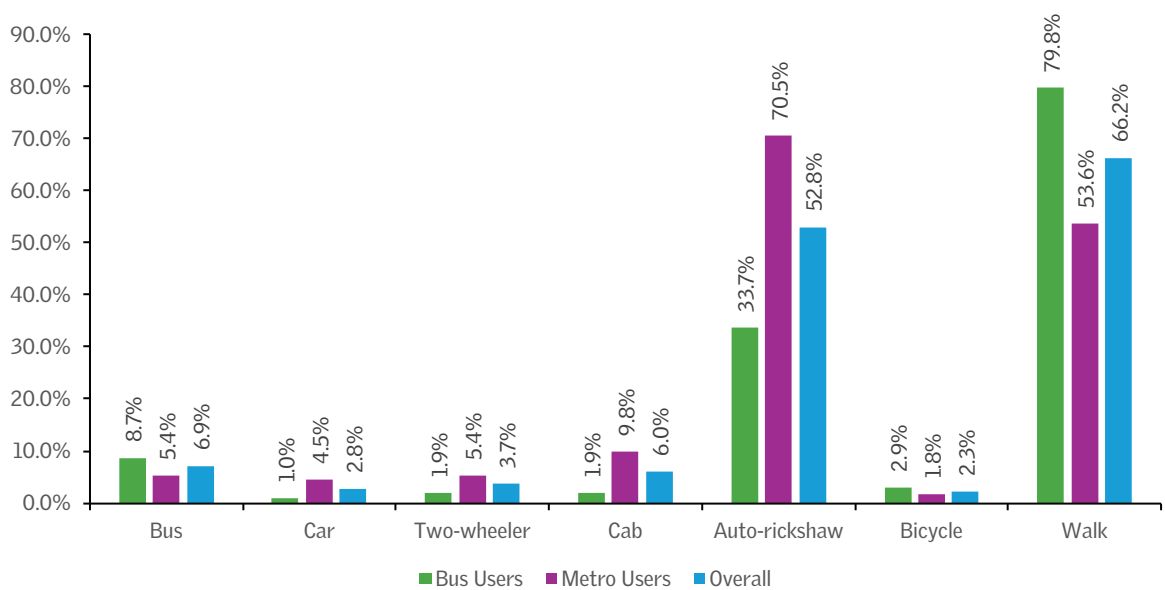
features may become more attractive post LEZ implementation, making metro a preferable option over buses for these individuals.

About 41.3 per cent bus users and 31.3 per cent metro users stated that they do not use any other mode to commute to the NDMC area. A significant portion of metro users (15.2 per cent use two-wheelers and 12 per cent use cars) and a smaller portion of bus users (7.7 per cent use two-wheelers) rely on private vehicles as alternate modes. Metro users also have a notable reliance on cabs (8.9 per cent) and auto-rickshaws (26.8 per cent), which might see reduced usage due to LEZ restrictions.

A significant proportion of bus users (29 per cent) already consider walking as an alternative mode, which suggests that improved pedestrian infrastructure could further encourage walking. However, only 6.3 per cent of metro users consider walking, indicating room for improvement in pedestrian connectivity to metro stations.

The implementation of LEZ in the NDMC area is likely to lead to a shift in commuter behaviour towards increased use of public transport and non-motorized modes like walking and cycling. To maximize the benefits and address current challenges, it is crucial to improve last-mile connectivity, enhance pedestrian infrastructure,

Graph 37: Modes used by public transport users for first/last mile



Prepared by CSE based on primary data; Note: Bus was chosen as last mile/ first mile mode by metro users.

integrate multi-modal transport solutions, and promote non-motorized transport.

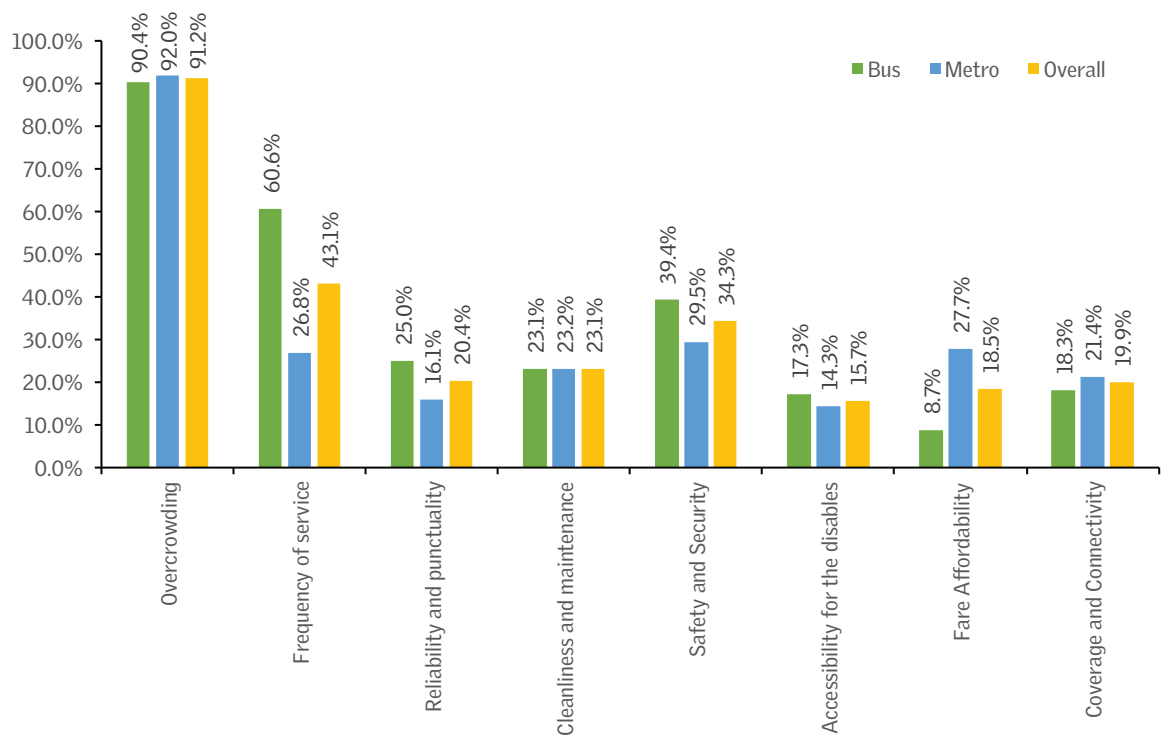
Public transport is also required to be integrated with reliable last mile and first mile connectivity options to ensure compliance with LEZ implementation. Users have indicated that walking is the most common mode used for first/last mile connectivity, with 66.2 per cent of total respondents (79.8 per cent bus users and 53.6 per cent metro users) choosing this option.

Auto-rickshaws are used by 52.8 per cent of respondents (33.7 per cent bus users and 70.5 per cent metro users), indicating a significant dependence on this mode for short first mile/last mile trips within the LEZ area, especially by metro users.

Cabs are used by 6.0 per cent of the respondents (1.9 per cent bus users and 9.8 per cent metro users), showing a moderate preference for this mode, particularly among metro users.

Cars and two-wheelers are less commonly used, with a combined usage of 6.5 per

Graph 38: Primary concerns regarding public transport service according to commuters



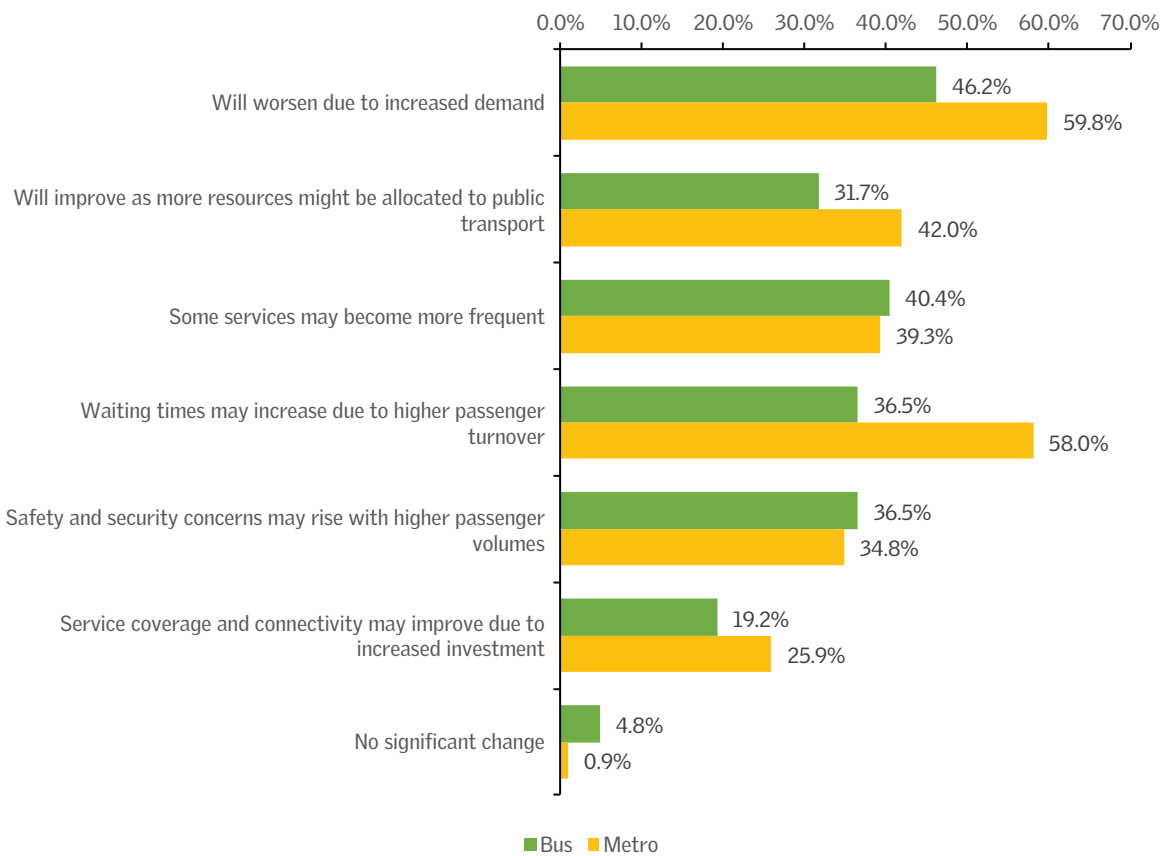
Prepared by CSE based on primary data

cent (2.8 per cent cars and 3.7 per cent two-wheelers), reflecting a preference for other modes over personal vehicles within the LEZ by the public transport users. Bicycles, however, are the least used mode, with only 2.3 per cent of respondents (2.9 per cent bus users and 1.8 per cent metro users) opting for them.

Given the high percentage of people walking, improving sidewalks, pedestrian crossings, and ensuring safe walking paths could further encourage this mode, making it safer and more attractive. Also, since auto-rickshaws are widely used, there could be initiatives to integrate them more effectively with public transport hubs, ensuring easy availability and regulated fares. The low usage of bicycles suggests potential for growth. Implementing dedicated cycling lanes, bike-sharing programs, and secure parking can promote cycling as a viable first/last mile option.

Almost all public transport users prioritise overcrowding as a major concern with

Graph 39: Impact of low-emission zone implementation on public transport service



Prepared by CSE based on primary data

the current service. 60 per cent bus users indicated that frequency of service of buses is poor, while for metros, the share is much smaller at 27 per cent. Metro's perception also performed better in safety and security, accessibility for differently-abled and reliability of the service.
However more metro users than bus users feel that fare affordability is an issue for the service. Same goes for coverage and connectivity of the service.

About 60 per cent metro users fear that the service will deteriorate after LEZ implementation due to increased demand. Share of bus users sharing the same sentiment is much smaller. A large number of metro users (58 per cent) also stated that LEZ can cause increase in waiting times due to increased passenger turnover. On the other hand, about 40 per cent metro and bus users both are optimistic, as increased demand and ridership for them can mean increased efforts towards service improvement.

Private electric vehicle (two-wheeler and car) owners

Among private electric vehicle owners, 72 per cent of the sample are car owners and 28 per cent are two-wheeler owners.

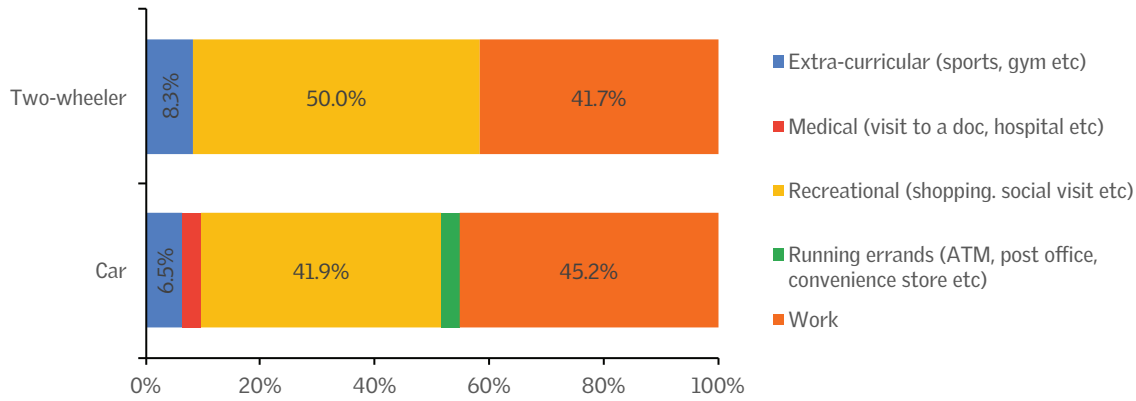
41 per cent electric two-wheelers and 45 per cent electric cars are used for work trips. The share of recreational trips in the sample in also high for both the segments, considering the nature of the study area.

Majority of both two-wheelers and cars charge their vehicles at the origin, 83.3 and 87.5 per cent respectively.

Among car owners, range anxiety is more prevalent as a challenge of driving their vehicle in Delhi, however if only NDMC area is considered, share of two-wheeler owners for range anxiety as a hinderance is higher than cars. This clearly states there is a need to increase the number of two-wheelers charging stations in the LEZ area as an immediate measure before LEZ implementation. Two-wheeler owners also highlight performance issues in extreme weather, difficulty in finding reliable service centre and compatibility issues at different charging stations as major challenges of owning an electric vehicle in Delhi.

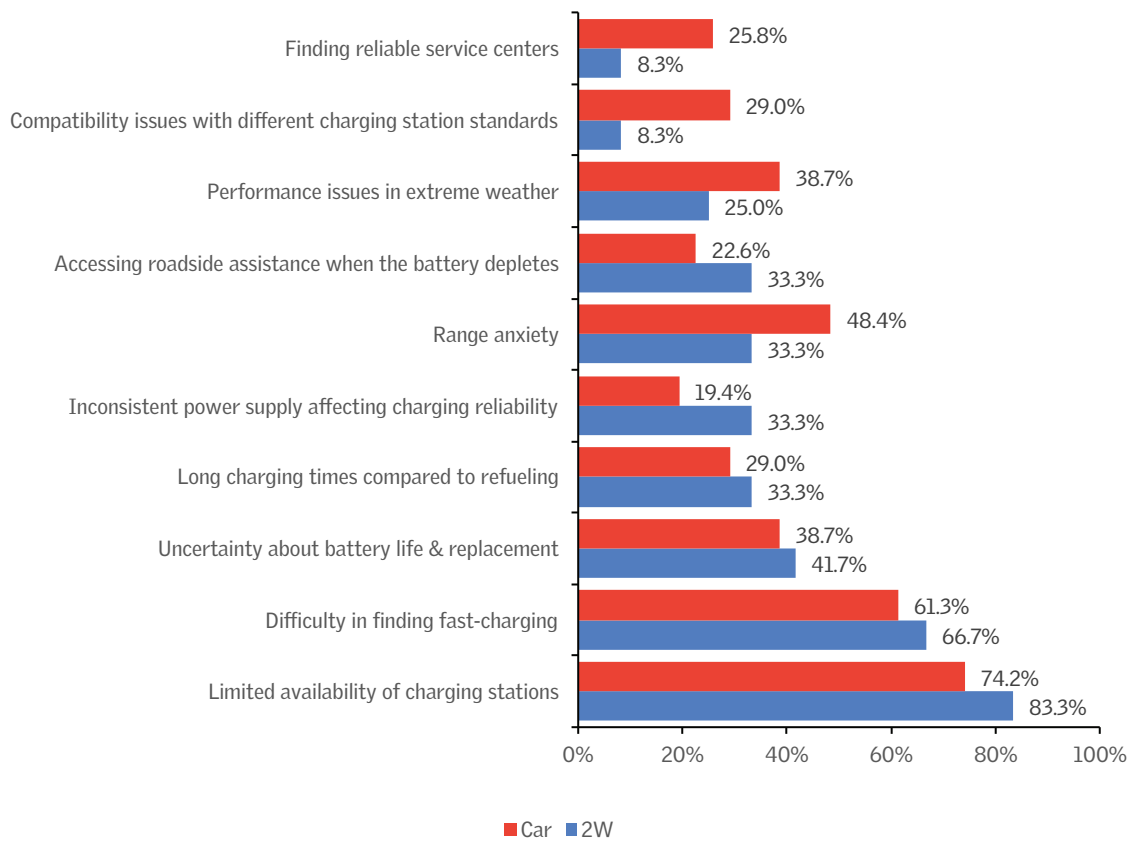
Limited availability of charging stations is the biggest concern for both two-wheeler and car owners when driving in either Delhi or specifically in the NDMC area.

Graph 40: Purpose of trip to study area among private electric vehicle users



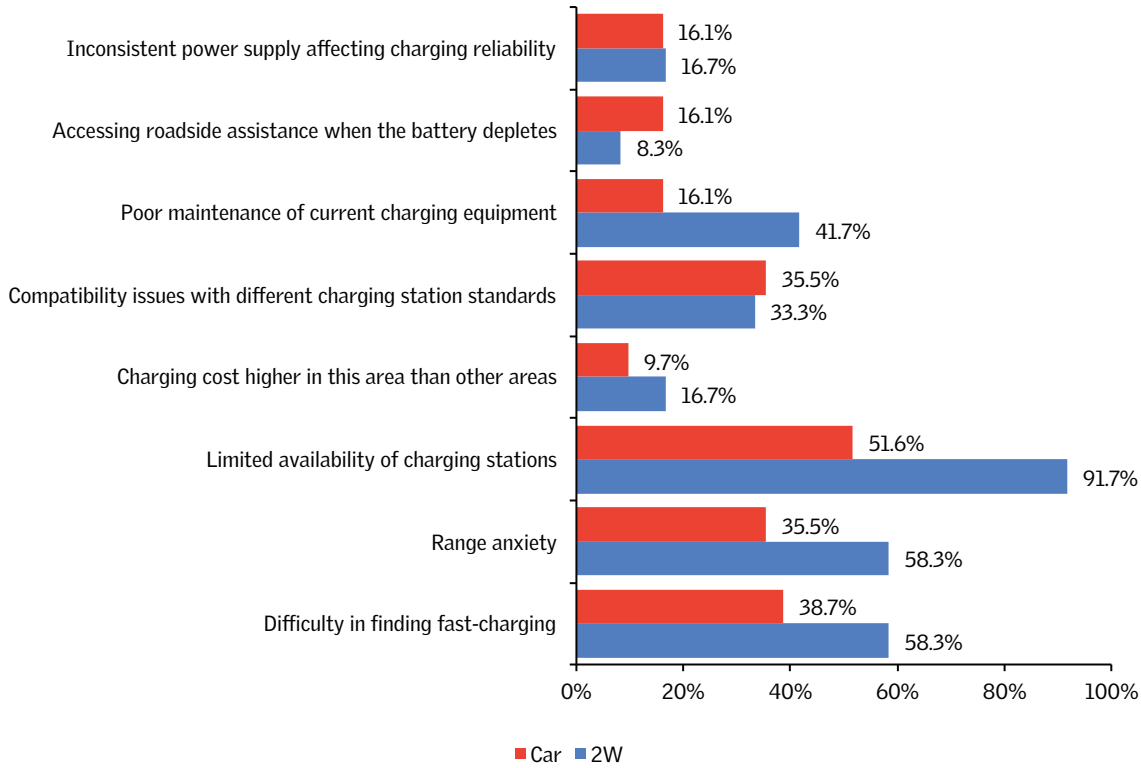
Prepared by CSE based on primary data

Graph 41: Challenges of owning an electric personal vehicle in Delhi



Prepared by CSE based on primary data

Graph 42: Challenges of operating an electric personal vehicle in the study area

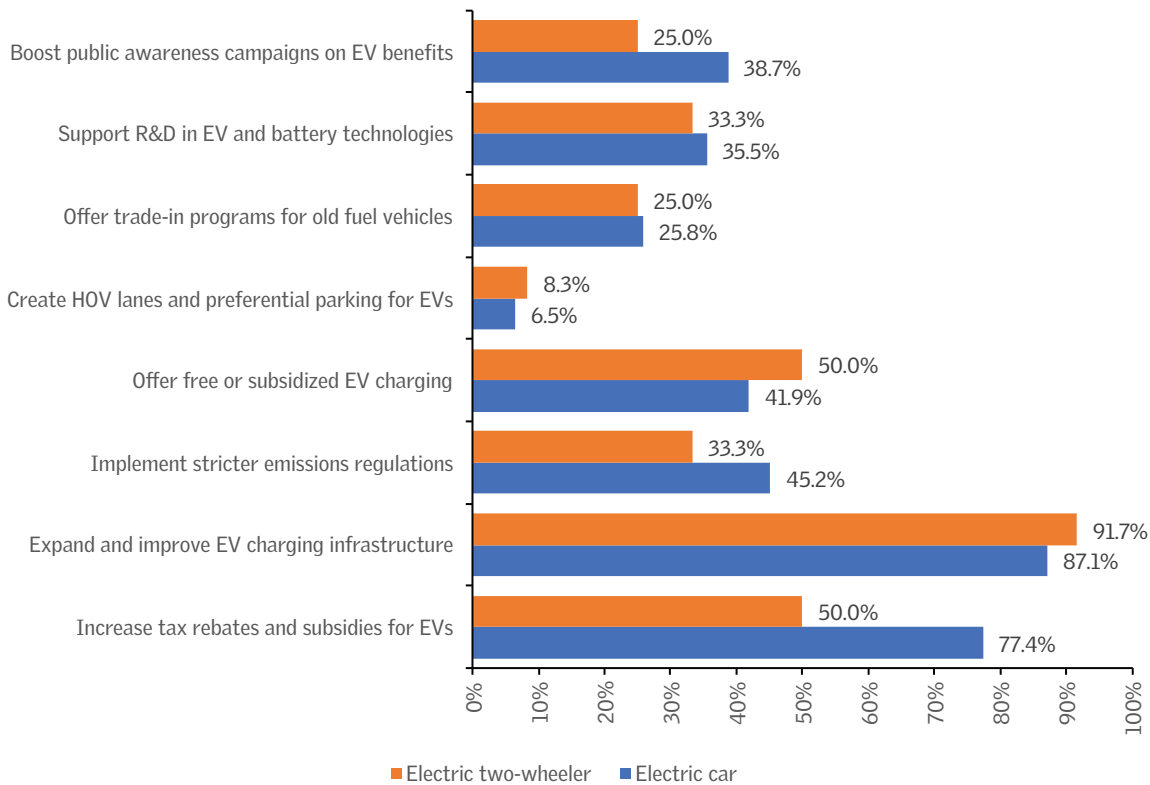


Prepared by CSE based on primary data

Other prominent concerns of owning an electric vehicle in Delhi were difficulty in finding a fast-charging station for longer trips, uncertainty about battery life and longer charging times compared to refuelling.

As far as NDMC area is concerned specifically, the additional biggest challenges faced by two-wheeler owners are poor maintenance of charging equipment, and compatibility issues at different stations. Car owners think charger compatibility, lack of fast chargers, inaccessible road-side assistance when the battery depletes, are some of the additional concerns which need to be addressed in the LEZ area.

Graph 43: Support required to drive electric vehicle adoption according to private EV owners



Prepared by CSE based on primary data

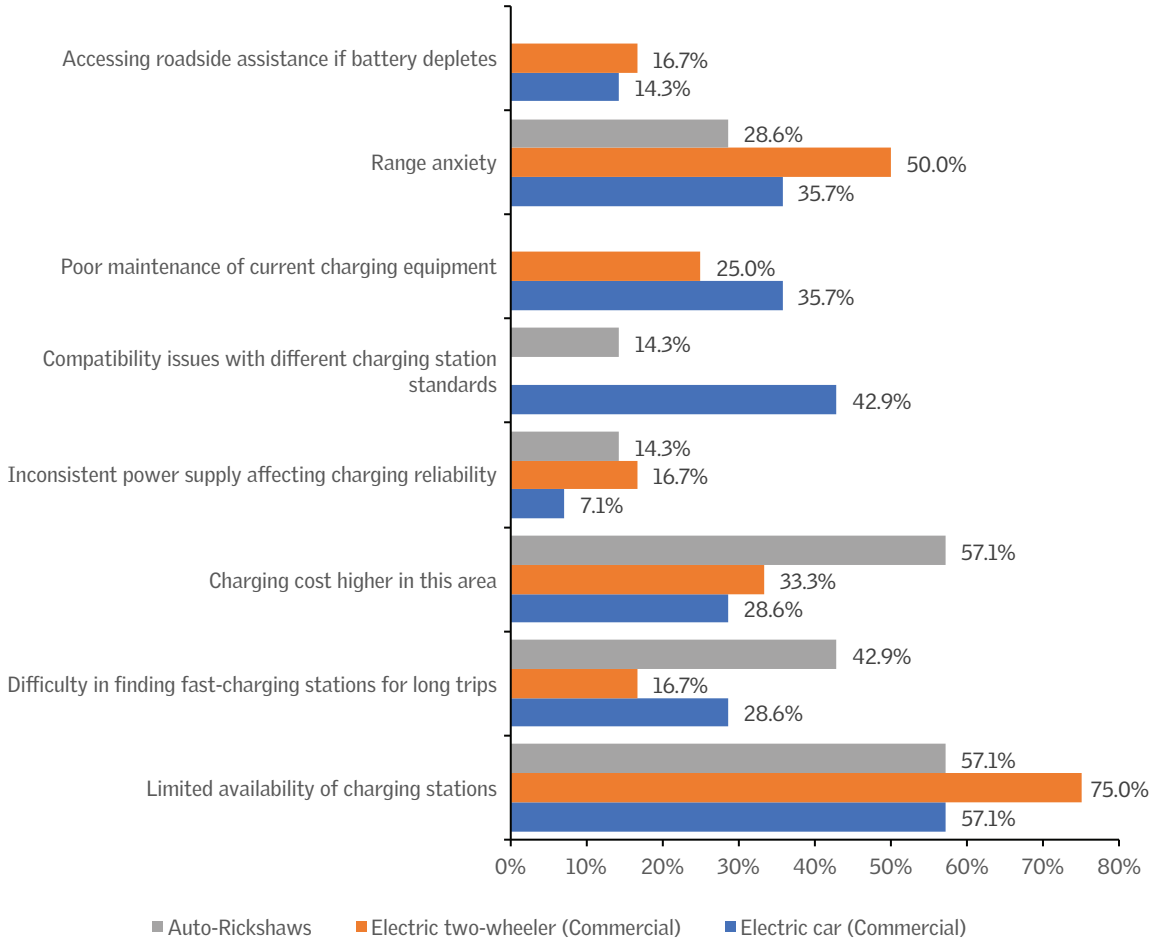
The highest priority support needed by two-wheeler users from the government to support LEZ implementation are expansion of charging network, increasing fiscal purchase incentives, implement stricter emission norms, and boost awareness and research in battery technologies. Aside from the aforementioned support tools, car owners have also given priority to subsidised charging and preferential parking and lane access.

Commercial electric vehicle (two-wheeler, auto and cab) operators

The commercial electric vehicle sample is divided into two-wheelers (36 per cent), cabs (42 per cent), and auto-rickshaws (21 per cent).

Among commercial electric two-wheeler segment, 75 per cent of the sample are

Graph 44: Challenges of operating an electric commercial vehicle in the study area



Prepared by CSE based on primary data

food delivery personnel, 16.7 per cent are grocery delivery personnel or couriers, and the rest 8.3 per cent are passenger drivers.

Among cabs, 78 per cent worked for cab aggregators with an all-electric fleet (such as BluSmart), and the rest worked for companies with a partial electric fleet.

In case of both two-wheelers and cabs, 50 per cent charge their vehicle at company grounds. 14 per cent cabs and 8.3 per cent two-wheelers charge exclusively during trips, and 35 per cent and 41 per cent cabs and two-wheelers respectively charge both at company grounds and during trips.

Only 28.7 per cent auto-rickshaws are rented, and rest are all owned by the drivers. Almost all auto-rickshaw drivers charge their vehicles during trips.

Among two-wheelers limited availability of charging options, range anxiety and charging cost at stations in the LEZ area are top three challenges faced in the area. For cabs, limited charging options, charger compatibility issues at different stations, range anxiety and poor maintenance of charging equipment are the major concerns. For auto-rickshaws, limited charging, high cost of charging and range anxiety are the major concerns.

Across segments drivers believe that increased tax rebates, fiscal purchase incentives and expansion of charging network can help the commercial electric segment to transition within the LEZ area. Additionally, two-wheeler drivers feel stricter emission norms, and free or subsidised parking can help. Cab drivers emphasised on the need for trade-in programmes for old fuel vehicles to increase demand and compliance within LEZ. Auto drivers suggest subsidised parking will help auto-drivers further.

SECTION 4: The way forward

LEZ is an important enabler to connect policies with ground implementation of mobility and electrification strategies. Several mobility and fleet electrification policies have evolved but these require an integrated and aligned approach to transform the urban spaces. This strategy has direct bearing on the commuters and communities in targeted zones.

While solutions related to technology, transportation and design are possible, their adoption within given socio-economic context is challenging. As its effectiveness depend on the wider acceptance by the community it is necessary to understand the disproportionate impacts on different socio-economic groups to identify the appropriate mitigation and support action.

The assessment brings out that potentially LEZ can influence technology and commuting choices – but this will have to be enabled at individual and community level.

Harsher restrictions including outright ban on entry of older vehicle technologies can have stronger impacts on choices as such measures do not provide options. But this may be more politically difficult to push through. This may also be the cause of public resistance jeopardizing the entire strategy.

There is also a sizeable inelastic section among the personal vehicle users who despite the harsher measures on entry and exit from the LEZ may continue to stay on with their personal vehicle usage and also resist change. This requires community oriented inclusive strategies.

Take steps

LEZ is an important enabler to connect policies with ground implementation of mobility and electrification strategies. Several policies on fleet renewal, fleet electrification and mobility management have evolved. But these require an integrated and aligned approach to transform the urban spaces. The LEZ strategy has direct bearing on the commuters and communities in targeted zones.

While solutions related to technology, transportation and design are possible, their adoption within given socio-economic context is challenging. As its effectiveness depend on the wider acceptance by the community it is necessary to understand

the disproportionate impacts on different socio-economic groups to identify the appropriate mitigation and support action.

The assessment brings out that potentially LEZ can influence technology and commuting choices – but this will have to be enabled at individual and community level by improving the overall service level of public transport services and also cushioning the cost of makeover for a section of the community.

Harsher restrictions including outright ban on entry of older vehicle technologies can have stronger impacts on choices as such measures do not provide options. But this may be more politically difficult to push through. This may also be the cause of public resistance jeopardizing the entire strategy.

There is also a sizeable inelastic section among the personal vehicle users who despite the harsher measures on entry and exit from the LEZ may continue to stay on with their personal vehicle usage and also resist change. This requires community oriented inclusive strategies.

Take steps

Expand the scope of the pollution hotspot plans to create low emissions zones for co-control of vehicular pollution: While the ongoing hotspot clean air plans are addressing the dispersed sources of pollution like dust and open burning, it is necessary to build on that to create a cohesive LEZ to address specifically the vehicular pollution and toxic exposures to reduce health risks for communities.

Delineate zones for creation of LEZ: Municipal corporations may be mandated to identify the potential zones for implementation of LEZ. The New Delhi Municipal Council and the Municipal Corporation of Delhi may identify the ward-wise zones that can implement LEZ. To lead the process, it is possible to identify the NDMC area that has several locational advantages to start the LEZ programme.

Notify LEZ policy and regulatory framework for implementation: It is necessary to frame and notify the LEZ policy along with the strategy for implementation. This needs to outline the guidance framework for the implementing agencies.

Phase in LEZ implementation for the targeted zone

- **Phase 1**: All area management plans need to converge for implementation in specified zones. Combine implementation of the parking management area plans (PMAP) along with variable parking pricing policy across all

neighbourhoods of the zone; initiate pedestrianization of key commercial areas; introduce access-based charges for entry of vehicle with higher charges for pre-BS IV vehicles; make entry of electric vehicles free, charge a nominal entry fee for BSVI vehicles and that may increase after the introduction of BSVII vehicles. Eliminate end-of-life vehicles from the zone and begin with time restricted movement for targeted vehicles. Simultaneously, enhance public transport services and accessibility of the zone.

- **Phase 2**: In the second phase while all the provisions of the phase one will continue, the strategy will be ramped up by restricting pre-BS-IV vehicles. Introduce more direct fiscal and non-fiscal incentives for promoting electric vehicles and apply polluter pay principle. Scale up electric vehicle charging infrastructure in the zone.

Addressing differentiated impacts on income groups: Moderate to high economic impacts on different income groups are expected in personal vehicle segments. This is particularly so in the policy scenario one that aims to ban entry of pre-BSIV vehicles, scale up electric vehicle requirements to be in the zone and encourage use of public transport.

It is evident from the survey that the economically vulnerable groups like old people, small income self-employed categories may require some fiscal support for the shifts to cleaner technology.

The overall assumption for the general category of owners of personal vehicles is that they need to move to public transport for primary trips and mobilise their own investments if purchase of new vehicles is required. However, a targeted and purposeful fiscal incentive can be considered if old vehicles are encouraged to be replaced with electric vehicles.

Commercial vehicles needs interest subvention and fiscal incentives to shift to electric vehicles. Moreover, align the LEZ policy with the city-wide scrappage policy and scrappage incentives and also incentive programmes for fleet electrification to help absorb the cost of transition in the zone. Under the current scrappage policy, the state governments are required provide tax incentives for scrappage of targeted vehicle. This can be further expanded in scope for one time support to lower income households, and small businesses.

Creation of dedicated funds from entrée fees and parking fees implementation of LEZ and infrastructure development: Dedicated fund from parking

management area plans and the access fees to enter the LEZ can help to fund the cost of transition, and the fiscal strategy to help people to tide over to adjust to the LEZ requirements. Earmark revenue for local area improvement and to regenerate infrastructure, connectivity and improve the service levels. The municipalities need to plan the enforcement infrastructure including the gantry, cameras and IT system for access fee collection, staffing for enforcement, and other support systems. A dedicated fund can help to meet its costs as well as that of incentives for replacement of vehicles and improvement in public transport services.

Augment public transport accessibility and service level of LEZ: Restrictions in LEZ need to be supported by enhanced public transport services as per the MoHUA benchmarks and safe walking and cycling access in the targeted zone. This can help to reduce traffic load, improve quality of transit and experience of commuting, EV charging network, among others.

Leverage LEZ to accelerate fleet electrification: The perception survey has brought out that even though the preference for BS6 compliant cars is high among the car owners, the preference for electric cars is also quite substantial – 20 per cent in the higher income category, and 11-13 per cent in relatively lower income groups. Among the two-wheeler owners there is a stronger preference for electric two-wheelers in nearly all income categories. Fee entry into LEZ and supported by charging infrastructure, free and preferential parking and higher charges for internal combustion vehicles can encourage more rapid shift towards electric vehicles.

Upgrade on-road emissions monitoring with the help of remote sensing measurements for efficient identification of grossly polluting vehicles. Real world data on on-road emissions performance can help to inform the strategy development and also enable implementation. Such evidences can also help to build public support for the LEZ initiative.

Design enforcement and compliance strategy: This will be a combination of regulatory and fiscal action with a legal back up.

Public campaigns and awareness on the benefits of LEZ will be a critical entry point. Engagement with communities and the small business will be crucial to build public support. It is necessary to demonstrate the benefits of the initiative for each of these groups and how the cost of change can be tide over.

LEZ implementation requires strong interface with city-wide strategy for public transport improvement and fleet electrification: LEZ implementation will have cascading effect on the larger communities beyond the LEZ that will be accessing the zone from outside. Moreover, transportation options and multi-modal integration need a scalable infrastructure across the city to connect origin and destination of masses efficiently. This requires a serious attention.

The advantage of the LEZ approach is that it can integrate multiple strategies to achieve both vehicle technology transformation and mobility transition. This can combine fleet renewal for quicker adoption of clean, energy efficient, and zero emissions electric vehicles. At the same time it can enable scalable, integrated, connected and reliable public transport system and services; upscaled network of walking and cycling infrastructure and efficient last mile connectivity; reduce automobility; promote compact urban form to keep jobs and home close; reduce distances, reduce demand for travel and vehicle usage; improve infrastructure for sustainable mobility; integrate the needs of urban poor and vulnerable groups and improve liveability of neighbourhoods.

LONDON

On 8 April 2019 the Mayor of London launched the world's first 24-hour Ultra Low Emission Zone (ULEZ) in central London.

It operates in conjunction with the London-wide Low Emission Zone (LEZ). LEZ covers the entire city of London; ULEZ covers 44% of the city area.

CHRONOLOGY

2008: LEZ introduced, targeting highly polluting diesel vehicles like lorries, buses, and coaches to reduce PM emissions.

2012: Large vans and minibuses included.t

2015: Standards for previously included larger vehicles tightened; now had to meet Euro IV standards for PM.

2019: ULEZ introduced in central London, covering same area as Congestion Charging Zone.

2019: Standards for buses increased to Euro VI.

2021: Emissions standards for heavy diesel vehicles (buses, coaches, lorries) upgraded to meet Euro VI (NOx and PM) standards.

accross Greater London. ULEZ expanded from central London to the inner London area bounded by the North and South Circular roads.

2022: Enforcement of stricter LEZ standards and higher charges for heavier vehicles begins, for non-compliance.

IMPACTS OF LEZ

60% reduction in non-compliant vehicles

46% reduction in NO2 (overall)*

56% reduction in NO2 (road-sides)**

41% reduction in PM2.5 across London

*46% in Central London, 21% in inner London
**At raod-side locations, 56% in Central London, 47% in inner London, 37% in Outer London

Source: Transport for London (TFL)

MILAN

Area B is an area where access is forbidden for polluting vehicles and for goods vehicles measuring more than 12 meters.

Area C is a congestion charge zone active in the city center of Milan, Italy, replacing Ecopass and based on the same designated traffic restricted zone.

CHRONOLOGY

2012: Area C introduced as a congestion charge zone in city center, limiting vehicle access during peak hours on weekdays.

2013: Area C made permanent following a trial given its effectiveness

2017: Area C regulations tightened; prohibiting diesel vehicles below Euro 4

2019: Further expanded its restrictions, banning petrol vehicles below Euro 1 and diesel vehicles below Euro 4

2019: Area B was introduced, significantly enlarging the scope of emissions control to include much of the city.

2021: Area B restricts access for diesel vehicles below Euro 4 on weekdays.
Area B restrictions were enhanced, with diesel vehicles below Euro 6 banned from entering on weekdays.

IMPACTS OF LEZ

30% reduction in non-compliant vehicles

31% reduction in NH3 in Area-C

10% reduction in NOx in Area-C

19% reduction in PM10 exhaust in Area-C

Before Area C, Europass inproved pollutant concentrations by 4% (PM10 annual average) and PM10 exceedences by 13%. Europass reduced CO_2 emissions by 9%, whereas Area C reduced CO_2 concentrations by 22%.

Source: Commune Di Milano, Urban Access Regulations (EU)

PARIS

The ring road (Boulevard périphérique), the Parisian streets outside the ring road, the Bois de Boulogne and Bois de Vincennes require Crit'Air 4, (an anti-pollution sticker.)

CHRONOLOGY

2015: Odd-even liscence plate restrictions on alternate days.

2015: Vehicles registered before 1997 banned from driving in the city center on weekdays between 8 a.m. and 8 p.m.

2017: LEZ introduced; older vehicles restricted

2019: Crit'Air sticker (a French air quality certificate) introduced. Vehicles without one banned.
Crit'Air 5 (most polluting banned within A86 motorway.

2019: The ban extended to include trucks and buses registered before 2006 during weekdays; two-wheelers registered before 2004 banned too

2021: Crit'Air 4 vehicles banned from the city on weekdays.

2022 and beyond: The city intends to ban Crit'Air 3 vehicles starting in 2025; total ban on fossil fuel by 2030 within LEZ

IMPACTS OF LEZ*

If Crit'Air 1 mandated by 2024,

76%-87%

reduction in passenger car NOx emissions (2016 baseline)

If banned vehicles shift to ZEVs,

91%

reduction in passenger car NOx emissions (2016 baseline)

*Since Paris LEZ is a fairly new project by the city, there are few credible sources that have explored the on-ground impacts of LEZ. Therefore, the above figures show the potential benefits of LEZ in Paris, projected by ICCT in 2020.

Source: GreenZones.EU, Urban Access Regulations (EU)

BEIJING

Beijing Low Emission Zone was implemented in 2003 within the 2nd Ring Road focusing on vehicles that cannot meet the Euro I emission standard (yellow label vehicles or YLVs).

The area was then expanded to the 5th Ring road in 2009, and further to 6th Ring road the same year.

CHRONOLOGY

2003: Initial restrictions began targeting Yellow Label Vehicles (YLVs) inside the Second Ring Road.

2008: First city in China to apply odd-even rule on license plates for two months prior to rhe Beijing Olympic Games

2009: YLVs restriction expanded to the Fifth Ring road. Later that year, expanded to the Sixth Ring road.

2010: Vehicles registered outside Beijing (non-local) need to apply for Beijing City Pass to enter Fifth Ring road.

2014: Non-local vehicle restrictions expanded to Sixth Ring road; Non-local trucks only allowed between 12 AM to 6 AM.

2015: YLVs prohibited to enter metropolital area.

2017: LEZ launched; restricting access to not only YLVs but also GLVs* such as heavy-duty freight vehicles with emissions below National IV Standards.

IMPACTS OF LEZ#

1.4%-2.2%
reduction in PM emissions

4.9%-7.4%
reduction in HC emissions

1.7%-1.9%
reduction in NOx emissions

7.8%-9.8%
reduction in CO emissions

* YLVs stand for Yellow Label Vehicles; GLVs stand for Green Label Vehicles.
# Little impact has been estimated due to LEZ restrictions, since these are not as strict in controlling higher polluting vehicles as in some European LEZs.

Source: WRI, TUMI, ICCT

Annexure 1: Details of surveys conducted for the impact assessment

Table 9: Details of non-compliant surveys:

Stakeholder groups	No of samples
Private two-wheeler owner	103
Private car owner	273
Auto operator	132
Auto user*	72
Cab operator	18
Cab user*	55
Freight service provider (LCV/HDV)	104
Total	630

Source: Primary data collected by CSE

Table 10: Details of perception surveys

Stakeholder groups	No of samples
Auto user*	72
Cab user*	55
Bus user	104
Metro user	112
Private e-2W user/owner	12
Private e-car user/owner	31
Commercial e-2W user/owner	12
Commercial e-car user/owner	14
e-Auto user	07
Total	419

Source: Primary data collected by CSE
Note: Both impact and perception of Auto and Cab users were collected through the same survey samples. Thus, there sample numbers are considered only under Perception survey category.

Annexure 2: Zone-wise distribution of survey samples

Table 11: Zone-wise distribution of survey samples

Zone no.	Non-compliant vehicle survey samples	User perception survey samples	Total sample size	Percentage share of samples
Zone 1	43	33	76	7.2%
Zone 2	63	48	111	10.6%
Zone 3	68	55	123	11.7%
Zone 4	80	66	146	13.9%
Zone 5	94	51	145	13.8%
Zone 6	84	73	157	15.0%
Zone 7	108	66	174	16.6%
Zone 8	90	27	117	11.2%
Total	630	419	1049	100%

Source: Primary data collected by CSE

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As cities struggle to upscale sustainable mobility options and accelerate adoption of clean and zero-emission vehicles, a new opportunity is emerging in the framework of the low-emissions-zone (LEZ) approach.

Delineation of targeted areas in cities as LEZs allows combined and aligned implementation of enhanced and integrated public transport services along with walking and cycling infrastructure while adopting fiscal incentives and regulatory measures to promote use of only clean and zero-emission vehicles in that zone. This can enable community-wide adoption while catalysing city-wide cascading effect for fast-pace transition.

This report provides, through a mix of perception surveys and policy scenario analysis, a nuanced understanding of how LEZs can be strategically implemented in an equitable way for clean and low-carbon pathways in Delhi.

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