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Creating Innovative Solutions for a Sustainable Future

ROAD MAP FOR ELECTRIFICATION OF URBAN FREIGHT IN INDIA

ROAD MAP FOR ELECTRIFICATION OF URBAN FREIGHT IN INDIA (PART-II)

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About Shakti: Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation, and clean energy finance.

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1. Potential of Electrification: **Organized Freight Movement in Bengaluru**

Bengaluru Urban Agglomeration is one of the fastest growing metropolises in India. The population of the region grew by 49% between 2001 and 2011, from 5.7 million to 8.5 million, and the area increased from 540 km2 to 748 km2 (Census 2011). The metropolitan city is the capital of Karnataka and is branded as the 'Silicon Valley of India' (OpenCity 2020). The growth of institutional establishments, industrial hubs, and Information and Communication Technology centres has created more employment opportunities and led to spatial growth of the city. The Information Technology (IT) and infrastructural development has led to rapid land-use change and increased the peri-urban transition (Varkey 2018). As of 2013–14, Bengaluru contributed approximately 1.9% to India's gross domestic product (GDP) and 34% to Karnataka's GDP. Over the years Bengaluru has transformed itself from being a hi-tech city to a city for well-rounded and future-ready enterprises (Balakrishnan 2019). Bengaluru is also expected to become the fastest-growing economy in the world by 2035 with its GDP increasing by 8.5% per annum (DownToEarth 2018). It is already the fourth largest FMCG market in India and one of the largest industrial hubs of the country (TheNewsMinute 2018). The aforementioned growth phenomena have made Bengaluru a crucial zone with increased commercial activity, which has further created the need and higher demand for freight movement and freight vehicles.

Bengaluru is also observing a shift towards more organized market in the warehousing sector; the demand for which is largely being driven by the e-commerce sector. In 2017, the warehousing transaction volume saw an increase of 91% as compared to the 2016 levels. This was primarily due to the strengthening of e-commerce, third-party logistics (3PL), and FMCG sectors (ET Bureau 2018; Knight Frank 2019). Bengaluru is also one of the primary logistic hubs for many of the e-commerce firms such as Flipkart and Amazon. One of the largest fulfilment centres of Amazon is in the outskirts of Bengaluru and even Flipkart plans to set up its biggest logistic park near Bengaluru (The Hindu Business Line 2018; Peermohamed and Mishra 2018). Logistics major Safexpress has also set up Karnataka's largest logistics park in Bengaluru (Singh 2018). In addition to being a major industrial and IT hub, the metropolis is also a hub of many upcoming tech start-ups; logistic service providers and trucking companies account for a significant number of such start-ups.

Changing Urban Freight Movement

Freight movement on Indian roads has largely been dominated by unorganized trucking segment both for the main haul trips and for first and last mile connectivity. However, recent years have seen a transition in the logistics and supply chain management with an increase in investment and demand of more tech-savvy organized freight services. Considering the potential of growth in the logistics industry, several start-ups have entered the domain and are offering efficient technology-based solutions (Mannan 2018).

This transition in the freight mobility is likely to streamline the currently fragmented segment as it offers several advantages over the conventional unorganized trucking industry. Some of these are listed as follows (Pillai 2016):

- Real-time tracking of vehicles
- Lower transit time
- Efficient loading and unloading services
- Supply of trucks based on client's requirement

- Reliable documentation
- Efficient route planning
- Reduced number of empty runs
- Use of data analytics and IoT

Bengaluru is becoming the driving force behind e-commerce growth in the country as online retailers are targeting last mile connectivity and increasingly focusing on getting customers to shop online. The logistic industry in Bengaluru has helped e-commerce companies win more customers through reliable deliveries and has also become an important component of the state's economy.

Potential of Electrification

Within the organized freight segment, several logistic firms are providing services for first and last mile delivery of goods (for instance delivery of goods from distribution centres to retail outlets or customer door). Most of these firms cater to B-2-B services and move goods for e-commerce and retail businesses. The first and last mile delivery services are primarily being carried out by small commercial vehicles (SCVs) which are below 3.5 tonne of GVW. Considering that a significant share of movement of goods within the city happens through these vehicles, targeting this vehicle segment for electrification at initial stages could pave the way for decarbonizing the freight vehicle segment. Given that most of these vehicles cover short distances and they offer an advantage of range and distance being covered in single charge. As most of the e-commerce and FMCG products do not pose the barrier of overloading the vehicles, they offer a favourable case for electrification without compromising on the payload capacity. The sheer size of the vehicle also makes them suitable for convenience charging as they can be easily charged at home or parking spaces.

In this context, the objective of this chapter is to understand the feasibility of electrification of SCVs and used for intra-city freight movement in Bengaluru. Through a mix of primary and secondary data analysis, this chapter aims to capture the movement of goods under postal services, movement of FMCG, and e-commerce goods provided through 3PL.

The chapter specifically focuses on the organized freight services. Key reasons behind the selection of this segment and the city itself are (Figure 1) as follows:

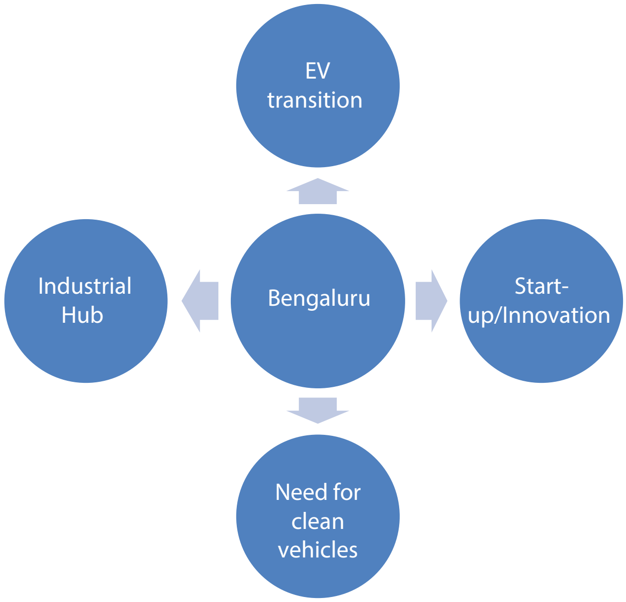


Figure 1 Bengaluru offers conducive environment for electrification of LCV freight vehicles.

- Karnataka was the ***first state to implement its electric vehicle and energy storage policy*** in India. The state provides conducive ecosystem for the development of electric vehicles with robust R&D facilities and manufacturing expertise. The state government also envisions making Bengaluru the electric vehicle capital of India (Commerce and Industries Department, Government of Karnataka, 2017).
- Bengaluru has the advantage as a city known for being the logistics hub of several e-commerce, parcel, and FMCG firms in Southern India.
- The technological environment of the city is conducive for innovation and growth of start-ups.
- Organized service providers undertake fleet-level operations and can act as major catalyst in enabling fleet-level transition.
- Issues such as scale of deployment, parking, availability of space for charging infrastructure, and affordability – viewed as major impediments for wider penetration of electric vehicles – are also expected to be taken care of by the logistic service providers.
- The new players in the field of organized freight services are particularly inclined towards adoption of cleaner technologies and are willing to experiment given that the operational efficiency is not compromised. Most of these players are already venturing into electric vehicle pilot projects.

Growth of Freight Vehicles in Bengaluru

Freight vehicles, which account for almost 34% of the total commercial vehicles operating in the city, account for a significant proportion of the congestion and pollution (Government of Karnataka 2019). Amongst the freight vehicles, LCVs accounted for 55% of the share in 2019 (Figure 2).

In terms of growth of freight vehicles, while the total registered freight vehicles grew at a CAGR of 4.8% between 2009 and 2019, the LCVs grew at a CAGR of 6.5% (Figure 3).

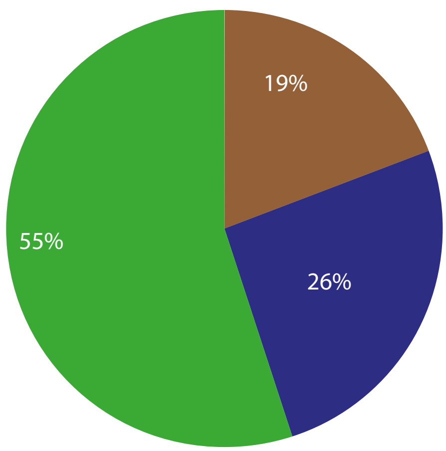


Figure 2 Composition of freight vehicles in Bengaluru

Source: Annual report, Government of Karnataka 2018-19 and TERI analysis

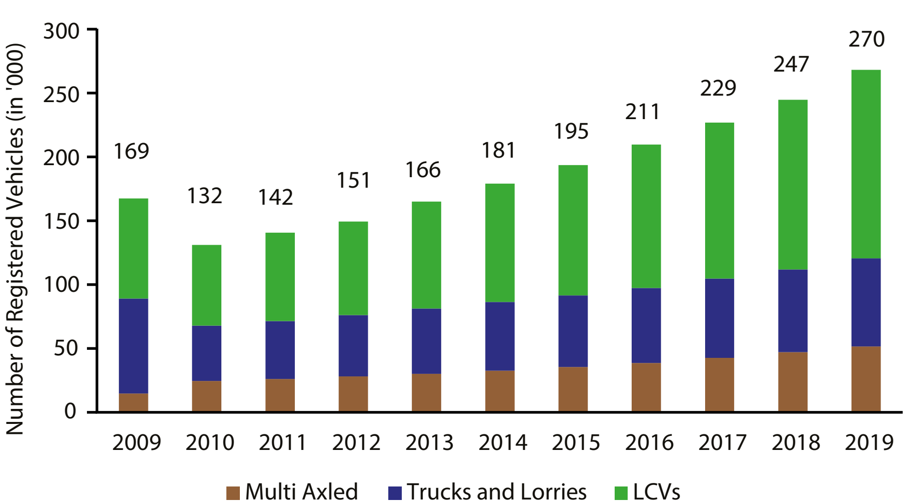


Figure 3 Registered freight vehicles in Bengaluru (2009–2019)

Source: Road Transport Yearbook of various years, MoRTH and TERI Analysis

While the data on stock of SCVs is not readily available, they account for significant share of vehicles within the LCV segment. Hence, the growth in LCV segment is reflective of the growth in SCV segment. As per data published by MoRTH, within the LCV segment in Bengaluru the share of four-wheelers is higher than three-wheelers and has been increasing year by year (Figure 4). The share of four-wheeler increased from 62% in 2015 to 66% in 2019.

Newly registered LCVs increased by 35% from 2018 to 2019 as compared to 9% between 2017 and 2018 (Figure 5).[1] The key reasons for such favourable growth in this sector are change in tax regime due to implementation of GST, increase in demand for LCVs/SCVs by the e-commerce segment, and the increased discretionary consumption. The segment has also benefitted from new product launches. Additionally, while the M/HCV segments were drastically hit by the liquidity crunch in the economy and revised axle load norms, LCV segment did not face the negative impact of these effects.

A continuous growth has been observed in registered LCV over the year 2018–19 (Figure 6). The LCV three-wheeler grew at a CAGR of 0.6% while the four-wheeler grew at a CAGR of 1%.

Intra-city freight Movement: Issues and Solutions

There are number of challenges for intra-city freight movement through unorganized players. These include

[1] Details available at https://www.newindianexpress.com/business/2019/apr/05/surplus-freight-carrying-capacity-hit-mhcv-sales-1960505.html

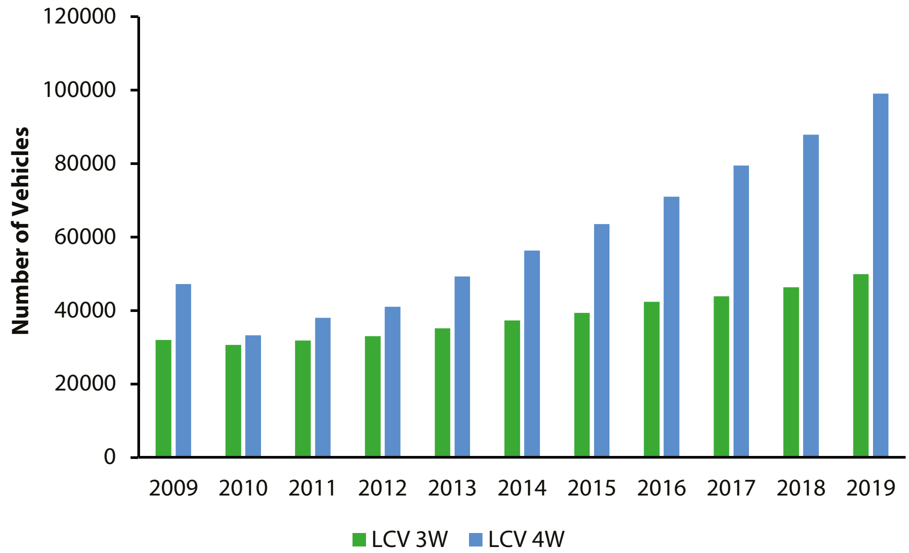


Figure 4 Number of three wheelers & four wheelers over the years in Bengaluru

Source: Road Transport Yearbook of various years, MoRTH and TERI Analysis

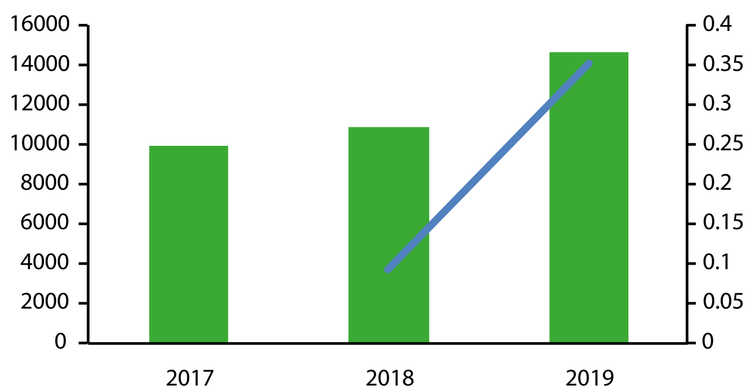


Figure 5 Newly registered LCV's 2017-19 in Bengaluru

Source: Annual reports Government of Karnataka and TERI analysis

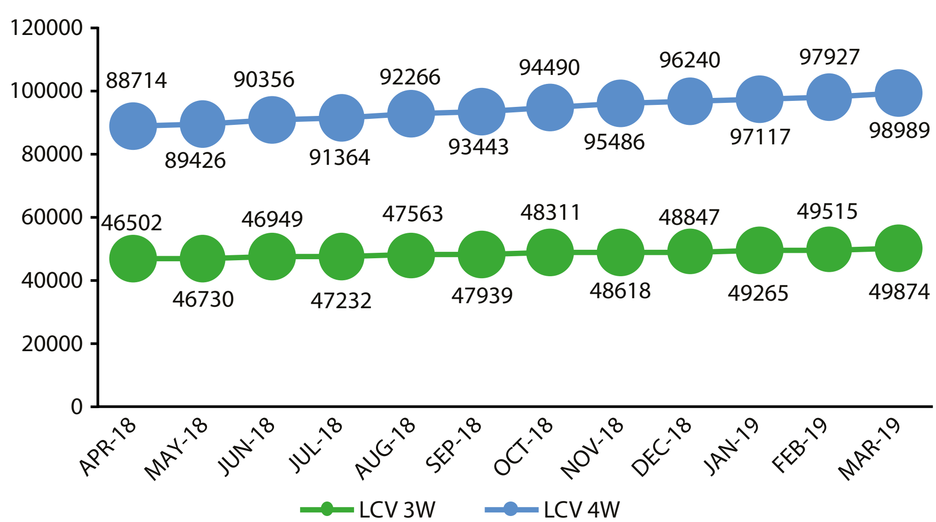


Figure 6 Month-wise total registered LCVs

Source: Annual Reports, Government of Karnataka and TERI Analysis parking management, storage and warehousing issues, lack of integration, movement restrictions, fleet management, inefficiency in delivery timings, and the associated negative externalities (Figure 7). Some of these factors act as barriers to sustainable urban goods movement. This is because there is a lack of awareness, understanding, and overall vision towards the urban goods movement; absence of coordinated actions related to urban freight policy involving various stakeholders such as transport operators, planners, decision makers, local authorities. Besides there is also absence of integration between urban freight in town planning and land use/infrastructure planning leading to logistics sprawl.[2]

Considering the negative externalities imposed by the unorganized freight a lot of organized freight players are coming into the market, enabling a smooth supply chain and also helping in improving the overall economic efficiency of the sector by ensuring time-bound movement of goods. With the fast-changing pace of technology and increasing competition in the segment, the future of freight sector is likely to be dominated by

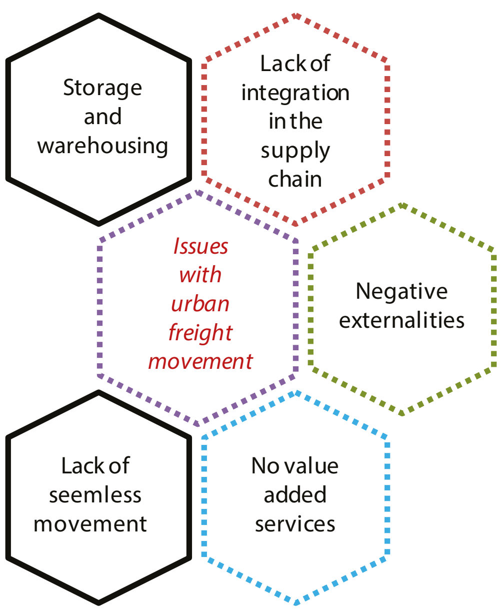


Figure 7 Issues with urban freight movement

the third-party logistics service providers, which will also ensure adherence to performance and economic standards.

This transition from unorganized towards organized freight services offers key opportunity for advancing towards the adoption of clean fuel technologies as well. Most of the business operations undertaken through the logistic providers are catered by SCVs within the city premises. As most of the drivers work on a contractual basis with specific service providers, a policy push and infrastructural support from the government can aid in large-scale electric vehicle adoption at fleet level. Considering that the vehicles are primarily owned by drivers, government can work with the logistic players to map out incentive programmes, training guidelines, etc. for the drivers in order to ensure a smoother transition

In order to assess the potential of transition, this study is undertaking an analysis of freight movement within the city of Bengaluru. By undertaking quantitative and qualitative survey-based approach, the study is going to map out the perception of drivers as well as service providers with respect to electrification of SCVs. The study is also going to assess the movement of these vehicles in order to better understand the potential and constraints associated with electrifying the segment and will further identify the key front runners.

Identified Logistics Players

In order to study operational and technical indicators of urban freight movement, the following cases will be studied through a stakeholder consultation in Bengaluru. As a part of primary consultations, mapping of local and established logistics players in the city has been done. Some of the players that have been consulted include Udaan, LetsTransport, India Post and Porter (Table 1).

A further detailed data analysis has been done of logistics movement of India Post and LetsTransport in Bengaluru, the findings of which are presented in the next section.

[2] The tendency of warehouses to move away from urban regions towards more suburban areas

Table 1 Consulted organized logistics players

Company	India Post	Udaan	LetsTransport	Porter
Fleet size operational in Bengaluru (<3.5 tonnes)	70 (owned)	1000+ (on contract)	2900 (on contract)	-
Commodity type	Parcels	Groceries, FMCG	E-commerce, Groceries, FMCG	All types of commercial operations
Clientele	B2B	B2B	B2B	B2B and B2C
Vehicle types	Mini trucks	Tata Ace, Tata 407 and Bolero	Tata Ace, Tata 407, Xenon Yodha	Tata Ace, Tata 407, and pick-up truck
Outsourced component	Vehicle and drivers (on contract)	Vehicle and drivers (on contract)	3PL	-
Fuel type	Diesel and petrol	Diesel and CNG	Diesel and CNG	
Electric vehicles (Pilot)	Not done	Electric rickshaws	Pilot with retrofitted vehicle	Not done
Willingness to switch	Keen to use	Not very keen	Keen to use	Keen to use

Source: Compiled by TERI

Case Study I: India Post

India Post functions under the Ministry of Communications and Information Technology, GoI. It is responsible for the planning, development and expansion, operation and maintenance of postal services in all the states. In the circles and regions, there are other functional supporting logistical units such as stamp depots, store depots, and mail motor service (MMS). The MMS is generally entrusted with main functions such as conveyance of mail bags between Post Offices, RMS offices, TMOs, and Railway Stations, Air Mail Sorting office, etc.

In Bengaluru also, the MMS office serves as the key hub from where the distribution and procurement guidelines are set and services are initiated. The regular supply chain of the parcels comprises three key destinations (Figure 8):

1. **The MMS office garage**: The drivers arrive at the garage office for their daily reporting and collecting trip schedules. The final reporting also happens here after the trip is completed.

2. **The major mail hubs**: There are three major collection/procurement hubs, namely, railway transit mail office, airport mail office or air mail sorting facility, and transit mail office at bus stations. The parcels in bulk are collected from these hubs and further distributed to other post offices. Similarly, parcels from various post offices in the city arrive at these hubs for distribution across the country.

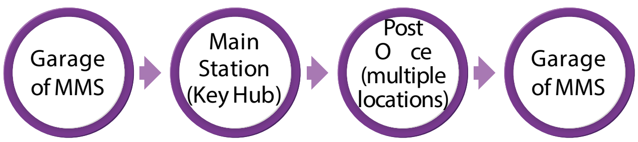


Figure 8 Route distribution of trip for parcel movement by India Post

3. **Post offices**: The mail bags from key transit hubs are distributed at several post offices from where the mails reach customer destination.

The MMS Bengaluru office currently has a fleet of 70 LCVs, 50 of which run on diesel while the rest on petrol. All these vehicles are owned by India Post and their movement is tracked through GPS. In addition to the aforementioned service vehicles, MMS also runs 12 fixed route services that are all catered by small commercial vehicles. The vehicles for these services are contractual schedules which are operated by a private agency (Figure 9).

In order to understand the movement pattern of the parcel vehicles, analysis has been done based on the route sheets and the data provided by MMS. Some of the key details that are present in the route sheet include number of stops, distance covered, time of arrival, and departure at each post office.

Regular Parcel Collection and Delivery Services

The data provided by MMS includes trip schedules of

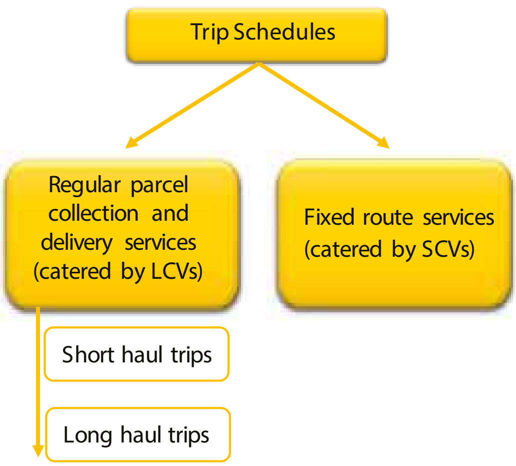


Figure 9 India Post trip schedules

42 vehicles. The analysis of trip schedules has been divided into two parts based on trip distance, i.e. short haul and long haul trips. The outcome of short-haul trip schedule data analysis is presented in Figure 10.[3]

The long-haul trip schedules comprise delivery/pick-ups from areas outside urban Bengaluru and largely cater to e-commerce clients (Figure 11).

Fixed Route Services

MMS also runs 12 fixed route services which are all catered by small commercial vehicles. The vehicles for these services are contractual schedules which are operated by a private agency. As these 12 schedules ply on fixed routes, they offer very good opportunity

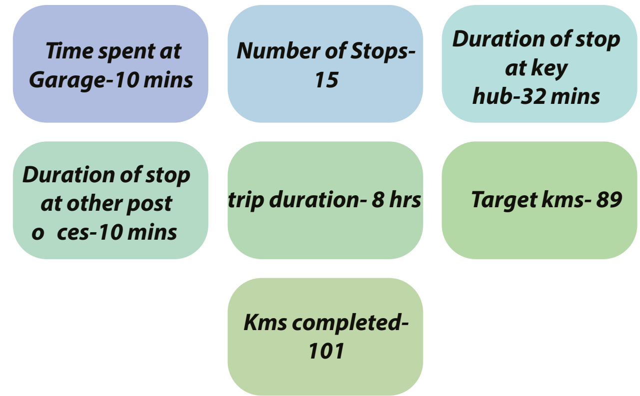


Figure 10 Findings from short- haul trip analysis

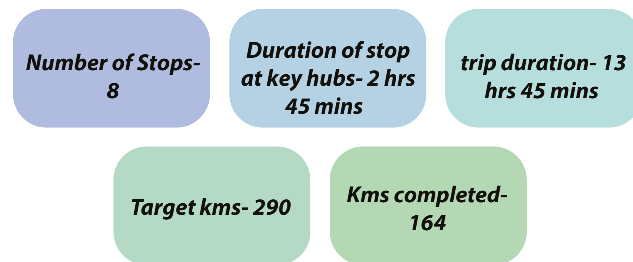


Figure 11 Findings from long-haul trip analysis

for electrification. The main advantage lies in terms of creation of charging infrastructure along those routes or at the key hub locations.

All the trips for fixed route services originate from National Sorting Hub in the city and cover an average daily distance of 95 km, spanning over 9 to 19 stops (Figure 12).

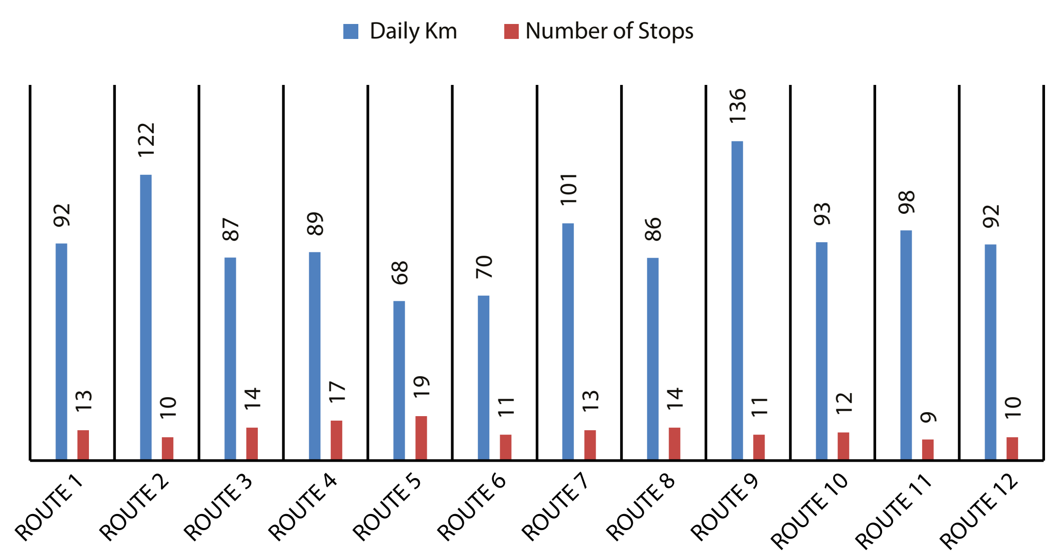


Figure 12: Daily km and number of stops covered by fixed route services

[3] All figures are averages

The average trip duration of these services is 12 h 25 min, which is longer than the short-haul regular parcel service trips and these vehicles also have long stops at key collection hubs for around three times in a day. The average waiting duration at each key hub is around 1 h 26 min. Considering that the vehicles make regular trips to these locations and often stop here for long hours in between the business operations, there exists an opportunity to set up charging infrastructure at theses hubs (Figure 13).

A further mapping of these 12 routes has been done to understand the spatial spread of drop-off locations. Undertaking such an analysis can be useful for developing a plan for creating charging infrastructure and identifying the appropriate locations for setting up such infrastructure.

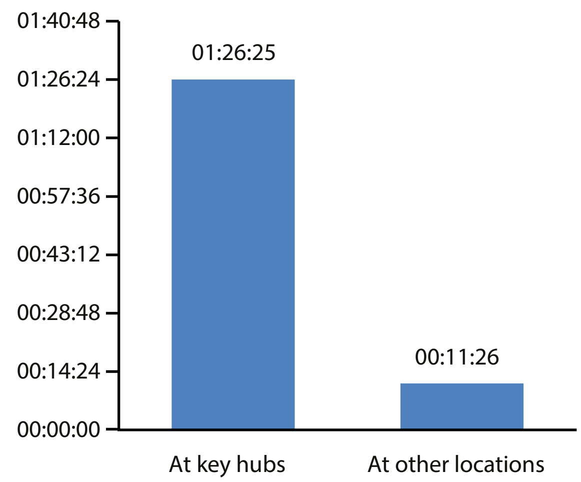


Figure 13: Analysis of waiting times at hubs

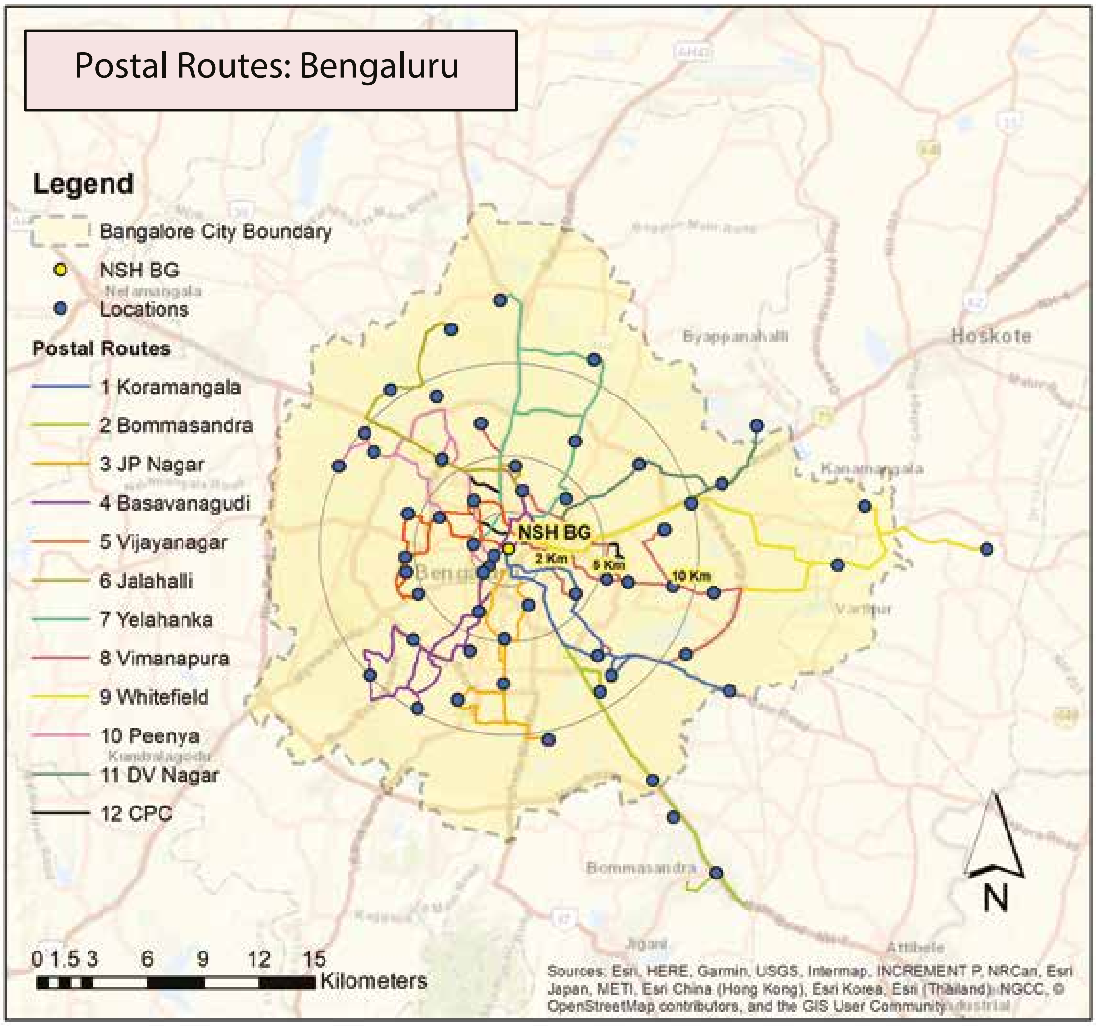


Figure 14 Spatial mapping of fixed routes

From Figure 14 we can see that of the total 61 drop points, only 4 points lie outside the Bengaluru city boundary and rest of them lie in urban Bengaluru. Additionally, 70% of locations lie within 10 km radius of the pick-up point. Considering that the pick-up point is in the centre of the city, setting up infrastructure around the 10-km radius would not only cater to the vehicles of India Post but would be adequately used by other personal and commercial electric vehicle users.

Policy Suggestions

- The analysis suggests that for both short-haul regular parcel service trips and fixed route services switching to electric could be a smooth transition as these services cover large share of their trips within the city boundary.
- As all the service routes have fixed number of stops and locations, setting up charging infrastructure at most visited post offices can further make this transition feasible. Considering that most of the vehicles stop at key hubs for more than 30 min, setting up fast-charging infrastructure would help in reducing the driver anxiety associated with re-charging the vehicle in the middle of the trip.
- The three main key hubs frequently visited by drivers include railway station, bus stop, and airport. Hence, placing charging infrastructure at these locations or creating a space for swappable battery systems in these locations can prove to be useful for charging other vehicles including taxis and buses.
- The daily distance covered by short-haul trips also goes up to 100 km and at present very few models are available in the market which can claim to provide that kind of range in a single charge. Hence, the adoption of electric vehicles in this segment can only be fast-paced in the short run by creating public charging infrastructure. This would also be applicable in the case of long-haul trips which have daily target distance of 300 km.
- All vehicles owned by MMS for regular parcel operations are between 3.5 and 7.5 tonne GVW. However, the average payload carried by these vehicles is approximately 500 kg which means the current ICE vehicles are being underutilized as far as capacity is considered and can be replaced by available electric cargo carriers which have lower payload. A further assessment can be done to assess the carrying capacity of electric vehicles in terms of volume-holding capacity.
- Further consultation with MMS suggests that while India Post is willing to incorporate electric vehicles into its fleet, currently available electric vehicles do not meet the requirements of capacity, speed, and efficiency expected by MMS. In order to meet the requirements of consumers, manufacturers need to undertake the market analysis of all the major parcel and freight service providers and understand their preferences as far as vehicle performance is considered.
- Considering that India Post is one of the oldest parcel service providers in the country and has the most extensive service network, there is a huge potential of electrifying the fleet of MMS at national level. For this more studies can be conducted at city level and some replicable models can be created for cities which have similar operational patterns.
- While this analysis has focussed largely on first- and mid-mile connectivity, feasibility of adopting electric two-wheelers can also be explored for last mile connectivity wherever necessary.

Case Study II: LetsTransport

LetsTransport, the Bengaluru-based firm, is a last-mile tech-logistics solution provider for intra-state freight deliveries. Founded in 2015, it is one of the largest urban logistics service providers in India. With its aim to improve the livelihood and work environment of urban trucking community along with improving the efficiency of the sector, the firm has on-boarded more than 65,000+ truckers at national level till date. Currently, the firm is catering to urban logistics operations of 17 cities in India by working across industry sectors such as organized retail, FMCG, e-commerce, distribution, and 3PL companies.

As part of this study, we aim to understand the current operational patterns of organized urban freight in India and the potential of transition of urban commercial fleet to electric. Considering the fact that LetsTransport is one of the largest players in this segment and is already in the process of conducting electric vehicle pilots, learnings from its experience would play a crucial role in creating the plan for uptake of electric vehicles in the urban freight segment. Given that the focus of the study is on the SCV segment, a preliminary small questionnaire-based survey (Annexure III) was conducted to assess the overall contribution of SCVs in the organized urban freight

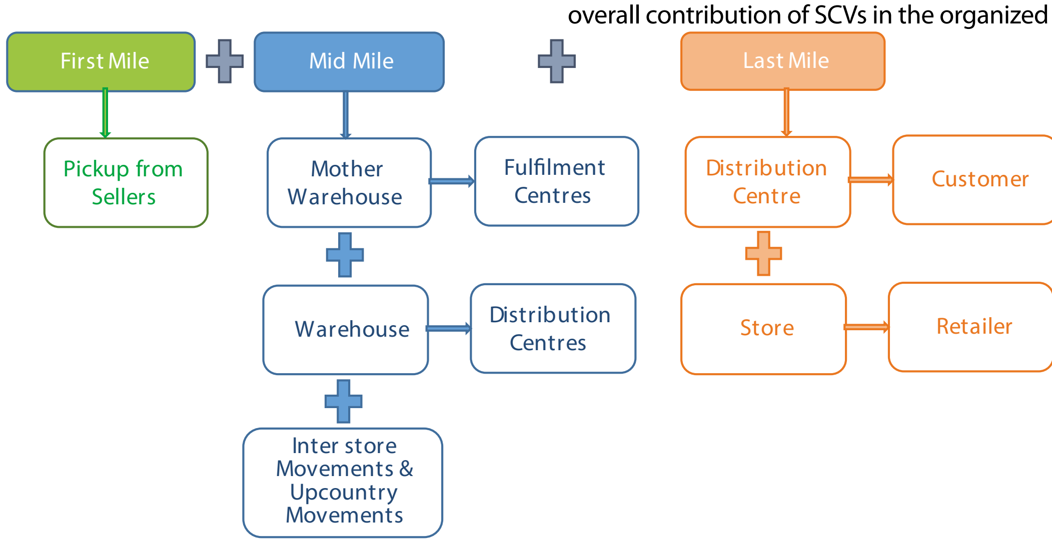


Figure 15 Logistic movement network of LetsTransport

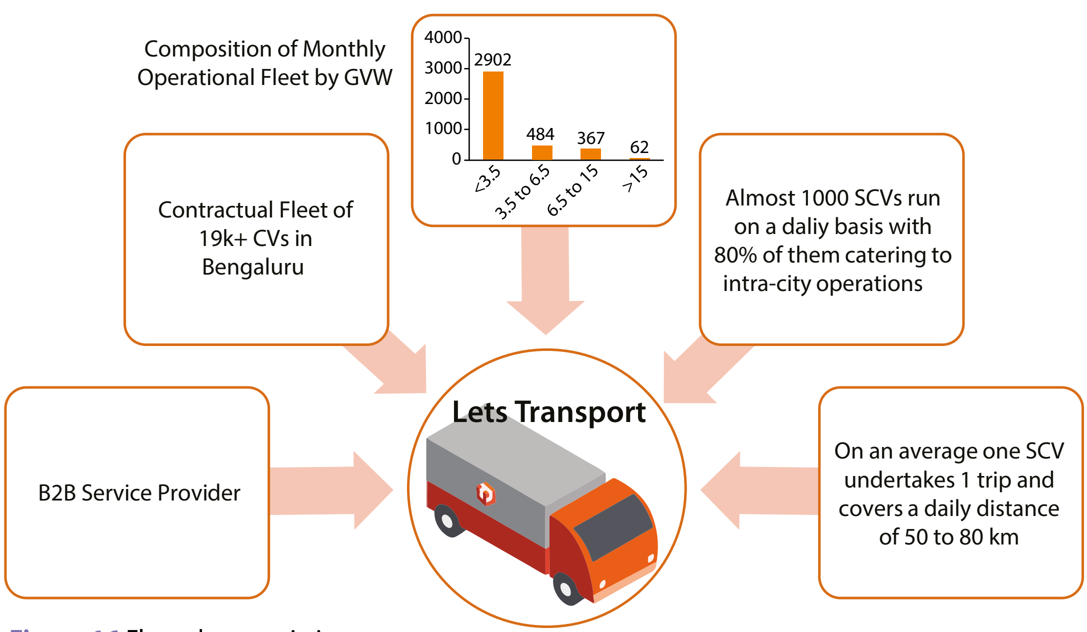


Figure 16 Fleet characteristics

movement. The outcomes of the survey are presented in Figure 16.

Driver Surveys

Based on inputs received in the preliminary survey, TERI planned to conduct the survey of drivers associated with LetsTransport. The survey was conducted telephonically in May 2020[4] using a standardized questionnaire (Annexure III). The questionnaire is divided into five sections to enumerate all the details regarding the journey undertaken by the driver along the day and to understand their knowledge about electric vehicles. A brief overview of the questionnaire is presented in Figure 17.

In total 100 ICE vehicle drivers were surveyed. The aim of the questionnaire was to assess daily vehicle usage patterns, vehicle characteristics, costs associated with operations, and their knowledge about electric vehicles.[5] A final set of 89 responses has been analysed after accounting for outliers. All of these 89 vehicles come in the category of SCVs. The findings of the survey are discussed in the ensuing sections.

Ownership and Purchase Method

While making purchase decision for any vehicle, the cost of the vehicle and the means to finance it play crucial roles. Understanding consumers' (in this case drivers') ability to pay and the ownership patterns for ICE vehicles will help manufacturers, policymakers, and financial institutions to design policies which can work in favour of purchase and financing of electric vehicles.

Through the survey drivers were asked to tell if the vehicle belonged to them or if it was taken on lease/ rent and if they are working for someone else. Once the ownership status was determined, drivers were asked questions related to financing mechanisms and the mode of procuring the finances.

Vehicle Ownership Status

Out of the total drivers surveyed, 74% of them stated that they are the owners of the vehicles (Figure 19). On salary basis, 20% were plying the vehicles. The remaining 6% who took the vehicles on rent were on average paying a monthly rent of Rs 10,600.

Financing Mechanisms

Analysis of financing methods adopted by drivers to purchase their vehicles indicates that 77% of the drivers who owned the vehicles bought it through loans and were paying EMIs, while the rest 23% bought the vehicles by paying up-front.

Those who bought the vehicles on EMIs, 66% were using formal sources for taking loans while 34% were dependent on informal sources (such as friends/relatives) (Figure 20). On average, the drivers paid Rs 80,431 as down-payment and were paying an EMI of Rs 11,220 over

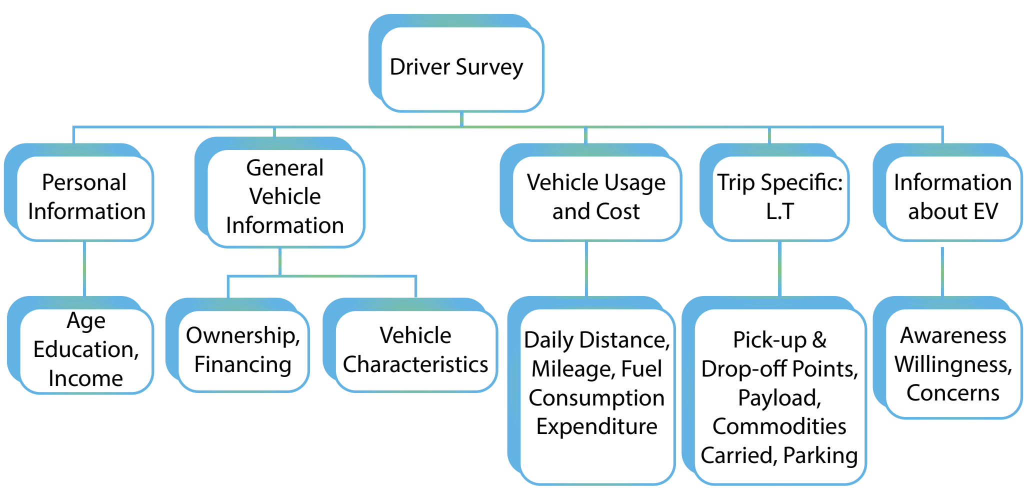


Figure 17 Questionnaire design

[4] Standard face-to-face surveys were not conducted due to COVID-19 restrictions

[5] Although the survey was conducted during the COVID-19 pandemic, the drivers were asked to provide information regarding their regular trip patterns before the pandemic.

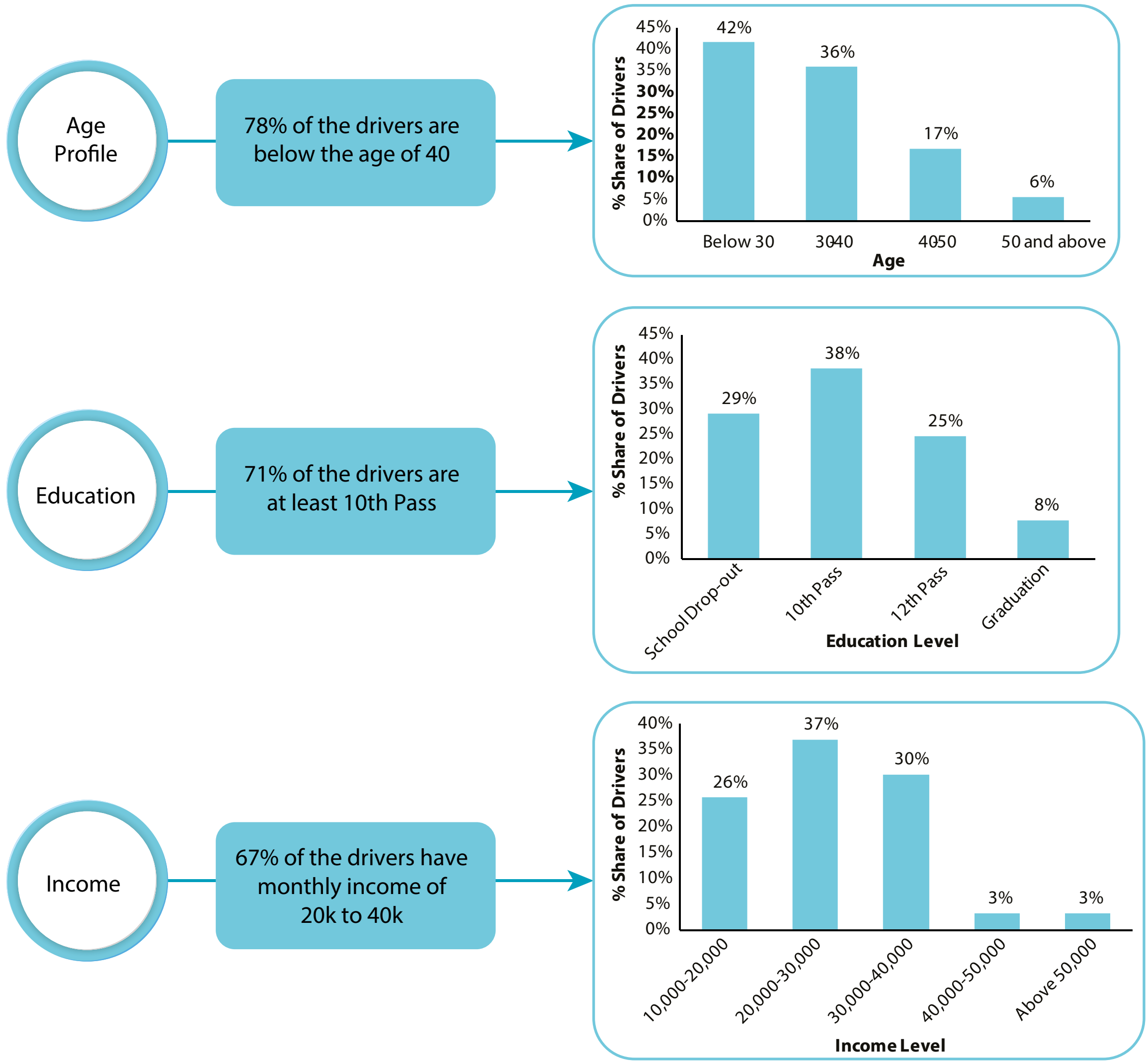


Figure 18 Drivers' personal characteristics

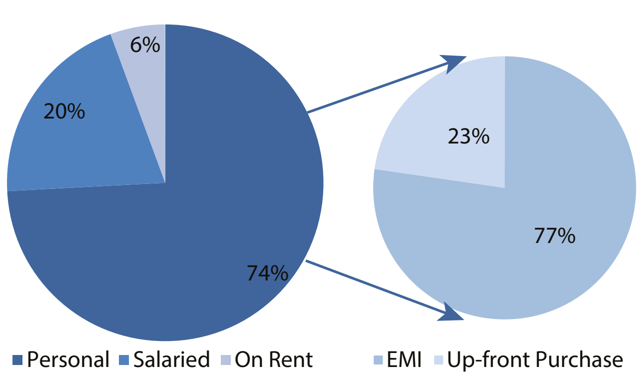


Figure 19 Ownership and purchase method

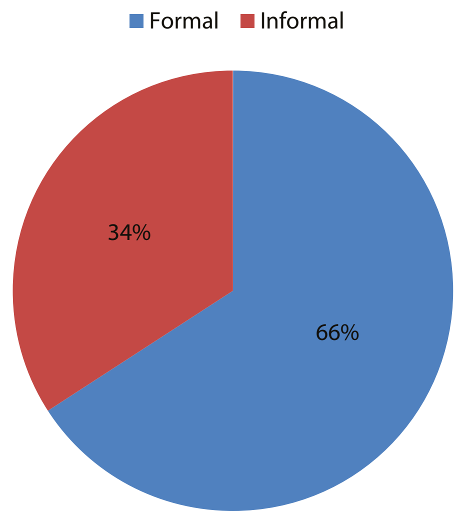


Figure 20 Source of financing

the period of 35 months.

Those who bought the vehicles by making an up-front payment had to spend Rs 183,250. Almost 80% of the drivers who made an upfront payment had bought a second-hand vehicle.

Additional Ownership of Vehicles

Of the 66 drivers who personally owned the vehicles when further asked if they owned multiple vehicles, 63 of them gave positive response. From the total reported samples of 63 drivers, 36 owned only 1 vehicle while 13

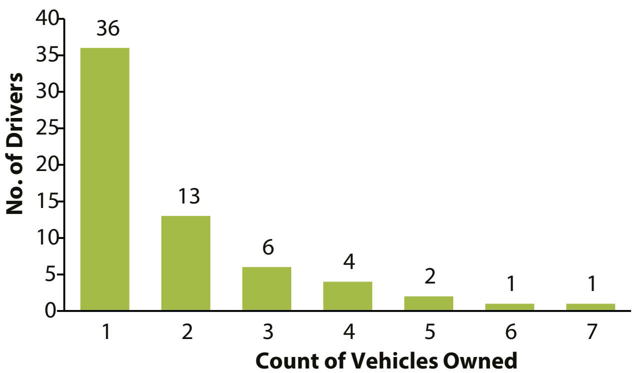


Figure 21 Multiple vehicle ownership

drivers owned 2 vehicles and the rest 14 drivers owned 3 or more vehicles (Figure 21). So these 63 drivers in total owned 119 vehicles of which 115 belonged to <3.5 tonne GVW, 1 belonged to 3.5–7.5 tonne GVW, 2 belonged to 7.5–15 tonne GVW and 1 belonged to >15 tonne GVW. Hence, the probability of bulk purchases of electric vehicles could increase by single owners given that adequate incentives/subsidies on such schemes are provided.

Fleet Characteristics

In order to assess the replacement potential of electric vehicles, it is important that the efficiency of urban freight segment is analysed by understanding the existing fleet characteristics. Parameters such as age of vehicles, fuel used, fuel economy, etc. help to frame policies around improving efficiency and emission standards for vehicles in use and also aid in identifying the timeline when policies related to adoption of new technologies could be more suitable.

Age of the Fleet and Total Fleet Utilization

In the survey drivers were asked to mention the year of registration of the vehicle. The number of vehicles has been further categorized as per the emission norms they comply with. As per the survey analysis, 14% of the currently operating fleet belong to pre-BS III norms and 47% comply with BS-III norms (Figure 22). The share of BS-IV vehicles stands at 39%. This implies that almost 61% of the vehicles belong to older norms and are highly polluting.

Figure 23 shows the utilization of vehicles based on their odometer readings. With the implementation of BS-VI norms and scrapping policy, pre-BS-III would most likely go out of the market. This outcome creates an opportunity for the government and manufacturers to introduce electric vehicles in this segment as early as by 2025.

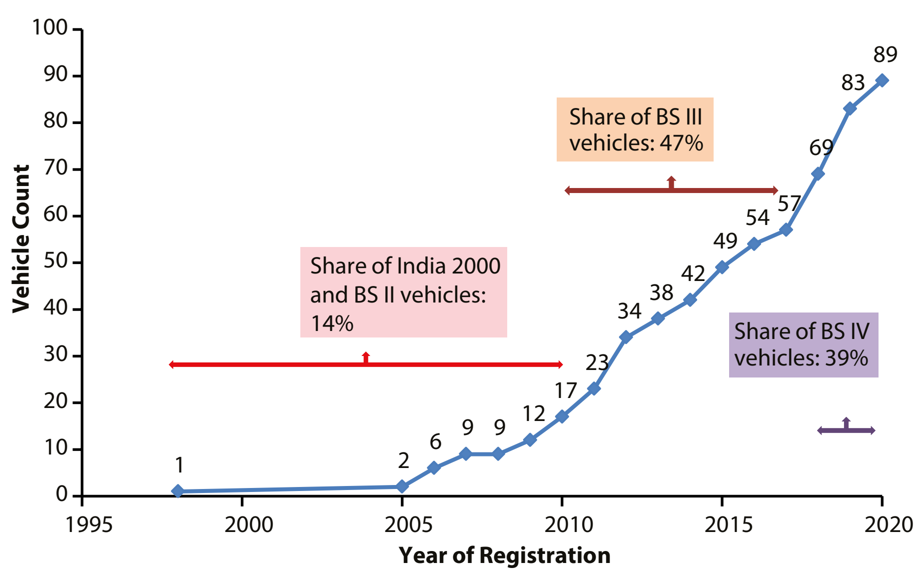


Figure 22 Share of fleet as per BS standards

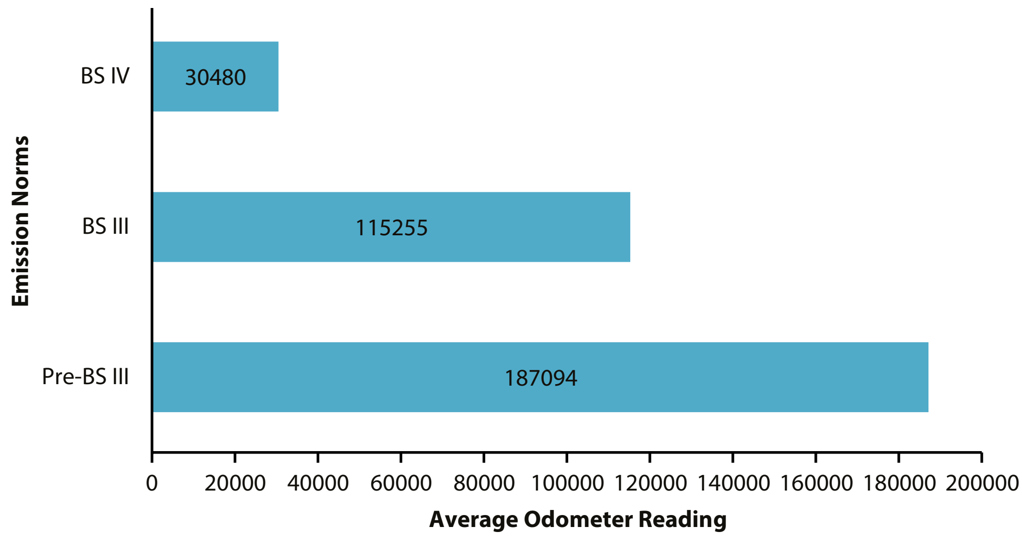


Figure 23 Odometer reading of vehicles

ii. Model, Fuel type, and State of Vehicle

In order to understand the overall fleet characteristics, drivers were asked to mention the model of the vehicle, the fuel type, and if the vehicle is new or second hand.

The survey responses indicate that 90% of the drivers have different variants of Tata Ace and another 10% comprise Omni Cargo, Mahindra Bolero, and Piaggio Cargo (Figure 24). In this case, the response indicates that a large number of drivers are inclined towards vehicles like Tata Ace and, hence, if ever they switch to electric vehicles, they would like to own a vehicle which is at par with the performance of their current ICE vehicle.

A significant share of urban freight vehicles runs on diesel due to lack of alternative technology options. The survey outcomes also point towards the same fact as 96% of the urban freight vehicles in Bengaluru run on diesel (Figure 25). Hence, there is a huge potential in such cities to promote alternative clean fuel technology options such as electric and CNG.

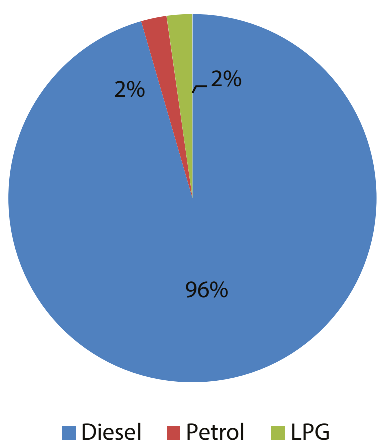


Figure 25 Vehicle by fuel type

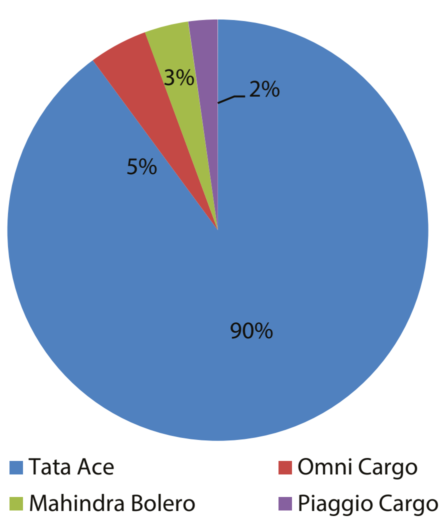


Figure 24 Vehicle model in use

Another important parameter with respect to fleet characteristics that the survey captured was the state of vehicle, i.e. if the driver is the primary owner of the vehicle or if it is a second-hand purchase. From the survey, we found that one-third of the drivers have second-hand vehicles (Figure 26). So one inference that can be made from this data is that while making a purchase for electric vehicles, these one-third of the drivers would prioritize available financing options while making their future decisions.

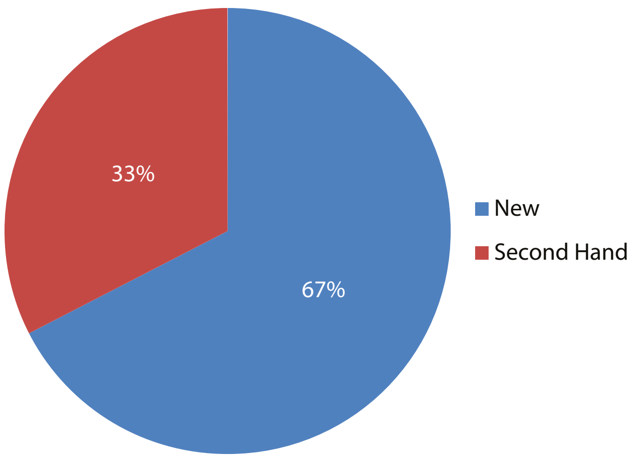


Figure 26 State of the vehicle

Vehicle Usage and Costs

General operational characteristics

Drivers were asked questions related to their number of working days, operational hours, and kilometres covered on a daily basis. Developing an understanding of these characteristics is important from the perspective of making policies for charging infrastructure requirements.

Most of the drivers reported that they work for all days in the month while some take two to four days off in a month. So on average all the drivers work for 29 days in a month. Drivers work in single shift of 10 hours on average in a day and cover a distance of 71 km on a daily basis (Figure 27). Hence, in the absence of adequate charging infrastructure at city level, it would be necessary that the electric freight vehicles have the battery capacity which can last for up to 8 to 10 hours in a day on a single charge and also have the range of up to 70 km.

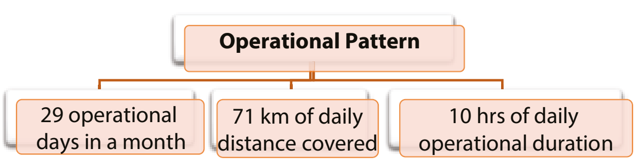


Figure 27 Vehicle operational characteristics

Managing electricity demand and load requirements is one of the other important factors that policymakers and power distribution agencies need to consider in making the electric vehicle transition successful in India. Hence, a further analysis of operational hours has been done to understand the distribution of charging load patterns in a scenario where all these drivers switch to electric vehicles in future.

Some of the drivers start their shift as early as 2 am, while 21% of the drivers stated that they begin their journey between 2 to 6 am. A larger number of drivers (57%) begin their daily journey in peak hours of 7 to 9 am (Figure 28). In this scenario, considering an average charging time of 8 hours, we can assume that highest peak demand of electricity will be between 11 pm till early morning hours. The rest of the demand can be shifted to daytime and early evening hours for the remaining 43% of the fleet. Hence, if the government plans to use the demand-based pricing for off-peak hours, it would be most applicable for 43% of the fleet.

Cost characteristics

Both cap-ex and op-ex costs are taken into account while purchasing a vehicle. Adoption of new technology vehicles is also directly related with the cost attractiveness of the vehicle. As electric vehicles are associated with lower op-ex costs, it is important to assess the kind of expenses that drivers are incurring which would reduce in case of an electric vehicle. The primary costs associated with running a vehicle include fuel costs, maintenance costs, and insurance costs. This section will discuss some of the findings associated with these costs.

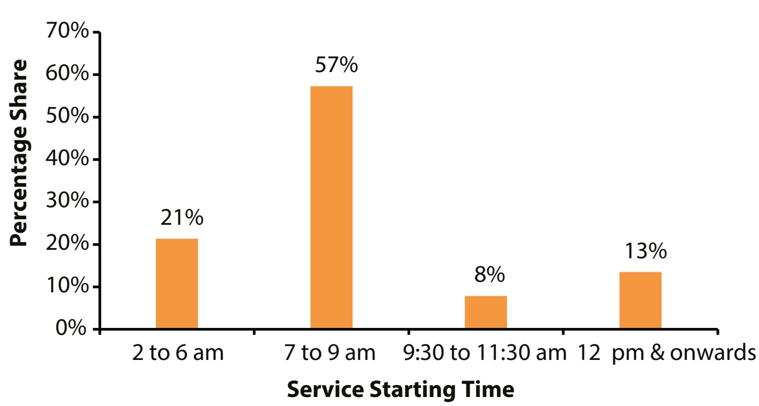


Figure 28 Vehicle operational timings

In order to assess the total fuel costs, drivers were asked to reveal the number of times they refuel the tank in a week and how much do they pay for refuelling at a single time.

Of the drivers, 46% mentioned that they refuel the vehicle only once in a week, 33% mentioned that they refuel it twice a week, while 7% mentioned that they refuel the vehicle every day (Figure 29). On average the expenditure on monthly fuel cost amounts up to Rs 11500. Comparing it with the incomes that these drivers earn, for a majority of them fuel costs consume up to one-third their monthly incomes. Hence, by switching to electric these drivers can save significant amount incurred on monthly fuel expenditure.

In the survey, as reported by drivers, the monthly maintenance costs range from as low as Rs 700 to as high as Rs 8000. Majority of the drivers (50%) paid between Rs 2000 and Rs 4000 for maintenance and service of their vehicles (Figure 30). On average, the monthly maintenance cost amounts up to Rs 3568 per vehicle. Switching to electric vehicles can bring down these costs significantly. However, with electric vehicles the costs associated with replacing battery is going to remain high.

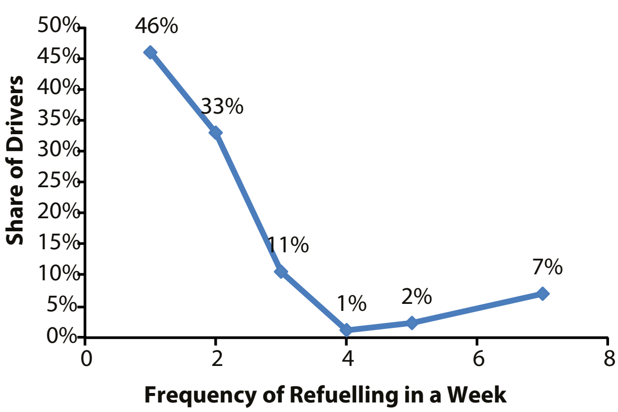


Figure 29 Frequency of refuelling of the vehicle

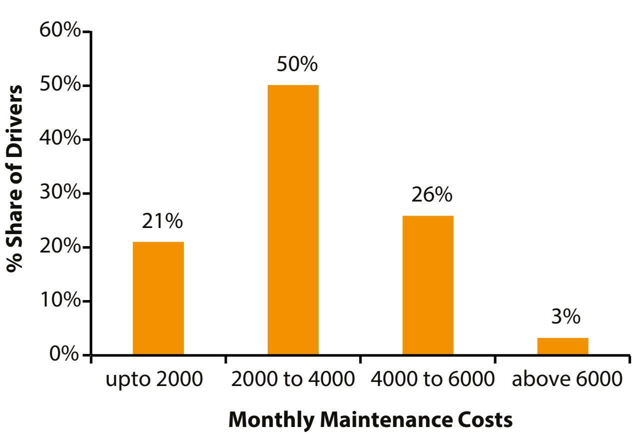


Figure 30 Monthly Maintenance costs of vehicles

In addition to the monthly costs associated with fuel and maintenance, drivers also pay insurance and fitness certificate-associated costs at an annual basis. As reported by drivers, the average annual insurance costs amount up to Rs 18,792 and the cost of fitness certificate is Rs 3,391.

Trip Pattern

Creating a road map for electrification of urban freight also requires an in-depth assessment of daily trip characteristics, payload capacity, and parking pattern of the vehicle. Assessment of these factors is crucial not just from the point of view of manufacturing of the vehicle but also for creating a feasible and accessible charging infrastructure. In this context, drivers were asked to give details regarding the pick-up and drop-off locations, type of commodities carried and the associated payload, time required for loading-unloading, idle time or empty runs, and information related to parking space and charges.

Pick-up and Drop-off Locations

SCVs are primarily used for catering to mid-mile and last-mile connectivity for moving urban freight and, hence, most of them usually have one pick-up point and multiple drops. As per the survey responses, most of the drivers said that they pick-up goods from a single point and then drop it to multiple locations. Only a few drivers had two to three pick-up points. These pick-up points could either be warehouses, distribution centres or stores.

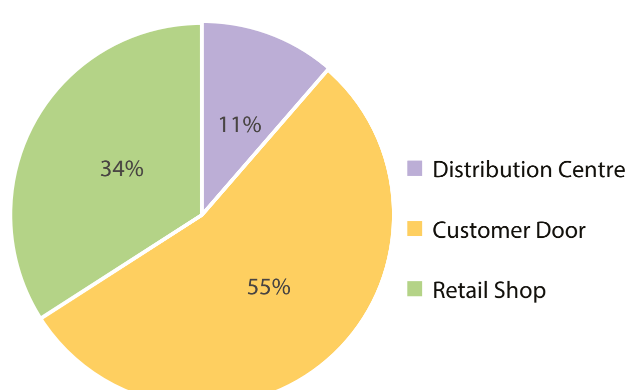


Figure 31 Drop off service points

For distributing the goods, the drivers usually cater to an area of around 10 km in the radius of pick-up point. The end finally delivery of the goods as stated by drivers is either to a distribution centre, customer door, or retail shop. Most of the deliveries from pick-up point happen directly to the consumers. Hence, 55% of the services are provided at a door-step of the customer. Delivery to retail shops, which is a B2B service, accounts for 34% of the total trips and the remaining 11% account for the mid-mile trips from warehouse to distribution centres (Figure 31). On average, one driver serves around 20 locations or distribution points on any given day.

Type of Commodities Carried and Payload

Undertaking an analysis of type of commodities carried by a vehicle as well as the payload is important from the perspective of manufacturing of an electric vehicle. The payload carrying capacity is one of the key criteria that a buyer considers while making the purchase decision. In case of an electric vehicle, payload of the vehicle also has an impact on the range of the vehicle. The urban freight movement is largely characterized by demand for daily essentials and e-commerce.

As per the driver responses with respect to the type of commodities carried by them, 44% of them carry e-commerce goods, followed by 29% and 21% carry groceries and FMCG, respectively (Figure 32). Groceries include things such as fruits, vegetables, fish, milk, etc. and other daily essentials. Things such as water, electronics, furniture, etc. are carried by 7% of the drivers.

As reported by drivers, the total weight of the commodities carried range from 200 kg to 2000 kg. However, only 7% of the vehicles carried a weight of 1500 kg and above indicating that overloading is not pertinent in these vehicles. On average the vehicles carried a load of 702 kg. As this average suggests that most of the vehicles are not even utilizing the full payload capacity of the vehicle and, hence, switching to electric would not be a major problem with regard to the payloads.

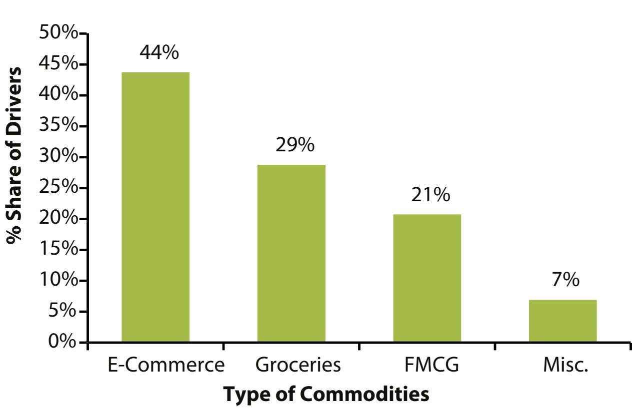


Figure 32 Commodities carried by LT vehicles

Potential of charging during working hours

Time taken for charging is another crucial factor that is of much importance to the driver. Opportunity cost associated with charging during business hours could be very high. Hence, while choosing for electric vehicles in indirect costs such as time costs also play a key role. Factor of time can determine if the drivers would be willing to purchase a fixed-battery vehicle or a swappable battery vehicle.

Hence, there is also a need to understand how much time would a consumer be willing to spend or can spend for charging the vehicle during daytime. Vehicles presently available in the market usually take anywhere between 4 and 8 hours for a full charge, and a fast charger can reduce this duration up to 30 min. Our survey was extended to understand the current idle time and waiting time of a trip undertaken by ICE freight vehicles. The drivers were asked questions related to time taken to load and unload the vehicles, idle time during business hours, and the kilometer of empty runs, if any (Figure 33).

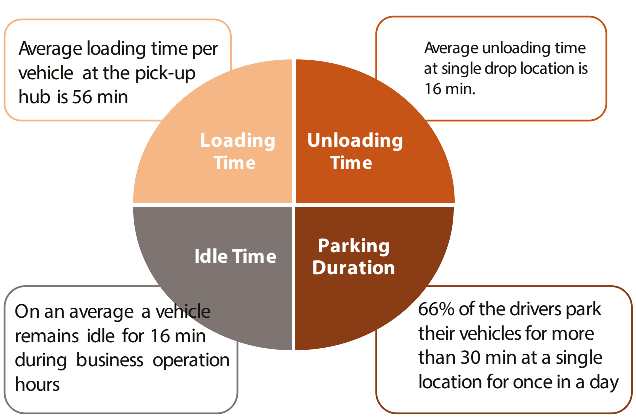


Figure 33 Potential of charging vehicle in between a trip

Spatial Analysis: Mapping for Charging Infrastructure

Easy availability of charging infrastructure is one of the key factors that buyers consider while making their purchase decision. In the case of passenger electric vehicles home charging could be a feasible solution; however, the same cannot hold true for freight vehicles whose battery capacity would be much higher. Presently, the charging infrastructure for freight electric vehicle pilot projects is being set up by the manufacturers at the e-commerce hubs and the cost of the same is largely being borne by the e-commerce companies. In order to ensure that investment in public charging infrastructure is increased and adequate spots and locations are identified in the city, feasible locations need to be identified and mapped.

In the case of LetsTransport, we found that the usual service area is within a 10-km radius of the pick-up points. On the basis of information provided by the driver, the pick-up points of the service locations have been spatially mapped along with a buffer zone of 10 km, which is the service area for drop locations. Additionally, based on driver responses, an assessment of originating trips from a particular pick-up hub has been made (Figure 34).

The survey analysis and the related spatial mappings suggest that while the traffic originates from all zones in Bengaluru except the western part, majority of the trips and traffic is concentrated in the southern part of the city starting from Binnypet and Kormangala and going further south till Hulimavu. The remaining 50% of the locations are evenly spread around the city but the originating traffic from these locations remains low.

Mapping of service areas like this can help in identifying locations where high traffic movement is experienced. Such areas can be prioritized for setting up public charging infrastructure. Setting up charging infrastructure in service areas can prove important from the perspective of reducing range anxiety that consumers often perceive they will face.

Another factor that needs to be considered while planning for creating charging infrastructure is parking

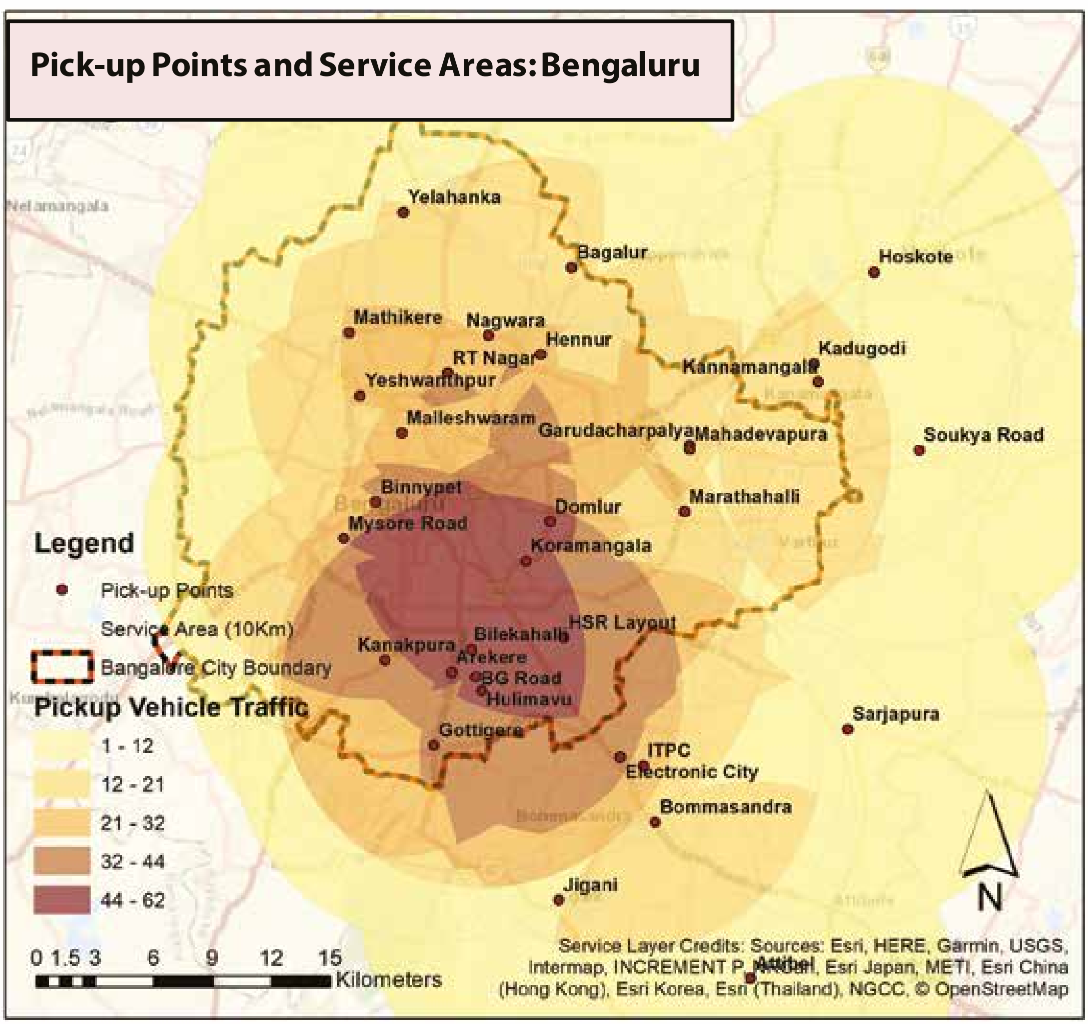


Figure 34 Spatial mapping of pick-up points and drop off service areas

locations of vehicles after the end of work shift of drivers. Parking the vehicle is one of the major concerns that Indian drivers face, which incorporates finding a suitable parking spot and the associated parking costs. Parking is another crucial factor that buyers take into account while making purchase decision in general and selecting the model of the vehicle in particular. In the case of electric vehicles, charging the vehicle is an additional parameter that the drivers will have to consider while looking for a parking spot as most of them would prefer to charge their vehicles overnight. From our survey we found that almost 38% of the drivers park their vehicles on road-side at night. In order to understand the spatial spread of parking spots, mapping of the stated parking locations have been done (Figure 35). Highest concentration of parking and pick up points of MMS is in the central zone of Bengaluru City. There is limited time spent by these postal vehicles in eastern and western parts of the city.

Awareness and Preference for Electric Vehicles

In India the widespread uptake of electric vehicles is being hindered by barriers such as cost of technology, availability of charging infrastructure, concerns regarding range, and vehicle performance, and, most importantly, consumer knowledge and awareness. Not many studies have been done till now to understand driver's perception about electric freight vehicles, their understanding of technology options, available incentives, barriers in adoption, etc.

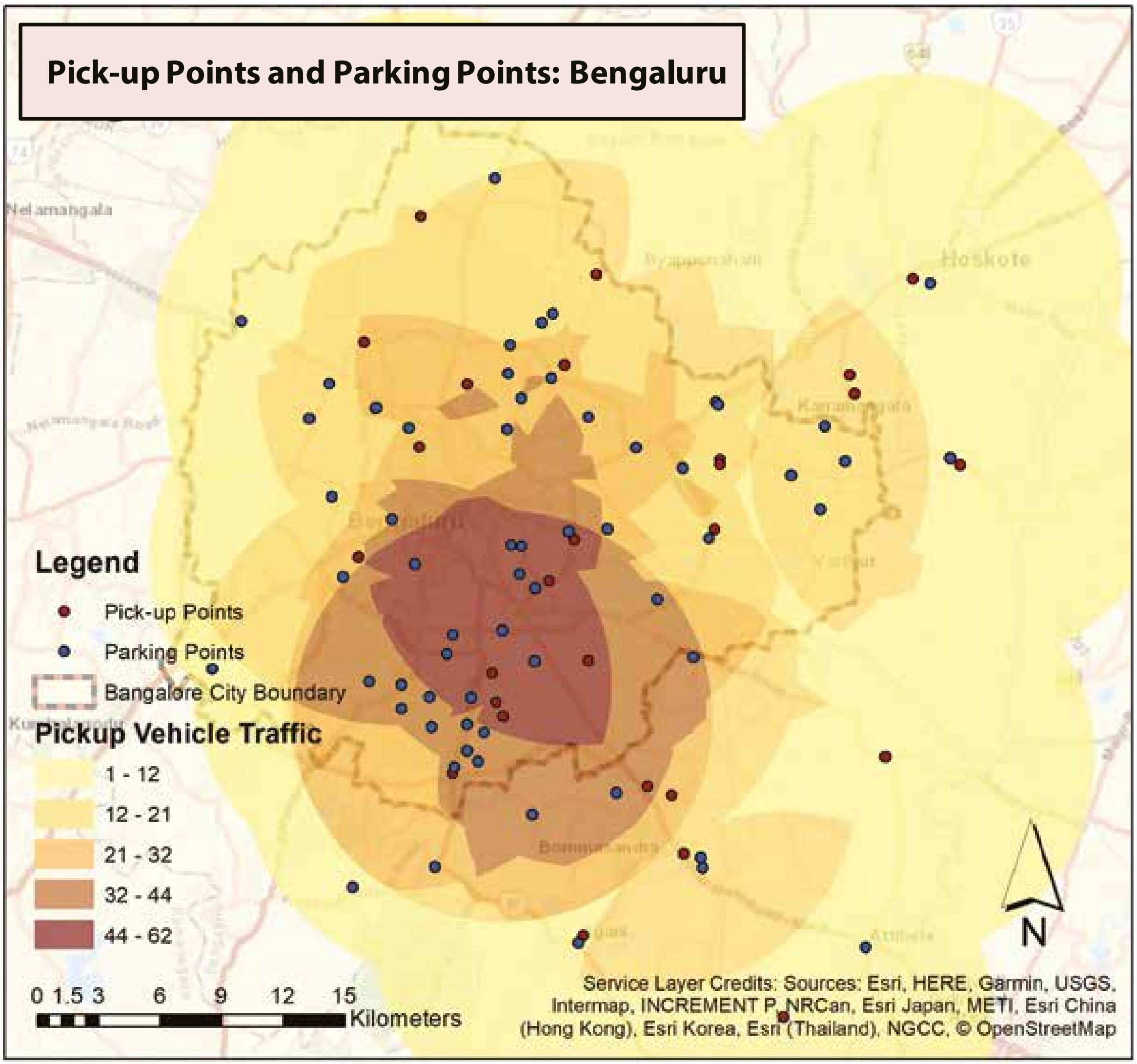


Figure 35 Spatial mapping of parking locations and pick-up points

Through this study we have tried to identify drivers' perception about electric vehicles in the urban freight segment. The survey was designed to capture four key criteria for gauging consumer perception: awareness about electric vehicles, willingness to shift to electric vehicles, information about available incentives and subsidies, and concerns associated with electric vehicles.

Acceptance of electric vehicles largely depends on consumer perception of the vehicles. Drivers with greater familiarity about electric vehicles and the associated benefits are more likely to shift towards them in future. The survey outcomes reflect a significant information gap in terms of familiarity of drivers with the new technology. Almost 63% of the ICE vehicle drivers stated that they have not heard about electric vehicles or do not have any knowledge of the same (Figure 36).

Of the 37% of the drivers who were aware about electric vehicles, 25% were willing to shift to electric vehicles in future and 46% were still not considering an electric vehicle as an option for future purchase. The remaining 29% stated that they might opt for electric vehicle while making their next purchase decision.

Those who knew about electric vehicles were further asked if they have any knowledge related to incentives and subsidies provided by the government. Just 10% of the drivers were aware of government incentive schemes (Figure 37).

Identifying barriers in adoption of electric vehicles is another criterion that policymakers should consider while framing policies. Through the survey, we found that even if the drivers are aware about electric vehicles, they are not inclined to use them. Performance of the vehicle is one of the major key concerns of drivers; this includes range of the vehicle, the speed, and the payload carrying

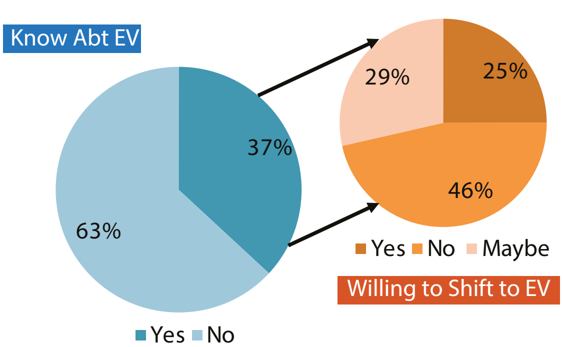


Figure 36 Knowledge about electric vehicle and willingness to shift

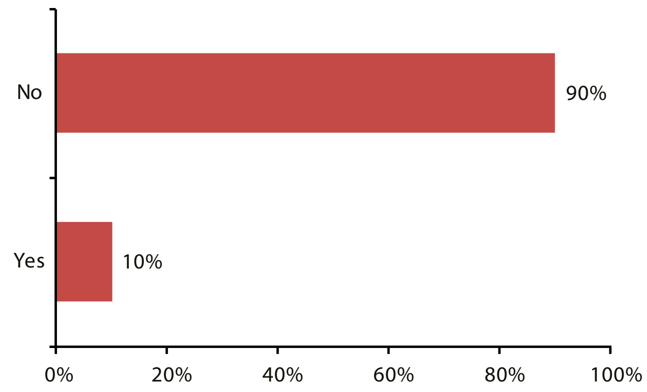


Figure 37 Knowledge about incentives and subsidies associated with EV's

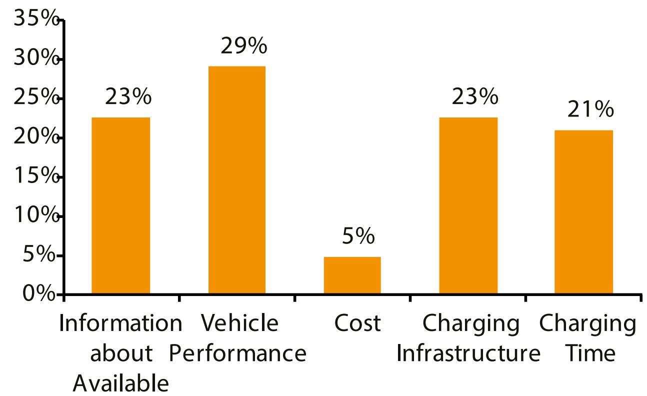


Figure 38 Concerns associated with the purchase of EV's

capacity (Figure 38). Another factor that hinders drivers' decision is the lack of information on available models (23%). Most of the manufacturers in electric commercial freight segment are new start-ups and drivers are not well acquainted with their products as they are with big players in the ICE segment. Lack of availability of charging infrastructure and the charging time are the other key concerns of drivers which can only be addressed if significant infrastructure is visible such as public charging stations. Interestingly, the cost associated with buying and operating an electric vehicle was the least of the concerns for the drivers.

Electric Vehicle Pilot by Lets Transport

As per the Competition Commission of India (CCI), India is currently the fastest growing market for e-commerce sector and has registered an annual growth rate of 51% in revenue generation between 2017 and 2020. In freight

[6] Details available at https://www.cci.gov.in/sites/default/files/whats_newdocument/Market-study-on-e-Commerce-in-India.pdf

segment, the industry has grown at a CAGR of 57% since 2013 and is expected to grow by 18.6% till 2022.[6] The e-commerce sector mainly depends on logistics delivery partners to efficiently manage their supply chain. The recent transition in IT applications and easy accessibility of technology has reshaped the entire business management system of these logistics service providers. Increased demand for freight services and increased innovation have created new opportunity for managing the urban freight system, which has so far remained disintegrated. Entry of players such as LetsTransport has made the system more efficient and, at the same time, improved the livelihoods of drivers. With the growth in e-commerce segment, demand for urban freight vehicles is also going to observe a massive growth and this creates an opportunity for organized logistics players to opt for new mobility options.

As several e-commerce majors are already setting up targets for converting their delivery fleet into electric, the logistics service providers are also aiming to partake in this green initiative. While the focus of several logistics service providers is on using electric two-wheeler and three-wheeler, there are very few who are adopting the technology in four-wheeler commercial vehicle segment. LetsTransport is amongst the few front runners in the sector who have collaborated with ETrio automobiles, the company behind the manufacturing of first retrofitted electric four-wheelers in India.

Considering the potential that electric vehicles have in terms of reducing the impact of urban freight segment on environment, it is imperative to promote the transition in this segment. However, the benefits of electric urban freight vehicles cannot be realised until and unless drivers/ owners adopt this technology. While logistics players seem to have a growing interest in electric vehicles but the concerns of drivers still remain unaddressed. As analysed in earlier section, only a small share of drivers are aware about electric freight vehicles and the share of those who are willing to buy electric vehicles is much lower. As identified, vehicle performance remains one of the key concerns of drivers. Hence, as a part of this study we have undertaken a further assessment of electric commercial vehicles that are being used for urban freight movement by LetsTransport.

LetsTransport is currently doing a pilot of electric vehicles in major cities of India. The vehicles that are being used by drivers include electric three-wheeler and retrofitted four-wheelers. To develop a better understanding of the vehicle performance, consumer perception and to know more about drivers' experience and satisfaction with the technology, we conducted a small survey of 11 electric vehicle drivers (Annexure III). Additionally, this exercise will help in understanding the challenges and opportunities in this segment in a holistic manner.

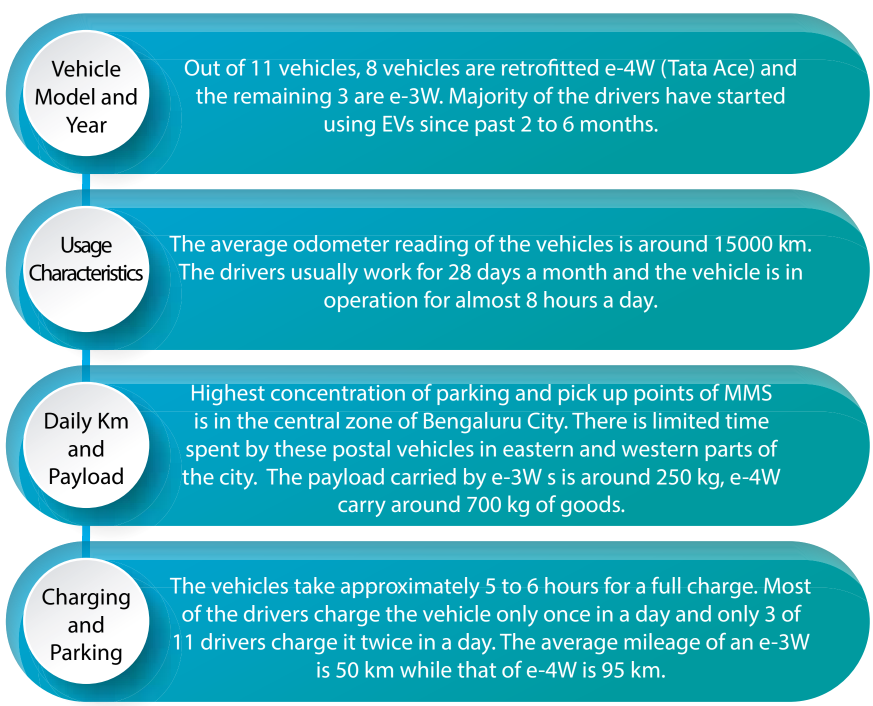


Figure 39 Electric vehicle usage and operational characteristics (case study-based survey outcomes)

Cost Implications

- Out of 11 vehicles, 8 vehicles are retrofitted e-4W (Tata Ace) and the remaining 3 are e-3W. Majority of the drivers have started using EVs since past 2 to 6 months.
- The remaining 2 drivers who own the e-3W have to spend only Rs. 150-250 per month for charging the vehicle.

Charging and Parking

- Salaried drivers park their vehicles at the pick-up hub/clients location where charging facility is available.
- Parking and charging facility is available free of cost to these drivers.
- Owners of EVs park the vehicle near their homes without incurring any expenses.

Savings Potential

- All the drivers reported that their monthly operational and maintenance costs have reduced after switching to electric.
- Drivers reported that on an average they are able to save Rs. 8000 per month on fuel and maintenance costs.

Figure 40 Factors impacting costs associated with electric vehicle

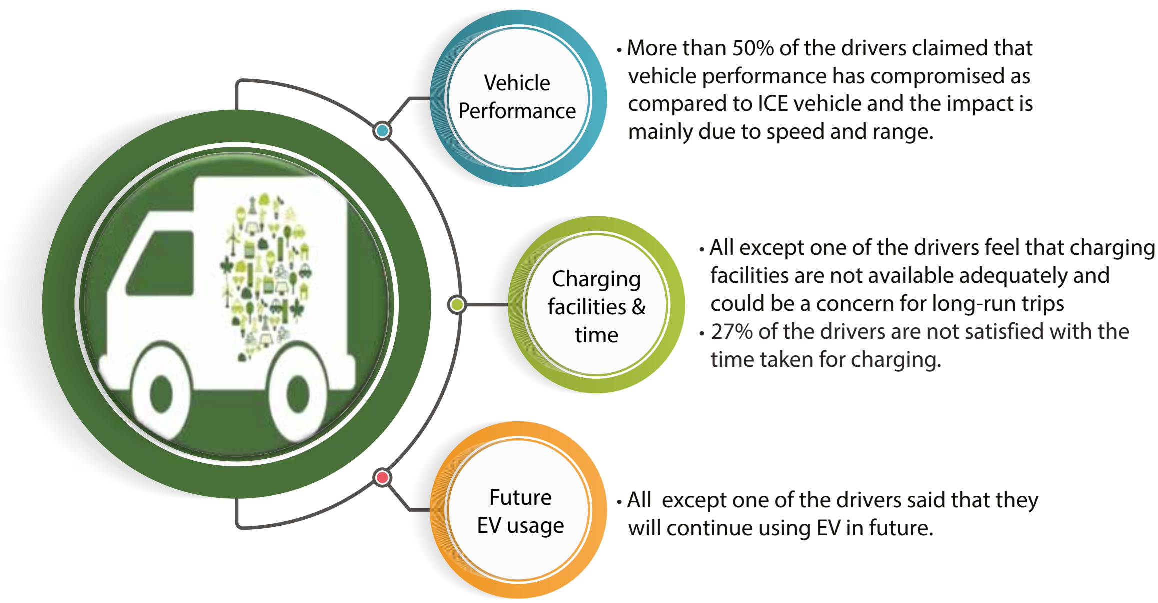


Figure 41 Opinion about electric vehicle by users

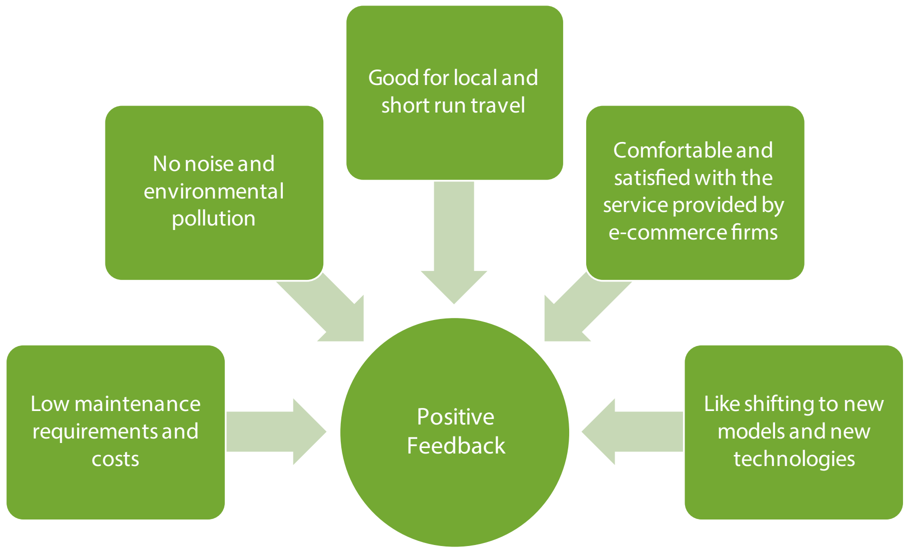


Figure 42 Reasons for using electric vehicle – positive feedback

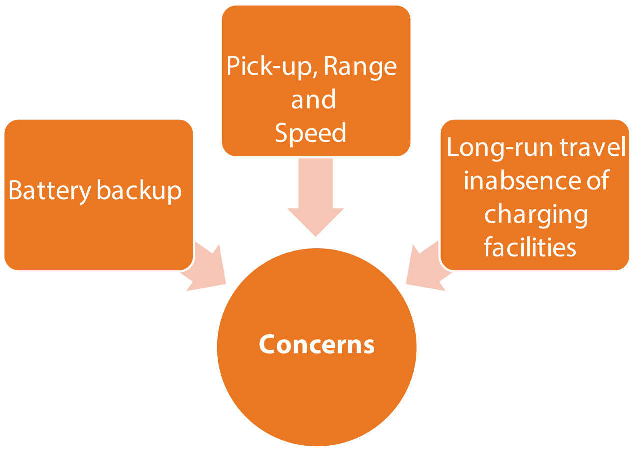


Figure 43 Concerns with electric vehicles

The key outcomes of the survey are presented here (Figures 39 to 43).

Total Cost of Ownership: Bengaluru Organized Logistics

Total cost of ownership (TCO) analysis of organized freight delivery service vehicles have been done for assessing the cost benefits that could be achieved by switching to electric vehicle in Bengaluru. Analysis of operational characteristics and cost characteristics of vehicles used by third-party logistics service providers has been done based on inputs received from drivers' survey and stakeholder consultation and listed in Table 2.

Table 2 Input parameters for TCO analysis: Bangalore organized logistics use case

Parameter	Value	Source
Average daily utilization	71 km	Based on drivers' survey
Diesel Cost	Rs 66	Based on average diesel price in Bengaluru in the last 5 years
Fuel efficiency for diesel vehicles	14 km/l	Based on drivers' survey
Price of electricity	Rs 7.8 per unit	Based on tariff for 2020-21 from BESCOM
Range for electric vehicles	70% of range provided by manufactures.	Based on stakeholder input and EV driver survey
Permit fees	No permit fees for vehicle <3.5 tonne GVW	Based on inputs from RTO
Road tax	Rs 10,000 plus 11% cess	Based on inputs from RTO
Registration charges (including road safety cess)	Rs 3,011	Based on inputs from RTO
Annual fitness certificate	Rs 3,391	Based on drivers' survey
Annual maintenance costs for ICE vehicles	Rs 42,816	Based on drivers' survey
Annual maintenance costs for electric vehicles	Rs 21,408 for newly manufactured electric vehicle Rs 32,112 for retrofitted electric vehicle	Assumed to be 50% and 75% of the cost associated with ICE vehicles for new electric vehicle and retrofitted electric vehicle, respectively. This is conservative as literature suggests that the maintenance costs associated with e-vehicles is one-third that of ICE vehicles.
Insurance premium discount for electric vehicles	15%	Based on IRDAI proposal for third part motor vehicle insurance from FY 2020-21 onwards.
Interest rate on loans	ICE: 9% Electric Vehicle: 15%	Based on stakeholder consultations
GST	Electric Vehicle: 5% ICE: 28%	As per GST tariffs

Source: TERI

Additionally, the individual specifications of the vehicles are also provided in Chapter 4 on TCO.

The survey indicates that diesel-based four-wheelers are primarily used to move urban freight in Bengaluru and presently a few logistics service providers are conducting electric vehicle pilots of retrofitted four-wheelers. Hence, the TCO analysis has also been done for diesel four-wheelers, newly manufactured electric four-wheelers, and a retrofitted electric four-wheelers. Table 3 shows the TCO per km across the three categories of vehicles.

Over the lifetime of the vehicle, costs associated with both the electric four-wheelers and the retrofitted four-wheelers are lower than the diesel four-wheelers presently in operation. But economically, the retrofitted electric four-wheelers is the most feasible over the lifetime of the vehicle. The financing costs associated with electric four-wheelers are more than three times the traditional diesel four-wheelers, despite the subsidies and lower GST rates. Retrofitted four-wheelers have a lower financing cost than the new electric vehicles, but it is still almost double that of diesel four-wheelers. The higher financing costs are made up by significantly lower fuel prices and

Table 3 TCO (Rs/km) comparison for four-wheelers: Bangalore organized logistics use case (Rs/km) (net present value)

Cost	Diesel Four-wheelers	Electric Four-wheelers	Retrofitted Electric Four-wheelers
Financing	Rs 1.22	Rs 3.76	Rs 2.54
Permit	Rs 0	Rs 0	Rs 0
Road Tax	Rs 0.06	Rs 0.06	Rs 0.06
Insurance	Rs 0.61	Rs 0.52	Rs 0.61
Registration charges	Rs 0.02	Rs 0.017	Rs 0.02
Fitness certificate	Rs 0.11	Rs 0	Rs 0
Fuel	Rs 3.79	Rs 1.37	Rs 1.32
Maintenance	Rs 1.39	Rs 0.70	Rs 1.04
Battery replacement	0	Rs 0.65	Rs 0.73
Total capital expenditure	Rs 1.22	Rs 3.76	Rs 2.54
Total operating expenditure	Rs 5.98	Rs 3.31	Rs 3.79
Total TCO (per km)	Rs 7.19	Rs 7.07	Rs 6.32

Source: TERI

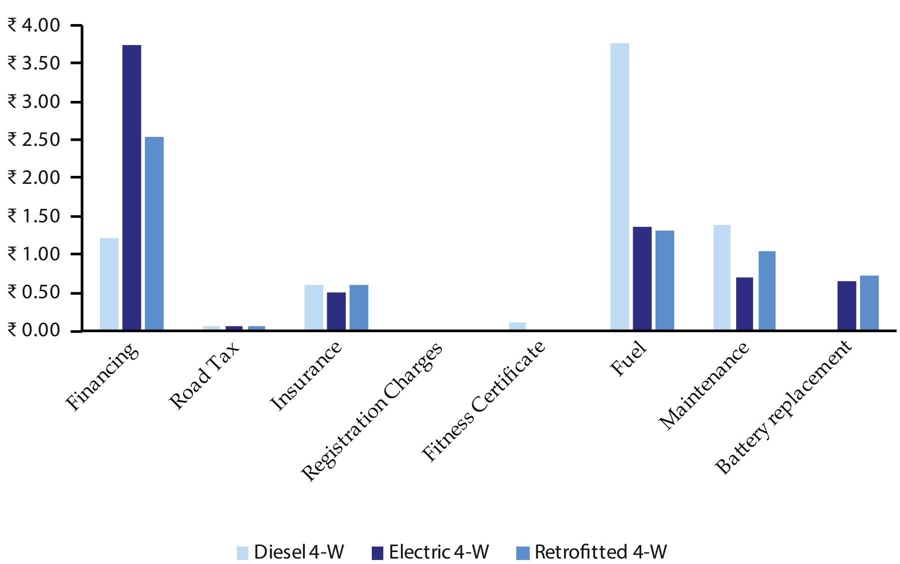


Figure 44 Break-up of TCO according to different kinds of expenditure

maintenance costs (Figure 44).

Figure 45 shows the cumulative expenses associated with the different vehicles across years. In the first year, the costs are higher for both the electric four-wheelers and the retrofitted four-wheelers. However, the retrofitted vehicles achieve cost parity with the diesel vehicle after the fourth year and then operate at lower cost throughout the lifetime. The electric four-wheelers take longer to achieve cost parity with the diesel vehicle, the cumulative costs between both the vehicles is almost same in the seventh year, after which the parity could be achieved. For both the vehicles, the major costs are borne in the loan repayment period and after year 4 when the battery replacement costs are incurred. This use case suggests the capital costs of new electric four-wheelers need to come down in order to make economic sense; therefore, there is a need to explore more financing options in this case with lower interest rates. Further, the reduction in price of battery pack could also improve the feasibility of electric vehicles in commercial four-wheelers segment.

Overview of Key Inferences and Policy Suggestions

- Comparing vehicle usage and operational characteristics of ICE vehicles and electric vehicles used for e-commerce movement in Bengaluru suggests that small commercial vehicles can lead the transition towards electric in the logistics and trucking segment in the coming years.
- The current range requirements of ICE vehicles vary from as low as 30 km to as high as 150 km and the payload requirements also lie between 200 kg and 2000 kg. Hence, the requirements of the fleet can be met by both existing three-wheelers in the market and the retrofitted four-wheelers such as e-Trio SCV.
- Considering the fact that more than 60% of the total surveyed fleet of vehicles is of pre-BS-IV standards and that the overall utilization of fleet has not reached up to its full capacity, there is immense opportunity to replace the older inefficient fleet with electric in the coming 4 to 5 years. Additionally, adopting retro-fitting options for older yet useful fleet would help minimize the resource use and will also reduce the fixed cost component of the vehicle. This could specially prove to be useful in the case adequate investments are not available for setting up vehicle scrapping units.
- For cities such as Bengaluru, where alternatives such as CNG are not available and complete reliance lies on diesel-run vehicle, electric vehicles could be the only clean and viable solution as of now.
- Cost of owning and running the vehicle are the key factors that drivers take into account in addition to the operational efficiency. From the survey, we find that switching to electric vehicle brings down the

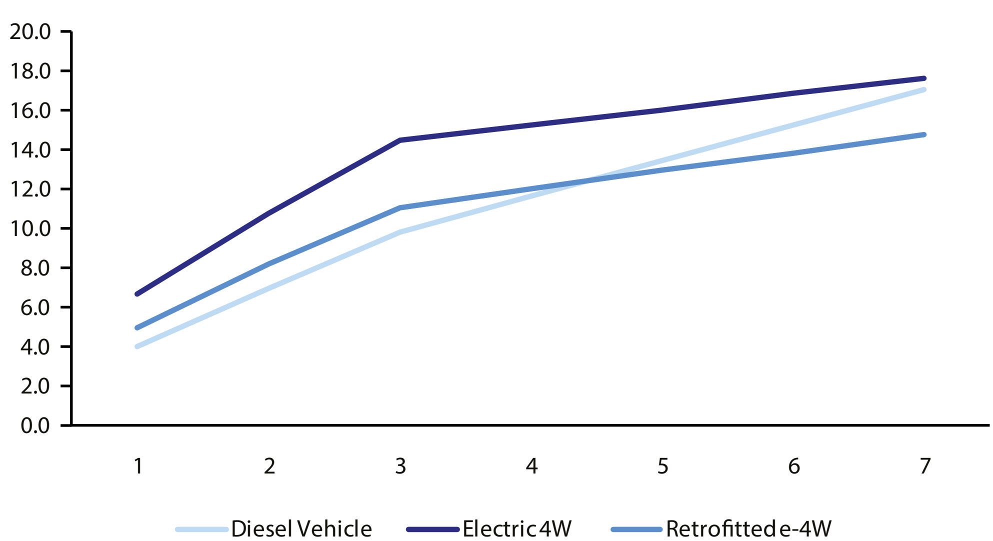


Figure 45 Year-wise break up of TCO for Bengaluru organized freight services

fuel and maintenance to the minimal. However, we observed that most of the electric vehicle drivers do not own the vehicles and are working on salary basis. Hence, in order to smoothen this transition at an early stage, e-commerce and logistics firms will have to invest in electric vehicle fleets. As 26% of the drives of ICE vehicles do not own the vehicles, these could be targeted by e-commerce firms to initiate the mass pilot projects. This will help in building the driver confidence with respect to new technology.

- As observed from the survey, large share of drivers rely on financing from formal sources for meeting the capital cost of vehicles. Hence, bringing financial institutions on board and creating easy-financing policy mechanisms will ease the purchase process of electric vehicles. As battery replacement cost is another major expense that drivers will have to pay for some financing provisions need to be given there as well.
- From the electric vehicle preference survey, we find that more than 60% of the ICE drivers are not aware about electric vehicles and even those who are aware are not willing to switch to electric vehicles. The key reasons for this being lack of knowledge about existing models, incentive schemes, vehicle performance, and concerns associated with charging. Hence, mass awareness and training programmes organized by RTOs or other city-level bodies could help in meeting the driver concerns. Learning can be taken from organized logistics players such as LT who are already conducting electric vehicle pilots. Given that most of the ICE vehicle drivers belong to the young age group and have decent level of education, the level of acceptance of new technology could be relatively higher.
- One of the interesting findings that came to light from the electric vehicle pilot survey was drivers reporting that they are choosing to drive electric vehicle as they know about the benefits of electric vehicles in terms of reducing noise and environmental pollution. Some of the drivers even said that they like to use new models and technologies. This signifies that creating more awareness about electric vehicles from both economic and environment perspective can induce more drivers to opt for them.
- There is also a need to bring out models in the market that can meet the requirements of logistics industries in a holistic manner. In spite of overloading not being so prominent in this segment, pick-up and speed are the key concerns of electric vehicle drivers.
- Availability of charging infrastructure is another factor that is impeding the current uptake of electric vehicles. As of now majority of electric vehicle drivers are keeping their vehicles at e-commerce hubs where the charging facility is provided by the companies. Battery backup and range anxiety with respect to long distance travel are some of the important concerns that need immediate attention. Hence a policy needs to be formulated based on extensive Origin-Destination (O-D) analysis and mapping of key logistics hubs and parking space is required to create the public charging infrastructure. In order

2. Potential of Electrification: **Urban Freight in Surat City**

Surat, the second most populated city in Gujarat, ranks eighth in the most populated cities of India. Census of India 2011 reports that Surat's population is 4,466,826 with a decadal growth of 55.29% (Corporation, Surat Municipal Corporation, 2019). It is also ranked as the 73rd largest urban area in the world. The city also boasts of its importance as a commercial and industrial hub in the country. The City Mayors Foundation (a globally recognized think tank on urban affairs) has ranked Surat as the fourth fastest growing city across the globe and the fastest growing Indian city in terms of economy (SUDA, Surat Development Plan 2035, 2017). Figure 1 summarizes some relevant characteristics of Surat City.

At the same time, this rapid growth of economic activity has come with various environmental externalities. The concentrates of average PM_{10} in Surat city have been above the national average since 2010 (SUDA, Surat Air Pollution Control Plan, 2018). Since 2014, $PM_{2.5}$ concentrates in Surat have been exceeding the national standards of air quality. This has prompted various strategies from the Surat Municipal Corporation (SMC), Surat Urban Development Authority (SUDA), and the Government of Gujarat. These include Surat Air Quality Action plan (2018), Parking Strategy for Surat (2017), Bus Rapid Transit System, etc. The top two sources of $PM_{2.5}$ particles in Surat are from the industrial sector (71%) and transportation sector (13%).

The total number of vehicles registered in Surat exceeds 24 lakh. Like most urban areas in India, two-wheelers and passenger cars dominate the number of vehicles registered. However, 3% of the vehicles registered with Surat RTO in 2018 were small commercial vehicles (SCVs). The new vehicle registrations in Surat have grown at a rate more than 34%.

According to the Comprehensive Mobility Plan 2046 (CMP, 2016) of Surat, the city has 29% external freight movement, 29% external–internal city movement, 28% internal–external movement, and 15% intra-city freight movement. It also reports that the freight movement is done for a total of 102 types of usages of which 30 were identified to be such that make use of LCV (up to 7.5 tonne). It states that LCVs are predominantly used for intra-city movement. Furthermore, almost 24% of the fatalities are caused by HCVs and 8% are caused by LCVs yearly (Corporation, Surat Municipal Corporation, 2018).

To understand freight patterns in Surat, we studied secondary data from Surat Comprehensive Mobility Plan (CMP), Gujarat State Pollution Control Board (GPCB), SMC, SUDA, RTO Surat, and driver surveys conducted by Centre for Excellence in Urban Transport (COE-UT). We further conducted primary stakeholder interviews to validate findings from secondary data and identified sectors to understand better the freight characteristics of SCVs in

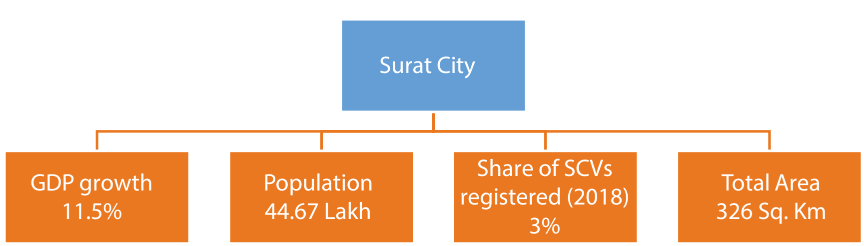


Figure 1 Surat city characteristics

Surat. A detailed analysis of the overall freight demand in Surat is given in the Annexure.

Textile industry is responsible for 44% of the daily vehicle trips, 34% of the daily tonnage, and 96% of the industrial units in Surat. This is clearly the most significant industry-generating demand for urban freight, as is clear from Figure 2.

Stakeholder Primary Interviews

To further understand the freight scenario in Surat, especially with respect to application of SCVs, we conducted personal interviews with various stakeholders in Surat. Figure 3 shows the list of stakeholders interviewed in Surat.

TERI interviewed stakeholders from the government, industry, transportation, and civil society in Surat. The questions posed in the structured interviews and the detailed transcripts of the same are attached in the Annexure. Other than validating the focus on the textile sector, the stakeholder interviews also helped identify that Solid Waste Management (SWM) functioned in an organized manner in the city. Small commercial vehicles (with modified bodies) were used for household door-to-door waste collection. The waste was brought to each zone's consolidation centre. We also learnt that there is GPS data monitoring of the waste services. As there was potential secondary data on trip generation, largely fixed routes and contracting controlled by SMC, the SWM sector was also selected along with the textile industry as a front runner for deeper assessment of the potential of electrification.

Case Study III: Textile Industry in

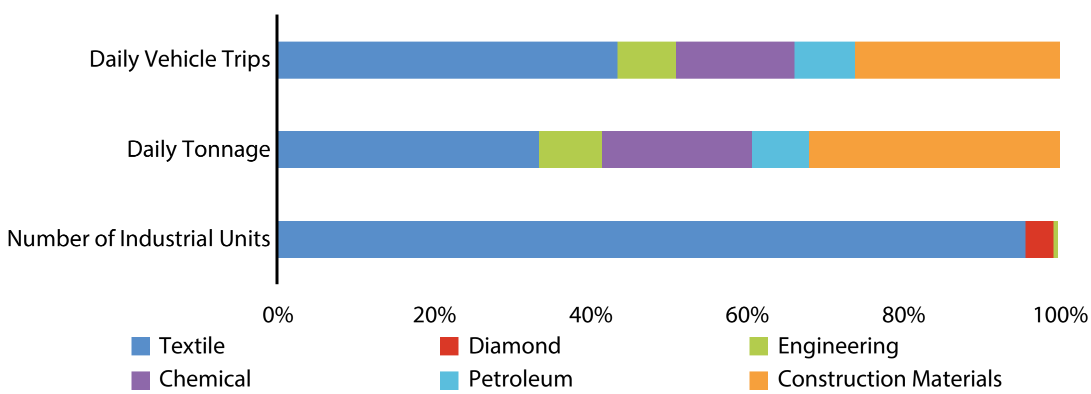


Figure 2 Freight demand from major industries in Surat

Source: Driver Survey COE-UT (2017), SUDA, Surat CMP

Government Stakeholders	Industry Stakeholders	Transport Operators	Civil Society
• Mayor • Municipal Commissioner • Chief Engineer • Solid Waste Department	• Weaving Mill owners • Processing Factory owners • Trader Union representatives	• Trucking Union representatives • Tempo Association representative • Solid Waste Management operator (Private agency)	• Local Architect • Chief Resilience Officer, Surat • Professor of Transport Planning, SVNIT

Figure 3 List of stakeholders interviewed in Surat

Surat

Textile industry in Surat has 124,981 industrial units within SMC boundaries. There are multiple stakeholders in the supply chain of textile production including yarn manufacturers, weavers, chemical processors, embroidery, and other value adders and traders. These are composed of small, medium, and micro enterprises. Transport service providers are the crucial players linking all the stakeholders along the supply chain of the textile product.

Freight Flow of Textile Industry in Surat

An approximate of 3000 tonne of yarn enters Surat daily from Silvasa, Hazira, and other parts of the country. Almost 4 crore metres of fabric is made in Surat daily. This incoming yarn goes to the weaving centres (power looms), which are scattered mostly in the north-west and eastern zones of the city. One-metre fabric weighs around 70–80 gm. The fabric (100-m cloth is called one taka) is then sent to the traders in the textile market in the central zone of the city. Depending on how the processing is done, the cloth is then sent to the processors for dying, printing, etc. The processing mills are mostly located in Pandesara, Palsana, Sachin, and Kadodara. These centres are within a 10-km radius from the city. The processing mills also require chemicals and other ancillary material, which is transported in the SCVs as well. The value addition stakeholders in the Surat textile industry are mainly micro enterprises and spread throughout the city. The traders are concentrated on the central parts of the city. As the traders are also central nodes in the textile supply chain, the textile industry's entire vehicle traffic gets congested in the central zone.

Figure 4 shows the supply chain of textile products. Each stage in the figure indicates transportation of commodity (raw material, semi-finished, or finished). As the traders are also central nodes in the textile supply chain, the textile industry's entire vehicle traffic gets congested in the central zone. This is explored further in the spatial analysis of surveyed trips in this chapter.

The textile product reaches traders at the textile market

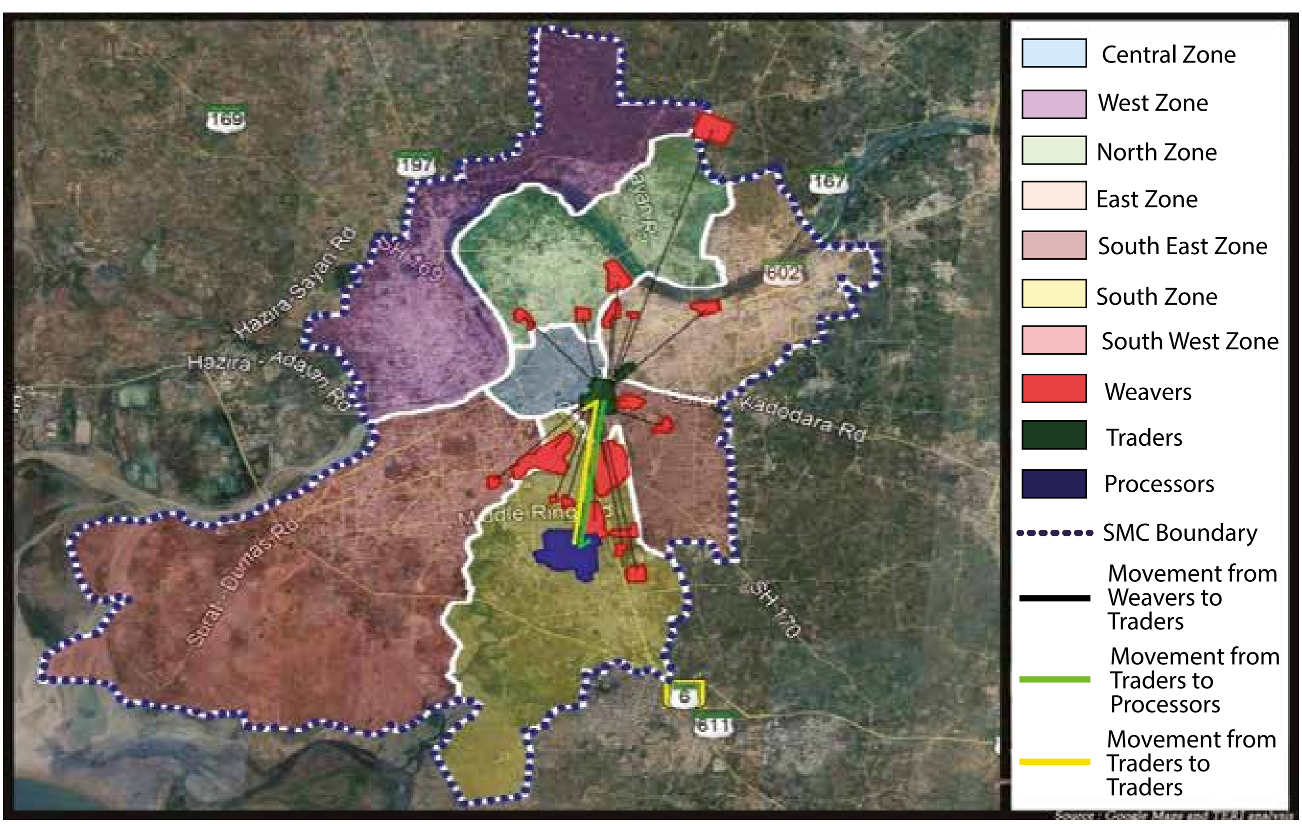


Figure 4 Distribution of stakeholders in supply chain of textile industry within Surat

Source: Primary Interviews

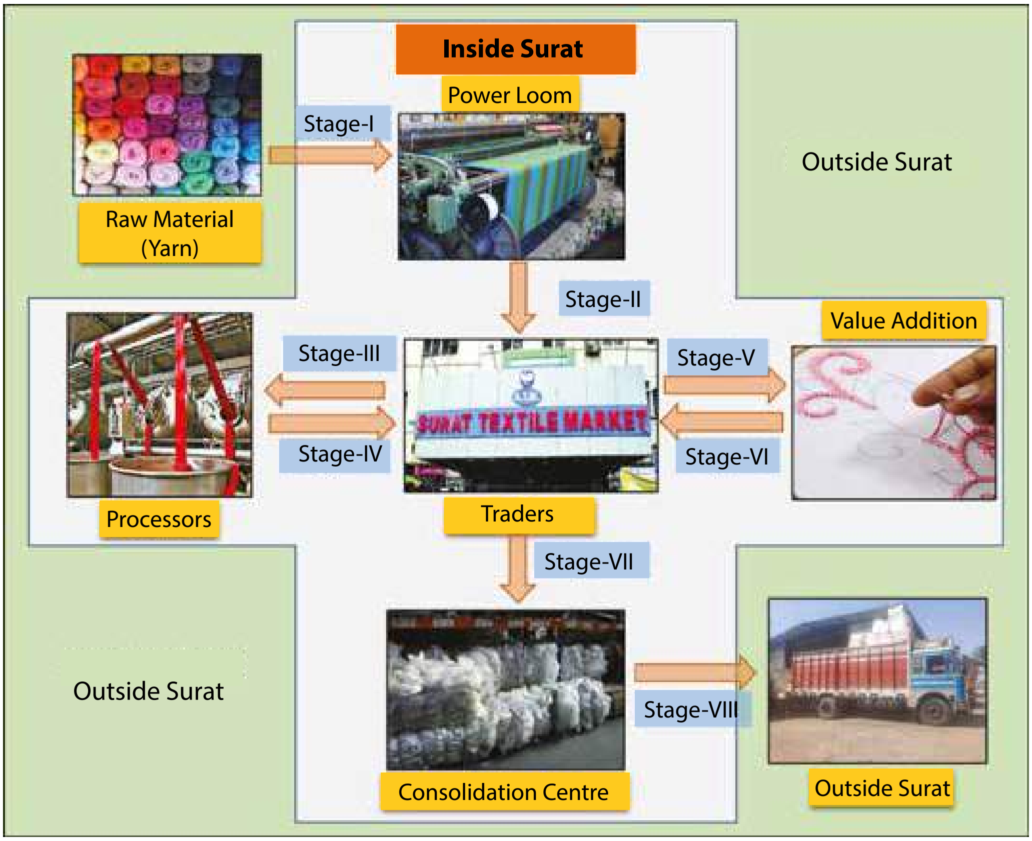


Figure 5 Freight flow of textile industry, Surat

Source: Primary Interviews, driver survey COE-UT (CEPT), SUDA

after multiple stages of product supply chain. Stage I and Stage VIII involve freight from and to outside Surat city (see Figure 5 and Table 1). All other stages involve majority of the textile freight traffic within the city. Further, trips in Stages II–VII involve smaller freight vehicles relative to external–internal and internal–external trips where HDVs (Heavy Duty Vehicles) are employed. Trips in Stages V and VI are undertaken by respective value addition micro-enterprises and are mainly done on two-wheelers. Hence, those trips are beyond the scope of this study.

Hence, within the supply chain of the textile product in Surat, we have focused on the SCVs employed in movement from:

Table 1 Stages in textile supply chain

Transportation stages in Surat Textile Industry	Movement w.r.t city boundaries	Types of vehicles used	No. of vehicle trips generated daily
Stage I: Raw Material to Power Looms	External–Internal	HDVs, LCVs	744
Stage II: Power Looms to Textile Market	Internal–Internal	SCVs	2406
Stage III: Textile Market to Processors	Internal–Internal	SCVs	3481
Stage IV: Processors to Textile Market	Internal-Internal	SCVs	3481
Stage V: Textile market to Value Addition Enterprises	Internal-Internal	Two-wheelers	NA
Stage VI: Value addition Enterprises to Textile Market	Internal-internal	Two-wheelers	NA
Stage VII: Textile to Market to Consolidation Centre	Internal-internal	SCVs, LCVs	8592
Stage VIII: Consolidation Centre to outside Surat	Internal-External	HDVs	NA

Source: Primary Interviews, SUDA

- Stage-II: Power looms to textile markets (movement of Grey)
- Stage-III: Textile market to processors
- Stage IV: Processors to textile market
- Stage VII: Textile market to consolidation centre

Textile Driver Survey

In June 2020, using standardized questionnaire 72 vehicles employed in the textile industry were surveyed telephonically. The drivers were paid an incentive to undertake the survey. The drivers were posed with questions under six main categories including ownership and purchase of the vehicles, vehicle type, vehicle age and utilization, costs and refuelling associated with the vehicle, operational characteristics, and parking characteristics (Figure 6). In this section, we will provide the origin destination (OD) analysis of the surveyed trips.

The survey captured 202 tonne of freight movement in 137 vehicle trips. This accounts for just 0.5% (approximately) of the tonnage generated by the textile industry each day. Due to mobility restrictions brought upon by the COVID-19 pandemic, the drivers were selected based on their willingness to be part of the survey based on the limited set of telephone numbers received from the Small Tempo Drivers Welfare Association in Surat city. Even though the sample may not be representative of the overall freight movement, it gives some crucial insights on the vehicle-specific characteristics of freight transportation for understanding the potential of electrification.

Ownership and Purchase

Of the vehicles surveyed, 96% were self-owned by the interviewed driver and 4% were salaried drivers. Of the self-owned vehicles, 84% were purchased through EMI. Sixteen per cent of the owners had bought their vehicles upfront (Figure 7)

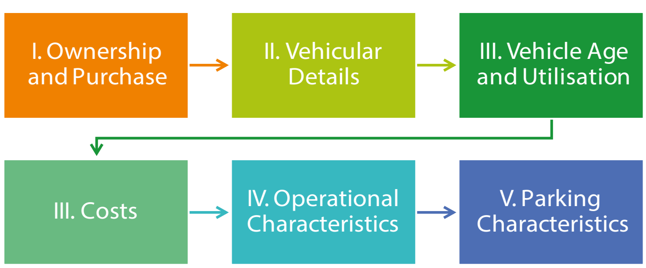


Figure 6 Six main categories of questions

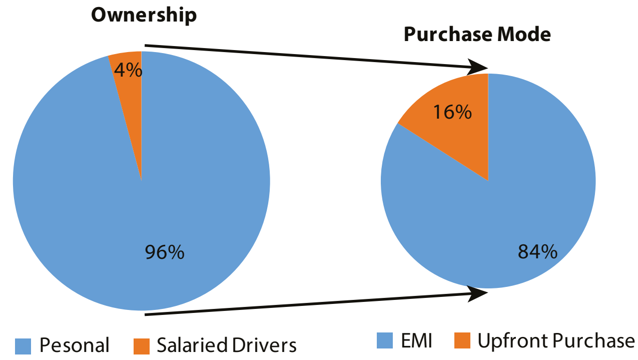


Figure 7 Ownership and purchase mode vehicles surveyed

Formal financing mechanisms were used in buying 79% of the vehicles. The financing included banks and private institutions such as auto finance companies. Informal financing including personal savings, loan from relatives, etc. were used for buying 21% of the vehicles (Figure 8).

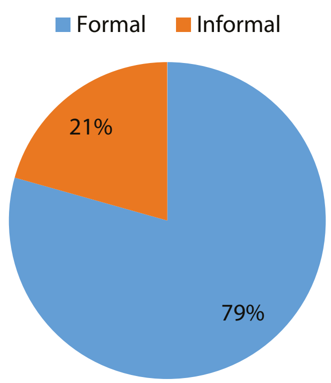


Figure 8: Source of financing

Vehicular Details

The survey captured three types of commercial vehicles: three-wheeler goods, mini trucks, and pick-up trucks. Mini trucks and pick-up trucks are four-wheeler small commercial vehicles. In 98.6% of the vehicles, diesel was used as the only fuel. The rest were diesel–CNG vehicles using diesel as the primary fuel. These diesel–CNG vehicles belonged to the pick-up truck category of vehicles.

Figure 9 shows the different vehicle models captured under the three types of SCVs done in this case. Of the vehicles captured in the survey, 26% were three-wheeler goods vehicles, 35% were mini trucks, and 39% were pick-up trucks, respectively. Figure 10 shows the proportion of SCV types captured in the survey.

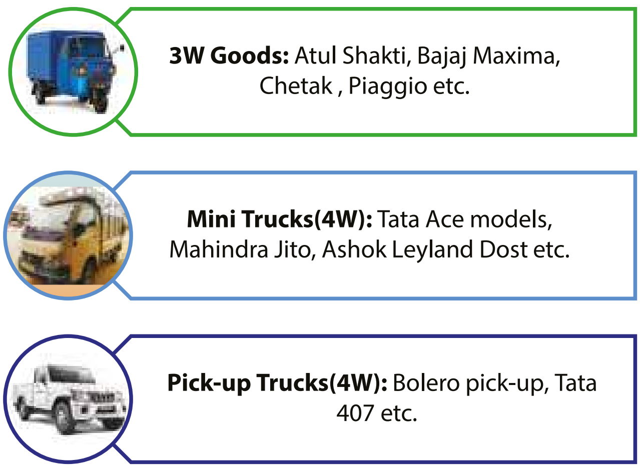


Figure 9 Types of vehicles employed in Surat textile freight

Source: TERI Field Visit, Primary Survey

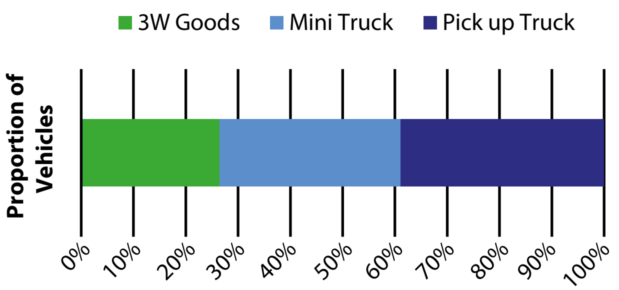


Figure 10 Proportion of vehicle types

Vehicle Age and Fleet Utilization

The SCVs surveyed were on average 4.5 years old. The average odometer reading of the surveyed vehicles was 93,275 km. Based on the odometer readings and the annual distance covered, the vehicles' age was estimated. This was cross-validated with the stated age of the vehicle by the drivers. Based on the purchase year estimated from the age, Bharat Stage (BS) emission standards of the each vehicle surveyed was estimated. Figure 11 shows the proportion of vehicles purchased under respective emission standards.

Of the surveyed vehicles, 62% are BS-III vehicles. These vehicles are between three years and less than 10 years in age. About 29% of the vehicles are BS-IV vehicles purchased less than three years ago. There are no vehicles older than BS III in the three-wheeler goods category. About 4% of the overall vehicles were BS-II and just 1% was BS I. The survey did not capture any pre-BS-I vehicles. The BS-I and BS-II vehicles are mainly in the pick-up truck category. With the new introduction of BS-VI standard and scrapping policy, electric vehicles may be an attractive proposition for owners of BS-I, BS-II, and BS-III vehicles. Of the vehicles surveyed, 98.7% were used solely for textile-related freight. This indicates a positive inference as the routes and utilization may be predictable for effective charging solutions.

Vehicle Operational Characteristics

Drivers were asked about general operational characteristics of the vehicle and trip, including the weight carried (Figure 12) and distance covered in a day. Developing an understanding of these characteristics is essential to analyse the technological potential of the current electric vehicles in the market in replacing these

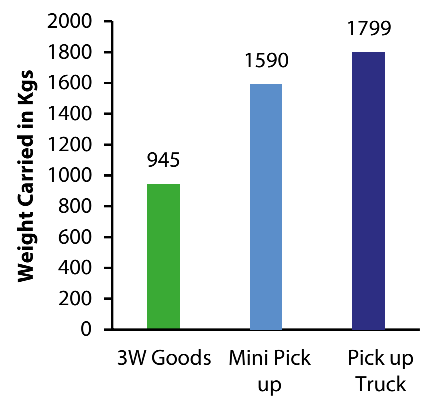


Figure 12 Average weight carried per trip (Surat Textile)

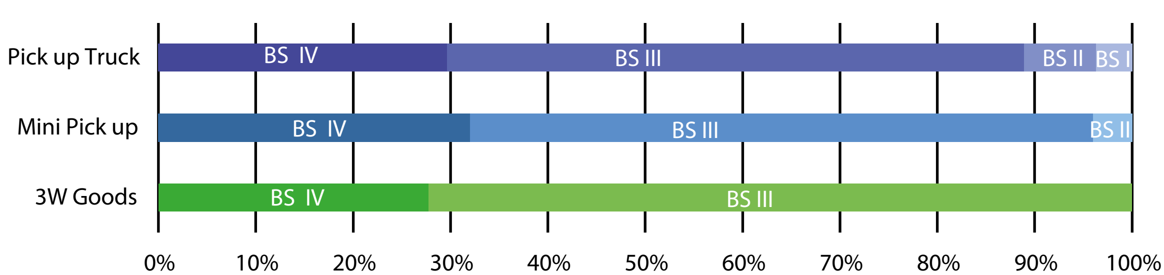


Figure 11 Vehicles categorized according to emission standards

operations. At the very least, electric vehicles must be able to carry the same load over the same distances as the current SCVs in use.

Weight

The survey revealed that on average, three-wheeler goods vehicles carried 945 kg per trip. Mini trucks and pick-up trucks carry 1590 kg and 1799 kg, respectively. The variation in the weights carried by vehicle types is proportional to their variation in manufacturer-prescribed payloads of respective vehicle models. However, there is considerable overloading in all the vehicle types studies here. Vehicle manufacturer prescribed payload of three-wheeler goods employed in Surat does not exceed 560 kg. The average payload actually carried by three-wheeler goods in the city is almost 69% more than this. Similarly, there is an overloading of 56% of the payload capacity of mini trucks. However, the average overloading in pick-up trucks is limited to just 6%.

Distance

It is crucial to understand the daily total distance covered by the ICE vehicles to determine both economic and technological potential of electric vehicles. The daily total distance travelled by three-wheeler goods, mini trucks, and pick-up trucks are 51 km, 78 km, and 96 km, respectively (Figure 13). All these distances are within the full charge range of many vehicles in the electric vehicle market. Low distance may be both positive and negative inference for potential of electrification. It is positive for technological potential for meeting the daily total distance in one full charge. It is negative for economic potential of recovering additional purchase cost spent on electric vehicles by higher operations.

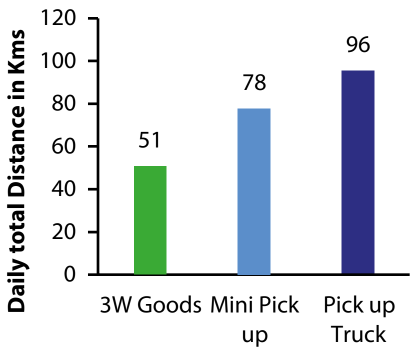


Figure 13 Daily total distance (Surat Textile)

Repetition of Trip

Figure 14 shows the repetition of trips in the surveyed sample. One trip is when the textile good is carried from an origin to destination. Hence, repetition of the same implies that the vehicle goes back to origin (empty) to reload and serves the same destination again. This repletion of trip is on the same route. This variable is crucial for understanding the potential of electrification as higher repetition of the same trip would improve the predictability of the movement. This is essential for planning charging solution at this stage of electric vehicle technology. Seventy three per cent of the vehicles repeated trips at least twice. Only 26% of the vehicles undertook trips only once. This is a positive step towards potential of electrification as 73% of the vehicles visit the same loading and unloading locations at least twice.

The operational characteristics of the vehicles in Surat reveal a mixed signal towards the potential of electrification. Although there is low daily total distance and high repetition of trips, it was found that there are several overloadings in the three-wheeler goods and mini trucks segments. These are the two segments where most electric vehicle counterparts are available. Switching to electric vehicles may require the vehicles to undertake multiple trips to carry the same load. The revenue earned by the drivers is directly related to only the amount of weight carried. Hence, switching to electric vehicles, which are capable of carrying lesser loads, may require the drivers to devote more time and distance for the same amount of earning. This is not a positive sign towards electrification.

Parking Characteristics

Understanding the parking characteristics is essential for planning effective charging solutions for electric vehicles. Drivers were asked about the idle time spent by the vehicle during loading, unloading, and at home.

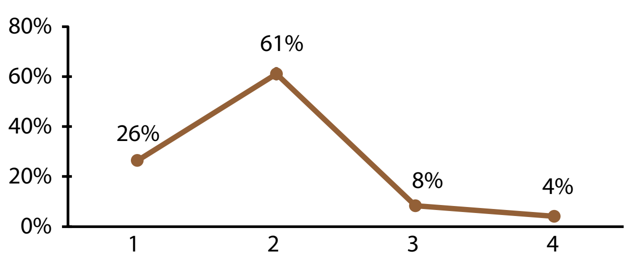


Figure 14 Repetition of trip (Surat Textile)

The drivers were also asked about the type of parking where the idle time was spent. These responses ranged from inside factory to paid parking to roadside. These results are crucial for understanding the potential for establishing charging infrastructure which blends in with the trip pattern.

A) Parking Time

On average, the surveyed vehicles were idle for 15 hours in a day. Of this, 10 hours were spent at home. An average of 5 hours was spent idle by vehicles while loading and unloading of goods. Figure 15 shows the spatial distribution of the loading and unloading locations.

The survey captured 24 unique loading locations and 4 unique unloading locations. The 4 unloading locations are also present in the 24 unloading locations. Of the surveyed vehicles, 36% spent at least 2 h and 30 min every day in loading goods from Sayan, which is located in the northern outskirts of Surat. Numerous power looms are situated in this region. All the four unloading locations are concentrated in the central zone in Surat. Sixty-nine per cent of the vehicles unload in Surat textile market and 26% unload in the ring road market, and both these locations are less than 1 km apart from each other. The central region faces heavy congestion due to freight traffic. As 95% of the SCVs in the survey spend at least 2 h and 30 min on average in the central zone, it is an ideal location for establishing charging infrastructure.

B) Type of Parking

Loading and unloading locations are attractive places to establish charging infrastructure. This would facilitate adoption of electric vehicles without much disruption into the current trip patterns. The observations presented in the previous section indicate that ample time is spent at limited locations for loading and unloading. The drivers were asked on the type of parking while the vehicle is being loaded and unloaded to better establish the possibility of establishing charging infrastructure or the possibility of integrating electric vehicle charging with existing infrastructure. Figure 15 shows the trips surveyed by the type of parking while the vehicle is being loaded

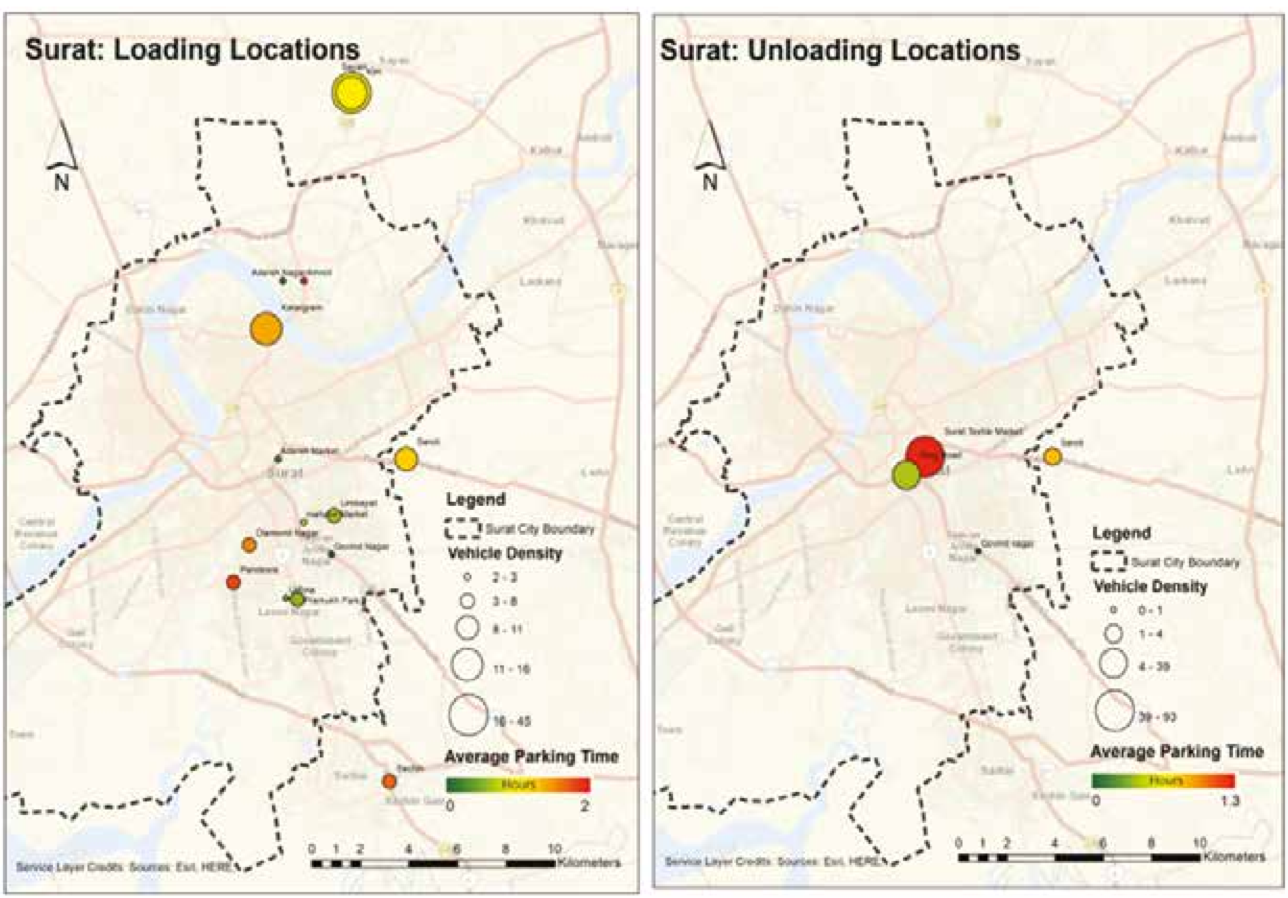


Figure 15 Loading and unloading locations in Surat

and unloaded. The three types of parking categories are commercial parking facility, inside factory, and roadside (Figure 16). Commercial parking facilities include paid parking in Surat including numerous underground/multi-level parking established by SMC in the central zone.

While loading, 50% of the vehicles are parked on the roadside, 39% are parked inside the factory, and 11% are parked in a commercial parking facility. Possible trips of electric vehicles originating from inside factories can easily provide charging solutions from the existing infrastructure of the respective factories. High share of roadside parking is a negative for potential of electrification as establishing charging infrastructure at such locations may be difficult. It is a positive that 61% of the vehicles are parked at a commercial parking facility while they are unloaded as establishing charging infrastructure would be convenient for the authorities at such a location. As the locations of the same are concentrated in the central zone of Surat, this comes out as an ideal location for establishing charging infrastructure. The numerous multi-level commercial parking facilities established by SMCs themselves could easily be locations for charging of most electric vehicles goods in Surat.

Figure 17 Surat loaded route trips

Origin-Destination Analysis of Freight Flow

The survey captured 137 trips in total. This accounted for movement of 202 tonne of textile freight composed of raw materials, intermediate, and finished goods. The drivers were asked for three sets of locations: home location, loading location, and unloading location. The survey captured 26 home locations, 15 loading locations, and 4 unloading locations making 137 trips among them by 72 vehicles. However, the repetition of the trip does not include a trip back to the home location but a trip back to the loading location. Moreover, home locations are scattered throughout the city. Hence, we analysed the loaded trips separately to understand the flow of goods and identify top origin destination pairs. Figure 17 shows the routes captured for loaded trips in the survey. There were 24 unique Origin-Destinations (ODs) for trips from

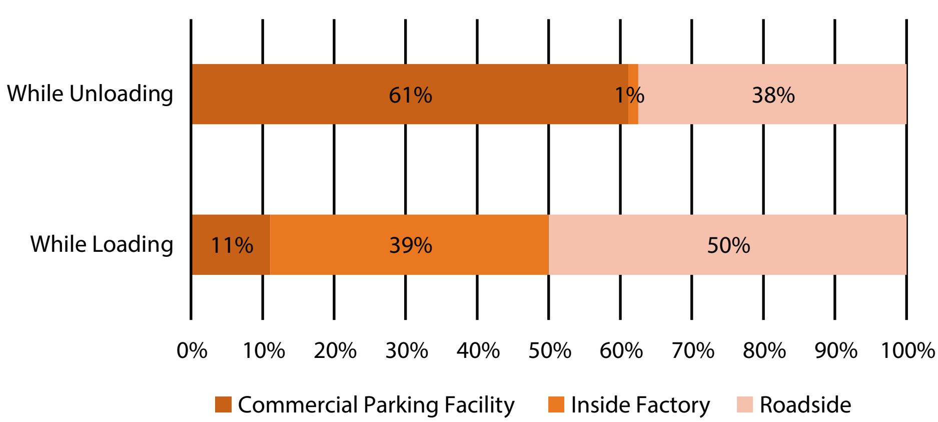


Figure 16 Type of parking at loading unloading location in Surat

loading locations to unloading locations. Table 2 lists the top ODs captured in the survey. 39% of the freight captured in the survey originated from Sayan. These are mainly carriers of raw material (grey) to processing factories.

Table 2: Top ODs in Surat Textile

Top OD pairs	Proportion of traffic (in tonne)
Sayan-Surat Textile Market	24%
Sayan-Ring road Market	15%
Katargam-Surat Textile Market	8%
Kim-Surat Textile Market	8%
Saroli-Ring road Market	5%

Source: TERI

Sayan to Surat textile market and Sayan to ring road market compose majority of the freight flow (in tonnes) captured in the survey. These are indicated by darker lines in the spatial map shown in Figure 16. As discussed earlier, Surat textile market and ring road market, which are not far from each other, compose 95% of the sample captured here. Even though the sample is small, primary stakeholder interviews and secondary data validate the concentration of freight traffic in the central zone of Surat, where both these markets are situated. Other than Sayan, the other main origins serving the central markets in Surat are Katargam, Kim, and Saroli. Saroli has a newly established textile market and also consolidation and distribution centres for outgoing traffic from Surat.

Table 3 reveals that the pick-up trucks mainly cater to the movement of goods from factories in Sayan and Kim. Similarly, three-wheeler goods focus on movement to the central zone from nearby markets and factories in Saroli and Limbayat. The mini trucks cater movement of goods from nearby Katargam factories, as well as from far away factories in Sayan and Sachin.

Total Cost of Ownership: Surat Textile Sector

Data from the driver survey and stakeholder consultations were used to obtain specific annual inputs for the Surat textile use case (Table 4). General inputs and methods used for the total cost of ownership (TCO) are described in the appendix. The lifetime of the vehicle was assumed to be 7 years based on the studies of LCVs in India and stakeholder consultations. The analysis is done separately for four-wheelers and three-wheelers with each being compared to a relevant electric vehicle available in the market. For four-wheelers, the comparison was done with diesel mini-pick-up trucks as the loads carried by these vehicles could potentially be carried by electric vehicles as well. The load carried by pick-up trucks is too high for the existing electric vehicles.

Analysis of four-wheeler

Based on the survey, we found that the average loads carried per trip by existing mini-pick-up trucks is higher than 1 tonne. The stated payload for existing electric vehicles is much lower than this (around 600 kg). To account for lower payload of electric vehicles, it was assumed that electric vehicles have to do additional trips compared to existing vehicles to carry the same total load. This is reflected in the higher electricity costs for the electric vehicles. The overall TCO for new electric

Table 3 Top ODs by vehicle type

Three-wheeler goods		Mini trucks		Pick-up trucks	
Top ODs	Distance	Top ODs	Distance	Top ODs	Distance
Saroli–Ring road Market	5.6 km	Sayan–Ring road Market	18 km	Sayan–Surat Textile Market	18.7 km
Limbayat–Surat Textile Market	5 km	Sayan–Surat Textile Market	18.7 km	Kim–Surat Textile Market	34.4 km
Amroli–Surat Textile Market	8.2 km	Katargam–Surat Textile Market	5.3 km	Sayan–Ring road Market	18 km
Katargam–Surat Textile Market	5.3 km	Sachin–Surat Textile Market	14.7 km	Pramukh Park–Surat Textile Market	7.5 km

Source: TERI

Table 4 Input parameters for TCO analysis: Surat textile sector use case

Parameter	Value	Source
Average daily utilization	Four-wheeler: 77.8 km Three-wheeler: 50.78 km	Average of daily distance covered across the seven zones
Monthly fuel cost for diesel four -wheeler	Four-wheeler: Rs 17,204 Three-wheeler: Rs 9,294	Average cost obtained from survey
Price of electricity	Rs 5.1 per unit	Based on expected tariff for 2020–21 from Dakshin Gujarat Vij Company (DGVC)
Annual maintenance costs for ICE vehicles	Four-wheeler: Rs 70,284 Three-wheeler: Rs 45,012	Based on driver surveys
Annual maintenance costs for electric vehicles	Four-wheeler: Rs 56,496 Three-wheeler: Rs 45,540	Assumed to be half of the cost associated with ICE vehicles. This is conservative as literature suggests that the maintenance costs associated with e-vehicles is one-third that of ICE vehicles.
Permit fees	Rs 360 for 5-year permit	Based on RTO Gujarat rates
Road tax	6% of vehicle cost	Based on RTO Gujarat rates
Registration fees	Rs 1000	Based on RTO Gujarat rates
Insurance premium discount for electric vehicles	15%	Based on IRDAI proposal for third part motor vehicle insurance from FY 2020–21 onwards.
Interest rate on loans	ICE: 9% Electric Vehicle: 15%	Based on stakeholder consultations
GST	Electric Vehicle: 5% ICE: 28%	As per GST tariffs

Source: TERI

Table 5 TCO (Rs/km) comparison for four-wheelers: Surat textile sector use case (net present value)

Cost	ICE 4-W	Electric 4-W	Retrofitted 4-W
Financing	Rs 1.31	Rs 4.31	Rs 2.58
Permit	Rs 0.00	Rs 0.00	Rs 0
Road tax	Rs 0.13	Rs 0.32	Rs 0.24
Insurance	Rs 0.70	Rs 0.60	Rs 0.70
Registration costs	Rs 0.01	Rs 0.01	Rs 0.01
Fuel	Rs 6.83	Rs 4.89	Rs 5.03
Maintenance	Rs 2.32	Rs 1.16	Rs 1.74
Battery replacement	0	Rs 0.66	Rs 0.75
Total capital expenditure	Rs 1.31	Rs 4.31	Rs 2.58
Total operating expenditure	Rs 10.00	Rs 7.64	Rs 8.48
Total TCO (per km)	Rs 11.31	Rs 11.38	Rs 11.07

four-wheeler was higher by around 5%, driven mainly by the much higher capital expenditure. The TCO for the retrofitted four-wheeler was lower by 3% at net present value. The operating expenditure for new electric vehicles and retrofitted four-wheeler was found to be lower by 24% and 16% respectively, compared to diesel. Despite assuming higher distances for electric vehicles, the expenditure on electricity is still less than 50% of the

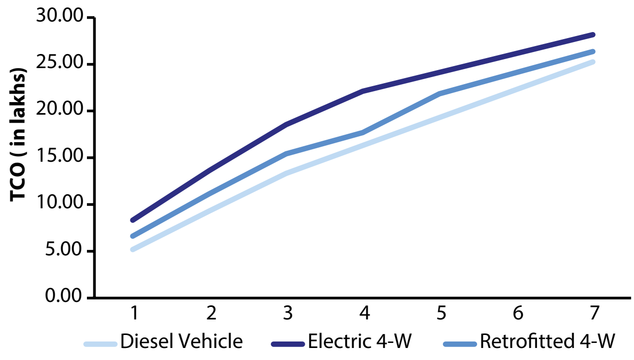


Figure 18 Estimated cumulative lifetime expenditure for ICE four-wheelers versus electric four-wheelers: Surat textile sector use case

fuel expense for diesel vehicles. This is mainly because of low electricity prices in Gujarat.

As shown in Figure 18, the cumulative expenses for the new electric vehicle are much higher than the cost of the diesel vehicle by almost 3 lakh. Interestingly, although the TCO per km at net present value is lower for the retrofitted vehicles, the cumulative expenditure on this vehicle is higher over the lifetime. This is because the retrofitted vehicle considered in the analysis has a very large battery size based on inputs from stakeholder. As a result, the costs incurred for replacing the battery at year 5 is very high. However, when this cost is discounted overall, the TCO per km at present value works out better for the retrofitted vehicle.

Three-wheeler analysis

For the three-wheelers as well, the utilization was adjusted to reflect the additional trips required to carry the same payload as an ICE vehicle. It was assumed that the electric vehicle would have to do one extra trip each day. As shown in Table 6, our estimates suggest that significant financial gains can be obtained from electrification in the case of three-wheelers. The TCO for both types of electric three-wheelers considered is around 40% less than the diesel vehicles at net present value. The main driver of this difference is the significant fuel cost savings an electric vehicle would provide, which is again driven by low price of electricity.

The additional cost incurred to purchase an electric vehicle compared to a diesel vehicle is not as high in the case of a three-wheeler. The fuel cost savings for electric vehicles is large enough to account for the additional expenditure on financing for low battery capacity three-wheeler from year 1. For the high battery capacity three-wheeler, the cumulative costs break even before year 2 (Figure 19).

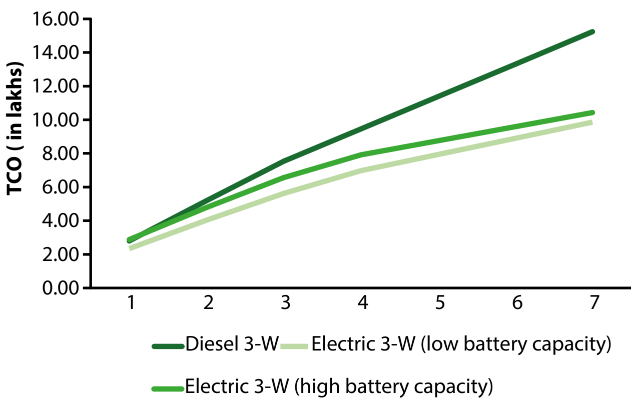


Figure 19 Estimated cumulative lifetime expenditure for ICE three-wheelers versus electric three-wheelers: Surat textile sector use case

Table 6 TCO (Rs/km) comparison for three-wheelers: Surat textile sector use case (net present value)

Cost	Diesel 3-W	Electric 3-W (low battery capacity)	Electric 3-W (high battery capacity)
Financing	Rs 0.82	Rs 1.26	Rs 1.86
Permit	Rs 0.01	Rs 0.01	Rs 0.01
Road tax	Rs 0.20	Rs 0.12	Rs 0.18
Insurance	Rs 0.94	Rs 0.80	Rs 0.80
Registration costs	Rs 0.01	Rs 0.01	Rs 0.01
Fuel	Rs 7.03	Rs 2.92	Rs 2.29
Maintenance	Rs 2.28	Rs 1.14	Rs 1.14
Battery replacement	0	Rs 0.25	Rs 0.34
Total capital expenditure	Rs 0.82	Rs 1.26	Rs 1.86
Total operating expenditure	Rs 10.47	Rs 5.25	Rs 4.76
Total TCO (per km)	Rs 11.29	Rs 6.51	Rs 6.62

Policy Inferences and Recommendations

This chapter attempts to understand the potential of electrification of urban freight in Surat. This section focuses on understanding the freight associated with textile industry in Surat. We used secondary data, primary stakeholder interviews, and primary driver survey to understand the freight flow and characteristics specific to application of SCVs in the textile industry. From the analysis presented in this chapter, w.r.t to potential of electrification of urban freight in Surat textile, there are some positive inferences and some barriers to adoption as well. This section lists the same and recommends some policy interventions for improving application of electric vehicles in the textile freight in Surat.

Positive Inferences

- ***High repetition of trips:*** Of the surveyed vehicles, 73% visit the loading and unloading locations at least twice for a period more than 5 hours in total. This is a positive inference for designing charging solutions.
- ***Loading/unloading in organized facilities:*** Of the unloading, 61% takes place in commercial parking facilities regulated by SMC. The urban local body (ULB) can establish charging infrastructure in the commercial parking facilities without having to involve any other stakeholder. As 39% of the loading locations are inside the factories, these can provide charging solutions to the electric vehicles using their existing infrastructure.
- ***Limited destinations:*** The survey found that 95% of the freight traffic was concentrated on just two destinations for unloading. Both these destinations are nearby textile markets in the central zone of the city. The same was validated through primary stakeholder interview and analysis of secondary data. As a large number of vehicles spend a considerable amount of time in the central market area, charging solutions and businesses focused in these areas would be successful.
- ***Low daily total distance:*** The average daily total distance of the vehicles surveyed ranges 51–76 km. This is well within the range on full charge for many electric vehicles in the market.
- ***High costs:*** The survey found out that high cost is involved in the operation of diesel vehicles; these are maintenance, fuel, parking, and other costs. Due to considerably low operational costs, electric vehicles may be an attractive switch for these drivers. This can be made more attractive by policy interventions to reduce other costs such as parking and road tax.
- ***Environmental benefits:*** All the vehicles surveyed use diesel as a primary fuel to operate. This is the fuel type with highest environmental externality in terms of air pollution. Hence, conversion of these vehicles into electric has high marginal environmental benefit for the people of Surat.

Barriers to EV Adoption

- ***Unorganized fleet:*** In the case of vehicles owned by drivers, the decision to switch to electric vehicles will largely be dependent on them. Their purchase decision is mainly influenced by their peers. These individual owners are unlikely to purchase new electric cargo vehicles without proper incentive.
- ***Overloading:*** The survey revealed that three-wheelers goods and mini trucks are severely overloaded. Considering electric vehicles cannot be overloaded to that extent, the drivers would need to increase their number of trips to earn the same revenue. This would mean higher time invested by the driver and higher vehicle kilometres on Surat's roads which will have a negative implication on the increasing congestion in Surat.
- ***Low distance:*** Low distance requirement for the drivers would imply slower recovery of the additional funds spent on purchasing electric vehicles. The economic benefits of lower operation costs of electric vehicles can be maximized by heavier usage of vehicles.
- ***Financing:*** It was revealed in the survey that a large majority of the drivers depend of formal sources of financing while purchasing ICE vehicle. It is obvious that availability of financing would be a crucial factor determining their choice of purchase of electric vehicles.

Policy Recommendations

Analysis of secondary data, primary driver survey, and primary stakeholder interviews with respect to textile freight in Surat have indicated for the possibility of electrification of the SCVs employed. Even though there are certain technological barriers identified such as overloading of vehicles, SMC and Gujarat government can still undertake some clear interventions to promote electric vehicles in this segment.

Recommendations for SMC

- Establishing charging infrastructure

As this study has already shown, most vehicles use SMC-operated commercial parking facilities for unloading. SMC can establish electric vehicle parking-cum-charging reserved areas in them. SMC in consultation with stakeholders can earmark specific parking facility in the central zone of the Surat textile market.

- Facilitate pilot projects

This study identified Sayan to Surat Textile Market (STM) as the route with the most traffic. The origin points of these trips are mostly power loom factories. SMC can facilitate electric pilot interventions in coordination with power loom factories, tempo driver's association, and electric vehicle OEMs in fixed routes like Sayan to STM. There are many other fixed routes like Pandesara to STM where too multiple trips are undertaken every day. The pilot projects will improve the visibility of electric vehicles and cajole other drivers to switch to this form of transportation.

- Reduce electric vehicle operational costs

SMC can make electric vehicles more attractive by the following:

  - Reserved parking/charging spaces at SMC facilities
  - No parking charges for electric vehicles
  - Reduced toll and other taxes for electric vehicles

Recommendations for Gujarat government

- ***Demonstration projects*:** The Government of Gujarat may initiate demonstration projects with the help of private players in the highlighted areas/routes in this study.
  - *E-freight ecosystem* may be developed around Surat textile market and in the central zone of the ring road market.
  - Charging infrastructure may be planned for freight parking facilities provided in business districts in the state.
- ***Financing*:** Purchase decision of electric vehicles is contingent on formal financing options which are available for ICE vehicles. Similar financing system in electric vehicles too will then encourage buyers for early adoption. Hence, bringing financial institutions on board and creating easy-financing policy mechanisms will ease the purchase process of electric vehicles.
- ***Higher subsidy for individual buyers:*** Current electric vehicle adoption is limited mainly to fleets. Individual buyers have to incur a lot of higher risk in purchasing electric vehicles in comparison to organized fleets. Individual drivers must buy and use electric vehicless to increase their visibility and adoption. Hence, the Gujarat government should give additional benefits to the already purchase incentive offered by FAME-II policy to the individual buyers of commercial electric vehicles.

Case Study IV: Solid Waste Management in Surat

Overview of Solid Waste Management in India

Solid waste management (SWM) is a crucial service for the healthy development of any city. With increasing population and urbanization, solid waste generation in India has increased significantly. Central Public Health and Environmental Engineering Organisation (CPHEEO) found that daily waste generation in India escalated from 100,000 tonne per day (TPD) in 2000 to 127,486 TPD in 2011.[1] By 2031,165 million tonne of solid waste is projected to be generated annually from urban centres in India, reaching up to 436 million tonne by 2050 (Rajkumar & Sirajuddin, 2016). Only around 60% of the total waste produced in urban India is collected and about 15% is processed (PIB, 2016).[2] The lack of an efficient SWM system in cities can have disastrous health consequences for its citizen. In the recent past, proactive legislative and policy steps have seen improvements in the overall scenario.

Ensuring environmental safety in waste management has been the main focus of government polices throughout the 1980s and 1990s. In the 2000s, concerns related to climate change and methane emissions from improper disposal of wastes started to receive more attention. A number of policy actions related to waste management have been put in place over the years. Presently, the waste management systems in India are guided by the Municipal Solid Waste Rules, 2016. The rules clearly outline the roles of the central, state, and local government agencies in the SWM system.

As per the MSW Rules, 2016, the ULBs are responsible for setting up a proper system of waste management and providing annual reports to the State and Central Pollution Control Boards. They are responsible for door-to-door collection of segregated waste, setting up of alternate collection facilities, waste processing, transportation, and disposal. Thus, ULBs are considered the legal owners of waste once it is collected or put out for collection in authorized areas. ULBs spend between Rs 500 and Rs 1500 per tonne of waste and between 10 and 50% of their annual budget is assigned to SWM. Within this, the majority of the total cost is spent on collection (60–70%), followed by transportation (20–30%), and final disposal (around 5%) (Kumar, et al., 2009).

Municipal solid waste (MSW) usually comprises food wastes, street sweepings, garden wastes, demolition and construction wastes, and appliances. Segregation of MSW is the first step of MSWM which means separation of waste into four types: organic, inorganic, hazardous, and recyclables. The next step involves collection and transportation followed by treatment and disposal of the waste.

Waste collection and transporting services can be classified as primary and secondary. Primary collection refers to the process of lifting and transporting solid waste from the source of its generation (households, shops, markets, hotels, etc.) and taking the waste to an intermediate storage area, such as transfer stations, or directly to the disposal site. This depends on the size of the city and the prevalent waste management system. Secondary collection includes picking up waste from intermediate storage points (community bins, depots, and transfer stations) and transporting it to waste processing sites or to the final disposal site. The establishment of intermediate transfer stations is determined by the distance between secondary waste collection points and the final treatment and disposal point. If the distance from the city jurisdiction to the final treatment and disposal points exceeds 15 km, transfer stations may be established (Swachh Bharat Manual for SWM).

The vehicles used for primary and secondary transportations are distinct from each other. Primary collection involves collecting smaller amounts of waste from multiple points; hence, these vehicles are smaller and have greater manoeuvrability. Vehicles used for this include pushcarts or tricycles with containers, motorized three-wheelers with containers, small mechanized vehicles (SCVs) with or without tipping containers. The choice of vehicles also depends on the terrain of the locality, width of streets, and building density. SCVs used for door-to-door collection usually have a payload capacity between 600–900 kg per trip. The loading height for these vehicles is around 1500 mm. As per the MSW

[1] Central Pollution Control Board. 2012. Consolidated Annual Review Report on Municipal Solid Wastes (Management and Handling) Rules, 2000. New Delhi: Ministry of Forest and Environment and Climate Change, Government of India

[2] PIB. 2016. Solid Waste Management Rules Revised After 16 Years; Rules Now Extend to Urban and Industrial Areas. Press Information Bureau, Government of India. Details available at http://pib.nic.in/newsite/PrintRelease.aspx?relid=138591

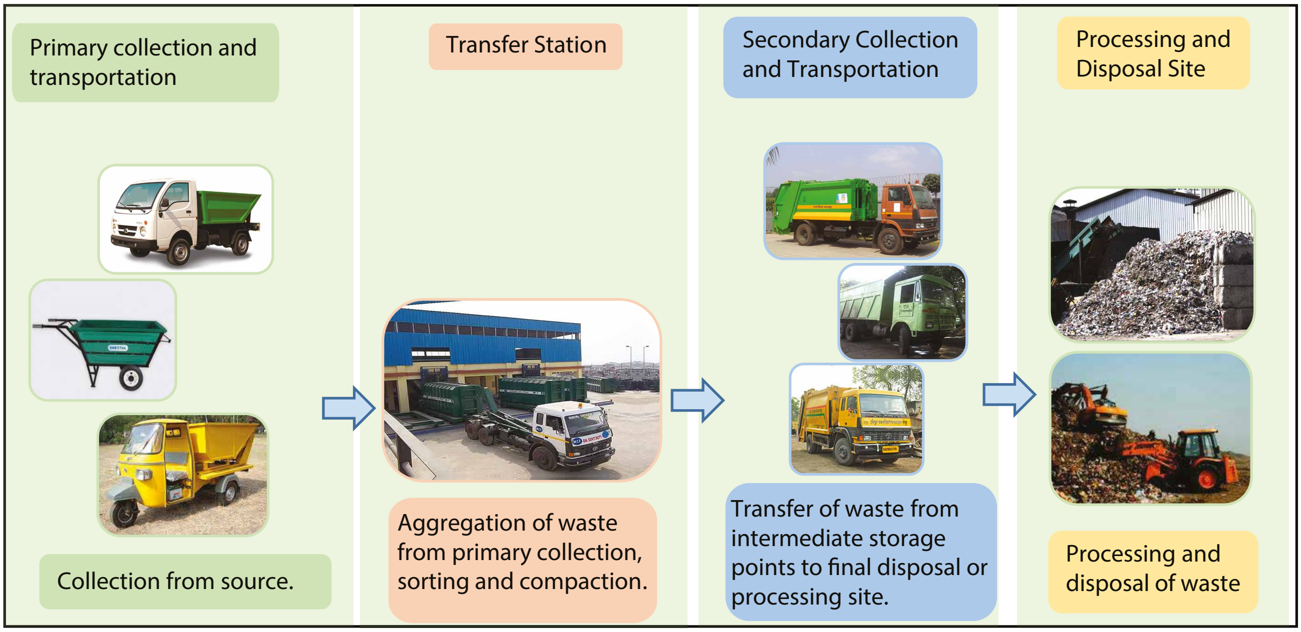


Figure 20 Typical solid waste management in Indian cities

Rules, 2016 these vehicles need to have leakproof bodies with drainage tube and plug. A small tipper should be built on a suitable chassis. The vehicles have two openings each side to facilitate direct transfer of waste from a domestic bin to the vehicle. They are also required to have separate bins to carry segregated dry and wet waste. It is desirable to use up to 3 m^3 bins in vehicle for door-to-door collection to cater to a large number of houses in a single trip (Swachh Bharat Manual for SWM).

Secondary transportation involves collecting aggregated waste from intermediate storage points and transporting to the final disposal or treatment site. Thus, middle and heavy-duty trucks (above 7.5 tonne) are used so that large amounts of waste can be transported in one trip. Some of the commonly used vehicles are dumper placer, refuse collector without compactor, refuse compactor, and hook loader or hook lifter. Containers on these vehicles are generally between 7 m^3 and 10 m^3, or larger.

Transportation of solid waste contributes significantly to greenhouse gas emissions and local pollution. The collection and transportation phase contributes significantly to emissions due to the type and number of vehicles used in the system (Barrera & Hooda, 2016). The vehicles used in transportation of MSW in India are mostly highly polluting diesel vehicles. The annual carbon dioxide (CO_2) emitted from the transportation of MSW in Mumbai alone was estimated to be 67,401 tonne/year and the total global warming potential was 0.07 million tonne CO_2 equivalent per year. Nitrous Oxide and particulate matter emissions were also found to be high (Sharma & Chandel, 2019).

The potential benefits from electrification of vehicles involved in SWM are significant and worth considering. Since these vehicles mostly ply within fixed routes inside the city, the potential for electrification could be high. Globally, waste management has already been recognized as one of the possible first adopters with many pilot programmes focusing on this application. Recently, some Indian cities have also deployed electric vehicles in their waste management system, albeit on a relatively small scale. Vijayawada was the first state to adopt electric three-wheelers in 2017 followed by Coimbatore which added 50 electric three-wheelers to the fleet in 2019. The Andhra Pradesh government had made a further commitment to purchase 7500 electric three-wheelers for garbage collection across the state by December 2019. Apart from the environmental benefits, the lower running costs were a major factor which influenced adoption. However, in Coimbatore there have been some issues with performance of the three-wheelers and the plan is to shift to four-wheelers in the future.

Given the seemingly high potential associated with electrification of waste management vehicles, there is a need to better understand the advantages and challenges of such a change. This section assesses the techno-economic aspects associated with electrification of SWM vehicles in Surat. Additionally, barriers to adoption are also identified and some policy steps are suggested for faster adoption of these vehicles.

Solid Waste Management in Surat

Historically, SWM system in Surat has been inadequate and inefficient. Improper disposal of waste led to Surat becoming the epicentre of the bubonic and pneumonic plague in 1994. Since then, the SWM system has seen a drastic overhaul to cope with the increased generation of solid waste and comply with the MSW Rules. The system has been decentralized and accountability of officials established. Some of the most significant changes included establishing door-to-door collection systems, use of private operators, community participation, and strict enforcement of penalties for littering. The change has led to widespread improvements over the last two decades. In fact, Surat was adjudged the best city in solid waste management in the Swachh Sarvekshan in 2019. Presently, about 2200 million tonne of solid waste is produced in Surat daily, of which about 2150 million tonne is collected and transported

The city of Surat is divided into seven different administrative zones and the SWM activities are carried out separately in each zone (Figure 21). The primary collection activities involve door-to-door collection, street sweeping, night brushing, hotel kitchen waste management, society ANUDAN programme, and miscellaneous collection (see Table 11). Vehicles involved in primary collection pick up the waste from the source and transport it to the transfer station from where secondary transportation vehicles are loaded for the purpose of transferring it to the disposal site at Khajod.

The vehicles used for primary collection depend on the specific activity. For door-to-door collection, mostly SCVs (<3.5 tonne) with tipping containers are used. The most commonly used models are the Tata Ace and Ashok Leyland Dost. Smaller vehicles allow access to smaller roads and greater manoeuvrability to access houses in different parts of the city. However, some vehicles in the door-to-door system are also larger trucks like the Tata 407. As part of the hotel kitchen waste management programme, waste from hotels and restaurant is carried by tractors with hydraulic trailers. Tractors are also used

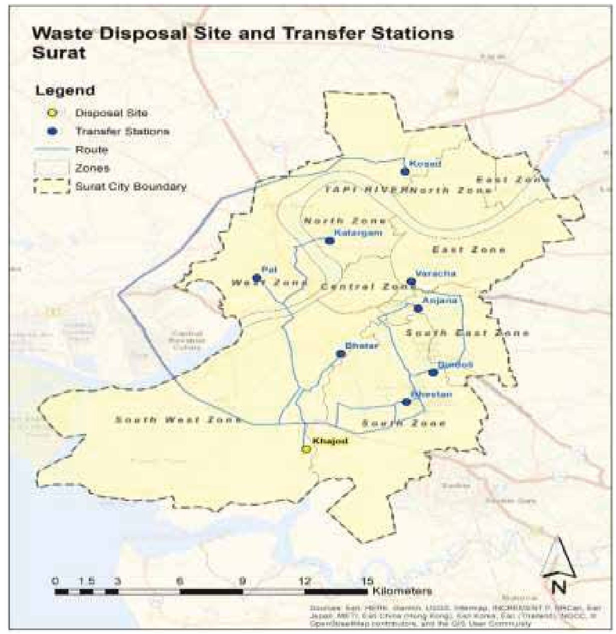


Figure 21 Spatial waste disposal site and transfer stations

for collecting wastes from street sweeping and night brushing/scraping activities. Currently, all vehicles in operation are diesel powered. These vehicles have increasingly been adding to the GHG emissions as well as air pollution.

The potential for electrification is only considered for primary collection vehicles. Secondary collection vehicles involve larger trucks (>7.5 tonne), such as compactors and hook lifters. On average these trucks carry close to 10 tonne of waste in each trip. Presently there are no electric vehicles in the Indian market that are capable of carrying such high loads.

Potential for Electrification of Door-to-door Collection

The door-to-door waste collection system was introduced in 2004. Currently, door-to-door collection accounts for around 55% of total collection. The whole door-to-door collection system is leveraged to private operators to ensure better efficiency. There are five different agencies involved in the door-to-door collection on a contractual basis (Table 7). The length of the contract is 7 years based of the useful life of the vehicles. The present tenure of the contracts is up to 2022. A private operator is responsible for the capital and the entire operational costs. A tipping fee is paid to the private operators based on per tonne of waste brought to the transfer station. The waste is collected twice daily, between 7 am and 2 pm and from 5 pm to 10 pm.

Table 7 Zone-wise details of Surat solid waste management door-to-door collection system

Zone	Transfer station	Responsible agency*	Average daily SW collected (million tonne)	No of vehicles operational
Central	Khatargam	M/s Jigar Transport Co.	181.61	81
East - A	Varachha	M/s Jigar Transport Co.	197.27	71
East - B	Varachha	M/s Jigar Transport Co.	117.47	43
North	Khatargam	Swachatha Corporation	201.37	60
West	Pal	Western Imaginary Transcon Pvt. Ltd.	137.81	56
South-West	Bhatar	Global Waste Management Cell Pvt. Ltd.	138.32	51
South	Bhestan	Om Swachatha Corporation	147.35	56
South-East	Dindoli	Om Swachatha Corporation	160.92	57

*The tender for these agencies is valid till 2022.

The operators use closed body SCVs with movement tracking systems for primary collection. The number of vehicles in the system has been growing continuously in all the zones to cope with the increased waste generation (Figure 22). Currently, there are about 475 vehicles involved in the door-to-door collection. Vehicles used are Tata Ace, Tata 407, and Ashok Leyland Dost. All vehicles used in the system run on diesel and most of the vehicles adhere to BS-IV emission standards.

Range

The aggregate annual data related to distance travelled by these vehicles was obtained from SMC. Across zones, the average daily distance travelled by a vehicle ranged from 30 km in the central zone to 53 km in the south-east zone. The data was analysed separately for each zone due to their distinct characteristics. On average, vehicles made three trips in a day. The per trip average distance travelled ranged from 9 km to 16 km (Figure 23). As these vehicles travel on fixed routes, the daily deviance from the average is likely to be low. Most electric vehicles available in the market can travel up to 70 km on a full charge with a full payload. Based on the average distance in all the zones, the potential for electrification is significant. Some vehicles are likely to travel more than 70 km as well, especially in south-west zone which spans 112 km^2. However, a majority of the electric vehicles in the markets should be able to complete their daily distance on a single charge.

Payload

Aggregate yearly data on payload carried was obtained from SMC. The per trip payload was obtained by using the

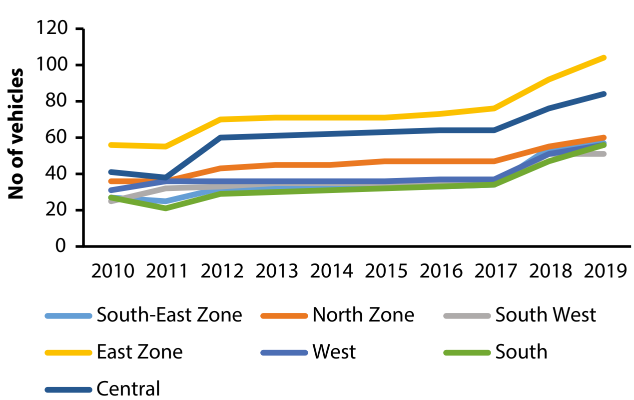


Figure 22 Surat SWM case study: growth of vehicles involved in door-to-door collection

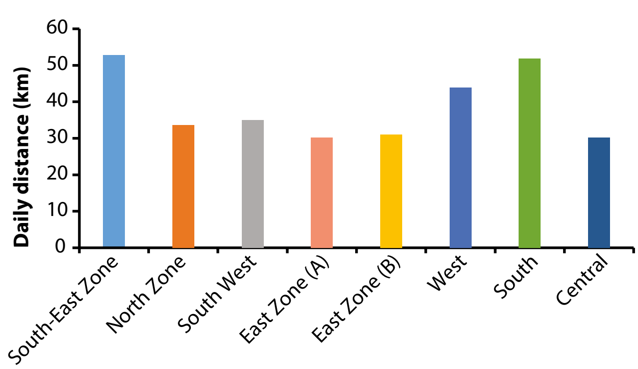


Figure 23 Surat SWM case study: average daily distance travelled

average number of trips completed in a day. The average payload per trip ranged from 607 kg in the central zone to 1.04 tonne in east zone (B) (Figure 24). The average payload is highest in the north zone and east zone (B). However, it must be noted that in east zone (B) most of the vehicles were found to be larger trucks like Tata 407, based on information from the SMC vehicle tracking system. These trucks have a higher payload (around 2 tonne) and are not likely being overloaded. Even in the north zone, some larger trucks are in operation. In all the other zones, the predominant vehicles have a stated payload of around 700 kg and the average load carried in most of these zones is around 800 kg. Thus, the evidence of overloading is there, with around 100 kg of extra weight being carried. The evidence of overloading is somewhat in line with other findings, which show that in developing countries the density of waste collected is high and overloading is common. It is also in line with the feedback received from stakeholders involved in SWM management in Surat as well as in other cities.

One limitation is that the total number of trips was only available as an aggregate for all the zones. In some zones, the average number of trips might be higher and in these cases the payload per trip may be overestimated.

There are also seasonal changes in the daily waste collected. Figure 25 shows the average daily SWM collection in each month for Surat, based on the data since 2012. It is clear that in some months the average is higher than others. The highest collection is seen in June. This is likely because this is the month in which monsoon tends to reach Surat and the rainfall increases the weight of the waste. The other months with higher waste collection are March and October. The existence of outliers means that the average payloads mentioned

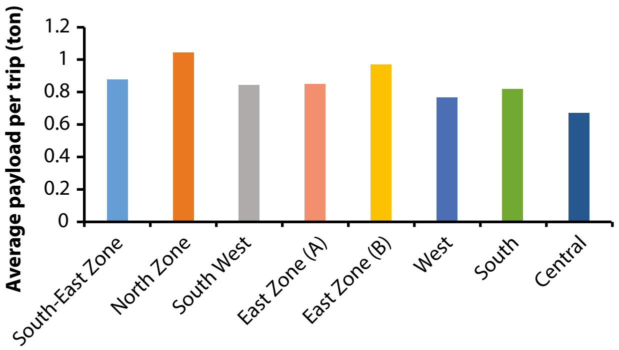


Figure 24 Surat SWM case study: average payload per trip

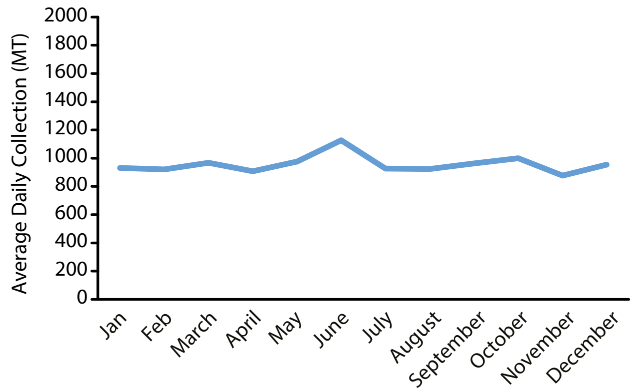


Figure 25 Monthly variation in SWM collection since 2012

earlier maybe inflated. For most of the year, the payloads are likely to be lower than the average and higher only in some months. Unfortunately, monthly data for each zone was not available separately.

Charging Infrastructure

Each zone has its own dedicated transfer station. The civil work for the transfer stations is facilitated by the SMC but the operations are contracted to private agencies while investments for machineries and equipment are borne by the operator. The vehicles in each zone have the same origin and destination, i.e. the transfer stations. As a result, these stations provide the ideal place for setting up charging infrastructure. The expenses for the infrastructure would have to be borne as a one-time expense by the municipal corporation. The private operators assigned for primary collection can bear the cost of the electricity used by entering into agreement with the agency running the transfer station. This arrangement is unlikely to lead to resistance from the private agencies, as the main burden of the cost will be borne by the municipal corporation. In initial talks with officers at the municipal corporation, a willingness was seen on their part for setting up the initial infrastructure.

Total Cost of Ownership: Surat Solid Waste Management

Data from secondary sources and stakeholder consultations was used to obtain the specific annual inputs for Gujarat and Surat door-to-door collection system (Table 8). General inputs used in the TCO are described in the appendix. The lifetime of the vehicle was assumed to be seven years based on the duration of the contract with private operators. This is also in line

Figure 25 Monthly average SWM collection in Surat since 2012 with other studies which have found that for SCVs the expected life span is between 8 and 10 years.

Presently only four-wheelers are in operation in door-to-door collection. Therefore, the relevant comparison is with existing or expected four-wheeler electric vehicles available in the market as well as retrofitted four-wheelers. Based on the market review and stakeholder consultations, a representative price, driving range, and payload associated with electric four-wheelers were identified. For existing ICE vehicles, data was already available regarding payload, range, and fuel efficiency. The individual specifications of all the three vehicles are provided in the appendix.

Table 9 lists the total cost of ownership associated with different vehicles for the door-to-door collection use case. Over the lifetime of the vehicle, costs associated with both the electric four-wheeler and the retrofitted four-wheeler are lower than the diesel four-wheeler presently in operation at net present value. This suggests that a shift towards electric vehicles could be beneficial financially in the long run. The TCO per km at net present value was lower for the new electric four-wheeler and the retrofitted vehicle by 6% and 9%, respectively.

The financing costs associated with electric four-wheelers are more than three times the traditional diesel-powered four-wheelers, despite the subsidies and lower GST rates. Retrofitted four-wheelers have a lower financing cost than the new electric vehicles, but it is still almost double that of diesel four-wheelers. Presently, retrofitted vehicles are not eligible for any government subsidies. The higher financing costs are made up by significantly lower fuel prices and maintenance costs. Fuel costs provide the most significant savings, as door-to-door vehicles are

Table 8 Input parameters for TCO analysis: Surat solid waste management use case

Parameter	Value	Source
Average daily utilization	39 km	Average of daily distance covered across the seven zones
Diesel cost	Rs 68.92	Based on average diesel price in Surat in the last 5 years
Fuel efficiency for diesel vehicles	7 km/l	Based on stakeholder consultations
Price of electricity	Rs 5.1 per unit	Based on expected tariff for 2020-21 from Dakshin Gujarat Vij Company (DGVC)
Range for electric vehicles	50% of range provided by manufactures.	Based on the difference between stated fuel efficiency and actual on road efficiency of existing ICE vehicles
Permit fees	Rs 360 for 5-year permit	Based on RTO Gujarat rates
Road tax	6% of vehicle cost	Based on RTO Gujarat rates
Registration fees	Rs 1000	Based on RTO Gujarat rates
Annual maintenance costs for ICE vehicles	Rs 70,000	Based on stakeholder interviews with private operators
Annual maintenance costs for electric vehicles	Rs 35,000	Assumed to be half of the cost associated with ICE vehicles. This is conservative as literature suggests that the maintenance costs associated with e-vehicles is one-third that of ICE vehicles.
Insurance premium discount for electric vehicles	15%	Based on IRDAI proposal for third part motor vehicle insurance from FY 2020-21 onwards.
Interest rate on loans	ICE: 9% Electric vehicle: 15%	Based on stakeholder consultations
GST	Electric vehicle: 5% ICE: 28%	As per GST tariffs

Source: TERI

Table 9 TCO (INR/km) comparison for four wheelers: Surat solid waste management use case (net present value)

Cost	Diesel four-wheelers	Electric four-wheelers	Retrofitted four-wheelers
Financing	Rs 2.25	Rs 7.42	Rs 4.45
Permit	Rs 0.01	Rs 0.01	Rs 0
Road tax	Rs 0.23	Rs 0.55	Rs 0.42
Insurance	Rs 1.06	Rs 0.90	Rs 1.06
Registration costs	Rs 0.01	Rs 0	Rs 0.01
Fuel	Rs 8.51	Rs 4.31	Rs 4.44
Maintenance	Rs 3.99	Rs 2.00	Rs 2.99
Battery replacement	0	Rs 0.91	Rs 1.29
Total capital expenditure	Rs 2.25	Rs 7.42	Rs 4.45
Total operating expenditure	Rs 13.81	Rs 8.69	Rs 10.22
Total TCO (per km)	Rs 16.06	Rs 15.13	Rs 14.67

Source: TERI

used very intensively and have to stop and start multiple times in each trip, which leads to very poor fuel efficiency. The fuel efficiency obtained from stakeholder interviews was around 50% of the fuel efficiency stated by the manufacturers. A similar adjustment was made for the range of electric vehicles by considering only 50% of the stated range. Even with this adjustment, the expenditure on fuel was reduced by almost one-fourth with both electric vehicles.

Figure 27 shows the cumulative expenditure on the different types of four-wheeler without accounting for the net present value. The retrofitted vehicles achieve cost parity between year 4 and 5. For the new electric four-wheeler, although the TCO at net present value is lower, the cumulative expenditure on the vehicle is higher. This is because the EMIs are much higher for these vehicles but these expenditures are incurred over the course of three years. The high battery replacement costs also drive up the cumulative costs but the net present value of these costs is low as these are incurred only in year 4.

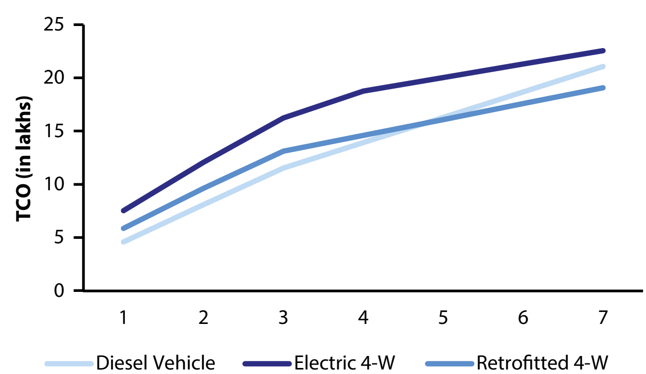


Figure 27 Estimated cumulative lifetime expenditure for ICE four wheelers vs electric four wheelers: Surat solid waste management use case

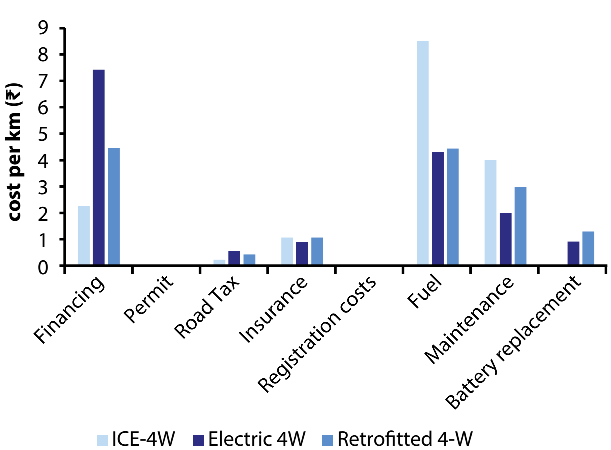


Figure 26 Break up of TCO for four wheelers according to type of expenditure: Surat solid waste management use case

Scenario Analysis: comparison with three-wheelers

The earlier analysis only compared diesel four-wheelers to electric four-wheelers, to ensure a one-to-one comparison without too many assumptions. Another possible substitution exists where available three-wheelers in the market could replace four-wheelers.

These vehicles have a lower payload than the existing four-wheelers but come with a purchase price that is one-third of the electric four-wheelers. There are also multiple manufactures who have already customized three-wheelers for solid waste collection. In some cities, these vehicles have already been deployed for door-to-door collection. In the case of Surat, if a certain part of the fleet was replaced by three-wheelers, the required load could still be carried by better planning of trips and more intensive use of the electric vehicles. Here we consider the financial aspects of such a substitution.

In order to account for the lower payload capacity of the three-wheelers, the total tonne km is adjusted to reflect that more trips would be required to carry the same overall payload, which reflects as higher electricity costs. The TCO associated with both electric three-wheelers considered (see appendix for description of vehicles) is lower than the diesel four-wheelers (Table 10). This is despite electricity costs for electric three-wheelers being greater than electric four-wheelers in the previous comparison. The lower purchase price of the vehicle combined with the subsidy is enough to offset the higher running costs due to increased usage and the costs are lower for three-wheelers throughout their lifetime. Even the cumulative costs in this case are much lower for both the three-wheelers considered (Figure 28).

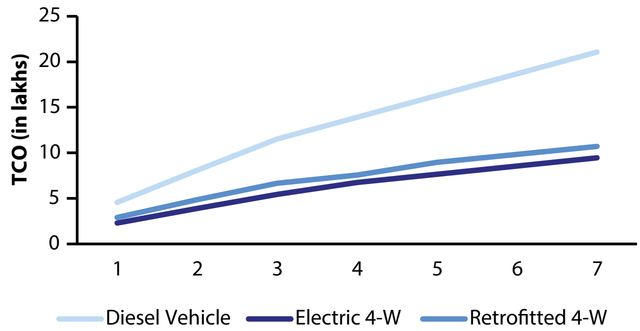


Figure 28 Estimated cumulative lifetime expenditure for ICE four wheelers versus electric three wheelers: Surat solid waste management use case

Source: TERI

However, it must be mentioned that assumptions related to increased use of three-wheelers to carry the same load are questionable. Moreover, other issues such as performance of the vehicle and ability to climb ramp at the transfer station might make this substitution practically unfeasible. Only by carrying out a pilot study with electric three-wheelers can these issues be addressed; the possible financial benefits suggest that such a study could be beneficial in the long run.

Table 10 TCO (INR/km) for the comparison of ICE four wheelers vs electric three wheelers: Surat solid waste management use case (net present value)

Cost	Diesel four-wheelers	Electric three-wheelers (low battery capacity)	Electric three-wheelers (high battery capacity)
Financing	Rs 2.25	Rs 1.41	Rs 2.09
Permit	Rs 0.01	Rs 0.01	Rs 0
Road Tax	Rs 0.23	Rs 0.13	Rs 0.20
Insurance	Rs 1.06	Rs 0.90	Rs 0.90
Registration costs	Rs 0.01	Rs 0.01	Rs 0.01
Fuel	Rs 8.51	Rs 2.26	Rs 2.10
Maintenance	Rs 3.99	Rs 2.00	Rs 2.00
Battery replacement	0	Rs 0.28	Rs 0.38
Total capital expenditure	Rs 2.25	Rs 1.41	Rs 2.09
Total operating expenditure	Rs 13.81	Rs 5.59	Rs 5.59
Total TCO (per km)	Rs 16.06	Rs 7.00	Rs 7.68

Source: TERI

Potential of Electric Vehicles in current Waste Collection Using Tractors

Tractors with hydraulic trailers are still used in the waste management system for collecting wastes from sources other than door-to-door collection. Some of these activities are described in Table 11. These tractors are operated by private operators on a contractual basis with SMC. The specific tasks performed by each vehicle and the tipping fee are defined in the contract.

Range

Information regarding range covered by these vehicles was not available. However, these vehicles do lesser trips in a day than door-to-door vehicles, and operate within the same zones. Thus, the average daily distance travelled is likely to be less or equal to door-to-door vehicles (9 km to 16 km across zones), a range easily achievable by electric vehicles in a single charge.

Payload

Payload data was available separately for night brushing activities and other activities. For night brushing, the average payload per trip was found be very low, at around 150 kg (Figure 29). This suggests that these vehicles could be used more efficiently, achieving the same tonne km in fewer trips. The low payload suggests that even the smaller three-wheeler electric vehicles with payload of around 450 kg could replace these trips. However, for other activities on average it was about 850 kg per trip since April 2019 (Figure 30). This high payload would be difficult for electric vehicles to achieve and a large number of electric vehicles would be required to carry out these operations.

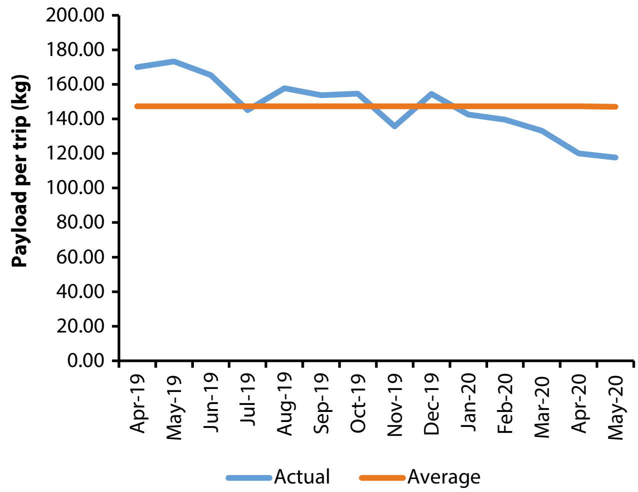


Figure 29 Surat SWM case study: monthly average payload per trip for tractors involved in night brushing activities

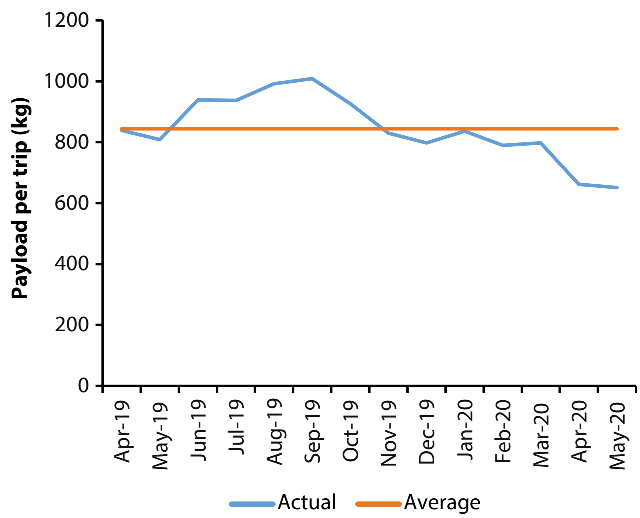


Figure 30 Surat SWM case study: monthly average payload per trip for tractors involved in other activities

Table 11 Surat SWM case study: Description of waste collection activities involving tractors for transportation

Activity	Description
Night scraping and brushing	Involves daily manual sweeping of streets at night by around 2000 daily wage workers. The activity is carried out under SMC supervision. It covers an area of around 500 km^2 across 200 routes
Hotel waste management system	Hotel kitchen waste is collected and transported by the hotel association. Around 300 hotels are involved, and around 18 vehicles are employed by the hotel association presently
ANUDAN Scheme	Street sweeping of societies on a PPP basis for internal cleaning of societies. More than 862 societies are involved in this and 800 daily wagers are employed.

Inferences and Policy Recommendation

Based on the above analysis, some positive inferences as well as potential barriers were identified. These are presented here along with some recommendations for enabling electrification.

Positive Inferences

- **Overall daily distance:** Since vehicles run within designated zones their daily distance travelled is limited, the average range across zones was 39 km to 53 km. This is ideal for electric vehicles as most of these vehicles can complete up to 75 km on a single charge with a full payload. As the routes are constant, variation in the travel patterns would be unlikely.
- **Economic benefits:** The total cost of ownership for the electric four-wheelers was found to be lower than the existing diesel vehicles. The total costs for new electric four-wheelers and retrofitted four-wheelers were lower by 14% and 21%, respectively. The main reason for this was the low fuel efficiency associated with existing vehicles. In door-to-door collection operations, the vehicles have to stop multiple times, increasing the idle time, and leading to very low mileage. Even after assuming the range of electric vehicles to be very low, the running expenditure for electric vehicles is low enough to cover up the additional financing costs within the first 4 years.
- **Fleet ownership:** In each zone, private operators run the whole fleet operations. These operators are well-established agencies with easy access to finance and a longer planning horizon. This allows them to better incorporate the benefits of electric vehicles into their decision making. One of the major issues is the higher up-front costs associated with electric vehicles which often cannot be borne by individual entities. For fleet operators, it is easier to take on these losses in the initial years as they lead to large profits in the future. Access to multiple financing options also allows them to spread out the losses in the initial years as they can obtain better interest rates on loans compared to individual operators.

Fleet ownership also allows better planning of trips to ensure optimal performance of electric vehicles. If the payloads for certain trips are too high for electric vehicles, the number of trips for the electric vehicles can be increased to ensure that all the waste is still efficiently collected.

- **Ease of setting up charging infrastructure:** A big advantage of electrification in this sector relates to the fact that the origin and destination for all the vehicles are the respective transfer stations. These transfer stations provide the ideal area for installing charging infrastructure, the costs of which can be borne by the municipal corporation.

Barriers to EV Adoption

- **Payload:** The average payload per trip of around 800 kg in most zones is higher than the payloads doable by available electric vehicles in the market. This problem can be solved without changing fleet size, better planning of trips, and increasing the frequency of trips so that the load in each trip can be easily handled by e-vehicles. In East Zone (B) and North Zone, where the use of larger trucks is prevalent, the total fleet of vehicles might have to be increased to achieve the same tonne kilometres with electric vehicles.
- **Performance issues with electric vehicles:** During the stakeholder conversations, one of the main concerns was related to the performance of the electric vehicle in terms of pickup and reliability. This concern mainly arises from lack of long-term information related to on-road performance of these vehicles. One issue that was specifically highlighted was the ability of the vehicles to climb the ramp of the transfer station when the vehicles are fully loaded. This issue was faced by municipal authorities when they did a pilot study with CNG vehicles in Surat. However, pilot studies could go a long way to curb doubts related to these issues.
- **Willingness of operators to shift:** The present operators are used to operating diesel vehicles so a complete shift towards electric vehicles may be met with some resistance due to the higher up-front costs and lack of road experience. However, awareness campaigns and driver training programmes could go a long way to appease these fears.

Policy Recommendations

Based on the techno-economic analysis and consultation with stakeholders, some key policy recommendations for adoption of electric vehicles are stated below:

- **Immediate need for pilots:** A pilot study with electric vehicles could be a major step in demonstrating the capability of electric vehicles to the private operators. This would help address concerns such as load carrying capacity and performance issues. A pilot study in Surat could also show the way for other cities who might be considering electrification of their waste transport vehicles. These pilot studies should ideally be carried out before the new tenders are issued in 2022 so that electric vehicles can be incorporated in the new tenders.
- **Add incentives for private operators in the new tenders:** The municipal corporation should consider basing the tipping fee provided to private operators on the number of electric vehicles in the fleet. In case private operators include electric vehicles in their fleet they could be made eligible for higher tipping fees, at least in the first three years of the contract. This will help them recover the additional financing costs associated with electric vehicles in the initial years.
- **Mandatory inclusion of electric vehicles in the fleet:** The new tender for private operators can mandate that a certain portion of the fleet must consist of electric vehicles. In the first stage, it could be recommended that only around 20%–30% must be electric. This will provide enough flexibility to the operators to plan their trips around any shortcomings for electric vehicles that may arise. This will also demonstrate on the ground the capability of electric vehicles as well as allow operators to assess financial gains from reduced running costs, leading to greater adoption in the future.
- **Implementing state-wide electric vehicle policy:** Implementing a state-wide electric vehicle policy with focus on commercial and freight operations could make the adoption process easier while also providing government backing. Some of the easier steps that can be included in the policy are waiver of permit and registration fees. Road tax in Gujarat is quite high, so waiving this tax for electric vehicles could go a long way to improving the on-road costs associated with these vehicles. As a further step, additional subsidies can also be provided on purchase of electric commercial vehicles. The Delhi government already provides an additional subsidy amounting to 50% of the FAME-II subsidy for commercial three-wheelers.

Based on the technological aspects, the potential for electrification seems to be significant for the Surat case study. The trip length and availability of transfer station for charging infrastructure favour the adoption of electric vehicles in this sector. The SWM management system followed in most other cities is also similar because they are all guided by the same set of rules, i.e. the Solid Waste Management Rules, 2016. All cities where the distance from the city jurisdiction to the disposal point is more than 15 km have a transfer station.

There is an immediate need to conduct pilot studies to gauge the performance of existing electric vehicles in terms of the payload to be carried. This is an issue with most SWM systems, especially where overloading is prevalent, but in some places, electric vehicles have already been introduced. In Vijayawada, more than 100 electric vehicles were introduced by the municipal corporation and have been running successfully. A pilot study conducted in Surat could lead the way for further adoption of electric vehicles in other cities.

Similar to Surat, several ULBs have now involved private sector players to make the SWM management system more robust and competent. The inclusion of private players also favours the adoption of electric vehicles because the costs over the long run are much lower for the electric vehicles. In Surat, one way suggested by the municipal authorities was to include a clause in the tender which makes it mandatory for part of the fleet to be electric. A similar process can also be followed in cities where such PPP arrangements already exist.

3. Potential of Electrification: **Distribution of Fruits and Vegetables in Delhi**

Movement of agriculture produce occupies a critical share in the overall urban freight transportation in a city. As per IIT-Delhi estimates, perishable agriculture produce accounts for 8.3% share in the total urban freight movement. In key Indian cities, the wholesale markets, or *mandis* as referred to in local term, are the key attractors of inbound agricultural produce (especially fruits and vegetables). These large inflows of agricultural products are first assembled at urban consolidation centres, which are mostly government-established marketplaces. The Agricultural Produce Marketing Committees (APMCs), situated within the city, are responsible as distribution centres for easier movement of goods.

The broader observations of the supply chain on how perishable agriculture goods move around the city shows that the goods are supplied to numerous city distribution centres from where freight carriers supply to the retail stores/vendors/small markets. The higher weight category/heavy duty vehicles (HDVs) are used to supply to the distribution centres from farms, while small commercial vehicles (SCVs) are used for deliveries to local stores/vendors. This chapter deals with the transportation of perishable agricultural products (fruits and vegetables) from large wholesale markets to retail stores, vendors, and small retail markets in the city of Delhi. Freight movement of non-food agricultural products like tobacco and rubber is beyond the scope of this chapter as the destination of the agri-produce is mostly factories and may reach the urban residents from a retail supply chain. On the other hand, perishable food commodities like fruits and vegetables move every day in large volumes, mainly by road.

The following section reviews the movement of agriculture freight in India, including volume of trade conducted and vehicles used for freight from APMCs. The later part of the chapter discusses the functioning of Delhi's Azadpur and Okhla wholesale markets, with the objective of understanding the potential of electrification of SCVs that are used for delivery of agricultural produce from wholesale markets to retail stores/vendors.

The reason for selecting Delhi APMCs (Azadpur and Okhla) as part of the unorganized movement of freight in a city is such that APMCs are also present in other states/cities and, therefore, recommendations/understanding towards electrification of SCVs could be applicable across cities in the country.

Current State of Movement of Agriculture Goods

In order to understand urban agriculture freight, it is crucial to review freight inflow and outflow from APMCs in Indian cities. APMCs act as urban consolidation centres for perishable agriculture products entering the city.

Agricultural produce markets are regulated under the Agricultural Produce Market Committee Act enacted by state governments. There are 2558 principal regulated markets based on geography (the APMCs) and 4388 sub-market yards regulated by the respective APMCs in India (Ministry of Agriculture 2017-18).

Wherever APMCs function, they play a key role in linking the rural and urban agriculture produce with markets. In the distribution of agriculture produce, road transport has a vital role as it is the major means of transporting agricultural produce from the farms to the markets as well as to various urban communities/centres. In such markets, there are a number of participants – farmers from nearby villages, wholesale as well as retail buyers and sellers, including local fruit and vegetable vendors who use bicycles, rickshaws, auto-rickshaws, motorbikes and small pick-up trucks as different modes of transportation (Business Line, 2018). Majority of the agricultural produce is transported through roadways from farmland to warehouses or wholesale markets in and around consumption centres/cities (Figure 1). More than 97% of the fruits, vegetables, and pulses are moved by the road in terms of tonnage.

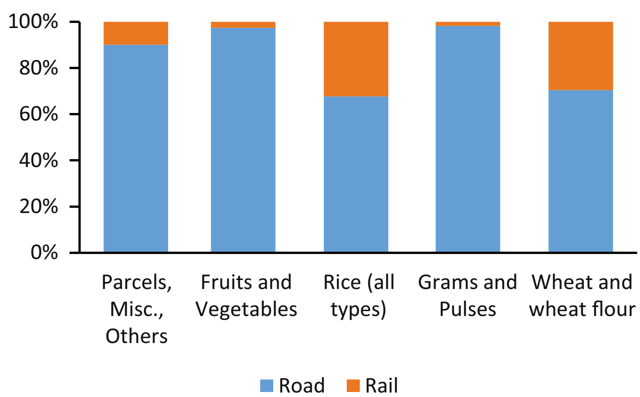


Figure 1 Comparative road and rail share of agriculture freight

The following are some inferences about movement of fruits and vegetables from the review of select APMCs.

- ***Regional Consolidation Centres:*** Most of the APMCs are consolidation centres for not just the specific urban area where they are located. They also serve as regional consolidation centres.
- ***Road Dependant:*** Outbound traffic from the APMCs is completely road dependent.
- ***Varied Vehicle Mix:*** There is a varied mix of transport vehicles, ranging from hand carts and auto-rickshaws to trucks and tempos, that are used for distribution of fruits and vegetables from these APMCs.
- ***Outbound SCVs:*** However, it is understood that outbound traffic comprises mainly of small and light commercial vehicles. Larger vehicles are attributed mainly to trips to subsidiary mandis of the respective APMCs.

Case Study V: Outbound Fruits and Vegetables Movement from Azadpur and Okhla APMCs

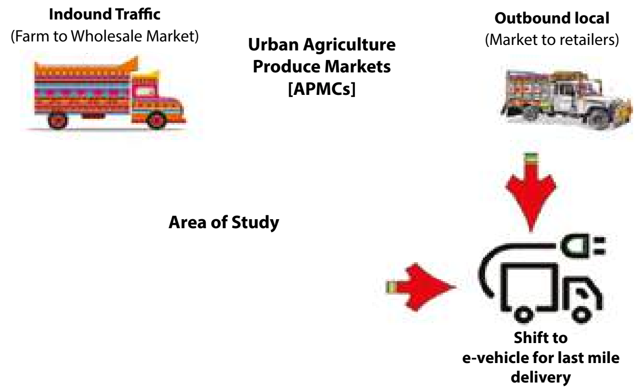


Figure 2 Selection of traffic from APMCs for evaluating potential of electrification

Source: TERI

Technological potential of electrification of HDVs is limited in the current scenario of electric vehicle technology. Further, the inbound traffic into APMCs comprises mainly of HDVs arriving from outside the city bounds. Hence, the environmental externalities attributed to them go beyond the scope of urban areas and urban freight as defined in this study. Figure 2 indicates the selection of the specific kind of freight flow from APMCs, which is the focus of this study, for evaluating the potential of electrification. The vehicles involved in the outbound local traffic from APMCs are mostly SCVs and fall within the vehicle category selected (GVW < 3.5 tonne) in the scope of this project.

Current Freight Movement in Azadpur and Okhla

Delhi has eight APMCs consolidating large volumes of agricultural produce from several states as well as international consignments. As part of the research work, TERI selected two APMC *mandis* to study the potential of electrification of urban freight movement in the unorganized sector. Azadpur APMC is unarguably the largest agricultural produce market in Asia and has a wide variety and volume of smaller vehicles redistributing to areas within Delhi. TERI also selected a smaller market, Okhla APMC, which is further inside Delhi, in order to derive generalized recommendations for electrification of freight movement from similar consolidation centres across cities. The ensuing are some of the observations regarding freight flow from vehicle arrival data recorded by the APMCs.

Azadpur APMC

Azadpur is the largest market of fruits and vegetables in Asia spread over 79.83 acre. Azadpur sees a monthly traffic of more than 1 lakh vehicles, both SCVs and HDVs. Every day 3652 vehicles enter Azadpur (MIS, Azadpur APMC 2019). Of these vehicles, 55% are empty. Everyday into the *mandi* 1632 vehicles carry in a total of 14,108 tonne of fruits and vegetables. SCVs compose 84% of the empty vehicles and 42% of the loaded vehicles entering Azadpur. Of the total SCVs entering Azadpur, 71% are empty (Figure 3).

The arrival data also records the origin state of the inbound vehicle. About 686 loaded SCVs enter Azadpur daily. These vehicles mainly come from within Delhi (19%) and neighbouring states of Haryana (43%), Uttar Pradesh (15%), Rajasthan (7%), and Himachal Pradesh (5%).

Okhla APMC

Similarly, Okhla is one of the smaller APMC markets to serve the local Delhi population with their daily fruits and vegetables supply. It is spread over 9.98 acre with 218 small shops. Almost 11,000 vehicles enter the Okhla *mandi* monthly. About 369 vehicles enter the APMC daily of which 35% are empty. SCVs comprise 95% of the empty vehicles and 58% of the loaded vehicles entering Okhla (Figure 4). Of the total SCVs entering Okhla, 46% are empty. However, unlike Azadpur, many vehicles loading goods are parked outside the *mandi* and never enter the APMC premises. The goods are carried outside APMC gates by human labourers to load the respective vehicles. Hence the empty vehicles entering Okhla are not representative of all the vehicles distributing fruits and vegetable from the same mandi. Approximately 240 vehicles carry in 1340 tonne of agriculture produce in Okhla every day. Unlike Azadpur, there are very few (one or two) HDVs entering daily into Okhla.

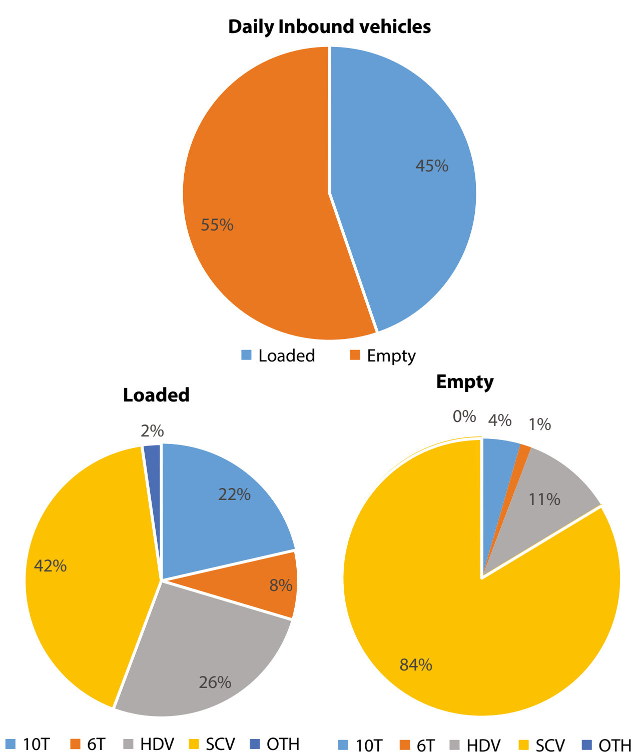


Figure 3 Daily inbound vehicle traffic in Azadpur (2019)

Source: MIS, Azadpur APMC (October 2018 to October 2019)

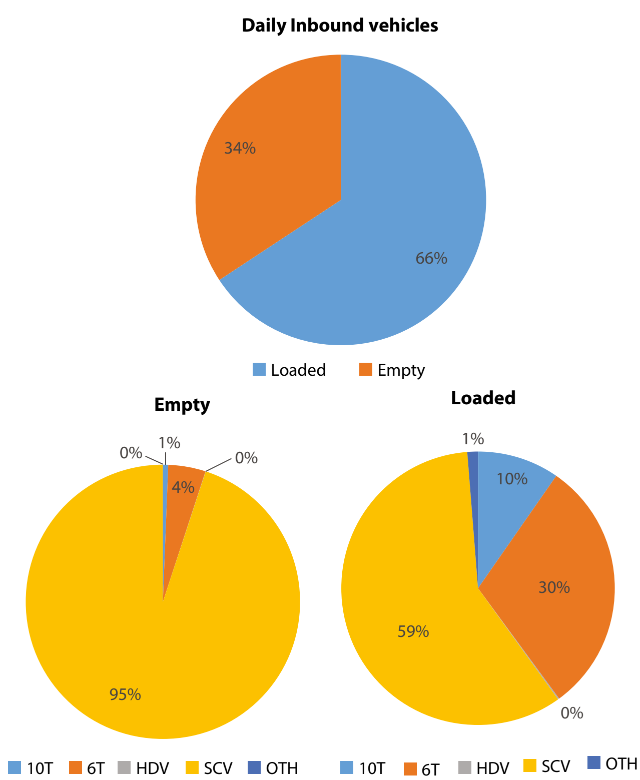


Figure 4 Daily inbound vehicle traffic in Okhla (2019)

Owing to the entry restrictions of heavy category vehicles in Delhi, most of the vehicles enter both Azadpur and Okhla *mandi* premises between 9 pm and 3 am. Through consultation with APMC officials, it was found that the outbound loading time of agriculture freight was between 3 am and 10 am. More secondary data analysis on the arrival data including the fuel mixes, time of day, and aggregate monthly traffic is mentioned in Annexure I.

Primary Survey: Outbound Agricultural Freight from Azadpur and Okhla

As explained in the previous section, the survey was conducted on outbound traffic from select APMCs. The drivers of the respective vehicles were surveyed while the vehicles were being loaded with agriculture products from the respective APMCs.

Questionnaire Design

The questionnaire collected information under six main sections to understand the potential of electrification of outbound freight from APMC (Figure 5). The sections are listed as follows:

- Ownership of vehicle and goods carried
- Vehicular details
- Cost details
- Operational characteristics
  - Trip characteristics
  - Vehicle usage

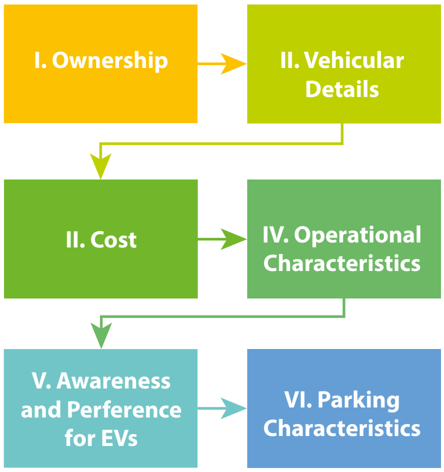


Figure 5 Questionnaire design

- Electric vehicle awareness details
- Parking characteristics

Detailed questionnaire is presented in Annexure II.

Sample Selection

The survey collected 635 responses from outbound drivers who were loading their vehicles with agricultural commodities from Azadpur and Okhla APMCs. Of the 635 respondents, 207 are captured from Okhla APMC and 428 from Azadpur APMC. See Figure 6.

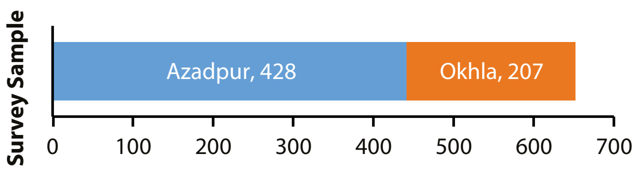


Figure 6 Sample selected from Okhla and Azadpur APMCs

Source TERI

A detailed methodology for sample selection is explained in Annexure III.

Spatial Distribution of Agriculture Freight in Delhi

Azadpur APMC

The survey captured 180 unique destinations of vehicles outbound from Azadpur APMC. This accounts for 281 tonne of outbound traffic of agriculture freight. This is approximately 2% of daily inbound traffic entering Azadpur.

Table 1 Top destination of outbound traffic from Azadpur APMC

Destination markets	Distance from Azadpur APMC	Proportion of overall daily outbound traffic
Rohini	11.5 km	5.01%
Jahangir Puri	1.5 km	3.79%
Wazirpur	4.3 km	2.24%
Noida, Uttar Pradesh	38.2 km	2.13%
Alipur	11.9 km	1.94%
Shalimar Bagh	1.3 km	1.85%
Gurgaon, Haryana	43.3 km	1.77%

Source: TERI

Table 1 shows the top destinations for outbound traffic of agriculture freight from Azadpur carried in SCVs (GVW < 3.5 tonne). Rohini in Delhi is the main destination for SCVs, composing 5.01% of the total outbound traffic from Azadpur APMC. Rohini is at 11.5 km distance by road from Azadpur. The second largest consumer of outbound traffic from Azadpur APMC is just 1.5 km away. Vegetable vendors in Jahangir Puri received 3.79% of the outbound freight by SCVs from Azadpur. Similar to Jahangir Puri, Wazirpur and Shalimar Bagh, at just 4.3 km and 1.4 km respectively, are nearby locations with significant freight flow from Azadpur APMC. These locations are also densely populated areas. A deeper understanding of the freight flows in close vicinity to Azadpur will help gauge the potential of electric vehicle diffusion in those areas. A significant proportion of Azadpur's outbound SCV traffic is directed outside Delhi. The main recipients are Noida is Uttar Pradesh and Gurgaon in Haryana.

Figure 7 shows the spatial distribution of outbound trips of SCVs from Azadpur *mandi*. It shows that Azadpur APMC caters to locations not only all around Delhi but also to neighbouring states of Haryana and Uttar Pradesh. Majority of the destinations are vendors in small markets.

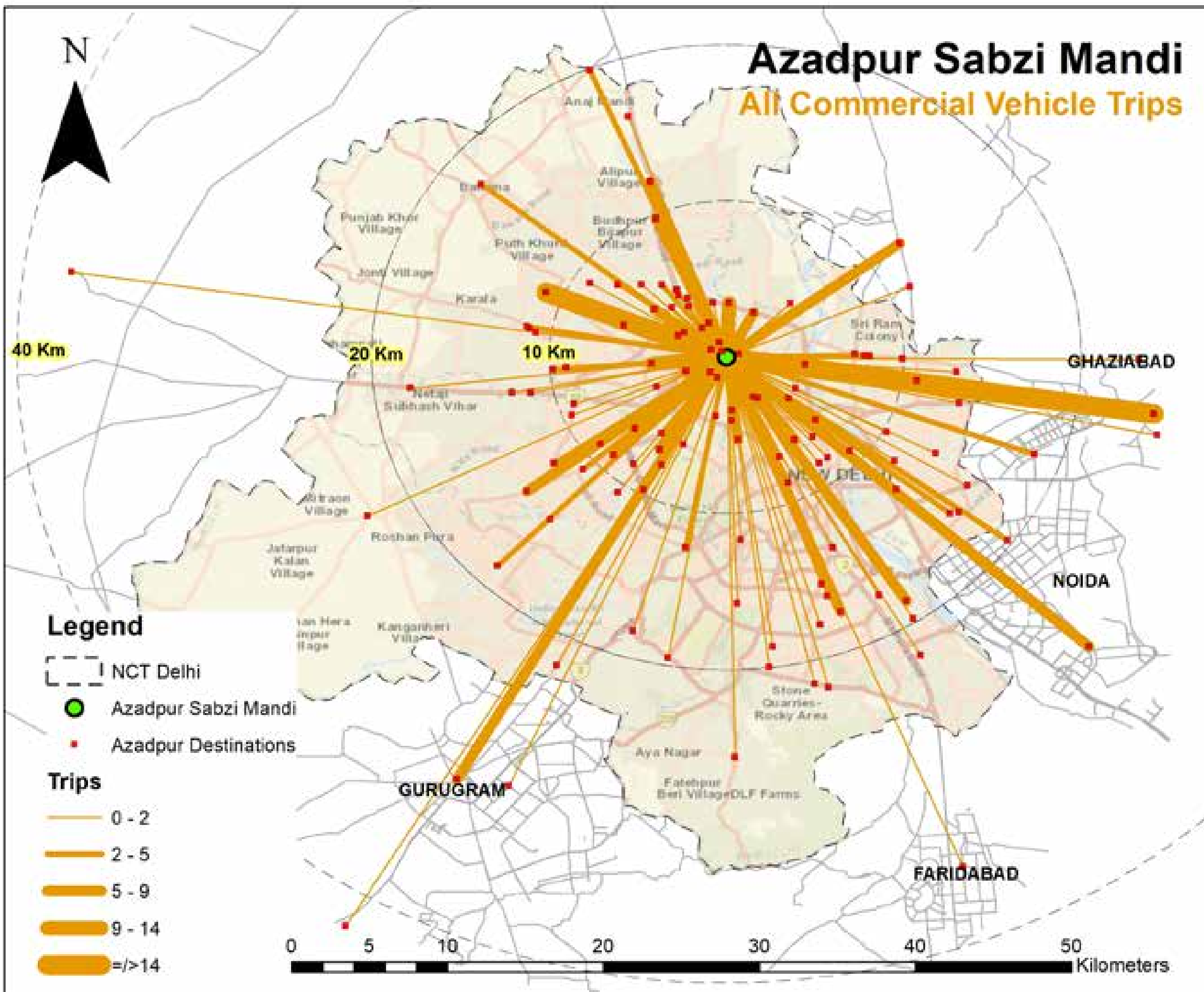


Figure 7 Spatial trip distribution from Azadpur APMC

Source: TERI

Okhla APMC

The survey recorded 66 unique destinations for the vehicles from Okhla APMC. This accounts for 106.5 tonne of outbound traffic of agriculture freight. This is approximately 8% of the daily inbound traffic entering Okhla.

Table 2 Top destination of outbound traffic from Okhla APMC

Destination market	Distance from Okhla APMC	Proportion of overall daily outbound traffic
Badarpur	8.1 km	15.67%
Sarita Vihar	5.9 km	7.69%
Nehru Place	2.9 km	6.00%
Sangam Vihar	11.8 km	5.63%
Noida	18 km	5.02%
Tughlakabad	9.4 km	4.03%
Saket	9.2 km	3.38%

Source: TERI

Table 2 shows the top destinations for outbound traffic of agriculture freight from Okhla carried in SCVs (GVW < 3.5 tonne). Badarpur in Delhi is the main destination composing 15.67% of the total outbound traffic on SCVs from Okhla APMC. Badarpur is 8.1 km distance by road from Okhla. The second largest recipient of agriculture freight from Okhla *mandi* is Sarita Vihar with 7.69% of the freight transported over 5.9 km distance. Nehru Place is just 2.9 km from Okhla and receives around 6% of the outbound freight from the fruits and vegetables market. Like Azadpur *mandi*, Okhla too supports agricultural produce demand from Noida in Uttar Pradesh. About 5.02% of the outbound freight by SCVs from Okhla is directed towards Noida.

Figure 8 shows the spatial distribution of outbound trips of SCVs from Okhla *mandi*. It is visually evident that vehicles go longer distances from Azadpur APMC than the vehicles from Okhla APMC. As discussed earlier, Azadpur fruits and vegetable market is significantly larger than Okhla, in terms of both area and throughput of agricultural freight. Even though trips from Azadpur and Okhla cater to locations/sub-markets outside Delhi, as National Capital Region (NCR) is a highly urbanized region, such trips do fall under the scope of urban freight and this project.

Ownership of Goods and Vehicles

About 98% of the surveyed drivers were transporting goods for someone else and hence can be classified as for 'third account'. Only about 5 of the surveyed drivers were transporting the goods on 'own account' (transport operated by manufacturers with their own employees or transport made by an independent retailer with his or her own vehicle to supply the store). This is in contrast to a typical North American or European city where both the categories make equal amount of deliveries (Dablanc 2009). Even though literature suggests many developing countries having higher share of 'own account' transport (like Medan), high share of 'third account' transport was also observed in Pakistan (Rizet 1993).

Even though ownership of the goods carried is on 'third account', most respondents (vehicle drivers) stated that they owned the vehicle. Basically, 87% of the respondents owned the vehicle but only 4% of the respondents owned the goods being carried in them. Of the respondents who did not own the vehicle, 13% were asked if they had leased the vehicle to operate or were employed as a salaried driver. Figure 9 shows the ownership of the vehicles surveyed. About 12% of the respondents were salaried drivers and just 1% operated a leased vehicle.

The highest proportions of salaried drivers were in the categories of pick-up truck (30%) and mini truck (16%), which are also the most expensive vehicle categories here.

As it was identified in the literature, adoption of electric vehicles in commercial uses is being spearheaded by fleet operators due to favourable economics. In the case of APMCs, as the ownership of vehicles is disaggregated among individuals, electric vehicle transition is dependent on all the individual decisions of switching to electric. If the vehicles were not individually owned but owned by fleet operators, the favourable economics of switching to electric could be exploited better. However, here the individual owners are risk averse and a single vehicle constitutes a huge portion of their investment. Such an individual is not much likely to purchase a new technology vehicle at a higher cost without visible evidence from peers regarding cost savings over lifetime.

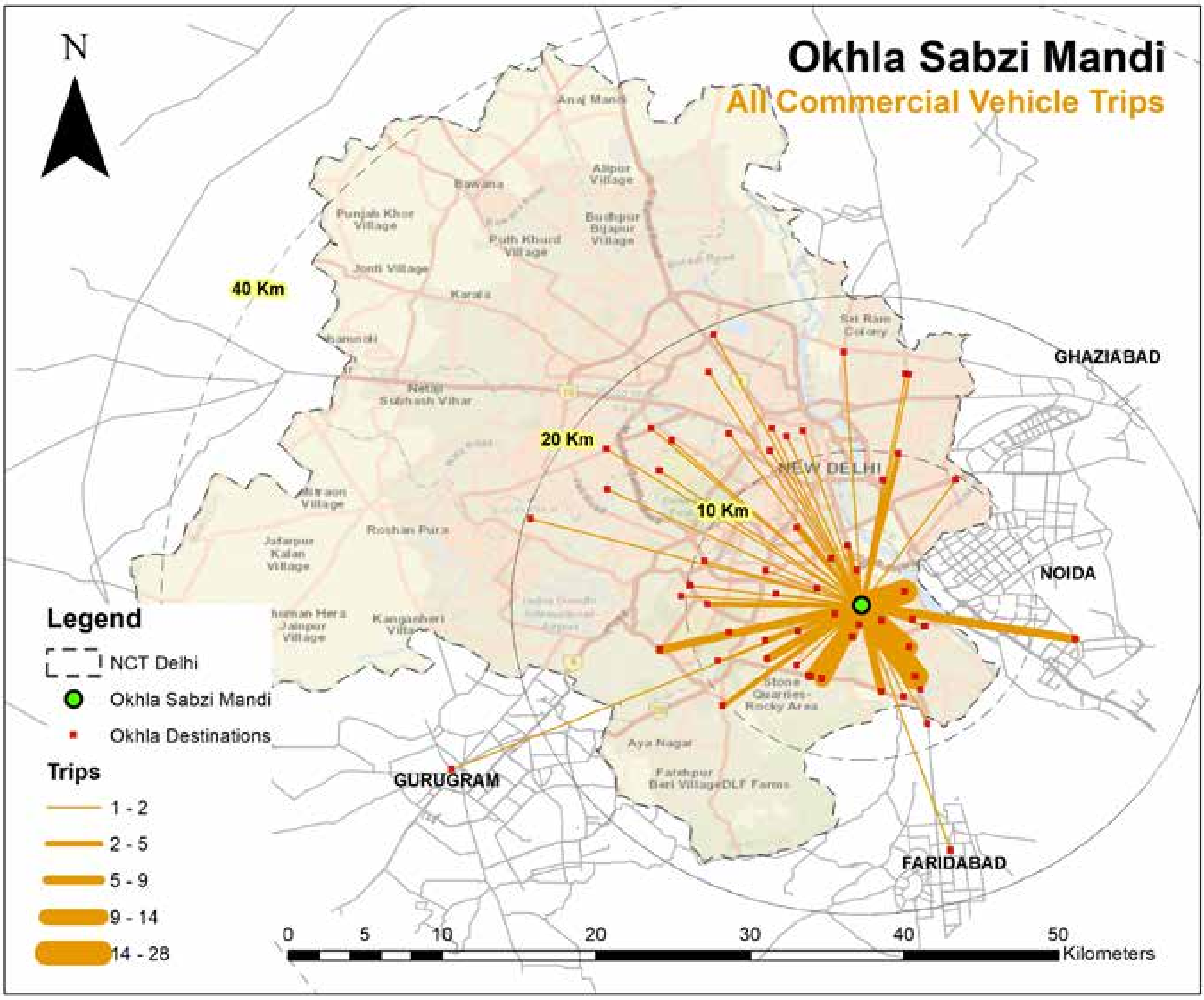


Figure 8 Spatial distribution across Okhla *mandi*

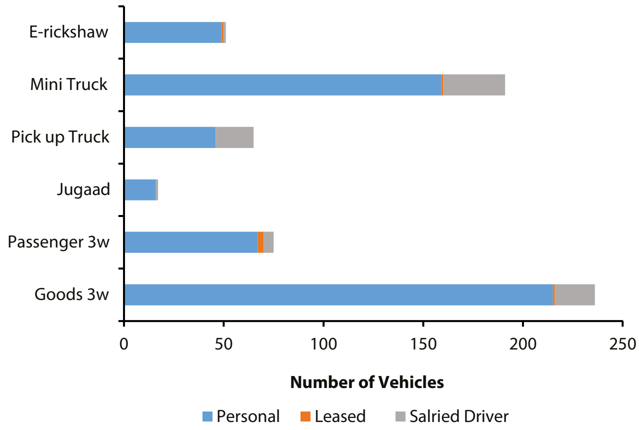


Figure 9 Vehicle ownership of total 635 respondents by vehicle type

Vehicular Details

The vehicle captured in the survey can be classified in six different types, as indicated in Figure 10. The percentages indicate the proportion of the vehicle category in the overall sample of 635 responses from both Azadpur and Okhla APMCs (also see Figure 11).

Drivers of three-wheeler goods were 37% of the respondents. Majority of the vehicles classified from the survey under this category were models from Bajaj, Mahindra, and Piaggio. Drivers of mini trucks or mini pick-up trucks were 30% of the respondents. Majority of the vehicles classified from the survey under this category were Tata Ace vehicle models. There were 75 responses captured from drivers of passenger three-wheelers. These vehicles are permitted to ply only passengers.

Figure 10 Vehicle types used for agriculture freight in the Okhla-Azadpur survey

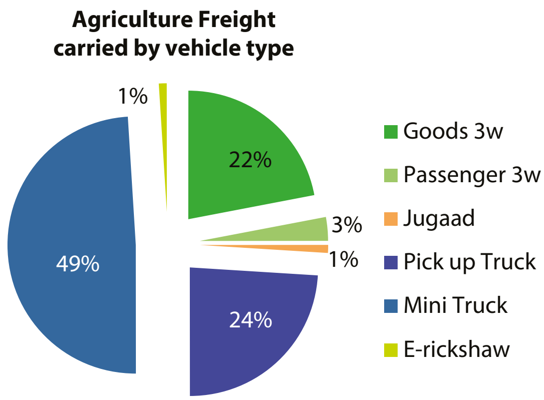


Figure 11 Distribution of Delhi APMC vehicle wise

However, drivers cited economic reasons for using these auto-rickshaws for agriculture freight as often 3–6 am, the timing of such operations, as they receive very little passenger demand during this demand. Employing these vehicles for freight applications has negligible opportunity cost for the auto-rickshaw drivers. There were 65 responses from pick-up trucks. Majority of the vehicles classified from the survey under this category were 'Mahindra pick-up' vehicle models. Apart from these, the survey also captured responses of 51 e-rickshaws and 17 *Jugaads*, which are makeshift vehicles and not registered under the Motor Vehicles Act. However, the same was included in our survey as these vehicles are highly polluting and are beyond regulation. Except for battery-powered e-rickshaws and *Jugaads*, which use petrol as a fuel, all the other categories of vehicles in the survey use CNG as primary fuel.

Figure 12 shows the distribution of responses by vehicle type for Azadpur APMC. Three-wheeler goods (38%) and mini pick-up trucks (36%) form the majority of the responses. Of the 51 e-rickshaws captured in this survey, 49 are from Azadpur. From Azadpur 11% of the responses were pickup trucks and <1% (5) were Jugaads.

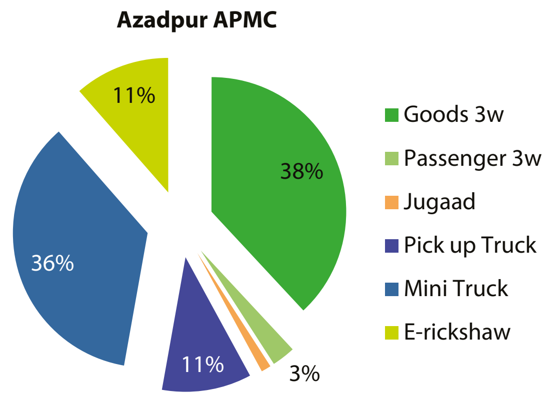


Figure 12 Vehicles category Azadpur

Similarly, Figure 13 shows the distribution of vehicles in Okhla. Three-wheeler goods (35%) and three-wheeler passenger (31%) vehicles form the majority of sample captured. Eighteen per cent of the vehicles are mini trucks and 9% are pick-up trucks. From Okhla APMC, 12 of the 17 Jugaads in the survey were distributing agriculture goods.

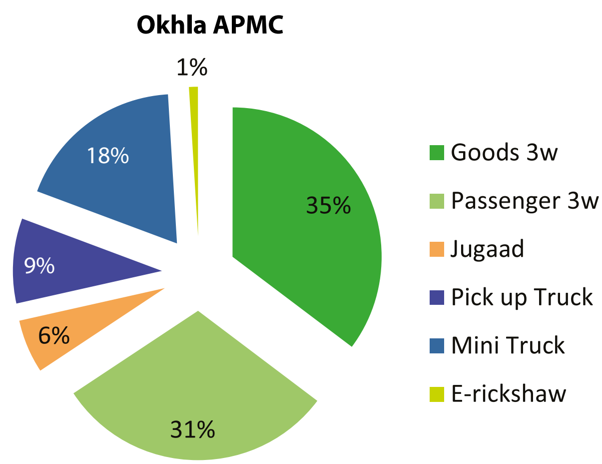


Figure 13 Vehicle types in Okhla

When analysing freight transportation problem, tonne kilometre is a more appropriate measure to gauge the intensity of freight mobility. For example, even though majority of vehicles in this survey are three-wheeler goods, they are not the largest or farthest movers of urban agricultural freight in the sample. Just the 635 vehicles surveyed are responsible for 11.3 million tonne kilometre (MTkm) of urban agricultural freight each day. The vehicles surveyed from Azadpur APMC, operate 9.1 MTkm of agricultural urban freight every day. Similarly, the sample from Okhla operates 2.2 MTkm of daily agricultural freight every day. Figure 11 shows the agricultural freight in MTkm accrued to various vehicle types from Okhla and Azadpur. Mini trucks, mostly TATA-Ace models, distribute 49% of the agricultural freight and are popularly known as 'Chota Hathi'. This validates other findings from the literature regarding gaining popularity of four-wheelers over three-wheelers in goods commercial vehicle segment.

When evaluated in terms of TKM, it is clear that mini trucks (four-wheeler small goods vehicles) are the largest distributors (49%) of agriculture fright from APMCs in Delhi. This is followed by pick-up trucks (24%) and three-wheeler goods (22%). Although employed in large numbers, three-wheeler passengers move a very small share of the agriculture urban freight from the *mandis* of Azadpur and Okhla. Hence, later in this chapter, we will evaluate the trip patterns of mini trucks, pick-up trucks, and three-wheeler goods from the survey data to understand the potential of electrification of those trips.

Costs of Operation

In order to assess the potential of transition towards electric goods vehicles, it is important to understand the economic aspects of owning and running a vehicle. Such costs primarily take into account the purchase cost and operational costs of the vehicle. Understanding the economic feasibility of electric freight vehicles is crucial for making them affordable and profitable for the drivers. Assessment of these costs can play an important role in making them a more favourable choice for the drivers. In the context of this study, the survey has been done to capture the present costs associated with different ICE freight vehicles.

The total operational costs are the highest for pick-up trucks with the owners spending Rs 12,500 monthly on average (Figure 14). Three-wheeler goods in Delhi incur approximately Rs 6000 monthly on overall operations of the vehicle.

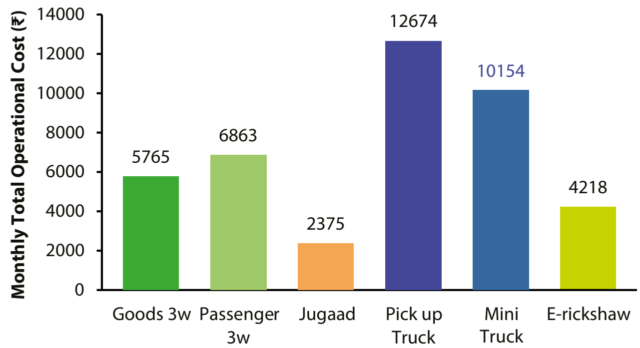


Figure 14 Average total operational cost of a typical commercial vehicle

These costs primarily consist of insurance and maintenance costs, commercial tax, fuel costs, and any other costs that the driver incur during the service time. A comparative analysis of the costs associated with ICE vehicles and electric freight vehicles will also be done to assess how the change in operational and fuel costs of the vehicle have an impact on the revenues earned by the driver.

Maintenance Costs

The average monthly maintenance costs of the vehicle range between Rs 474 and Rs 3128 (Figure 15). The analysis was also done to identify if there are any differences between maintenance costs of new and second-hand vehicles but no significant difference was found.

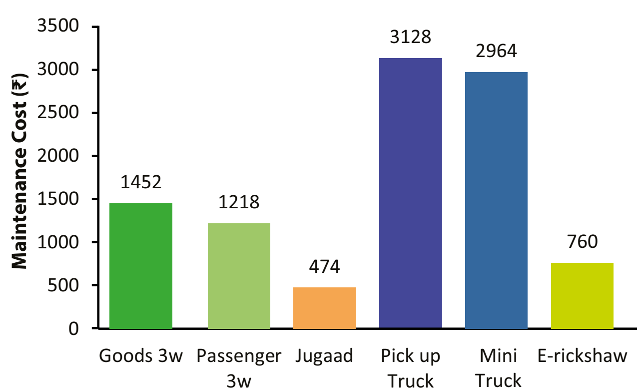


Figure 15 Average monthly maintenance cost of vehicle

Fuel Costs

The average monthly fuel costs (Figure 16) are highest for pick-up trucks (Rs 7143) and lowest for *Jugaads* (Rs 1610). Unlike maintenance costs, the fuel costs difference is higher between pick-up truck and mini truck. Also, 93% of the drivers have reported that they pay Rs 20 as *mandi* entry fee and 5% have reported that they pay Rs 10. The entry fees are the same at Azadpur and Okhla.

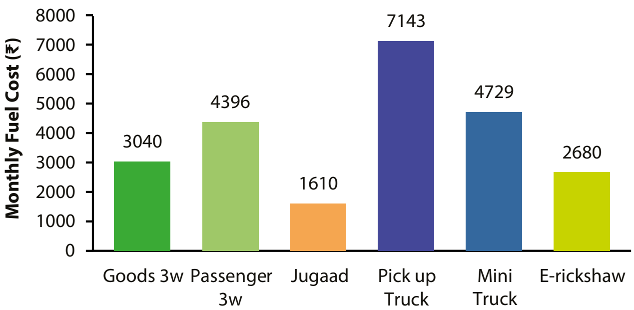


Figure 16 Average monthly costs of vehicles

Operational Characteristics

The argument that it is economically cheaper to switch to electric is contingent on the ability of the electric vehicles to replace the current trips undertaken by ICE vehicles. That is, will electric vehicles be able to carry the load carried by ICEs and will they be able to cover the distance covered by the ICEs. For this, we assess each of the ICE vehicles separately for their current freight patterns in Okhla and Azadpur *mandis*. Mini trucks, pick-up trucks, and three-wheeler goods vehicles were responsible for 96% of the outbound freight on SCVs from Azadpur and Okhla. Hence, in this section, operational characteristics of three types of vehicles will be assessed in depth to understand the technological potential of electrification of the trips presently catered by them, respectively.

Mini Trucks

The mini trucks are responsible for the highest share of daily freight movement captured in the survey. These vehicles are responsible for 22% of the daily freight movement (in terms of tonne kilometres) from Okhla and 55% of daily freight movement recorded from Azadpur. Majority of the vehicles classified from the survey under this category were Tata Ace. The vehicles on average were about 3.5 years old.

Trip Characteristics

Figure 17 shows the trip distribution of mini trucks. Mini trucks outbound from Azadpur cater to destination markets at longer distances. However, majority of the agriculture freight movement by mini trucks are towards destinations within Delhi. Table 3 lists the top destinations for outbound mini trucks from Azadpur and Okhla *mandis*. The top destinations are ranked based on daily flow of agriculture freight in tonnes.

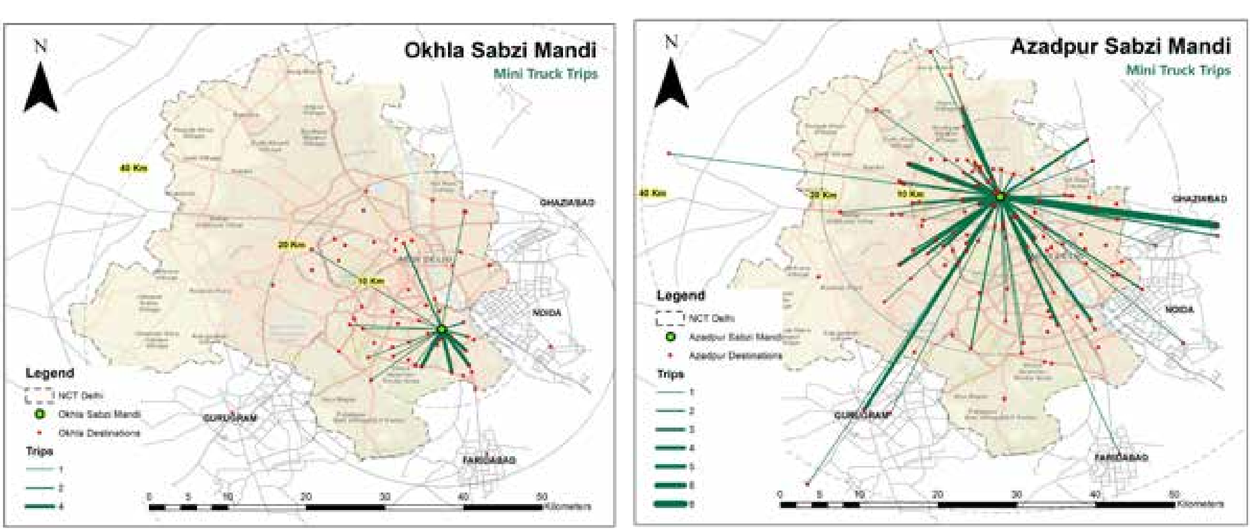


Figure 17 Spatial trip distribution of mini trucks

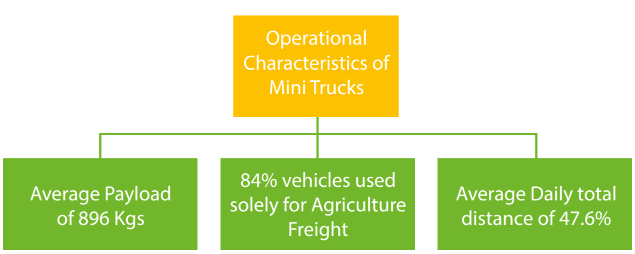
Vegetable markets/vendors in Badarpur and Jahangir Puri are the top destinations for outbound mini trucks from Okhla and Azadpur, respectively. Jahangir Puri, which is at a distance of 1.5 km, receives about 4% of the outbound freight by mini trucks from Azadpur.

Table 3 Top destination of outbound traffic of mini trucks

Okhla APMC		Azadpur APMC	
Top Destination Markets	**Distance from APMC**	**Top Destination Markets**	**Distance from APMC**
Badarpur	8.1 km	Jahangir Puri	1.5 km
Sarita Vihar	5.9 km	Fatehpur	10 km
Jasola	5.3 km	Wazirpur	4.3 km
Tughlakabad	9.4 km	Shalimar Bagh	1.3 km
Govindpuri	3.8 km	Rohini	11.5 km

Overall Vehicle Usage

It can be observed that there are more instances of overloading in agriculture freight associated with Azadpur than with Okhla. However, the range of payload stretches wide from well below 500 kg to almost 200 kg in some cases. The average payload for a mini truck is 758 kg in Okhla and 930 kg in Azadpur. The daily total distance is 48.6 km for Okhla and 47.3 km for Azadpur. There is not much difference between the overall usage of mini trucks in terms of daily total distance.



Pick-up Trucks

Pick-up trucks are responsible for the second highest share of daily freight movement captured in the survey. These vehicles are responsible for 39% of the daily freight movement (in terms of tonne kilometres) from Okhla and 20% of daily freight movement recorded from Azadpur. Majority of the vehicles classified from the survey under this category were 'Mahindra pick-up' vehicle models. The vehicles on average were 3.9 years old.

Trip Characteristics

Figure 18 shows the trip distribution of pick-up trucks. Pick-up trucks outbound from both Okhla and Azadpur cater to destination markets in Noida, Uttar Pradesh and Gurgaon, Haryana. However, a large portion of trips by the pick-up trucks are also within Delhi. Table 4 lists the top destinations for outbound pick-up trucks from Azadpur and Okhla mandis. The top destinations are ranked based on daily flow of agriculture freight in tonnes.

Noida receives the maximum outbound freight traffic of pick-up trucks from Azadpur. Noida is also the second-best destination for pick-up trucks from Okhla. A significant portion of pick-up truck traffic from Azadpur is also headed towards Gurgaon in Haryana. Badarpur is the top destination market for pick-up trucks outbound from Okhla, which is the same as that of mini trucks. Surprisingly, outbound trucks from Azadpur also cater significant volumes to Shalimar Bagh and Adarsh Nagar. These locations are very near to the Azadpur *mandi*.

Table 4 Top destination of outbound traffic of pick-up trucks

Okhla APMC		Azadpur APMC	
Top Destination Markets	**Distance from APMC**	**Top Destination Markets**	**Distance from APMC**
Badarpur	8.1 km	Noida	38.2 km
Noida	18 km	Sonia Vihar	12.5 km
Ghazipur	13.9 km	Gurgaon	43.3 km
Katwaria Sarai	10.1 km	Shalimar Bagh	1.3 km
Paharganj	15 km	Adarsh Nagar	1.2 km

Except for Badarpur and Noida, the top destinations for pick-up trucks differ in comparison to mini trucks, for outbound vehicles from both Okhla and Azadpur, respectively.

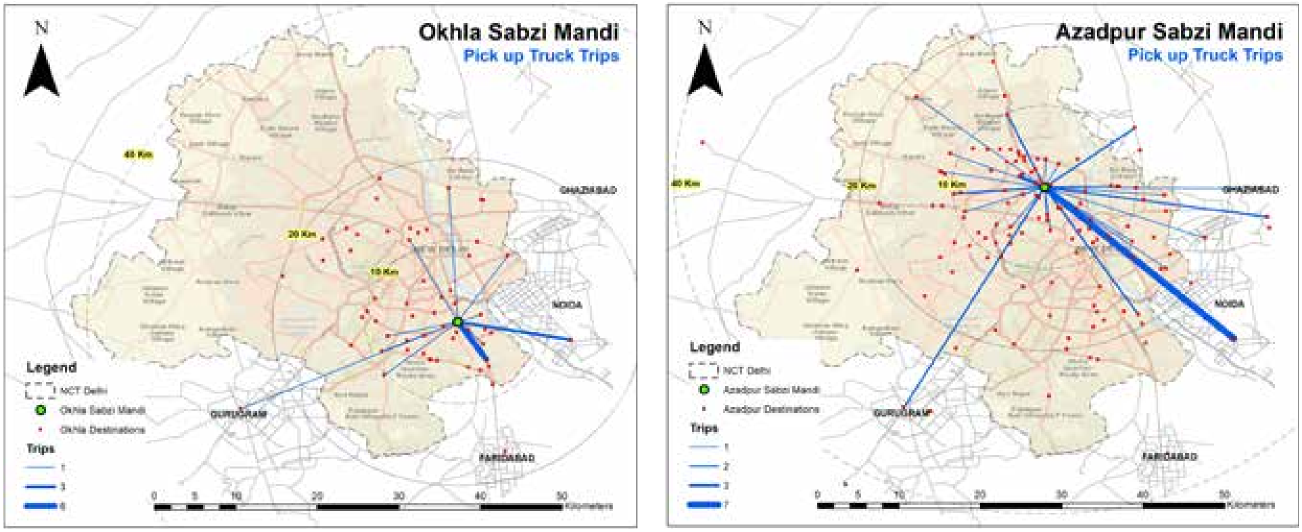


Figure 18 Spatial distribution of pick-up trucks

Overall Vehicle Usage

Except for a few outliers, pick-up trucks too, like mini trucks, are more likely to be overloaded in Azadpur than in Okhla (Table 5). However, it can be observed that almost all the pick-up trucks carry agricultural freight that weigh more than 500 kg. However, the daily total distance by pick-up trucks has a wide range, from 20 km to almost 250 km per day.

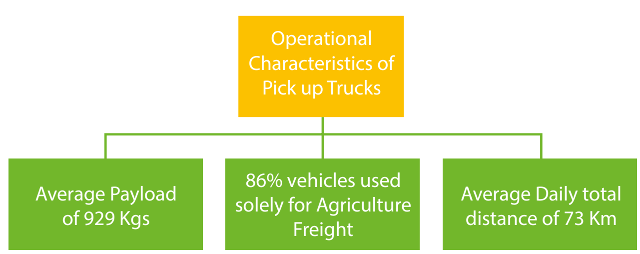
Table 5 Average payload and daily total distance of pick-up trucks

Pick-up trucks	Okhla	Azadpur	Overall
Payload	893	943	929
Daily total distance (km)	71.6	73	73

The average payloads from the two APMCs make it clear that the payload demand at Azadpur is significantly higher for pick-up trucks than for the payload demand in Okhla. Surprisingly the daily total distance for pick-up trucks is not much different for Azadpur and Okhla. Even though pick-up trucks from Azadpur cater out of the Delhi destinations, many pick-up trucks were found to carry goods to nearby markets in Shalimar Bagh and Adarsh Nagar. This might be the reason for averages of pick-up trucks in Okhla and Azadpur to not differ by a large margin.

Three-Wheeler Goods

Three-wheelers goods are responsible for the third highest share of daily freight movement captured in the survey. These vehicles are responsible for 26% of the daily freight movement (in terms of tonne kilometre) from Okhla and 21% of daily freight movement recorded from Azadpur. Majority of the vehicles classified from the survey under this category were models from Bajaj, Mahindra, and Piaggio. Three-wheeler goods surveyed had an average age of 4.3 years.



Trip Characteristics

Figure 19 shows the spatial distribution of the three-wheeler goods from Okhla and Azadpur. Three-wheeler goods from Okhla and Azadpur serve markets in Faridabad, Haryana and Noida, Uttar Pradesh. Three-wheeler goods vehicle from Azadpur also carry agriculture produce to Ghaziabad in Uttar Pradesh. However, unlike mini trucks and pick-up trucks, no three-wheeler goods vehicle from

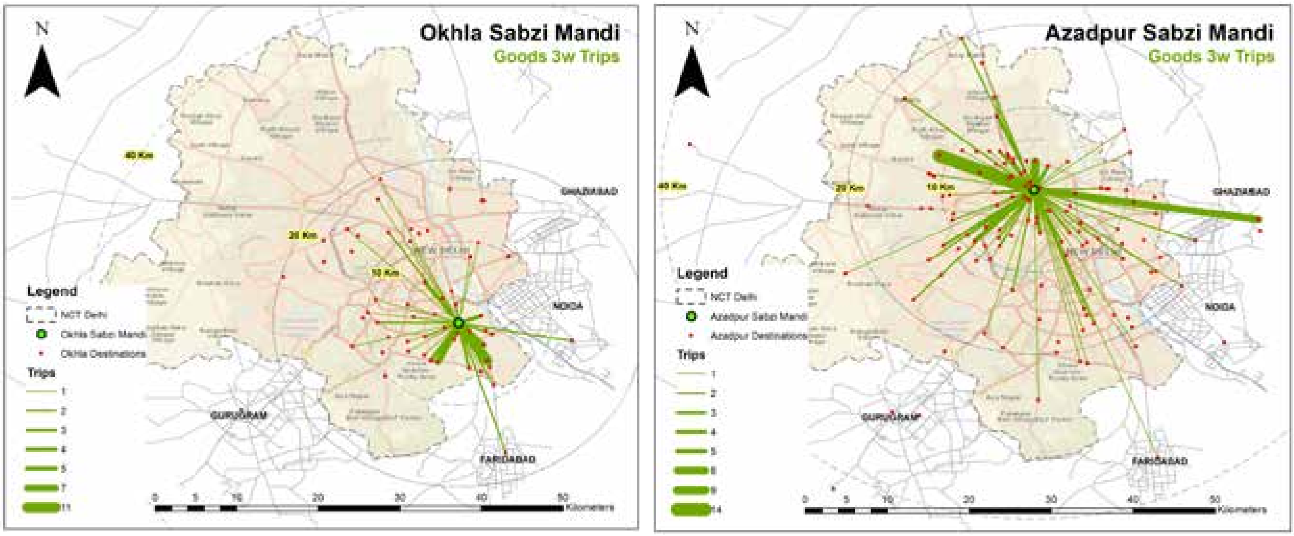


Figure 19 Spatial distribution of three-wheeler goods

Okhla or Azadpur have a destination market in Gurgaon, Haryana. Table 6 shows the top destinations of outbound agriculture freight carried by three-wheeler goods from Okhla and Azadpur.

Like mini trucks and pick-up trucks, Badarpur is the top destination for outbound three-wheeler goods vehicles from Okhla. Three-wheeler goods vehicles from Okhla also share Sarita Vihar and Govindpuri as the top destinations along with mini trucks. Surprisingly, for three-wheeler goods outbound from Azadpur the closest markets, such as Jangir Puri, Adarsh Nagar, Shalimar Bagh are not the top destinations. Other than Rohini, all the other top destinations for three-wheeler goods from Azadpur are different from those of mini trucks and pick-up trucks.

Table 6 Top destination of outbound traffic of three-wheelers goods

Okhla APMC		Azadpur APMC	
Top Destination Markets	**Distance from APMC**	**Top Destination Markets**	**Distance from APMC**
Badarpur	8.1 km	Rohini	11.5 km
Sarita Vihar	5.9 km	Samaypur	5 km
Sangam Vihar	11.2 km	Rajouri Garden	13.2 km
Nehru Place	2.9 km	Kirti Nagar	11.6 km
Govindpuri	3.8 km	Karol Bagh	11.1 km

Nearby destinations, Nehru Place and Govidpuri, receive a large share of outbound fruits and vegetables from Okhla. Similarly, the second-best destination for three-wheeler goods from Azadpur is just 5 km away.

Overall Vehicle Usage

The distribution of the payload does not show any significant difference for three-wheeler goods between Okhla and Azadpur. However, the stated payload is distributed over a wide range from 100 kg to almost 1.7 tonne (outlier).

Table 7 Average payload and daily total distance of three-wheeler goods

Goods three-wheeler	Okhla	Azadpur	Overall
Payload	475.6 kg	507 kg	497 kg
Daily total distance	53.1 km	54.5 km	54.1 km

The average values in Table 7 confirm the observed trend of higher loading in Azadpur than Okhla. The average

total distance covered by three-wheeler goods in Okhla and Azadpur do not differ much. Amongst the three types of vehicles studied in depth here, three-wheeler goods have the lowest average payload.

In this section, agricultural freight was explored to understand the potential of electrification of the vehicles involved in the same. Three-wheeler goods carry the lowest payload and mini trucks (four-wheelers) have the smallest daily utilization. The total distance covered by the three types of vehicles is well within the capability of electric vehicles in the market.

Awareness and Preference for Electric Vehicles

In order to gauge drivers' knowledge about electric vehicles, they were asked if they have any idea about the presence of electric goods carriers or battery-operated goods carriers. The outcomes reveal that only 1.4% of the 635 drivers knew about the existence of such vehicles.

Drivers were also asked if they would be willing to shift to electric vehicles irrespective of their knowledge about the same. Around 2.4% of the drivers said yes and showed willingness to shift to electric vehicles. However, it is interesting to note that a higher proportion of the drivers who are willing to shift are those who do not know about the technology yet, that is, 1.6% of the people who said they are willing to shift are from the pool of drivers who had not heard about electric vehicles and only 0.8% of the drivers had an affirmative response to both the questions.

Majority of the drivers (97%) did not have information about electric vehicles and were not even willing to shift to electric.

Parking Characteristics

Parking Location While Loading

- Of the vehicles in Okhla 55%are parked outside the mandi for loading. The goods are carried by manual labourers from the vendor inside the *mandi* to the vehicle parked outside the mandi. This is because the *mandi* is small in area and becomes congested due to the large HDVs carrying inbound freight. As a result vehicles are parked along the road which is outside the APMCs area. Establishing a charging infrastructure in the same location would require participation of other stakeholders concerned with the location.
- All vehicles in Azadpur are parked inside the APMC premises while loading the vehicle. Based on the traffic management inside the mandi, appropriate charging solutions may be planned to promote electric vehicles.

Parking Location When Idle

- Drivers were asked where the vehicle is parked when it is idle between the trips. They were given options to choose from: whether it was within the *mandi* premises, at a private paid parking space, or roadside. All the drivers from Azadpur stated that their vehicles are parked within the *mandi* premises when idle. However, there was a diverse response from the drivers loading goods from Okhla. Figure 20 shows that while 47% of the vehicles are parked in and around the mandi premises, 43% are parked in private spaces, and 10% are parked on the roadside.

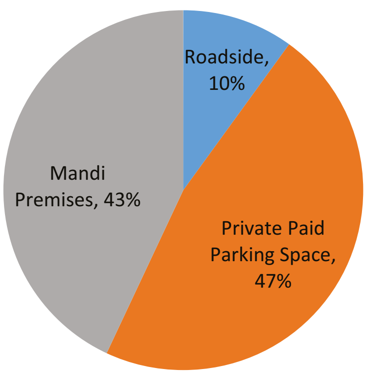


Figure 20 Parking location when idle (Okhla APMC)

- Better understanding of the vehicles parked within the mandi premises must be gained to devise appropriate charging solutions to promote electric vehicles.

Idle Time During Loading

Drivers were asked regarding the time the vehicle was idle while it was being loaded.

- On average, an SCV in Okhla spends 56 min parked at a location while it being loaded.
- Similarly, an SCV in Azadpur spends 1 h and 20 min parked at a location while it is being loaded.

Idle Time End of Day

Drivers were asked how much time the vehicle was idle and parked at end of day.

- On average, drivers from Okhla stated that their vehicles are idle at the end of day for about 4 h and 10 min.

- Similarly, drivers from Azadpur stated 4 h and 50 min as idle time at the end of day.

Total Cost of Ownership– Agriculture Freight

In order to understand the economic potential of electrification of existing vehicles, a total cost of ownership analysis was carried out. The specific method used, cost components considered, vehicle specifications, and assumptions are available in the later chapter on TCO and the appendix. Costs and use characteristics related to agricultural freight operation of the vehicle were taken from the survey as stated in the sections above. Some Delhi-specific inputs are presented in Table 8. In addition to the general subsidies available from FAME scheme, the Delhi government provides some additional incentives for electric vehicles as part of the Delhi Electric Vehicle Policy 2020,[1] which are included in the analysis.

Table 8 Input parameters for TCO analysis: Delhi unorganized freight use case

Parameter	Input	Source
Daily utilization	46 km	Survey
Average payload	904 kg	Survey
Fuel efficiency of CNG vehicles	12.61 km/kg	Survey
CNG price	43.65	Average of the last year
Electricity tariff	Rs 7/kWh	Based on average tariffs for general consumers
Permit fees	Rs 2000 every 5 years	Based on Delhi transport department tariffs
Registration charges	Rs 600	Based on Delhi transport department tariffs
Maintenance costs for electric vehicles	Assumed 50% of maintenance cost for ICE vehicles obtained from survey	Conservative estimate, most literature suggests the maintenance costs for electric vehicles are one-third of cost of ICE vehicles.

Source: TERI

Analysis of Four-wheeler Operation

The analysis was carried out separately for four-wheelers and three-wheelers. For four-wheelers, the specifications of the vehicles considered are provided in the appendix. Table 9 shows the TCO per km, the estimated costs at net present value worked out in favour of the CNG four-wheeler over the lifetime of the vehicle. Both the capital expenditure and the operating expenditure are higher for the new electric vehicle as well as the retrofitted vehicle. The overall TCO for the new electric vehicle and the retrofitted vehicle were higher by 57% and 36%, respectively. The main driving force behind this is the low cost of CNG as well as the high fuel efficiency of CNG vehicles. The fuel costs for the CNG vehicle is only about 50% higher than the electricity costs, which is much less than the diesel vehicle. The purchase price of the electric vehicles is also much higher, contributing to the unfavourable TCO outcome (see Figure 21).

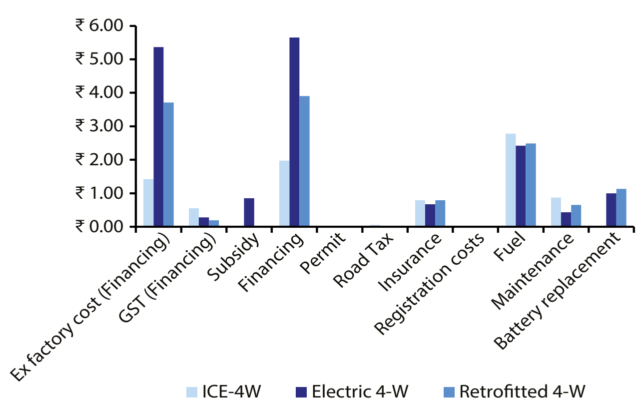


Figure 21 Break up of TCO for four-wheelers according to type of expenditure: Delhi unorganized freight use case

Source: TERI

[1] Details available at https://transport.delhi.gov.in/sites/default/files/All-PDF/Electric%20Policy%202018.pdf

Table 9 TCO (Rs/km) comparison for four wheelers: Delhi unorganized freight use case (net present value)

Cost	CNG- four-wheeler	Electric four-wheeler	Retrofitted four-wheeler
Financing	Rs 1.98	Rs 5.65	Rs 3.90
Permit	Rs 0.01	Rs 0.00	Rs 0
Road tax	Rs 0.05	Rs 0.00	Rs 0.00
Insurance	Rs 0.79	Rs 0.67	Rs 0.79
Registration costs	Rs 0.01	Rs 0	Rs 0.00
Fuel	Rs 2.78	Rs 2.42	Rs 2.49
Maintenance	Rs 0.87	Rs 0.44	Rs 0.65
Battery replacement	0	Rs 1.00	Rs 1.13
Total capital expenditure	**Rs 1.98**	**Rs 5.65**	**Rs 3.90**
Total operating expenditure	**Rs 4.51**	**Rs 4.52**	**Rs 5.06**
Total TCO (per km)	**Rs 6.49**	**Rs 10.17**	**Rs 8.96**

Source: TERI

Analysis of Three-wheeler Operation

Two types of electric three-wheelers are compared to the existing CNG vehicles. This is because, during the market review, it was found that the available three-wheelers come with a number of different specifications related to payload, range, and speed. The specific characteristics of the vehicles considered in this analysis are provided in the appendix. The trade-off for the three-wheelers is between capacity versus better range and payload. The low-range three-wheeler has a slightly lower payload and range but a much lower top speed compared to the high range vehicle. This is compensated by a lower price due to smaller battery size; the question is whether the fuel costs saved can compensate for the higher price.

Both the electric three-wheelers considered have a lower estimated total cost per km compared to the existing CNG vehicles. The capital costs are higher in the case of the three-wheelers; however, the difference is not as large that for four-wheelers. However, the TCO per km of the high battery capacity three-wheeler is 17% higher than the other electric three-wheelers despite the fuel costs being lower (see Table 10), suggesting that the capital costs are not made up over the lifetime of the vehicle. However, it must be noted that the performance of these two vehicles is not directly comparable as the high battery-capacity three-wheelers also offer higher speed and might perform better on the road.

Table 10 TCO (Rs/km) comparison for three wheelers: Delhi unorganized freight use case (net present value)

Cost	CNG three-wheelers	Electric three-wheelers (low battery capacity)	Electric three-wheelers (high battery capacity)
Financing	Rs 0.69	Rs 0.95	Rs 1.43
Permit	Rs 0.00	Rs 0.00	Rs 0
Road tax	Rs 0.03	Rs 0.00	Rs 0.00
Insurance	Rs 0.30	Rs 0.25	Rs 0.25
Registration costs	Rs 0.01	Rs 0	Rs 0.00
Fuel	Rs 1.91	Rs 0.59	Rs 0.49
Maintenance	Rs 0.73	Rs 0.37	Rs 0.37
Battery replacement	0	Rs 0.84	Rs 0.95
Total capital expenditure	Rs 0.69	Rs 0.95	Rs 1.43
Total operating expenditure	**Rs 2.98**	**Rs 2.05**	**Rs 2.07**
Total TCO (per km)	**Rs 3.67**	**Rs 3.00**	**Rs 3.49**

Source: TERI

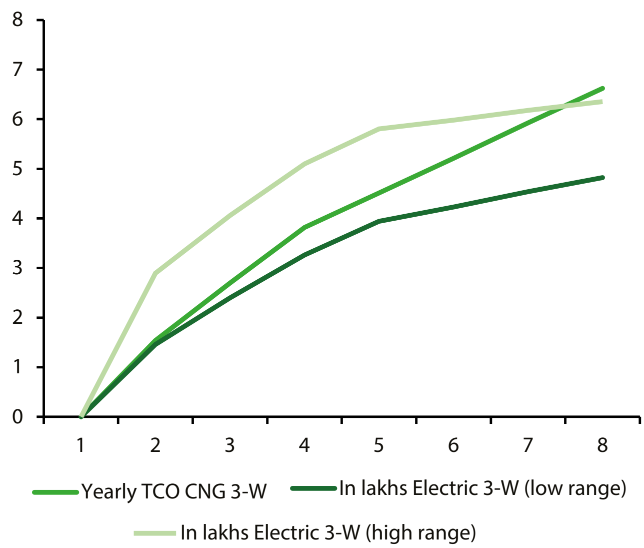


Figure 22 Estimated cumulative lifetime expenditure for ICE three-wheelers versus electric three-wheelers: Delhi unorganized freight use case
Source: TERI

For the electric three-wheelers with low battery capacity, the cumulative cost of ownership is lower than the CNG three-wheelers throughout the lifetime of the vehicles, aided by the subsidy which accounts for 25% of the price of the vehicle. Significantly, even in year 4 the cost for the electric three-wheelers remains lower despite the additional expenditure on replacing the battery. For the electric three-wheelers with higher battery capacity, the breakeven point occurs between years 5 and 6 after the battery replacement costs have been accounted for. It must be noted that the replacement of battery at 4 years is a very conservative estimate. In reality most manufacturers and some literature suggest that batteries can last up to eight years before needing replacement.

Policy Inferences and Recommendations

The survey presented in this chapter was conducted to understand the potential of electrification of agriculture freight in Delhi. The results of the survey bring out certain positive inferences and barriers towards electrification of agriculture freight. Based on the same, we lay out some policy recommendations for APMC authorities and Government of Delhi.

Positive Inferences

- **Overall daily distance:** The current range requirements of ICE vehicles deployed in agriculture freight vary from as low as 30 km to as high as 250 km. However, the average daily distance covered by the three primary ICE-based SCVs used for agriculture freight is less than 80 km. This falls within the range of many electric vehicles in the market. Mini trucks (four-wheelers) and three-wheeler goods have the lowest average total distance of 47.6 km and 54.1 km, respectively.
- **Payload:** The average payload of three-wheeler goods vehicles was found to be 497 kg. This falls within the capability of many electric vehicles in the market.
- **Restricted usage:** Of the three primary vehicle segments utilized for agriculture freight (three-wheeler goods, mini trucks, and pick-up trucks), 86% are not utilized for movement of any other type of freight. This suggests higher predictability of freight demand and routes which is crucial for deploying electric vehicles at this stage.
- **Agriculture freight intensive areas:** This survey identified some specific routes/areas where there is large movement of agriculture freight. Two of those are discussed here:
  - **Markets around Azadpur APMC:** It was observed in the survey that a significant portion of outbound SCV traffic from Azadpur was headed to neighbourhood markets in Jahangir Puri, Adarsh Nagar, and Shalimar Bagh. All these locations are less than 2 km from the Azadpur APMC. Deeper understanding of freight flows in these areas can help develop specific e-freight solutions for agriculture freight in this area.
  - **Okhla APMC to Badarpur Market:** Of the outbound SCV-based freight traffic from Okhla APMC, 16%is headed towards Badarpur market, which is little more than 8 km away. Badarpur is the top destination for three-wheeler goods, mini trucks as well as pick-up trucks from Okhla. Both markets are connected to the same National Highway (NH 19) whicht is the shortest route between them. Similar to how e-rickshaws are deployed in fixed routes for passengers in Delhi (often with metro stations as destinations), a pilot deployment of electric vehicles can easily be planned for freight movement between these two markets. The fixed route makes charging solutions for electric vehicles easy to implement.

Barriers to EV Adoption

- **Unorganized fleet:** Eighty seven per cent of the vehicles are owned by individuals and are not part of any organized fleet. The decision of switching to electric vehicles will have to be made by the driver themselves. The individual drivers may not make the decision to switch to a new technology as the same would be a significant investment for them.
- **Electric vehicles visibility:** Vehicle purchase decision by individual drivers is mainly influenced by visibility of the vehicle being used amongst their peers. Even though electric vehicles are visible to the drivers, those are mainly e-rickshaws, which are clearly inferior vehicles in terms of performance in comparison to their current ICE vehicles. So, most drivers will consider electric vehicles only if they see their peers adopting the same, which is not the case as observed in the survey.
- **Overloading:** It was observed of that vehicles were mostly loaded above the OEM prescribed payload of ICE vehicles. The ability of electric vehicles to sustain efficient operations with varied loading is yet to be understood. The same apprehension was expressed by some drivers.
- **Roadside parking:** It was observed in Okhla that vehicles are mainly parked outside the mandi while loading. There is no specific loading location for these vehicles. This ambiguity is a negative inference for planning successful charging solutions.

Policy Recommendations

Understanding vehicle usage and operational characteristics of ICE vehicles used for agriculture freight in Delhi suggests that small commercial vehicles have potential for transition towards electric. There are certain interventions that could be done from the APMC authorities and state government for increasing the adoption of electric vehicles in this sector.

- **Intervention by APMC authorities**
  - » Remove *mandi* entry costs/restrictions for electric vehicles
  - » Remove parking charges inside *mandi* for electric vehicles
  - » Provide specific parking and loading locations for electric vehicles
  - » Provide charging facilities at allocated locations for electric vehicles
  - » Facilitate electric vehicle pilot deployment along with relevant stakeholders
- **Intervention by state government**
  - » ***Demonstration projects:*** Government of Delhi may initiate demonstration projects with the help of private players in the highlighted areas/routes in this study.
    - E-freight ecosystem may be developed around Azadpur
    - EV deployment and charging infrastructure may be planned for a large freight flow on a fixed route between Okhla and Badarpur.
  - » ***Financing:*** Purchase decision of electric vehicles is contingent on formal financing options which are available for the ICE vehicles. Availability of a similar financing system will nudge the early adopters of electric vehicles in this segment. Hence, bringing financial institutions on board and creating easy-financing policy mechanisms will ease the purchase process of electric vehicles.
  - » ***Higher subsidy for individual buyers:*** Current electric vehicle adoption is limited mainly to fleets. Individual buyers take a lot higher risk in purchasing electric vehicles than organized fleets. Individual drivers must buy and use electric vehicles to increase the visibility and adoption of these. Hence, the purchase incentive offered by Delhi electric vehicle policy may be increased for individual buyers of electric vehicles.

4. Urban Freight: Comparative TCO Analysis

The uptake of electric vehicles depends heavily on the cost economics associated with them. Regardless of environmental benefits, if electric vehicles cannot compete cost-wise with ICE vehicles, then uptake will be low. The cost structure associated with electric vehicles is quite different from that of conventional ICE vehicles. Thus the total cost of ownership approach is widely used to compare the economics of these vehicles. The TCO is defined as 'a purchasing tool and philosophy which is aimed at understanding the true cost of buying a particular good or service from a particular supplier' (Ellram, 1995).

The case studies described earlier cover a wide range of urban freight segments. Using the data from these case studies, TCOs were carried out for each use case. The specific TCOs for each individual case are provided in detail in the respective chapters. Here we aim to summarize the results across the case studies and establish an overall picture of the cost economics associated with electric vehicles in use in urban freight operations. Sensitivity analysis is also carried out to better understand which policy actions may lead to improvement in the TCO for electric vehicles. For a detailed description of the methodology applied including cost components considered and assumptions, refer to the appendix.

Vehicle Specifications

Existing ICE vehicles in each use case are compared to electric vehicles available in the market or expected to enter the market soon. Three types of vehicles are considered in the TCO for four-wheelers: existing ICE vehicle, new electric vehicles, and retrofitted electric vehicles. A representative set of specifications for these vehicles was obtained based on stakeholder consultations.

Table 1 Technical specifications for four-wheelers considered in the TCO

Parameter	ICE four-wheelers	New electric four-wheelers	Retrofitted four-wheelers
Purchase price	375,000	11,00,000	675,000
Payload	710	600	700
Stated fuel efficiency/ range*	16 km/l	110 km	110 km
Battery capacity	N/A	14.4 kWh	17.2 kWh

*This is adjusted for each case study based on the intensity of vehicle use obtained from the present ICE vehicles.

For the analysis for three-wheelers, two types of electric three-wheelers are compared to the existing ICE vehicles. During the market review, it was found that the available three-wheelers come with a number of different specifications related to payload, range, and speed. The specific characteristics of the vehicles considered in this analysis are provided in Table 2. The trade-off for the three-wheelers is between higher battery capacity versus better range and payload. The low range three-wheeler has a slightly lower payload and range but a much lower top speed compared to the high range vehicle. This is compensated by a lower price due to smaller battery size; the question is whether the fuel costs saved can compensate for the higher price.

Table 2 Technical specifications for three-wheelers considered in the TCO

Parameter	CNG three-wheelers	Electric three-wheelers (low range)	Electric three-wheelers (high range)
Price	Rs 152,000	Rs 220,000*	Rs 352,185
Payload	710	400	500
Stated fuel Efficiency/range*	16 km/l	55	70
Battery capacity (kWh)	N/A	3.6	4.8
Top Speed		25 km/hr	55 km/hr

*After FAME-II subsidy

Data from Case Studies

The data obtained for each of the case studies from driver surveys and secondary data was applied in the TCO analysis. Some of the key observations are as follows:

- The daily utilization was highest in Bengaluru logistics (71 km) and lowest from Surat for four-wheelers (38 km).
- A wide range of daily payloads are also covered, ranging from 548 kg in Delhi to 2911 kg in the case of four-wheelers in Surat.
- The price of electricity was lowest in Surat at Rs 5.1/kWh and highest in Bengaluru at Rs 7.2/kWh

Table 3 Inputs for the different use cases studied in the TCO

Parameter	Delhi Fruit and Vegetable Distribution		Bengaluru Logistics	Surat SWM	Surat Textiles	
	Four-wheelers	Three-wheelers	Four-wheelers	Four-wheelers	Four-wheelers	Three-wheelers
Average daily utilization	46 km	61 km	71 km	39 km	38.49 km	50.78 km
Average daily payload	1,012 kg	548 kg	702 kg	2478 kg	2911 kg	2133 kg
Average trips in a day	1.12	1.09	1	3.16	1.81	2.27
Annual maintenance costs for ICE vehicles	Rs 35,568	Rs 17,424	Rs 42,816	Rs 70,000	Rs 70,284	Rs 45,012
Fuel efficiency for ICE vehicles	12.61 km/kg	18.39 km/kg	14 km/l	7 km/l	10km/l	11.39 km /l
Fuel price	CNG: Rs 43.65 per kg		Diesel: Rs 66 per litre	Diesel: Rs 68.92 per litre	Diesel: Rs 68.92 per litre	
Electricity price	Rs 7 per unit		Rs 7.8 per unit	Rs 5.1 per unit	Rs 5.1 per unit	
Additional subsidies	50% of FAME-II subsidy for commercial three-wheelers		NA	NA	NA	

Summary of Results

The TCO was calculated assuming a 7-year life of vehicles. This was the lower bound for vehicle lifetime identified from literature and stakeholder consultations. Taking a shorter lifetime provides conservative estimates for the electric vehicle because with time the TCO favours electric vehicles more owing to lower operating costs. To make the analysis more representative, all vehicles were assumed to be purchased through a vehicle loan, with 80% of the value being paid through EMIs over 36 months. The cost associated with electric vehicles is adjusted to reflect government incentives such as FAME-II subsidy and discounts on insurance premiums.

Four-wheelers TCO Analysis

Figure 1 shows the comparative TCO per km across the use cases for four-wheelers at net present value:

- The capital expenditure per km at net present value is higher for the electric vehicle and retrofitted vehicles compared to the ICE vehicles across use cases. On average, the capital expenditure on new electric vehicles and retrofitted vehicles is higher by 313% and 99%, respectively compared to ICE vehicles. The highest capital expenditure per km was highest in the Surat solid waste use case due to the low daily distances travelled by these vehicles.
- The high capital expenditure on electric vehicles is compensated to an extent by lower operating expenditure per km across all use cases, except for Delhi where the comparison is with CNG vehicles. For the Delhi use case, the operating expenditure was almost identical between ICE and electric vehicles. Across the other use cases, the operating cost savings ranged from 26% for Surat textiles to 55% for Bengaluru logistics. The major part of the savings was due to significantly lower fuel costs for electric vehicles when compared to diesel vehicles.
- Overall, in the case of Surat solid waste and Bengaluru organized logistics, the TCO per km at present value for new electric vehicles was lower than ICE vehicles by 6% and 2%, respectively. For Surat the low fuel efficiency of the existing vehicles is a driving factor, whereas for Bengaluru the high daily utilization is a major factor.
- For retrofitted vehicles, the TCO per km at present value is lower in all use cases except for Delhi where the comparison is with CNG vehicles. The TCO per km was lower by 9%, 3% and 2% for Surat solid waste, Surat textiles, and Bengaluru logistics, respectively. The lower capital expenditure on retrofitted vehicles was the main reason for a more favourable TCO compared to ICE vehicles.

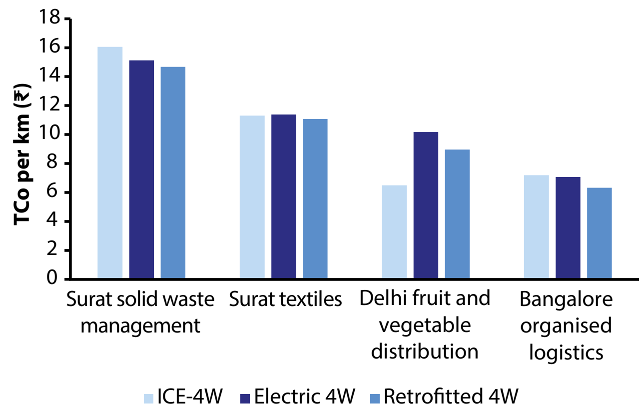


Figure 1 Comparative TCO per km (net present value) for four-wheelers across use cases

Three-Wheeler TCO Analysis

Figure 2 shows the comparative TCO per km across the use cases for three-wheelers at net present value:

- The capital expenditure on electric three-wheelers is higher than the existing ICE vehicles, but not as high as that for four-wheelers. The capital expenditure at net present value on low battery capacity electric vehicle was higher by 53% and 37% for Delhi and Surat textiles, respectively. Whereas for the electric vehicle with high battery capacity, the capital expenditure was higher by 226% and 207%, respectively.
- The operating expenditure per km was much lower for both electric vehicles, mainly driven by the significant savings in fuel costs. For the low battery capacity vehicles, savings on operating expenditure at net present value was estimated to be 50% and 32% for Surat textiles and Delhi, respectively. For the high battery capacity vehicle, it was even higher at 55% and 33%, respectively.
- Overall, the TCO at net present value was lower for both electric three-wheeler across both use cases, suggesting significant financial benefits from a

switch to electric vehicles in this segment. For lower battery capacity three-wheeler, the overall TCO at net present value was lower by 43% and 29% for Surat and Delhi use cases, respectively. For the high battery capacity vehicle, it was lower by 42% and 5%, respectively.

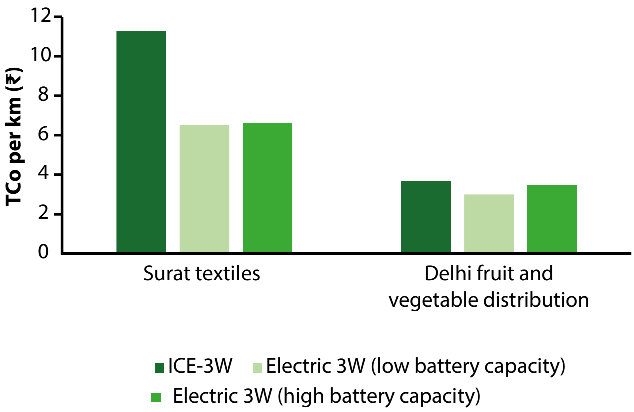


Figure 2 Comparative TCO per km (net present value) for three-wheeler across use cases

Sensitivity Analysis

The TCO for electric vehicles is influenced by a number of factors including prevailing incentives, electricity prices and parameters related to financing. In order to understand the relative importance of different parameters, sensitive analysis on some input. Some of the parameters analyses and their effects are reported here and in Table 4:

- *Range of electric vehicles:* Since electric vehicles are largely untested in freight operations, there some doubt regarding the actually range these electric vehicles can provide with a full payload. Similar to ICE vehicles, it is perceived that with full or overloaded payloads the actual range provided by electric vehicles may be lower than expected. To assess the effect of this on operating costs, a sensitivity analysis was carried out by lowering the range of the electric vehicles by 20% in each use case. On average, this led to an increase in the TCO of electric vehicles by 6.7%, with the highest effect of 10% seen in the case of Surat textiles. In fact, this change increased the TCO per km enough to make the electric vehicle more expensive than the diesel vehicle in this use case. Given that overloading is often common in urban freight operations, the performance of the electric vehicles with full load could have a significant impact on the operating expenditure associated with these vehicles. This is in addition to the charging issues that would come up with uncertain range of the electric vehicle, this issue can be resolved by carrying out pilot studies to assess the performance of the electric vehicles on ground.
- *Subsidy:* The high purchase price of electric vehicles, especially in the four-wheeler space is presently a major hurdle for electric vehicle adoption. With the FAME-II subsidy considered the financing costs for an electric vehicle make up about 50% of the total TCO for electric four-wheelers. The effect of removing the subsidy on the total TCO is found to increase the TCO by around 6% across the case studies on average. This parameter has the largest effect on the TCO after the range related sensitivity analysis. In the case of three-wheeler in Delhi, the effect is the highest (10% increase) due to the existence of additional state subsidies.
- *Electricity price:* A decrease of 20% in the electricity prices translated into a 3.2% reduction in the TCO on average. With states implementing specific charging policies with special rates for public charging and home charging, the rates are expected to go down in the future and could lead to more widespread adoption of electric vehicles.
- *Battery cost:* Battery costs are expected to reduce significantly in the future with technological innovation happening at a very high pace. With a reduction in battery price of 20%, the average decrease in TCO was 1.4%. However, this reduction is only reflected in the battery replacement cost at year 4, with actual reduction in battery prices, the vehicle prices themselves would be lower, especially for four-wheelers, translating into a better TCO in the future.

Summary of TCOs

The TCO analysis demonstrates that the cost economics associated with *electric vehicles* are quite different between the four-wheeler and three-wheeler segment. In the four-wheeler segment, the high cost of financing the vehicle is not significantly offset by the savings in operating expenditure. Only in two of the use cases

Table 4 Sensitivity analysis of TCO parameters

Parameter	Value in sensitivity analysis	Effect on TCO per km for new EV						
		Delhi fruit and vegetable distribution		Bengaluru logistics	Surat SWM	Surat Textiles		Average change
		4W	3W	4W	4W	4W	3W	
Range of electric-wheeler	Decrease by 20%	9.6%	4.0%	4.8%	7.0%	10%*	8.1%	6.7%
Subsidy	No subsidies	9.0%	10.0%	4.7%	4.0%	3.0%	3.1%	5.6%
Electricity price	Decrease by 20%	-4.0%	-3.0%	-3.9%	6.0%	-8.0%	-6.5%	-3.2%
Battery replacement cost	Decrease by 20%	-2.0%	-1.9%	-2.0%	-1.0%	-1.0%	-0.5%	-1.4%

*TCO for electric wheeler became higher than TCO for ICE vehicles in the sensitivity analysis

the TCO at net present value was lower for the electric vehicles. It must be mentioned that although the net present value is lower the cumulative expenditure on the electric wheeler was still higher in the case of Surat SWM, this is feasible as the battery replacement costs are significant but only incurred in year 4. For three-wheeler, the conclusions are much more favourable, with electric vehicles having lower TCO both at net present value and cumulatively. This bodes well as in this segment there are already a number of electric models available in the market, mostly from small manufacturers.

Government initiatives have also gone a long way towards improving the TCO of electric vehicles. Permit and registration fees pay a minimal part in terms of the cost but greatly increase the convenience of reducing paperwork related to electric wheelers. The waiver of road tax could provide some savings in some states where the rates are high. The FAME-II subsidy also plays a major role. Without it the TCO was found to be higher by around 6% across case studies. State-specific subsidies for freight vehicles could help further reduce the TCO, as seen in the case of three-wheelers in Delhi. Reduction in battery costs and increased battery life are likely to further improve TCO by reducing the cost of vehicles as well as running costs related to battery replacements. Certain types of lithium ion batteries also have a longer life and manufacturers are aiming to start incorporating these in their models as prices start falling. This would help extend the life of the battery up to 8 years as compared to 4 years considered in this analysis.

The findings show the electric vehicles are already cost competitive for three-wheeler despite conservative assumptions related to vehicle lifetime considered, maintenance costs, range, and interest rates. For four-wheelers, the high purchase costs present the most significant challenge for widespread uptake.

Thus, based on the above parameters it could be concluded that the potential for electrification is high in the postal services, waste management services, and third-party logistics service providers. The sectors can adopt short-term, medium-term and long-term policies.

5. Stakeholder **Consultations**

TERI undertook a wider consultation process under the study to understand perspectives of key stakeholders across the urban freight sector. The objective of stakeholder consultation was to interact with manufacturers/associations, financiers, operators, and logistics players associated with urban freight sector. This gave us an opportunity to understand their needs, requirements, issues, and the overall perception to recommend and promote the electrification of freight vehicles.

Original Equipment Manufacturer (OEM)

Currently, the market is more conducive for the growth of electric three-wheelers as a high proportion of last mile deliveries exists in the range of 60–70 km. Financially, also it is more feasible to own two electric three-wheelers than one electric four-wheeler.

Views on Electric Vehicle Supply Equipment

- Consultations with several original equipment manufacturer (OEMs) suggest that the emerging and upgraded technology in coming months would definitely bring down electric vehicle prices in comparison to Bharat Stage Internal Combustion Engines (BS-IV ICE) models and a further significant drop will be observed in comparison to the BS-VI model pricing of ICE vehicles.
- Several industry players had developed and integrated a separate platform for their electric vehicle segment. Electric vehicles in this platform include products such as electric power trains and new features integrated with battery management system (BMS).
- Also in order to promote the adoption of electric vehicles in Indian market, many big players are planning to enter the electric four-wheeler segment.
- In the existing scenario where the cost of electric vehicle is going to stay higher than ICE, this would make the e-commerce and logistics segment have the lead in the transition.
- Due to availability of higher number of second-hand vehicles present in the Indian market, there is a huge potential for retro fitment.

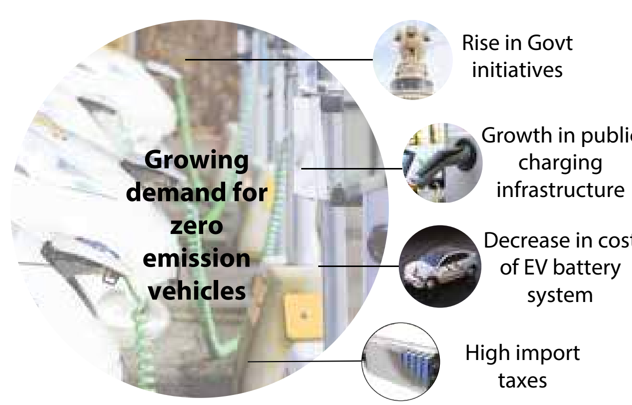


Figure 1 Impacted factor for battery management system in India

Source TERI analysis

Barriers to Electric Vehicle Adoption

- Non-availability of financing for electric vehicles makes it difficult for OEMs to get drivers on board.
- Unavailability of higher capacity power connections, especially for swapping stations, is also one of the hurdles for OEMs interested to work using swapping technology.
- Fast charging is also a significant factor to be considered for mass adoption of electric vehicles. In the case of electric two-wheelers and three-wheelers, the slow charging mechanism would not be feasible enough.

Experience So Far

Cost competitiveness of electric vehicles compared to ICE vehicles is as follows:

- Savings on fuel
- Savings on manpower

Performance of electric vehicles compared to ICE vehicles is as follows:

- Efficient payload capacity
- Good range of speed
- In a realistic world and based on condition on Indian roads, the vehicles can go up to 75 km with a payload of 400 kg

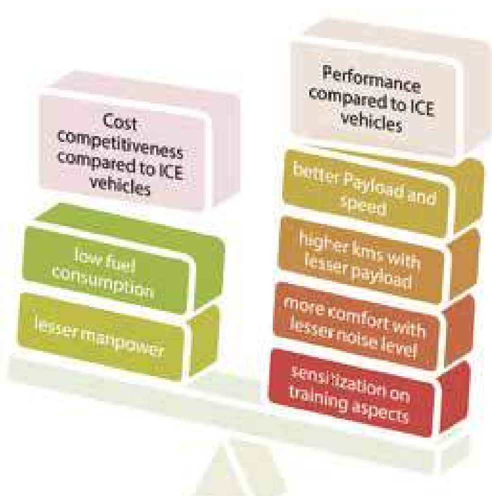


Figure 2 ICE versus electric vehicles

Source TERI analysis

- Higher convenience and comfort level without noise (absence gears and clutch)
- Driver trainings are required for good results
- Uptake of small electric vehicle pilot projects would help to identify the usage and travel pattern of customers. This will further enable OEMs to identify the requirement of routes, charging stations, estimated load factor, and other technical parameters required for electric vehicle implementation.
- In order to understand the real life feasibility of electric vehicles, pilot projects should be undertaken with an optimum fleet of 50–60 vehicles

Way Forward

- It is recommended that the government should step in and provide a loan guarantee mechanism to initiate a momentum among financiers, sellers, and buyers of electric vehicles.
- In the current scenario, many electric vehicle players expect the rate of growth of these to be optimum during the initial years of implementation.
- Big operators and e-commerce companies are looking forward to electrify a larger part of their existing fleet size at pan-India level.
- OEMs opined that the government should also allocate dedicated parking lots in malls and offices for electric vehicles. This would further help in incentivizing the uptake of electric vehicles.
- As part of their expansion plans, many electric vehicle players and companies are planning to launch a huge fleet of electric vehicles soon in the four-wheeler and three-wheeler segments.
- OEMs are also looking forward to developing models on fixed battery architecture for electric vehicles. In order to ease down the financing aspect, players are also looking towards de-associating the battery part from the vehicles.
- E-commerce players are likely to go for mass adoption of electric vehicles for their last mile deliveries and expect the optimum range of vehicles to be approximately 100–150 km.

Financiers

Views on Electric Vehicle Supply Equipment (EVSE)

Financiers consider the commercial vehicle segment to play a crucial role in electric vehicle mass adoption as their economics works well due to high usage.

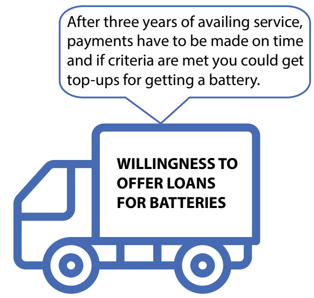
- Eventually bank financiers are also expecting the risk on SCVs to be shared with other stakeholders. A few pilots are also being carried out under this agreement. Presently, there is no specific product (financial model) for electric vehicles, especially the SCVs.
- Several financing entrepreneurs are working on developing innovative and green financing models on aggregated loan and asset management technology to offer a competitive loan, removing barriers for uptake, while de-risking their lending.
- Presently in the three-wheeler segment, financing models are available with focus on loan repayment on a weekly and monthly basis.

Provision of Loans for Three-wheeler Segment

- There are lending models available for both passenger and cargo three-wheeler segment with lesser demand for cargo. Most cargo electric vehicles are being used by large buyers such as government and e-commerce companies but the financiers and institutions generally provide retail loans.
- There are lesser number of financiers who provide loans for retrofitted vehicles.

Rates of Interest for Electric Vehicles and ICE Vehicles

Usually, there are two ways to evaluate loans: i) interest rate and ii) loan to value (LTV) ratio. In the case of electric vehicles, mostly LTV is higher while in the case of ICE, it is low. If the customers are aware of the benefits and are willing to purchase electric vehicles, it is likely that the customer is less of a risk and, hence, financiers would be willing to give loans.



Barriers to Electric Vehicle Adoption

- Resale price for the product is uncertain.
- Due to unstable financial customers and lack of regulatory mechanism, the three-wheeler segment becomes a risk preposition for financial institutions.
- In the current market, non-availability of an integrated model with OEMs, banks, financial institutions, NBFCs etc.
- Due to scattered demand in the segment and lack of data on vehicles in the market (because of the presence of multiple players including dealers, manufacturers, etc.), the banks cannot reach out to their potential customers.

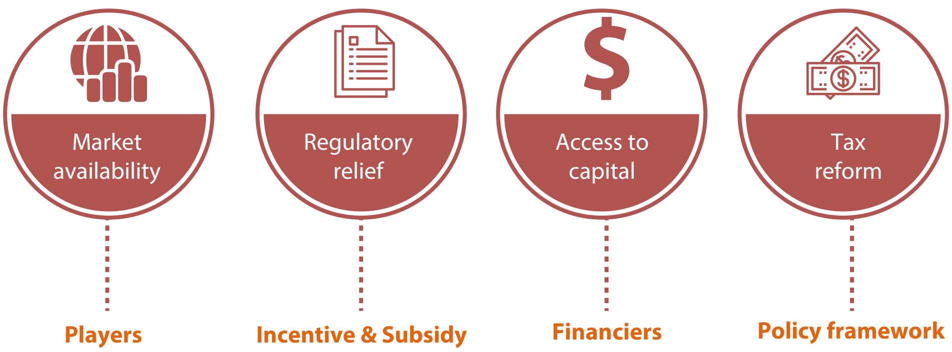
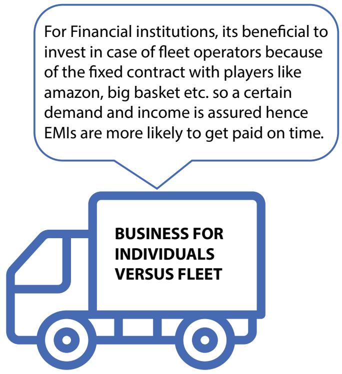


Figure 3 Important factors to promote electric vehicles

Source TERI analysis

Experience So Far



- Financing for passenger versus freight segment is not a similar process. It reflects various kinds of risk and advantages for both financiers and users.
- The passenger segment is at a higher risk than the freight segment. The freight segment is also location and competition specific but is likely to be more profitable. In contrast, the passenger segment is difficult because of the permit system and other underlying regulatory issues.
- The biggest problem for passenger segment is higher EMI defaults because most drivers are daily earners and pay EMIs on monthly basis. In the freight segment, the risks are lower but would be segment specific, for example e-commerce business will be at low risk. Cargo segment is also highly dependent on macro-economic situation.

Way Forward

- There is a need for uniform and dedicated policy framework that can be placed throughout the country. Currently, government officials like Regional Transport Officers (RTOs) are not clear with the norms and processes to register and approve electric vehicles in cities. Hence there is a lack of clarity internally in the city departments.
- Training and awareness among all Govt stake holders should be the primary focus for better alignment with the policies.
- Due to longer process taken for registration of electric vehicles, it is hard for the buyers to start paying their EMIs and many do not want to take on this risk. Even for financiers, the cost of obtaining documents is also higher because of these complications.
- The process for strict quality control of manufacturers entering the market should be applicable due to an increased influx of multiple vehicles in the market. This results in complications and resale becomes a problem.
- Also many bank financiers propose that the subsidy should be linked to the loan component. It also creates incentives for the buyer to use the loan money for other personal expenses. And the loan to value (LTV) of banks will also not get affected.
- There should be an integrated platform or a single window setup for all schemes and policies concerning the sector. Hence enabling better clarity and understanding for purchasers as well.
- Manufacturers, government, banks, research institution and startups should collaborate and this will greatly speed up the uptake for these vehicles at pan-India level.
- Good products should come into the market and manufacturers should tie up with finance institutions and create ecosystem for risk sharing between partners. Currently bigger players like e-commerce companies are willing to switch to electric vehicles as the usage is high.
- Also there is a need to develop feasible and viable loan models and products for fleet operators in order to facilitate them in promoting uptake of electric vehicles in cities.

Logistics Service Providers

Views on Electric Vehicle Supply Equipment (EVSE)

Currently there are limited category and models of electric vehicles available in the freight segment, which can be used by logistics service providers. These include a few models of e-bikes, electric three-wheelers, only two to three models are available in the case of four-wheelers.

- Also the suitability of electric vehicles in the four-wheeler segment for e-commerce (high payload under 700 kg and low volume goods with a vehicle utilization of 120–140 km) would be the best case. However, operational constraints remain high due to lack of infrastructure.

Barriers to Electric Vehicle Adoption

- Unavailability of transporters/drivers (to purchase and operate electric vehicle)
- Lack of political willingness is also one of the significant factors to promote and implement electric vehicles at city and municipal levels.

Figure 4 Impacted parameters of ICEs in e-commerce segment

Source TERI analysis

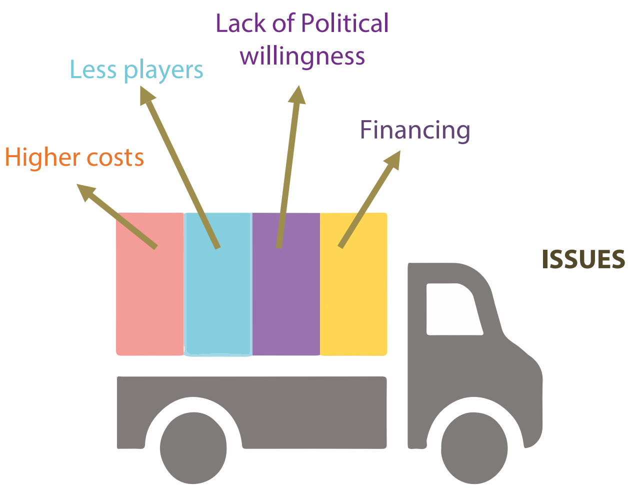


Figure 5 Issues for logistics providers

Source TERI analysis

- Majority of banks are not willing to finance electric vehicles. In a few cases, it is due to a bad experience in case of e-rickshaw. (The issue with e-rickshaw is that they are perceived to not last more than eight months. In fact, the default rate for e-rickshaws is as high as 50%–60%).

Experience So Far

- Small-scale pilots had shown results in terms of huge savings and less expense on vehicles.
- In few cases using electric vehicle had shown good savings on fuel.

Way Forward

- Identification of suitable business models is required for uptake of electric vehicle by logistic players. suitable business models is required for uptake of electric vehicle by logistic players.
- A mechanism needs to be developed to ensure proper training of drivers so that they are willing to own and operate an electric vehicle for logistics service providers.
- There is also a need to work towards a technology upgradation of electric vehicles.
- In order to recover total cost ownership (TCO) and profitability of electric vehicles in the freight segment, one of the significant factors is to achieve an optimum vehicle utilization.

Manufacturing Associations

Views on Electric Vehicle Supply Equipment (EVSE)

Currently, there is limited category of electric vehicles available in Indian market to cater to the freight segment. For the three-wheeler segment, there are two broad categories available in the market: L3 and L5 category. L3 can have a payload of 310 kg, container size not exceeding

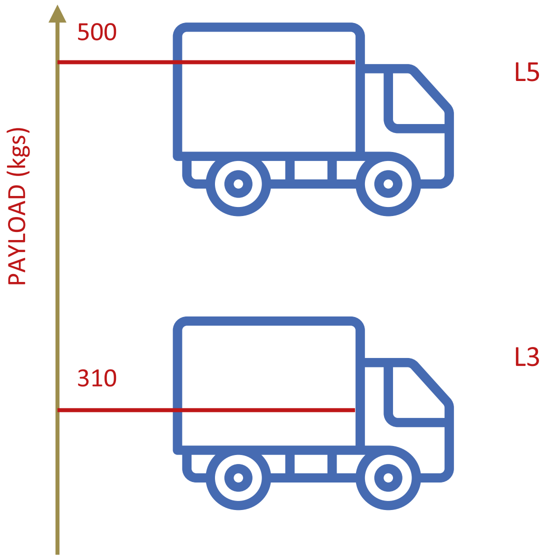


Figure 6: Payload for L3 and L5

Source TERI analysis

2.8 m, width 1 m and overall height not more than 1.8 m. In the case of L5 category, the permissible payload is 500 kg and there is no restriction on container size; hence, it can be used for more purposes. For four-wheelers though the options are limited owing to cost issues.

- With respect to an electric mobility sector, there are technological constraints such as battery swapping where there is a need for battery standardization. Battery standardization will entail costs, and also might lead to monopolization of the market.
- The charging infrastructure needs to be located at an appropriate distance so that the deliveries can be completed and also alternate batteries are available. In the case of longer trips, batteries will have to be swapped mid-trip, which will also require necessary infrastructure.

Barriers to Electric Vehicle Adoption

- Currently, there are no guidelines for standardization of batteries. Also the battery pack sizes are different for all manufacturers.
- Financing is another issue and leasing models should be considered.
- Limited success has been observed in the retrofittment technology

Experience so far

- Existing electric vehicles cost more because of the battery cost and modifications required for freight operations.
- In the case of ICE vehicles, drivers need to spend substantial amount on fuel, but the charging costs (in the case of electric vehicles) are much less. Hence, they can fully charge the batteries at the cost range of Rs 35–50 and with a life of three years.
- At present, various kinds of experimentation are taking place in the case of batteries. Lead acid batteries have been found appropriate for certain functions such as garbage collection where daily utilization is comparatively lower. Owners of electric vehicles also opt for lead acid batteries because the initial cost is low. However, because of (Faster Adoption and Manufacturing of (Hybrid) and Electric Vehicles (FAME) subsidies lithium ion batteries are more popular.

Way Forward

- The policymakers have to take a lead in drafting specific norms pertaining to mass electric vehicle adoption.
- New technologies such as swapping and retro fitment should be streamlined and refined for electric vehicle adoption.

Vehicle Operators

Views on Electric Vehicle Supply Equipment (EVSE)

Currently, many of big operators are aiming to replace nearly 30–50% of their fleet size with electric vehicles in the last mile delivery segment. For instance, Flipkart is expected to replace 40% [1] of its delivery fleet with electric vehicles by March 2020. These vehicles could be e-bikes or e-vans, electric three-wheelers, etc.

- Currently in the e-commerce segment, majority of operators arrange their set up of charging infrastructure at their hubs or depots to ensure seamless operations.
- Usage of electric vehicles in the last mile logistics can help reduce cost of delivery and improve company margins.

Issues on Adopting Electric Vehicles

- Non-availability of charging infrastructure across the city.

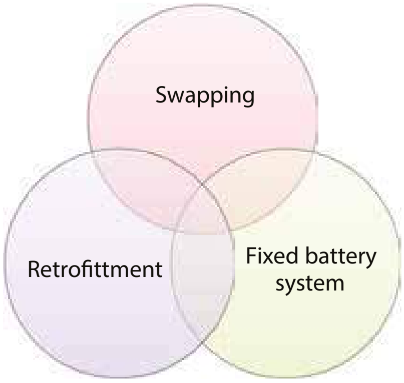


Figure 7 Emerging technologies

Source TERI analysis

[1] Details available at https://stories.flipkart.com/flipkart-ebikes/

Figure 8: EV adoption process

Source TERI analysis

- Non-availability of higher capacity power connections for public charging stations.
- Currently these are available at a few locations and as per the new charging stations' expression of interests, the scenario will improve.
- Figuring out between emerging technologies such as swapping versus fixed battery system.
- Adverse effects on ventures branding and market visibility due to lack of standardization in swapping technology.

Experience so far

- Several players had already conducted multiple small pilots for electric vehicle deployment in their supply chain and also witnessed impressive performance results.
- They have also noticed good savings in electric deployment and also noticeable reduction in emission levels.

Way Forward

- Operators plans to work closely with various electric vehicle manufacturers to produce vehicles suitable for e-commerce deliveries.
- Mostly operators do not own fleet; hence, they look forward to an integrated model, which could ease down the process of collaboration with other stakeholders of supply chain including transporters and fleet aggregators

6. Policy **Road Map**

The small commercial vehicles (SCVs), which comprise both three-wheelers and four-wheelers with GVW < 3.5 tonne, are an important part of the urban freight system in Indian cities. In this section we will synthesis the results from the assessment of representative urban freight operations in India and put forward short-, medium-, and long-term policy recommendations with the aim to promote electrification of urban freight vehicles.

Comparative Assessment of Policy, Technology, and Financial Parameters

The electrification of the identified sectors depends upon various policies, and technological and financial parameters. These parameters are the push and pull factors determining the pace of adoption of electric vehicles. The policy parameters are used to assess how conducive the present policy scenario is towards electrification of existing vehicles in each case study. For instance, policies, such as Delhi Electric Vehicle Policy, have special provisions for goods electric vehicles could induce individual owners to buy electric vehicles. Similarly, pilot schemes run by both government and private fleet operators such as waste management services and third-party logistics could help in reducing driver anxiety and make them adept in using new technology.

From a technology perspective, while it is important that the performance of electric vehicle is at par with ICE vehicles, access to charging facilities also becomes a crucial parameter which determines the overall vehicle usage. From the case studies, it is seen that postal services, waste management services, and the third-party logistics services have easy access to fixed parking spaces, which paves the way for the creation of fixed charging infrastructure. Additionally, some of these sectors provide fixed route services which make it easier for identifying the infrastructural needs as far as charging infrastructure is considered. The listed technology parameters also highlight the technical performance that electric vehicles will require to have to meet the urban freight demand. Financial parameters aim to assess the potential of aggregators or individual drivers in terms of gaining access to finance. The analysis suggests that government-owned fleet aggregators such as postal services, waste management services could lead the transition by implementing pilot projects as they are owned at a fleet level, have predictable routes, fixed parking areas, have better access to finance, and are replicable and scalable.

Table 1 Parameters for assessing potential of electrification of the sectors

Policy parameters					
Case study	**Fleet ownership**	**Policy**	**EV subsidy**	**Current application of electric vehicles**	**Key policy influencers**
India Post-Bengaluru	Government Owned	Karnataka State EV Policy, FAME subsidy	Applicable as per FAME scheme	No pilot application	Ministry of Communication &Information Technology, Department of Posts, India Post, Contract Agency
Waste management services in Surat	Government Contracted	Gujarat State EV Policy and Smart City Mission Surat, FAME subsidy	Applicable as per FAME Scheme	The city of Coimbatore, and Vijayawada are using Smart waste electric three-wheelers	Municipal Corporations, Private fleet operators
Third-Party Logistics Service Providers (LSP)	Individual Ownership Aggregated	Karnataka State Electric Vehicle policy, individual targets of the e-commerce companies, FAME subsidy	No incentive for the retrofitted vehicles, applicable as per FAME scheme for new e-vehicles	There are LSP in Bengaluru, Hyderabad and Delhi using e-vehicles	Regional transport offices
Fruits and vegetable distribution Delhi	Individually owned	Deliver Electric Delhi, Delhi EV policy, FAME subsidy	Additional subsidy on commercial as per electric vehicle policy	No pilot application	APMC, Local operators
Textile industry vehicles	Individually owned	Gujarat State electric vehicle policy, FAME subsidy	Applicable as per FAME scheme	No pilot application	Trade Unions, Local operators
Technological parameters					
Sectors	**Evidence of overloading**	**Ease of introducing charging infrastructure**	**Trip characteristics-**	**Total daily distance**	**Average daily payload**
Postal services	No	Fixed parking at postal garages. The charging infrastructure can be provided	Fixed route	95 km	600 kg
Waste management services	Yes	Fixed parking	Fixed route	123.24 km	2478 kg

Technological parameters

Sectors	Evidence of overloading	Ease of introducing charging infrastructure	Trip characteristics-	Total daily distance	Average daily payload
Agriculture Freight Vehicles	Yes	Variable – Agriculture freight has roadside parking while loading and unloading	Variable	3 W–56 km 4 W–50.6 km	3 W–548 kg 4 W–904 kg
Textile Industry Vehicles	Yes	Textile freight vehicles unload in corporation-run commercial parking facilities. These locations can have charging spots.		3W-51 KM 4W-78KM	3 W- 945 kg 4 W-1595 kg

Financial parameters

Sectors	Current source of financing	Access to finance	Financer's perception of driver's risk	Replicability and scalability	Cost of acquiring customers for financiers
Postal services	Formal	Access to formal finance	Low	High	Low
Waste management services	Formal	Contractors will provide guarantee for formal finance	Low	High	Medium
Third-Party Logistics Services	Formal and informal	Lease-based model	Low	High	Medium
Agriculture Freight Vehicles	Formal and Informal	Limited, mostly individual owners with low creditworthiness. Many are presently not part of the banking system or are underbanked	High	Low	High, potential loan takers are spatially distant and unconnected would require multiple tie ups with dealers to meet demand
Textile Industry Vehicles					

Table 2 Sector-wise policy recommendations

Type of fleet	Sectors	Short term (1–2 years)	Medium term (3–5 years)	Long term (6 years)
Organized	Postal services	1) Feasibility studies can be conducted at the city level and some replicable models can be derived for scaling up. 2) The key transit hubs with high-frequency railway station, bus stop, and airport cab have charging infrastructure or swappable battery systems	1) Explore the feasibility of electric two-wheelers for the first and last-mile distribution 2) Conversion of short-haul trips to electric 3) The pilot for the feasibility of electric vehicles	1) Conversion of long-haul trip to the electric 2) Setting up of fast-charging infrastructure 3) Scaling up of the pilot and 100% fleet conversion in the India Post
	Waste management services	1) Pilot project that can be scaled up and replicated to other cities 2) Add an incentive to the private operator for adopting electric vehicles in the tendering process	1) Mandatory inclusion of electric vehicles in the solid waste management contract	1) State-wide policy for the usage of electric vehicles in freight operations.
Mixed	Third-Party Logistics Services	1) Providing awareness regarding retro fitment technology to the drivers 2) Incentivizing pilot for electric vehicles with the aggregators 3) Mass training and awareness programmes for the drivers by the aggregators	1) Mass pilots to increase the adoption of EV's 2) Developing easy financing mechanisms both for retrofitted and for purchase of new electric vehicles. 3) Training to use the electric vehicle by the e-commerce companies	100 per cent adoption of electric freight vehicles Mapping of the key logistics hub and providing charging solutions
Unorganized	Agriculture freight vehicles	1) Reducing the entry/exit ticket costs for electric vehicles. Reduce the parking charges for electric vehicles 2) Connecting the drivers with the financial institutions	1)Deploy pilot charging infrastructure and dedicated parking points 2) Facilitate leasing business models of electric vehicles to increase visibility.	1) Provide public charging infrastructure at all fixed loading and unloading locations
	Textile industry vehicles			

Source: TERI

Policy Recommendation

Based on Tables 1 and 2, the following policy road map has been suggested to be adopted in the various periods for electrification for urban freight.

Short-Term Measures (Within 1–2 years)

Policy Interventions

- **Ease in the freight movement and timings:** Within the cities electric freight vehicles could be allowed to move at all times of the day for the initial period or increase the mobility time for e-freight vehicles.
- **Demarcation of zero-emission zones:** The city can identify zones in the commercial areas or the trade areas where electric or zero-emission freight vehicles can be given preference.
- **Urban E-freight studies:** The municipal corporation can initiate electric vehicle feasibility studies in the city-specific identified freight sector.
- **Parking incentive:** The electric urban freight vehicles can have reduced parking fees or no parking fees. They can also have a dedicated parking spot in the city transport hub or other freight centres with the provision of charging.
- **Reduced permit:** The permit cost or the permit requirement can be reduced for the electric freight vehicles by the RTO.
- **Reducing road tax:** The RTO can reduce road tax for the electric freight vehicles so as to minimize the overall cost of ownership of the vehicle.
- **Ease in the registration process:** The registration process should be less cumbersome and should be paced up for the urban freight e-vehicles as this can reduce the time for accessing EMI and finances.
- **Increased awareness among RTO official:** Although policies for registering electric vehicles are in place, the knowledge among RTO officials regarding electric vehicles is low. This leads to increased time and problems with registering vehicles and obtaining documents. Training of RTO officials regarding specific policies and processes related to electric vehicles should be carried out for smoother operations.

Consumer Awareness and Capacity Building

The city can run an awareness drive to encourage the use of electric freight vehicles. It can disseminate regional content to the driver unions or other driver areas about the benefit of adopting electric freight vehicles. Organizing an exhibition or connecting to the vehicle manufacturers are other ways of creating access to electric freight vehicles.

Partnerships

- The city can encourage private–public partnership for plying of electric urban freight vehicles. A preference-based mechanism can be adopted for the selection of operators for city-based urban freight tasks. Different models such as lease based, rental platforms can be encouraged for adoption within the cities for electrification of urban freight segment.
- Online platforms could be developed for these logistics service providers and retailers

Financial interventions

- **Incentive schemes:** The regional transport authorities can give incentives to the drivers for scrapping the old vehicle and investing in the new electric urban freight vehicles. Some regional transport offices have these schemes to passenger three-wheelers which can be extended to the commercial vehicle segment as well. The RTO can be part of the loan guarantee mechanism to aid vehicle finance. The incentive scheme can also be extended to retrofitted technologies.
- **Reduced interest loans:** The financial institutions can facilitate reduced interest for electric freight vehicle. They should also provide loans to retrofitted vehicles to encourage the transition to electric. Retail finance for electric vehicles should be made part of priority sector lending for higher financing availability by banks to electric vehicles.
- **Risk-sharing mechanisms:** One of the key problems identified from financiers was related to the perceived risk associated with individual freight vehicle owner, especially three-wheeler drivers. Loans provided to these segments require lots of monitoring and micro-management. These kinds of loans are best provided by smaller special finance banks or NBFCs. However, in order for nationwide scaling of these loans the government and the bigger banks should enter into co-agreements with the smaller banks so that the risk is shared and also the loans are managed well.

Medium-term Measures (3-5 years)

Policy Interventions

- **State action plans for electrification of urban freight:** The state can encourage the use of electric freight vehicles in the industrial areas and other state freight services. Specific/additional incentives can be provided to the third-party or other private operators in the state electric vehicle policies to encourage deployment of electric vehicles. States should encourage and sensitize the trade associations and *mandi* board for reducing parking and other fees for electric vehicles. Additional support for charging infrastructure should be provided within these areas.

- The states should create a policy/guideline to incentivize all major e-commerce players to convert their last-mile delivery operations to all-electric by 2025, beginning with year-wise targets (20% by 2021, 50% by 2023 and 100% by 2025).
- The state should create a central monitoring system to check congestion, pollution, rider's demand to transport availability etc. and data should be shared with operators for demand management.
- **Mass awareness and capacity building programme:** The states should start sensitizing cities for the adoption of urban freight through pilot programmes in the capital cities which can be later replicated. The government should promote drivers to charge their vehicles during off-peak times at low subsidized rates. Off-peak hours also coincide with the time when some renewable power sources are at their strongest.
- **City plans:** The existing city planning documents such as Master Plans, Mobility Plans, Smart City Plans, etc. should identify and integrate electrification potential of urban freight sectors wherever possible.
- The municipal corporations can give preferences to the contract agencies using electric vehicles for solid waste management and other freight-related public service activities.

Pilot Implementation

- The states should conduct pilot projects for small conversion of small electric freight vehicles which can be further scaled up. The pilot project will also provide a tailor-made solution to access the suitable charging model as well for the pilot.

Financial Interventions

- **Integrated platform:** The states should have an integrated platform which provides one access point to all the schemes and policies. The platform should be integrated with the financial institutions and manufacturers for easy access.
- **Financial credibility framework: The government should** develop a financial credibility framework for the manufacturers and drivers so that there is transparency and awareness regarding the financial loan process.

Long-Term Measures (6 years)

Policy Intervention

- **National-level programme:** Most of the European cities have led a countrywide national programme for electrification of urban freight sector. Similarly, in India, the Ministry of Road Transport and Highways could launch a nationwide programme specific to the urban freight sector. Since the market availability is more in the urban freight small commercial vehicles; therefore, they can become a viable option for implementation.
- **Electric freight procurement schemes for government sectors**: The government can initiate the green procurement schemes for government delivery services such as postal services, banking services, airport freight management, and other services.
- **Integration with other government interventions**: The government can integrate the electrification of the freight sector with its other schemes and programmes such as Swachh Bharat Mission, Smart City Mission, AMRUT among others.
- **National programme for charging infrastructure**: Mass adoption of charging infrastructure within the cities along with clean grid initiatives. This is more of a blanket initiative which would accelerate the adoption of both passenger and commercial vehicles. Under the same capacity building of DISCOM's can be done for EV charger installation training for all licensed electrical contractors.
- **Scrapping policy:** The nationwide scrapping policy programme should be initiated and ensuring its implementation in the cities.
- **Battery Recycling:** The government should also lay mechanisms for recycling of batteries.

Institutional Instruments

- National Committee focusing on urban freight should be encouraged. The committee should focus on enabling electric vehicle manufacturing capabilities within the country for creating a constructive ecosystem for faster adoption of cleanest technology in the freight sector.
- Develop an impact assessment framework for policies and schemes applied to urban/inter-urban freight transport interfaces.

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Annexures

Annexure I Assumptions for Emission Estimations

Assumptions:

	Payload	Daily Utilization
Three-wheelers	500 to 550 kg	49 to 55 km
Four-wheelers	1300 to 1500 kg	51 to 57 km

Source: TERI Survey
Fuel Economy Factors: Taken and Estimated based on the criteria given in report published by UNEP DTU (Malik, Tiwari, & Mohan, 2015).

Annexure II Permit Process

Bengaluru

Table A1: Checklist of documents required for LGV-related permit in Bengaluru

Form requirement	Documents required	Permit approach *	Fitness certificate	Insurance certificate	National permit validity	Vehicle type	Permit						Renewal penalty
							Local permit		National permit		Composite fee		
							Fee payable	Validity period	Fee payable	Validity period	Fee payable	Validity period	
	Permit request application	Local RTO	Valid insurance	Authorized insurer	5 years	Less than 3.5 tonne	Permit not required				NA		NA
Form 36	Registration certificate	Inspection of vehicle	Temporary registration (if any)										
Form 36 (B)	Insurance certificate (original)	Registration of vehicle	Prescribed fee			More than 3.5 tonne	Rs 850	5 years	Rs 2015	5 years	NA	NA	Rs200 up to the date of expiry, Rs 50/ day after expiry of permit
	RC Smart card (original)						Rs1100 (Authorization)	1 year	Rs 500 (Authorization)	1 year			
	PUC certificate												
	Fitness certificate												

Source: RTO, Bengaluru and TERI

Table A2: On-road documentation process for freight vehicles in Bengaluru

	PUC	Road tax
Period	2 years (at the time of registration), after 8 years, every one year	<3.5 tonne,Rs11,100 (Life Time Tax)
Issuance	Pollution checking centre	>3.5 tonne,Rs16,500 (Quarterly Tax)
Fee	Two-wheeler- Rs 50, Three-wheeler- Rs 60, Four-wheeler (Petrol)-Rs-75, Four-wheeler (Diesel)-Rs 125	

Source: RTO, Bengaluru and TERI

Surat

Table 3: Checklist of documents required for LCV related permit in Surat

City	Form requirement	Documents required	Permit approach *	Fitness certificate	Insurance certificate	National permit validity	Vehicle type	Permit						Renewal penalty	PUC		Road tax
								Local permit		National permit		Composite fee					
								Fee payable	Validity period	Fee payable	Validity period	Fee payable	Validity period				
Surat		RC Book & PUC	STA	Form P. Pu. C.A.	Authorized insurer	12 Years ,15 year (Multiaxle)	LGV	Rs 350	5 years	350	5 years	Rs 15000	5 Years	Rs 300/ day	Period	>1 year (After registration)	6% of sales price
		Insurance certificate	Inspection of vehicle	Valid insurance					1 year	Rs 500 (Authorization)	1 year				Issuance	Pollution checking centre	
	Form P. Pu. C.A.	Fitness certificate	Registration of vehicle	Temporary registration (if any)			HGV	Rs 2500	1 Year	Rs 1500	5 Year	Rs 15000	5 Years	Rs 1000/ day			
		Proof of payment of tax	LOI not required for Goods vehicle	Prescribed Fee											Fee	3W- Rs 60, 4W- Rs 80, Diesel- Rs100	

Source: RTO Surat and TERI

Delhi

Table 4: Checklist of documents required for light commercial vehicle related permit in Delhi

City	Form requirement	Documents required	Permit approach *	Fitness certificate	Insurance certificate	National permit validity	Vehicle type	Permit						Renewal penalty	PUC		Road tax
								Local permit		National permit		Composite fee					
								Fee payable	Validity period	Fee payable	Validity period	Fee payable	Validity period				
Delhi	20	Address Proof	STA	20,21,22	Authorized insurer	12 years, 15 year (Multiaxle)	LGV	Rs 2,000	5 years	Rs 2015	5 years	Rs 1215	5 years	Rs 200/ day	Period	>1 year (After registration)	<1 T = Rs 665
	21	Insurance certificate	Inspection of vehicle	Valid insurance				Rs 500 (Authorization)	1 year	Rs 500 (Authorization)	1 year				Issuance	Pollution checking centre	1-2 T = Rs 940
	22	Fitness certificate	Registration of vehicle	Temporary registration (if any)			HGV	Rs 2500	1 year	Rs 2515	5 year	Rs 1615	5 years	Rs 300/ day		Number of Centres: 572(LPG/CNG/ Petrol), 381 (Diesel)	2-4 T = Rs 1430
	34	Letter of Intent (Comm.Pas)	LOI not required for goods vehicle	Prescribed fee											Fee	3W- Rs 60, 4W- Rs 80, Diesel- Rs 100 (Penalty-Rs 1000(1st), Rs 2000 (Subsequent))	

Source: Delhi Transport Department and TERI

Annexure III Questionnaires

Information about the Logistic Service Provider:

1. Name of the logistics service provider:
2. Types of Industries being catered to by the service provider (Can choose multiple):

   a) E-commerce b) Retail c) FMCG d) 3PLe) All of the mentioned

3. Type of Services: a) B-2-B b) B-2-C
4. Type of Fleet: a) Owned b) Contractual
5. Total Fleet Size at: a) National Level: _____b) Bengaluru: _____
6. Composition of Fleet in Bengaluru:

GVW	<3.5 tonne (SCVs)	3.5-7.5 tonne	7.5-15 tonne	15 tonne and above
Number of Vehicles				

7. Average number of vehicles (SCVs) that are in operation on a daily basis:
8. Proportion of trips by these Small Commercial Vehicles (SCVs) that are undertaken within the city boundary:
9. Operational hours of SCVs:
10. Average no. of daily trips by SCVs:
11. Average kilometres run by a SCV in a day:

ICE vehicles driver survey (Bengaluru)

Survey Location: _________ **Survey Date and Time:** __________

I. Driver Survey:

A. Personal Information:

Name:		**Age:**			**Mobile No.:**	
Education Level:	10th Pass	12th Pass		School Drop-out	Graduation	Others
Income Level (Monthly):	Below 10,000	10,000-20,000	20,000-30,000	30,000-40,000	40,000-50,000	Above 50,000

B. General Vehicle Information:

1. Vehicle ownership: a) Personal b) Leased/Rent c) Salaried
2. How was the vehicle purchased? a) Up-front payment b) EMI, c) Rent (amt)
3. If on EMI, please list the:

Down-Payment amount	Total months for EMI	Amount of monthly payment

4. Make and model of the current vehicle:
5. Fuel Type: a) Petrol b)Diesel c) CNG d)Electric
6. Registration number of the vehicle (Click photo also):
7. State of the vehicle: a) New b) Second-hand
8. Age of the vehicle:
9. Number of vehicles owned by the owner:
10. If more than one vehicle then what is the mix of vehicles in each category?

    a) up to 3.5 tonne b) 4-7.5 tonne c) 8-15 tonne d) 16 tonne and above

C. Vehicle Usage and Costs:

1. What is the odometer reading of the vehicle?
2. Is this vehicle in operation for all the 30 days of the month? If not, then how many days is it in operation?
3. Average daily total kilometres:
4. What are your daily operational hours? (ex- 8 am to 6 pm)
5. What is the mileage of the vehicle (km per litre)?
6. What is the frequency of refuelling? (1/2/3 times in a week):
7. On an average what is the cost of refuelling the vehicle at a single time (Rs/per time)?
8. How much do you spend monthly on maintenance of the vehicle?
9. What is the annual insurance cost?
10. What is the renewal period of the insurance?
11. What is the amount of road tax paid?
12. Are there any other costs associated with the operation of the vehicle, if yes, what is the amount?

D. Trip Specific Questions:

1. Total kilometre for a particular trip with LetsTransport in Feb/early march:
2. What is the pick-up point/location:
3. Where is the Drop to (if applicable): a)Distribution Centre b) Customer Door c) Retail Shop
4. Drop off location(s):
5. What types of commodities are being moved?
6. What is the total payload carried?
7. Average time spent in loading the vehicle?
8. Average time spent in unloading the vehicle?
9. Average time for which the vehicle stays idle during business operations?
10. Are there any empty runs, if yes then how many km?
11. Do you have to park your vehicle anywhere for more than 30 min during your operational hours?
12. If yes, where do you park it? a) Road-side b)Designated Parking Space
13. Are there any parking charges that you have to pay for the same?
14. Where do you park your vehicle after the work? a) Road-side b)Designated Parking Space
15. Location of parking after the work:
16. Do you pay any charges for that, if yes then how much?

E. Information about electric vehicle:

1. Are you aware about the electric vehicles? a) Yes b) No
2. Would you be willing to shift to an electric vehicle? a) Yes b) No
3. Do you have information about available subsidies/incentives on using electric vehicle? a) Yes b) No
4. If you know about electric vehicle, what are your concerns for not using it: (Rate on a scale of 1 to 5, with 1 being least concerned and 5 being most concerned)

Lack of Information about available models	Reduced vehicle performance: Range Impact on Payload Speed	Concerns regarding cost	Charging infrastructure	Charging time

Electric vehicles driver survey (Bengaluru)

Survey Location: _________ **Survey Date and Time:** _________

II. Driver Survey:

F. Personal Information:

Name:			Age:		Mobile No.:	
Education Level:	10th Pass	12th Pass		School Drop-out	Graduation	Others
Income Level (Monthly):	Below 10,000	10,000-20,000	20,000-30,000	30,000-40,000	40,000-50,000	Above 50,000

G. General Vehicle Information:

1. Make and model of the current electric vehicle:
2. Registration number of the vehicle (Click photo also):
3. Age of the vehicle:

H. Vehicle Usage and Costs:

1. What is the odometer reading of the vehicle?
2. Is this vehicle in operation for all the 30 days of the month? If not, then how many days is it in operation?
3. Average daily total kilometres:
4. What are your daily operational hours? (ex- 8 am to 6 pm)
5. Is financing of vehicle an issue? a) Yes b)No
6. Do you have to pay any fee at any time of the charging duration? a) Yes b)No
7. If yes, how much?
8. Impact on monthly operational and maintenance cost: a) Increase b) Decrease
9. Are they paying it out of there on pocket
10. By how much?
11. How much are they saving on their total monthly cost?

I. Trip-Specific Questions:

1. Total kilometre for a particular trip in Feb/early March:
2. Pick-up location:

3. Where is the drop to (if applicable): a)Distribution Centre b) Customer Door c) Retail Shop

4. Drop off location(s):

5. What types of commodities are being moved?

6. What is the total payload carried?

7. Average time spent in loading the vehicle?

8. Average time spent in unloading the vehicle?

9. Average time for which the vehicle stays idle during business operations?

10. Are there any empty runs, if yes then how many km?

11. Do you have to park your vehicle anywhere for more than 30 min during your operational hours?

12. If yes, where do you park it? a) Road-side b)Designated Parking Space

13. Are there any parking charges that you have to pay for the same?

14. Where do you park your vehicle after the work? a) Road-side b)Designated Parking Space

15. Location of parking after the work:

16. Do you pay any charges for that, if yes then how much?

J. Information about Charging and Performance:

1. What is the mileage of the vehicle (km per charge)?

2. What is the frequency of charging? (1/2/3 times in a day):

3. Average duration of charging in a day (in hours):

4. In a typical day, what is the charging pattern?

Place	At home	At workplace	At clients location	In between the trip (on way somewhere)
Duration (in Hours)				

5. Do you feel that the vehicle performance has been compromised as compared to IC vehicles? a) Yes b) No

6. If yes, in what context?

7. Speed b) Payload c)Range

8. Are the charging facilities adequately available? a) Yes b)No

9. Do you have concerns about time taken for charging? a) Yes b)No

10. Would you continue using electric vehicle? a) Yes b)No

11. Reason for the above?

Driver Survey Fruits and Vegetables Freight (Delhi)

Respondent Details

Is the vehicle being loaded or Unloaded? YES / NO

If Being Loaded, Proceed

1. Name of the Driver?

2. Address of the Driver?

3. Mobile Number of the Driver?

4. Ownership?

   Personal

   Leased

   Salaried Driver

5. Vehicle Usage?

   Sale of own goods

   Distribution of others goods

6. What is the number of vehicles owned by the owner?

Vehicular Details

Type of Vehicle






7. What is the fuel technology being used?

a. Diesel b. Petrol c. CNG d. Electric

8. Make and Model (e.g. Tata Ace)

9. What is the registration number of the vehicle? (e.g.UP81CT3542)

10. What is the registration number of the vehicle? (Upload Image)

11. Did you buy it as a new vehicle or a second hand vehicle?

a. New Vehicle B. Second-hand Vehicle

12. How old is the vehicle? (e.g. 3 years)

13. What is the odometer reading/total distance travelled by the vehicle? (in km)

14. What is the mileage of the vehicle? (Gas - km/kg, Petrol/Diesel - km/litre)

Costs

15. Vehicle Purchase Cost/ Monthly Rent/ Monthly Salary

16. Maintenance Cost (Monthly)

17. Insurance Cost (Annual)

18. Commercial Vehicle Tax (Annual)

19. Toll and Entry Costs (Daily)

20. Other Vehicle Costs (Monthly)

Driving Characteristics

21. Did the vehicle enter the mandi loaded or empty? a. Loaded b. Empty

22. Where is the vehicle coming from? (Defence Colony Market, South Ex)

23. Are you delivering to a single location or multiple locations?
    1. Single
    2. Multiple

24. Where are the places you are going to deliver? (Rohini Sector-5 Market)

25. What is the distance covered by the vehicle in one trip? (from where you came to market, and then to the place where you will deliver) (in km)

26. How many such trips to the mandi do you make in a day?

27. Is the trip route repeated on a daily basis?

28. How many days do you work in a week?

Overall Vehicle Usage

29. Is the vehicle used for other activities on the same day (other than delivery from mandi)

30. What is the daily distance covered by the vehicle including all other activities?

31. What is the weight you are carrying? (in kg)

32. How often do fill fuel in the vehicle (in days)?

33. How much do you fill the tank each time? (in terms of Rs.)

Electric Vehicle Awareness

34. Are you aware of the electric vehicles used for carrying goods? Yes/No

35. Would you be willing to drive an electric vehicle? Yes/No

Parking Characteristics

36. Are you parked outside the market or inside the market?

37. What is the average time spent in loading in Okhla?

38. What is the average idle time between multiple trips for the vehicle?

39. What is the average idle time at the end of the day?

40. Where is the vehicle parked?
    a. Paid market parking
    b. Private space
    c. Outside paid parking space
    d. Roadside parking

Annexure IV Sampling Method (Delhi Survey)

The study was conducted in the largest APMC; Azadpur and one of the smaller APMCs which is Okhla. The sample size was determined based on the incoming traffic numbers provided from the secondary data available. Cochran's formula was used to arrive at the specific sample size number. The formula uses a degree of variability of 0.5 assuming the maximum variability in a population. The sample size was obtained for a confidence level of 95% and a precision level of ±5%.

Formula for calculating a sample for proportions

$$n_0 = [(Z^2pq) / e^2]$$

where p is the estimated attribute that is present in the population. The formula is corrected for a finite population

$$n = n_0 / (1 + (n_0 -1)/N \quad \text{(Richardson, 1995)}$$

where n is the sample size and N is the population size.

Table 9: Sample size for markets

Market	Day	SCV population/ day	Sample size
Azadpur	Thursday(Normal)	561	228
	Sunday(Low)	333	178
Okhla	Saturday (Peak)	148	107
	Tuesday(Normal)	135	100
	Thursday(Low)	83	68

The days were selected on the basis of inflow traffic. In Azadpur, it was observed that the traffic around the week remained similar with slight variation around the week except Sunday when it was low. Two days were taken to capture a broader range of data within a week, one on a normal day and the other on a low day as seen in table. Secondly, in Okhla the number of vehicles varied per day differed on three different days. There was a peak, a normal and a low day. Accordingly, three days were selected to make meaningful assertions in the future.

Annexure V Primary Stakeholder Interviews (Surat)

To understand the front runner segments of freight transport in Surat, TERI conducted a series of interviews with stakeholders in February. This included stakeholders from the industry, transport service providers, Solid Waste Management (SWM) department, local government and civil society. The stakeholders from the industry included trader unions, textile manufacturers, weavers, processors and private agencies contracted for SWM. The mayor and the municipal commissioner of Surat Municipal Corporation (SMC) were also interviewed. TERI also conducted interviews with the Chief Resilience Officer (CRO) of Surat, transport professors from Sardar Vallabhai National Institute of Technology (SVNIT), and local architects and planners.

Questionnaire for Interviews (Surat)

The following are the discussion points which were used for direct personal interview with the stakeholders in Surat.

Textile and Weavers Association

- Which vehicles do you use?
- Do you own the vehicles or hire/rent them from some tempo association?
- How many vehicles are run on a daily basis?
- What is the volume of goods which is being transported on a daily basis?
- Of the daily volume, how much is of finished goods and how much is the raw material?
- Of that volume how much is transported within the city and outside the city?
- How do you send it – SCVs to railway stations; by HCVs?
- What is the outgoing traffic and incoming traffic in terms of urban freight?
- Incoming volume-outgoing volume- where and how- what are the modes and location?
- What are the hubs and collection/consolidation centres for textile retail and wholesale shops?

Transport Service Providers

- What is the average fleet size?
- How many vehicles in the fleet are <= 3.5 tonne (GVW)?
- How many vehicles within the LCVs are being used for inter-city freight movement and intra-city freight movement? Are all the vehicles less than 3.5?
- What is the average daily distance travelled by one vehicle?
- What are the kinds of fuels use?
- What different types of commodities are being moved within the city?
- What industries do you cater to?
- Which industry is most of your revenue coming from/which industry you most business?
- Where do you park the vehicles?
- Are the vehicles owned by individual owners or are multiple vehicles owned by individuals?
- Are there any electric autos/vehicles used for goods transport or otherwise in Surat?
- What is the fuel mix of the tempos in Surat?
- What is the average run of one tempo in a day?

SWM Agency

- What type of vehicles do you use for collecting waste? (e.g. SCV-LCV-Trucks)
- What is the average distance covered by one vehicle daily?
- How many vehicles run every day?
- Where do they take the waste- how far the collection/disposal centre?
- Do vehicles repeat their trip?
- Is there fixed schedule/route for their movement?
- What is the total fuel consumption by SWM?
- Does the department own all the vehicles?
- Where are the vehicles parked overnight?

Transport Research Team (Academia)

- What type of studies have you conducted for analysing the freight movement in the city?
- Which can be the best stakeholders for this study?
- What is the pattern of freight movement in the city?
- What industries are involved in major consumption of urban freight? (specifically, for vehicles less than 3.5 tonne GVW)
- Has there been any regulation on urban freight?
- What is the e-mobility scenario in Surat?

Learnings from Stakeholder Interviews

The following are some primary information collected through interviews with industry stakeholders, transport service providers, and civil society members in Surat.

Industry Stakeholders

An approximate 3000 tonne of yarn comes into Surat on a daily basis from Silvasa, Hazira and other parts of the country. This incoming yarn goes to the weaving centres which are scattered all over the city mostly in the north-west and eastern zones of the city. Almost 4 crore metre of fabric is made in Surat daily; 1-metre fabric weights around 70 – 80 gm. The fabric (100 m cloth is called one taka) is then sent to the traders in the textile market area which is a 2 km^2 area in the central zone of the city. Depending on how the processing of the taka is to be done, the cloth is forwarded to the processors for dying, printing etc. The processing mills are mostly located in Pandesara, Palsana, Sachin and Kadodara, these centers are all within a 10 km radius from the city. The processing mills also require chemicals and other ancillary material which is transported in the SCVs as well.

After the processing of the cloth is done, they are sent back to the textile markets where they are cut into sarees or suit pieces and packed before being transported to the shops within the city as well as to other states.

As reported by the stakeholders the takas are mostly transported in SCVs with tonnage up to 4 tonne, these tempos travel at the most 100 km in a day between markets and processing houses. The vehicles are mostly used in textile industry only and do not take up any other work apart from that because they get enough revenue from the textile industry itself. They are owned both by individuals and some traders also have their own fleet. Each tempo makes at least three trips in one day. It was also reported by the processors that vehicles are mostly overloaded.

The city has almost 150 textile markets with 80,000 shops and about 300-400 processing mills. Furthermore, the city does not have any particular consolidation centre, the material is collected and cut in the warehouses owned by the textile markets and then sent to shops.

Transport Service Providers

The tempo association head reported that most of the transported material in Surat is the grey (taka) which comes from the weavers. He further told that most of the tempos are owned by the drivers themselves and they park their vehicles at their homes hence charging them would not be a problem. The cost of carrying one taka is usually between Rs 5 to Rs 7 and one tempo usually make three trips in one which adds up to at the most 100 km in a day. The fuel cost incurred by them is approximately Rs 280-Rs 300 daily. Almost 90% of the tempos moving in the city are loaded beyond their capacity so as to reduce extra trips. The freight vehicles mostly found running in the city are TATA Ace, Piaggio Ape, Bolero Pickup Trucks and Atul Shakti autos. In his opinion the electrification of freight vehicles would be most effective if it was done for vehicles running in the local markets since they carry a similar load as that provided by the electric vehicles.

The total number of tempos running the city is approximately 3600 (2100 by weavers, 700 by traders and 800 by processors)

Civil Society

Ar. Sanjay Punjabi, architect of Image and Space designs suggested that charging infrastructure for the electric vehicles could easily be provided under the flyovers in the textile market area. This is also the space where they are parked during day time. Like the other stakeholders he also reported that one vehicle is dedicated to one activity only because it is able to generate enough revenue from that only. The textile market is extremely congested most of the day. The area is also prone to accidents and fatalities due to congestion.

The chief resilience officer of Surat and Transport research team from SVNIT further suggested that while preparing a road map for electrification of freight vehicle an important factor to work on is how to phase out the current vehicles that are being used without causing financial losses to the tempo drivers. There should be a 5- to 10-year plan with the help of which old vehicles can be replaced with new electric vehicles. Furthermore, the entire running pattern of the vehicles and their operating mechanism should be understood by both stated preference surveys and revealed preference surveys post which an alternative model for replacing the existing vehicles should be presented which would highlight both the economic as well as the environmental benefits of this switch. The discussion also highlighted the need to sensitize the tempo and textile associations and create awareness among them; in addition to this the Surat Municipal Corporation should be informed of this initiative and its economic, social and environmental benefits should be clearly told to them so that their help can be taken in proper implementation of the same.

Annexure VI Overall Freight Demand in Surat

Table A10shows a sectoral distribution of industrial units, freight requirement (in tonnage), time of movement of freight and the primary mode of moving the commodities.

Table A10: Freight Demand in Surat

Sector	Number of industrial units	Tonnage (in tonne)	Time of movement	Primary mode
Textile	124981	46477	Day & Night	Road
Diamond	4289	Negligible	Day & Night	Road
Engineering	667	11303	Day	Road
Chemical	369	26249	Night	Road
Petroleum	23	10228	Day & Night	Road
Construction Materials	110	44174	Day & Night	Road
Cement	600	4050	Day & Night	Rail
Food Processing	37	3175	Day & Night	Road
FMCG AND FMCD	NA	6868	Day & Night	Road
Fertiliser	63	Unavailable	Day & Night	Rail
Dairy	35	746	Day & Night	Road
Food Grains	1	2604	Day & Night	Rail
APMC	2	2143	Day & Night	Road

Source: Driver Survey COE-UT, 2017

Over 96% of the industrial units in Surat are accrued to the Textile industry. Although a significant sector by value and number of industrial units, the Diamond sector has a very small freight need in terms of tonnage. In fact, the entire Diamond sector in Surat may have a daily production of about only 14 kg. Except of Engineering-related industries and Chemical industries, all other freight in Surat moves both day and night. However, regardless of the industry, entry of heavy vehicles and goods carriers between 7 am to 1 pm and 5 pm to 11 pm is restricted into SMC territory (TOI, 2016). Additionally, vehicles up to 3 tonne GVW are exempted from the provision of permit. For other goods vehicles, a permit is issued for a period of 5 year throughout the state of Gujrat. More details about the permit process is attached in Annexure-I. The Surat Junction (Railway Station) deals primarily with three commodities: Cement, Food Grains, and Fertilisers. The top sectors in Surat are Textiles, Diamond, Construction materials, Engineering and Chemical (See Table A112).

Table A11: Major industries in Surat

Sector	Number of industrial units	Tonnage	Total vehicle trips	Types of yVehicles used
Textile	124981	46477	5214	SCVs, LCVs, HDVs
Diamond	4289	0.014	NA	Private Cars
Engineering	667	11303	869	LCVs
Chemical	369	26249	1813	SCVs, LCVs
Petroleum	23	10228	937	HDVs
Construction Materials	110	44174	3113	LCVs, HDVs

Source: Driver Survey COE-UT (2017), Surat CMP, Primary Interviews

Primary Interviews

The Diamond sector is not the focus of this study as the sector barely has any freight demand in terms of tonnage and the same is catered by private vehicles of the respective traders. The freight demand of the petroleum-related units is mainly catered by the HDVs. There are relatively very few industrial units for construction materials, and they generate variable freight demand in terms of both tonnage and routes. The engineering and chemical industry in Surat is ancillary to the Textile industry. The machinery for textile production and chemical processing for textile products are handled by these industries.

Annexures VII Inferences from APMC Arrival Data (Delhi)

Insights from Arrival Data

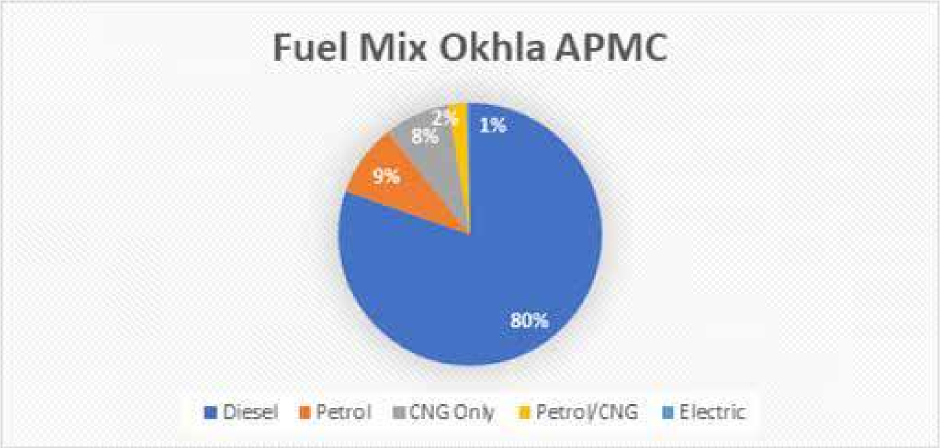
The monthly average of number of vehicles entering the premises of Okhla and Azadpur are mentioned in Table A12.

Table A12: Arrival data of Azadpur and Okhla Markets (September 2019)

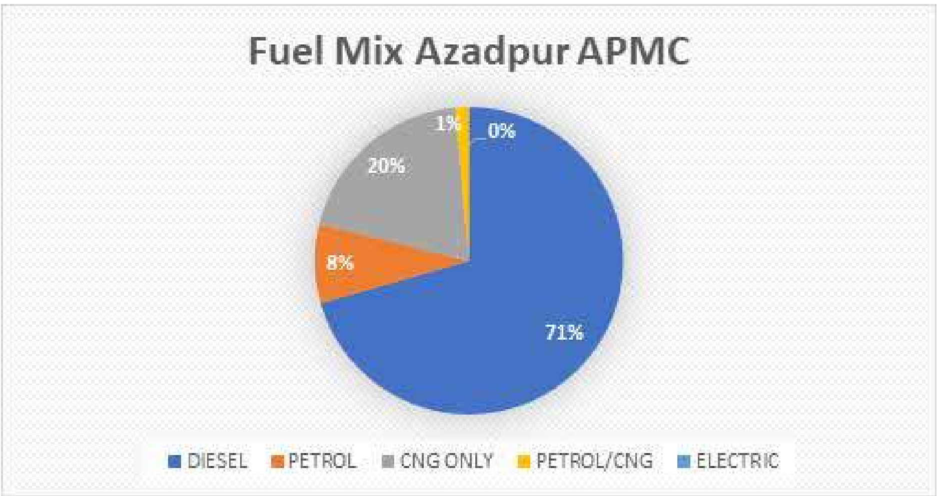
Market	Azadpur	Okhla
Number of empty vehicles	60483	3785
Number of loaded vehicles	48967	7261

Fuel Mix

The share of different fuel types in Okhla and Azadpur on a specific day varies as shown in the graph below.



Fuel mix of arrival vehicles in Okhla

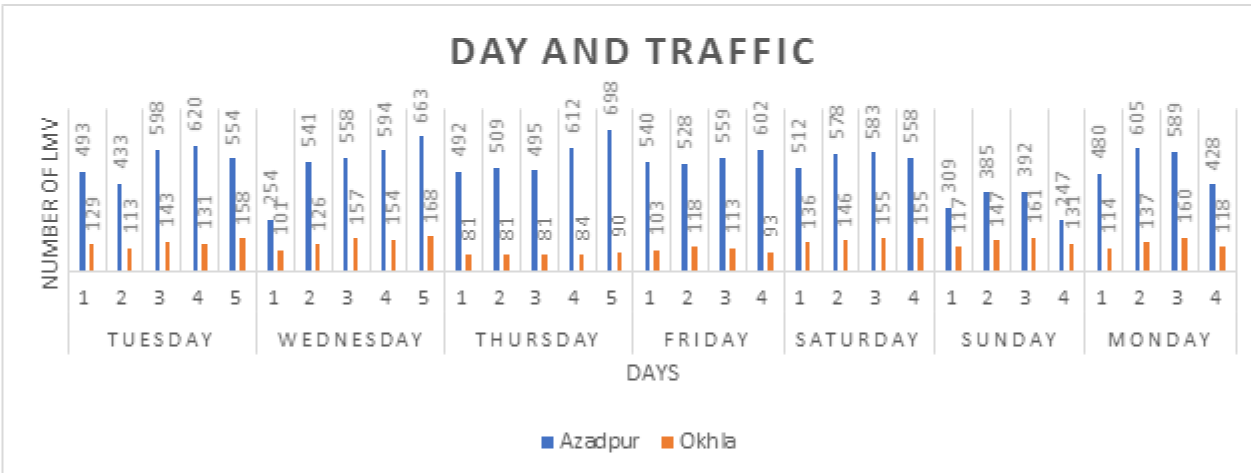


Fuel mix of arrival vehicles in Azadpur

Majority of the vehicles entering APMC are diesel vehicles. However, most of the LMVs entering the selected APMCs are CNG vehicles

Days of Arrival

It was observed that the entry of vehicles was frequent for different days within Okhla and Azadpur. The data below shows the day and traffic for Azadpur and Okhla for all the days over a month.



Variation of LMV along the week in Azadpur and Okhla

Time of the Day

It was observed that the entry of vehicles entering the *mandi* premises was maximum between the time period of 9 pm and 3 am because of the entry restrictions of heavy category vehicles in Delhi. The talks with the APMC officials also gave us an insight into the loading timeline of vehicles from the *mandi* which was between 3 am and 10 am.

Annexure-VIII Methods and Inputs for TCO analysis

The TCO compares the total cost of ownership for an existing ICE vehicle with available electric vehicle alternatives for different use cases. The comparator electric vehicle models were selected based on stakeholder consultations with manufacturers and from the market review presented earlier. The total cost of ownership is calculated per km travelled by the vehicles. Each case study was selected as a use case and the TCO was estimated based on the specific characteristics of the region incorporating prevailing electric vehicle policies.

Net Present Value (NPV)

The TCO aims to summarize a stream of costs; some costs are one time while others recur over time. In order to make all these costs comparable, the present value of each cost stream is calculated. This is necessary as costs accruing in the future have less of an impact on persons' decision than more immediate costs. The NPV of each stream is calculated using the following formula:

$$NPV = \frac{(Cash\ Flow)}{(1+i)^t}$$

where,

i = discount rate

t = number of time periods

The estimated present value is divided by the total number of vehicle km during the vehicle lifetime to compute a cost per kilometre. A discount rate of 5.81% is applied, which represents the present return on 10-year government bond, assumed to be the 'risk' free rate of return in India.

Costs Components Considered

Based on a literature review of previous TCO studies for electric vehicles as well as stakeholder inputs the following cost components were considered, these components do not account for all costs incurred but tries to account for the most relevant when considering electric vehicles.

Purchase Price of the Vehicle: This was estimated based on the available secondary information and through consultations with manufacturers. To make the analysis more representative, all vehicles were assumed to be purchased through a vehicle loan, with 80% of the value being paid through EMIs over 36 months. The costs associated with EVs are adjusted to reflect government incentives such as FAME-II subsidy and discounts on insurance premiums.

Permits, Registration and Road Tax: Each state has separate criteria for obtaining the documentation required to bring a vehicle on road, guided by some overarching principles provided by the Central Government. For each case study, the specific criteria for the state and data from the driver surveys were taken into consideration while computing these costs.

Insurance: In India third party insurance is necessary for vehicles before they can be on road, cost insurance is calculated based on the premium caps set by IRDAI for commercial vehicles and specific survey data for each use case. A 15% insurance discount is included for electric vehicles as per the recent recommendations by IRDAI.1

Maintenance: Maintenance costs include the cost of keeping the different components in working order and protecting from wear and tear to keep vehicles operational, it also includes the costs of cleaning the vehicle. Maintenance costs for existing ICE vehicles for each of the case studies were obtained from structured interviews with drivers and operators.

The cost for EVs is lower as there are fewer working parts and no engine, some estimates suggest the maintenance cost for EVs is as low as one third of the costs associated with ICE vehicles. In our analysis, we assume the maintenance cost of EVs is half that of ICE vehicles in order to keep our estimates conservative.

Fuel/electricity expenditure: Fuel and electricity expenditure is calculated based on the efficiency of the vehicle,

$$\frac{\textit{Tonne km achieved by electric vehicle on a full charge}}{\textit{Battery capacity of the electric vehicle}}$$

utilization, and fuel/electricity price in the particular area being studied. To calculate the electricity costs for electric vehicles the following steps were followed:

- Estimate the load carrying capacity of existing electric vehicles per kWh by applying the following formula:
- Tonnekm for an electric vehicle are estimated based on the payload and range of the electric vehicle on a full charge. The range is adjusted to reflect not just the distance travelled but also the intensity of use obtained from stakeholder surveys.
- Estimate the electricity requirement to carry the required annual tonne km for a particular use case based on the per kWh load carrying capacity of the electric vehicle.
- Estimate expenditure on electricity based on the prevailing tariffs in the respective city considered.

Battery replacement costs: Electric batteries have a limited life and need to be replaced after a certain number of cycles. Most manufacturers in India provide a warranty of up to 3 years on the battery; however, stakeholder consultations suggest that batteries usually need to be replaced during the fourth year of operation for freight vehicles. The battery cost was estimated based on the global average cost of batteries in 2019 ($156 per kWh). The cost of battery is expected to decrease significantly in the next few years. However, since the price of batteries in India is higher than the top global manufacturer presently, it is assumed that the global average price in 2019 will be the price of batteries in India in 2024 when the replacement costs are accrued. This is a conservative estimate as the actual price of batteries in 2024 is likely to be much lower.

Assumptions

The following assumptions were made based on previous published TCO studies and stakeholder inputs:

- Lifespan of each vehicle was assumed to be 7 years based on useful life of vehicle considered in government contracts for freight vehicles and studies on LCVs conducted in India (Malik & Tiwari, n.d).
- Car prices were obtained based on interactions with car manufacturers, for four-wheeler electric vehicles the price represented the expected price when these vehicles are available for purchase. The actual price when it enters the market might differ.
- The electricity tariffs for domestic consumption were applied in the analysis, since initially home charging might be the most relevant option. Commercial rates may be applicable if the charging occurs at certain commercial hubs like in the case of Bengaluru logistics. However, another option would be public charging, for which tariffs may be

1 Details available at https://economictimes.indiatimes.com/wealth/personal-finance-news/irdai-proposes-to-hike-third-party-insurance-premium-for-cars-two-wheelers-for-fy-2020-21/articleshow/74498254.cms?from=mdr#:~:text=Proposed%20two%2Dwheeler%20third%2Dparty%20premium%20rates&text=For%20two%2Dwheelers%20between%20150,323%20for%20fiscal%202020%2D21

lower based on a recent amendment to the Electricity Act,2003 which aims to cap 'per unit cost' of electricity for charging an electric vehicle at a public charging station to 15% of the state's average cost of supply (ACS). Taking the domestic rates also provides a mid-point between these two possible options.

- The maintenance costs for electric vehicles were assumed to be half of the cost associated with ICE vehicles. This is conservative, as literature suggests that the maintenance costs associated with is expected to be one-third that of ICE vehicles.
- Interest on loans for electric vehicle was assumed to be 15% compared to 9% for ICE vehicles. The difference in interest rate represents the higher risks associated with electric vehicles presently, this was obtained based on discussions with stakeholders involved in financing of electric vehicle.

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