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FACTORS INFLUENCING ELECTRIFICATION OF URBAN FREIGHT VEHICLES: A CASE STUDY OF THREE INDIAN CITIES - AHMEDABAD, DELHI, AND SURAT

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ABSTRACT

India's high levels of transport-related air pollution endanger public health. The transition to electric mobility will address this challenge while also reducing the country's dependence on oil imports. The Government of India has offered incentives to electric vehicle manufacturers and purchasers that promote faster adoption of electric vehicles. The states have framed electric vehicle policies offering additional fiscal and non-fiscal incentives supporting this objective, but the adoption rate of electric vehicles in India is far below expectations.

This paper aims to understand the factors that influence the electrification of urban freight vehicles. It does so with reference to urban freight movements linked to textile markets in Ahmedabad and Surat, and the fruit and vegetable market in Delhi.

By studying these, it attempts to assess the impact of key policy and market conditions on the adoption of electric vehicles. Based on stakeholder perceptions, it further tries to identify the enablers and barriers to the electrification of urban freight vehicles.

Keywords: *Electric Freight Vehicle; Urban Freight Vehicle; Case Cities; Total Cost of Ownership; Potential Shift*

1. INTRODUCTION

India has signed the Paris Agreement, committing to reduce the greenhouse gas (GHG) emission intensity of its GDP by 33–35% of its 2005 levels, by 2030 [1]. In 2017, Niti Aayog, a public policy think-tank of the Government of India (GoI), released a roadmap for adopting electric vehicles (EVs) in India.

Key objectives of the policy were to reduce India's oil consumption for transportation needs, reduce its impact on pollution, enable better transportation mode choices, facilitate customer adoption of electric and clean energy vehicles, and encourage technology enhancements for faster adoption, adaptation, research, and development of EVs [2].

The Government of India offers financial incentives under the FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) scheme, of which the primary focus has been the electrification of public transport (buses), taxis, two-wheelers, four-wheelers, passenger three-wheelers, and freight three-wheelers.

Freight vehicles in urban environments produce more emissions than passenger vehicles [3]. Difficulties in loading and unloading and navigating traffic to serve last-mile deliveries often contribute to local air pollution, affect urban air quality, and ultimately impact people's health.

In India, light commercial vehicles (LCVs) accounted for 26.9% of the total registered vehicles in 2017; 16.2% of them were four-wheelers and the remaining 10.7% were three-wheelers [4]. Most urban freight vehicles at the city level run on diesel and are a critical source of GHG emissions [5]. Therefore, it is imperative that these are considered under the electrification strategy.

There are several benefits to switching urban freight vehicles (UFVs) from internal combustion engines (ICEs) to electric power. The benefits, when compared with ICE vehicles, are that electric vehicles result in reduced air emissions, lower noise levels, provide greater driving and riding comfort for drivers and passengers, and incur lower energy and maintenance costs; leading to an overall reduction in operating costs [5].

However, despite these apparent benefits, the adoption of EVs in general and urban freight transport in particular, remains below expectations. Total EV sales in 2021-22 were 276.3 thousand, of which only 971 (0.35%) were freight vehicles and three-wheelers, including passenger vehicles, were 126. 7 thousand (45.87%) [6].

The electrification of freight vehicles will be challenging due to the complex nature of the sector, which is characterised by informal operations, small vehicles, and multiple stakeholders. The public sector has a limited role in the urban freight EV transition decision process, which also constrains the adoption rate.

2. LITERATURE REVIEW

In addition to the environmental benefits of EVs when compared with conventional fuelled vehicles, several other considerations influence the decision of UFV operators to switch to EVs. They may be grouped into technical, economic, market, and policy and regulatory considerations. Additionally, the potential buyer's characteristics also influence the decision. The technical factors include battery size and range, charging time and station access, capacity and energy quality, and reliability; the economic factors include the comparative costs of ownership and operations, and access to finance. The market factors include the availability of electric vehicle models, the availability of spares, and the presence of servicing infrastructure [7] [8]. Analyses of the EV potentials in commercial transport have shown that, in terms of trip patterns and daily mileage, EVs are suitable for urban freight transport and city logistics [9]. However, due to high battery costs, the upfront costs of EVs are 1.5 to 2 times the costs of diesel or CNG vehicles [10].

Due to the high cost of batteries and their weight, manufacturers tend to optimise the size of the battery pack. This has a direct impact on the potential range per charge, vehicle capacity, and energy efficiency. The range is a limiting issue and depends entirely on the city's logistics operations [11]. To overcome the limitation on the range potential, the options explored are opportunity charging or swap. Long charging times limit the operational flexibility of commercial vehicles. The ecosystem to provide for battery swap is yet to evolve. According to a survey, many fleet operators are also resistant to electric freight vehicles (EFVs) unless they can be assured that quick repairs can be made to their vehicles to avoid extended periods of downtime [12]. Failing batteries support, equipment availability issues, long charging times, and the need to adapt charging infrastructure for fleet demands were all identified as technical issues [13].

The average payload of e-commerce delivery may not be a range killer (they usually "space out" before "weighting out"), but several other factors, also applicable to ICE vehicles, will affect range. Factors that affect battery life include payload (including goods/tonnage), road slope, driving style, speed, weather, driving surface, battery state of charge, ambient temperature, and battery degradation over time—which reduces maximum charge capacity [14]. The cost-parity of EVs with diesel, petrol, and CNG vehicles is a necessary condition for wider acceptance. It is widely accepted that EVs have a high purchase price compared to petrol or diesel-fuelled counterparts, primarily driven by R&D costs [15] and the need for additional components such as battery packs. These costs are passed on to consumers [9]. While initial capital costs are higher, the operating costs of electric vehicles are much lower. A comparison of the available models in terms of cost economics is necessary to assess the potential for EV adoption. A Total Cost of Ownership (TCO) model, which includes capital and operating costs of the vehicle over the life of the vehicle, could be used to analyse the cost-parity of electric vis-a-vis conventional vehicles [10]. To bring cost-parity, national and state governments have provided fiscal and non-fiscal incentives. The fiscal incentives include subsidies for the purchase of vehicles and the establishment of public charging infrastructure. Some states have also waived the registration charges for EVs [16].

The market factors in terms of product choices, the existence of critical mass, and the availability of infrastructure should also be assessed while analysing EV adoption scenarios [11]. The limited availability of standard vehicles and vehicle types (particularly for larger vans and trucks) has been noted as a significant barrier to the introduction of EFVs [13]. It is noted that several initiatives, aimed at fostering the use of EVs by public bodies and politicians have proven less successful than expected. Lack of knowledge and information among companies is the most inhibiting factor [9]. The potential buyer characteristics in terms of socio-economic characteristics, their awareness about the market, ownership characteristics, and UFV operating characteristics would also influence the decision to electrify.

3. OBJECTIVES, APPROACH, AND METHODOLOGY

In the light of the above, the primary objective of this paper is to understand the factors that influence the electrification of urban freight vehicles. More specifically, the paper addresses the following questions:

- What are the characteristic features of freight mobility in the three case cities for select commodities? What are the operational requirements of UFVs?
- What is the status of the electric vehicle offering for urban freight transport in India? What types of EFV models are available? How suitable are they for urban freight transport?
- What are the potential shifts to UEFVs under various policy and market conditions?

The paper assesses the urban freight movements in the case cities of Ahmedabad, Delhi, and Surat. It attempts to identify key factors influencing the adoption of EFVs and to assess the impact of key policy and market conditions on such adoption. Of the case cities, Ahmedabad and Surat are located in the state of Gujarat, and Delhi is a city-state. Gujarat and Delhi are front runners in the promotion of EVs in India. The freight movements in cities are anchored on commodity-specific markets or industrial nodes. This paper focuses on textiles in Ahmedabad and Surat, and fruits and vegetable distribution in Delhi as these contribute to significant externalities in respective cities [17] [18] [19]. The markets for primary surveys were identified after studying various commodities, total intra-city trips made to transport the commodity, total tonnes carried, and potential for faster electrification.

The paper is organised into seven sections. In the first, we set the context for the study. A brief literature review on factors influencing UFV transition to electric vehicles is presented in Section 2. The objectives, approach, and methodology of the study are presented in Section 3. Section 4 presents a review of the status and trends in electric vehicle use for urban freight transport in India based on market analysis. Freight mobility characteristics in case cities are assessed based on a primary survey of UFV operators: these are presented in section 5. The suitability of EFV for urban freight transport is assessed based on the available vehicle models vis-a-vis the requirements derived from primary surveys; these are presented in section 6. As a part of this, a comparative assessment of the electric vehicles to conventional fuel freight vehicles is done adopting the TCO approach. Various policy and market scenarios are constructed, and utilising Stated Preference Analysis, the market potential of EFVs is assessed and presented in section 6. Section 7 concludes the paper.

4. URBAN ELECTRIC FREIGHT ECOSYSTEM IN INDIA

An electric mobility ecosystem includes the physical components like EV models, an energy source within the vehicle (i.e. battery), a charging mechanism for the battery, a source of energy to the battery (i.e. electricity from the distribution network with defined mechanisms); and stakeholders. The urban electric freight ecosystem in India has been detailed in this section.

4.1. Urban Electric Freight Vehicle Models

In India, EFVs may be two-wheelers, three-wheelers, or light commercial vehicles (LCVs). Two-wheelers are used for less than 30 kg delivery of lightweight Business to Consumer (B2C) parcels (groceries, food parcels, e-commerce shipments), whereas three-wheelers and LCVs are used for heavyweight B2C parcels (furniture, electric appliances) and B2B supply from manufacturers to retail shops (Fast Moving Consumer Good (FMCG) supply). These vehicles are being targeted because of their price competitiveness with ICE vehicles, ease of setting up charging stations given their use in a hub-and-spoke model, and high utilisation rates as Business to Business (B2B) and B2C supply accounting for 40% of all logistic movements in the country [20].

The paper explores E-three-wheelers and E-LCVs, as they are used on a large scale for deliveries in wholesale markets involving a large number of unorganised transporters. This segment of vehicles has been unexplored for electrification. Currently, available models are in the E-three-wheeler category. Only one model is available in the E-LCV section with a 0.75-tonne capacity catering to the last mile urban freight movement. However, the market is evolving and new models of EFVs are anticipated across all payload categories.

4.2. Batteries

A battery impacts the driving range and charging time of the electric vehicle. Lithium-ion is currently the most widely used battery type. The battery capacity of goods vehicles is marginally (1.5 kWh) higher than that of corresponding passenger vehicles. The battery capacity of an E-three-wheeler is between 4.8–7 kWh, and for an E-LCV with a payload of 0.75–1 tonne, it is about 20 kWh. The battery can be fixed or detachable, with an on-board or off-board charger; these influence the charging mechanism. The battery can also vary based on input voltage; impacting charging time. Table 1 shows a few Indian battery manufacturers and their battery specifications. Different vehicle manufacturers have paired with battery manufacturers to introduce EFVs.

Table 1: Battery manufacturers with battery specifications

Manufacturers | Providers	Chargers	Battery Type	Battery voltage
Gayam Motor Works	Onboard	Detachable	48 V
DOT	Onboard	Detachable	60 V
Lithium Power	Off-board	Detachable	48 V
Technigence	Off-board	Fixed	48 V
Omega Seiki	Offboard	Detachable	48 V

Source: [21]

4.3. Charging Infrastructure

Charging infrastructure varies according to the combination of vehicle and battery specifications used. For in-home charging of EFVs, a 15A socket suffices; public charging stations are subject to standards set by the Ministry of Power, Government of India. Bharat DC 001 can be used to charge E-three-wheelers and Bharat AC-001 can be used for E-LCVs. Swapping stations are currently limited to E-three-wheeler, and no standards have been set, as swapping varies according to battery design and hence the manufacturer.

4.4. Others

The EFV ecosystem components also include owners (transporters or drivers), battery and charging infrastructure manufacturers and providers - Original Equipment Manufacturers (OEMs), and Distribution Companies (DISCOMs), and lastly, the regulatory bodies which are planning and development organisations.

5. FREIGHT MOBILITY IN CASE CITIES

A primary survey was carried out at three identified markets of the case cities—Ahmedabad, Surat, and Delhi—to understand urban freight mobility. The primary survey included a sample size of 100–120 freight three-wheeler and LCV fleet owners per city. The current vehicles and operational characteristics provide inputs to the definition of UEFV requirements. In this section, we describe vehicles, supply chain, operator and operating characteristics.

5.1. Case Cities

Ahmedabad, with over seven million people, is the seventh-largest metropolis in India and the largest in the state of Gujarat. Historically, Ahmedabad has been one of the most important centres of trade and commerce in the western part of India. The city is the second-largest producer of cotton in India and has an economy primarily dependent on textile, pharmaceuticals, and natural gas [17]. The city was also known as the 'Manchester of India' on account of its textile industry. The total number of registered vehicles, in the year 2021, in Ahmedabad was 0.12 million, of which 2,204 (1.83%) were freight three-wheeler vehicles and 2,549 (2.12%) were LCVs. Much of the textile commodity movement is linked to the new cloth market located in the old city of Ahmedabad near the main railway station. Over 300 wholesale agents operate from the market. An estimated 2,727 freight vehicles (1,841 3-wheelers and 886 LCVs) operate through the market.

Surat is India's eighth most populous city and the second most populated city in Gujarat. The city houses a population of 4.5 million and spans an area of 1351 sq. km [22]. Surat is known as the textile hub of India. There are 10 textile industrial zones, 125 thousand textile units, 165 textile markets, 65,000 wholesale agents, and 75,000 textile shops in the city, mainly being concentrated on the inner ring road [18]. The total number of registered vehicles in Surat was 0.13 million in 2021, of which 1,617 (1.24%) were three-wheeler freight vehicles and 1,457 (1.12%) were LCVs. An estimated 4,442 goods vehicles (2,074 3-wheelers and 2,368 LCVs) operate through the market.

Delhi, the National Capital Territory of Delhi (NCT), is spread over an area of 1,484 sq. km and houses a population of 16.78 million [22]. 3.4% of the LCVs and HDVs contribute to 63% of GHG emission levels in the city. Urban freight trips identified within the city are 3.95 lakhs and constitute three percent of the total urban trips. The total number of registered vehicles, in the year 2021, in Delhi was 0.46 million, of which 2,555 (0.56%) were three-wheeler freight vehicles and 13,865 (3.02%) were LCVs. An estimated 16,119 goods vehicles (9,372 3-wheelers and 6,747 LCVs) operate through the market.

5.2. Freight Vehicle Operations in Case cities

The movement of commodities in Ahmedabad is linked to the manufacturing and distribution of textile goods. The textile supply chain is described in five stages. In the first stage, raw material (yarn) from outside the city reaches Ahmedabad's power looms to produce grey (greige) cloth. This cloth is transported to the textile market for further processing in heavy and medium commercial vehicles (HCVs and MCVs). Subsequently, in stages two and three, the cloth from the textile market is dispatched for processing (dying and printing) and the processed fabric is sent back for physical quality checks in LCVs. In stage four, the processed fabric from the textile market is sent to various small-scale retailers for trading or value addition in freight three-wheelers and two-wheelers. In the final stage, after the quality checks in the textile market, the processed and value-added fabric is sent to the warehouse or distribution centre for export in LCVs and freight three-wheelers. At various stages of the supply chain, the fabric is sent back to the textile market for quality checks, which results in significant empty vehicle trips. The supply chain is explained in Figure 1 below.

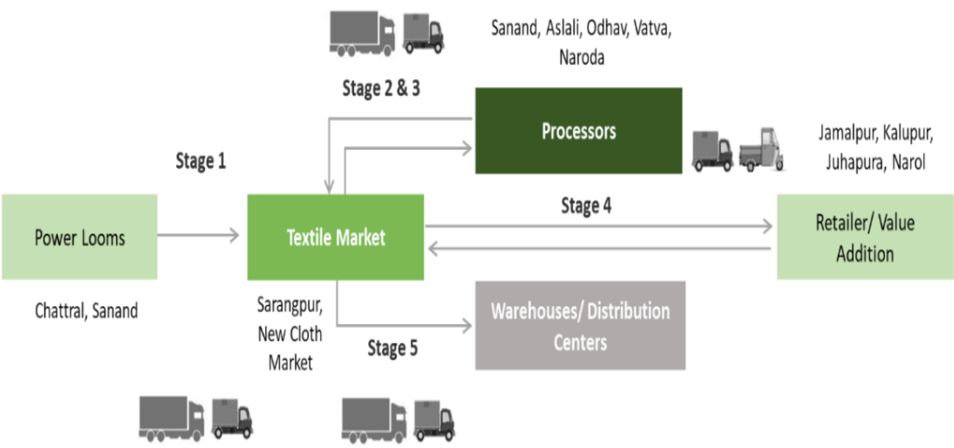

Figure 1: Diagrammatic representation of the stages of textile supply chain in Ahmedabad

The supply chain movement in Surat is similar to Ahmedabad except that the use of freight 3-wheelers and LCVs are predominant in stage one. This may be attributed to the large number of individual operators in Surat.

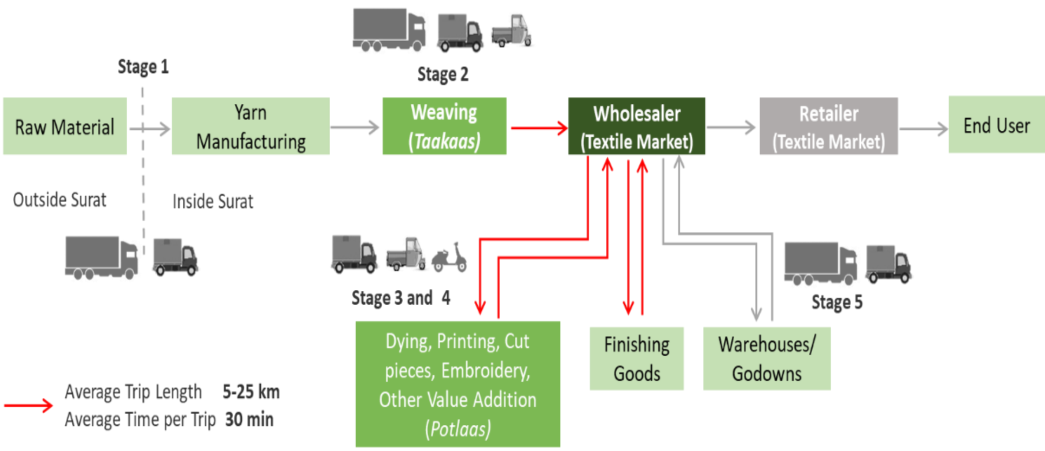

Figure 2: Diagrammatic representation of the stages of textile supply chain in Surat [18]

In the territory of Delhi, there are three Agriculture Produce Market Committee (APMC) *(mandis - consolidation centre)*, namely, APMC Azadpur, Keshopur, and Shahdara. These mandis receive the supply of fruits and vegetables from farmers. This produce is brought in large trucks. In stage 2, the commodity is distributed to several other local mandis located district-wise in LCVs, MCVs, and HCVs, depending on demand. From the local mandis, the produce is picked up by local fruit and vegetable vendors. Depending on the vendor operating capacity, the product is picked up by two to three vendors jointly riding with an LCV or by the vendors' themselves using LCV or freight three-wheeler. Cycle rickshaws and animal carts are also used for distribution purposes. Some vendors even directly purchase from the APMC.

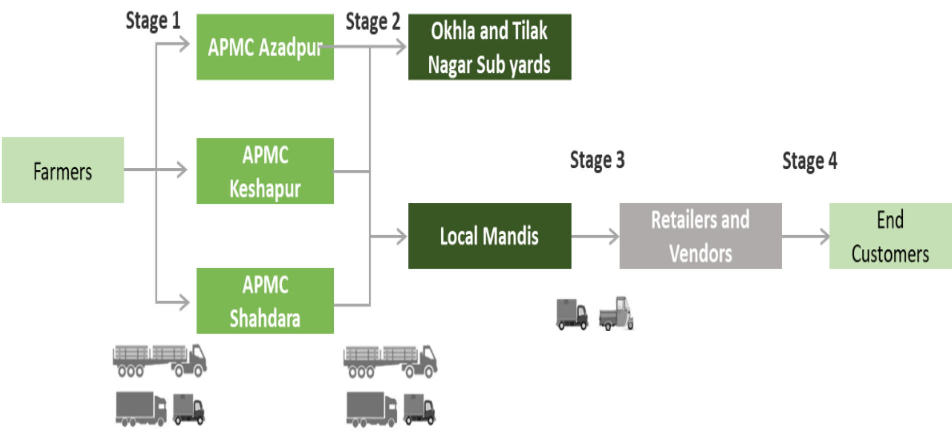

Figure 3: Diagrammatic representation of the stages of the F&V supply chain in Delhi [23]

6. SUITABILITY OF URBAN ELECTRIC FREIGHT VEHICLES

The suitability of the adoption of electric vehicles for urban freight transport is analysed in two parts. The first is in terms of the availability and specifications of the electric vehicles vis-a-vis the requirements, and the second, analysing the comparative economics of operations.

6.1. Requirements of UEFVs

The comparative UFV characteristics are presented in Table 2.

Table 2: EFV and Conventional Freight Vehicle Characteristics

Vehicle Model	Fuel Type	Vehicle purchase cost (in Thousands)	Payload (Kg)	Fuel tank capacity (L/Kg/kWh)	Fuel efficiency (Km per L/Kg/kWh)	Range (Km/Fill)
Freight 3-Wheeler						
Atul Shakti Premium	Diesel	225	575	10	35	350
Atul Shakti Delivery Van	Diesel	200	575	10	36	360
Bajaj RE Maxima	CNG	215	619	5.6	33	185
Piaggio Ape	CNG	224	494	5.1	24	122
Mahindra Champion	CNG	250	665	24	22	528
EV Option	Electric	120-273	310-550	4.3-7.4 CT* (3 to 8 hours)	18	70-130
Light Commercial Vehicle (LCV)						
Mahindra Supro	Diesel	650	1050	33	21.2	700
Tata Ace	CNG	500	640	12	20.1	241
Ashok Leyland Chota Dost	CNG	750	1208	21.6	15	320
EV Option	Electric	775-1081	600-750	14.4-20 CT* (4.5 to 8 hours)	8	112-120

CT* - Charging Time

Source**:** [24] [25]

From the table above, it is evident that the available non-EFV models have significantly higher payload and range. However, the requirements in urban applications require a lower payload and range. The surveys reveal that the urban freight operators own and operate the vehicles themselves. About 60% of vehicles are freight three-wheelers and 40% are LCVs. The case cities of Surat and Delhi have mostly single fleet owners whereas Ahmedabad has an equal mix of single and multiple fleet owners. The average age of the vehicles in the case cities is five to seven years. The operators have on an average expense of 25% of income on fuel, operation and maintenance (O&M), and parking fees, with a daily profit ranging between INR 700-1400. Their daily operations vary significantly by season and the day of the week. They, on average, perform seven to eight trips a day with an average vehicle utilisation of 60-80 km. In some cases, the maximum goes up to 110-130km; matching the range potential of currently available UEFV models.

All the case cities have drivers with multiple deliveries in a day and have 50-80% of the vehicles overloaded. The actual load carried often exceeds the capacity by 40 to 50%. This may still act adversely in deciding to shift to EFVs. There are also apprehensions expressed about the capability of EVs in negotiating flyovers with a full load. Charging infrastructure is an essential part of EV deployment. The available options include charging overnight when the vehicle is parked. The vehicles come with a charger and operators prefer home charging as it is an easier option. It is also to be noted that home charging is subject to domestic electricity rates, which are cheaper than commercial rates.

The operators are from poor economic backgrounds and have limited housing facilities. As they predominantly operate on an own-operate basis, they park on-street near home during the night time and in the markets during daytime. Provision of charging points at the markets is necessary to promote faster adoption of EFVs. In between trips, operators find adequate time for opportunity charging. As trip patterns are pretty well-defined, dependence on opportunity charging may not be an adverse factor for adopting EVs in urban freight transport.

6.2. Total Cost of Ownership

Based on the preliminary survey, it was also found that the higher purchase cost of EFVs may act as a barrier, but the lower O&M costs act as a significant enabler in increasing the willingness of shifting to EFVs. Considering the available vehicle choices in the market and the evolving EV ecosystem, the influencing factors streamlined are the capital and O&M costs, to be analysed adopting the TCO approach.

TCO of any mode of transport is a function of its capital and operational cost over its period of service [26]. TCO analysis also considers cost variation due to factors such as inflation, fluctuating battery cost, residual value or salvage value of the vehicle, and infrastructure after the period of service [27]. Sensitivity analysis for TCO calculations provides insights into the impact of factors such as vehicle usage, subsidies, and lower operational cost on vehicle ownership cost [28].

TCO is compared between ICE and electric vehicles for freight three-wheeler and goods LCV under the same payload capacity. ICE vehicles are considered to have CNG as the fuel type as per the government notification for freight vehicles to be CNG in tier-1 Indian cities; concurrently creating a constructive TCO comparison between the choice probable's.

The following assumptions apply:

- vehicles operate for 310 days for an average of 80 km per day with a design life of 15 years;
- the fuel rate of CNG is ₹ 53/kg and the electricity price is ₹ 4/kWh;
- fuel inflation rates are 3% and 1% per year for CNG and electricity respectively; as per WPI (Wholesale Price Index);
- cost of the workforce is assumed to increase by 3% per year, and the cost of the battery is assumed to be decreasing at 5% per year considering the trends from 2010 to 2020 [29];
- battery replacement is considered after every five years;
- cost of setting up charging infrastructure is reflected as 15% of the energy rate; and
- battery range of only 70% is achieved during operations.

Table 3: TCO Comparison Parameters

Parameters	**Freight 3-wheeler**		**Goods LCV**	
	Bajaj RE Maxima	Kinetic Safar	Tata Ace BS-VI	E-trio LCV
Model				
Fuel type	CNG	Electric	CNG	Electric
Payload (in kg)	470	550	750	750
Subsidy (FAME II)*	NA	42	NA	NA
Subsidy (Delhi State)*	NA	30	NA	NA
On-road price * (W/O Subsidy)	207	225	481	790
*All prices are in ₹ Thousand				

Source: [24] [25]

Under freight three-wheelers, Bajaj RE Maxima (CNG) is compared with Kinetic Safar (Electric); both having similar payload capacity. TCO per km of an ICE vehicle is ₹ 11.9 and for EFV is ₹ 9.8, i.e. profit per km for an EFV is ₹ 2.1. TCO of electric freight 3-wheeler is 17% lesser than CNG freight 3-wheeler and with the FAME II capital subsidy addition of ₹ 42,000, the difference increases to 18%.

Under goods LCVs, TATA Ace (CNG) is compared with E-trio (Electric) having similar payload capacity. TCO per km of an ICE vehicle is ₹ 19.7 and for EFV is ₹ 18.6, i.e. profit per km for an EFV is ₹ 1.2. TCO of E-Goods LCV is 6% lesser than CNG Goods LCV. Currently, there is no subsidy available on E-LCVs.

The above values have been calculated based on a daily operational distance of 80 km and price of CNG of ₹ 53/kg, whereas in the case of Delhi, the average operational distance under the fruits and vegetable (F&V) market is 50 km, and the price of CNG is ₹ 47/kg. Hence savings per km for electric freight three-wheeler changes to ₹ 1.9/km and that for E-LCV to ₹ 0.8/km. Thus, it can be deduced that the savings per km on electric freight vehicles increase with a longer operational distance. A summary of TCO across the three cities is given below in Table 4.

Table 4: TCO comparison across cities

Market Attributes	**Surat and Ahmedabad**				**Delhi**			
	Textile Market				**Fruits and Vegetables**			
Average trip length (km)	80				50			
Price of CNG (₹/kg)	53				47			
Vehicle	Freight 3-Wheeler		LCV		Freight 3-Wheeler		LCV	
Fuel type	CNG	Electric	CNG	Electric	CNG	Electric	CNG	Electric
TCO (₹/km)	11.9	9.8	19.8	18.6	17.3	15.5	19.4	18.6
O&M Cost (₹/km)	2.9	0.7	4.5	2.3	2.8	0.9	4.1	2.3

Currently, for urban freight trips, freight three-wheelers and goods LCVs have a strong presence in the market. The cost factors have a critical impact in choosing vehicles, and the comparative analysis of TCOs found that even when the TCO of EFVs is much lower than that of the ICEs, their initial capital cost is much higher. Upon operations, the ICE vehicles degrade, increasing the maintenance costs, which is not the case with EFVs with lesser moving elements. The total capital cost of E-Trio over its lifetime (15 years) is 40% (₹ 0.32 million) higher than Tata Ace (CNG), attributing to the higher initial capital cost, absence of subsidy, and battery replacement costs. However, the O&M cost of Tata Ace (CNG) is 57% (₹ 1.04 million) higher than E-Trio, attributed to the higher fuel and regular maintenance costs.

7. ESTIMATING POTENTIAL SHIFTS TO ELECTRIC FREIGHT VEHICLES

Stated preference (SP) methods are widely used in travel behaviour research to identify behavioural responses to choice situations that are not revealed in the market and where the attribute levels offered by existing choices are modified to such an extent that the reliability of revealed preference models acts as predictors of response [30]. The preferences would be input to the discrete choice model, formulated based on the utility theory and maximisation. The model estimates the exclusive choices to maximise the utility while considering the socio-economic conditions of the consumer [31]. The utility equation is expressed as a linear relationship of the independent variables.

The target year considered for demand estimation is the year 2030, in alignment with national targets. The vehicular freight growth has been estimated based on the growth rates from the vehicle registration data. The projected goods vehicles on the road by the year 2030 have been provided in Table 5 below.

Table 5: Growth of goods vehicles in the market

Attribute	Ahmedabad		Delhi		Surat	
	Freight 3-Wheelers	LCV	Freight 3-Wheelers	LCV	Freight 3-Wheelers	LCV
Registered vehicles (2016)	53,130	1,49,463	66,741	1,99,822	40,424	54,045
Growth rate	4%	2%	3%	5%	5%	4%
% Goods vehicle share in the market	5%	1%	20%	5%	5%	4%
On-road goods vehicles (2030)	2,561	1,023	12,811	9,576	3,123	3,448

Source: [19] [32]

7.1. Discrete Choice Model

In transport demand estimation, discrete choice modelling has been used for modelling mutually exclusive choices to achieve utility maximisation. The choice of the shift towards electric freight vehicles will depend on the vehicle operators and their weighted benefits against the use of existing ICE vehicles.

A stated preference survey is conducted with the freight operators of the respective case city markets based on existing (ICE) and proposed scenarios (electric) across combinations of show-cards. The scenarios are then converted into levels based on how the capital and O&M cost of the vehicle might increase, decrease or remain the same under different scenarios. The differences of electric freight vehicles based on capital and O&M costs are presented in Table 6 and this forms the base for setting the levels for existing and proposed scenarios.

Table 6: Setting attributes and levels based on operator survey

Type	LCV		Freight 3-Wheelers	
	Tata Ace	E-Trio	Bajaj RE Maxima	Kinetic
	ICE	Electric	ICE	Electric
O&M (₹/km)	3.63	1.58	2.85	0.78
Percentage difference	-	-60%	-	-70%
Capital purchase (₹ lakh)	4.81	7.92	2.07	2.25
Percentage difference	-	+64%	-	+9%

Through orthogonal design in SPSS, four-choice sets (showcards) are generated.

i. **Showcard 1** consisted of existing scenario 1 (E1) for purchase cost and O&M cost as same as of now and proposed scenario 1 (P1) has a purchase cost 20% more than ICE vehicle and O&M cost 85% less than ICE vehicle,

ii. **Showcard 2** consisted of existing scenario 2 (E2) as same as of now for purchase cost and O&M of ICE vehicles 20% more than the current scenario. Proposed scenario 2 (P2) has a purchase cost 20% more than ICE vehicle and O&M cost 65% less than ICE vehicle,

iii. **Showcard 3** consisted of existing scenario 3 (E3) 15% more than the existing purchase cost of ICE vehicles and O&M of ICE vehicles 20% more than the current scenario. Proposed scenario 3 (P3) has a purchase cost 15% less than ICE vehicle and O&M cost 65% less than ICE vehicle,

iv. **Showcard 4** consisted of existing scenario 4 (E4) 15% more than the existing purchase cost of ICE vehicles and O&M as now. Proposed scenario 4 (P4) has a purchase cost 15% less than ICE vehicle and O&M cost 85% less than ICE vehicle.

The show card chosen by the operator represents the combination of capital and O&M cost that maximises the utility. After entering the recorded choices, a binary logit model was run in SPSS to formulate the utility equations for proposed (P1, P2, P3, P4) and existing (E1, E2, E3, E4) scenarios. The output consists of beta (β) and significance value (Sig.), as shown in Table 7 below.

Table 7: Output sample for freight 3-wheeler under the textile market of Surat

		β	S.E.	Wald	Df	Sig.	Exp(β)	95% C.I. for Exp(β)	
								Lower	Upper
Step 1[a]	Purchase	-3.371	.390	74.67	1	.00	.034	.016	.074
	O&M	-9.140	4.753	3.698	1	.05	.000	.000	1.192
	Constant	9.317	.971	73.400	1	.00	4094.723		
a. Variable(s) entered on step 1:Purchase, O&M									

Significance value determines whether the relation between the two attributes is significant or has come out by chance. A significance value less than or equal to 0.05 is statistically significant and a value greater than 0.05 is statistically insignificant. The utility equation is formulated by the summated product of beta (β) coefficients to the respective independent variables i.e. purchase and O&M cost. The utility equations obtained for different case cities are provided in Table 8 and are found to be statistically significant.

Table 8: Utility equations of different cities

City	Mode	Equation
Ahmedabad	Freight 3-Wheeler	(-0.178)*(Purchase Cost) + (-1.128)*(O&M Cost)
	LCV	(-0.223)*(Purchase Cost) + (-1.448)* (O&M Cost)
Surat	Freight 3-Wheeler	(-3.371)*(Purchase Cost) + (-9.140)* (O&M Cost)
	LCV	(-0.440)*(Purchase Cost) + (-2.326)* (O&M Cost)
Delhi	Freight 3-Wheeler	(-1.924)*(Purchase Cost) + (-7.801)*(O&M Cost)
	LCV	(-0.538)*(Purchase Cost) + (-3.701)*(O&M Cost)

The utility equations define the relationship between independent variables, and the values are derived for the proposed and existing scenarios. The exponential of the utility equation values for both the scenarios ($U_{proposed}$ and $U_{existing}$) is calculated (*Equation 1 and 2*) to identify the choice as provided in *Equation 3*.

$U_{proposed}$ = ln[p/(1-p)] = (β1*(Purchase cost $_{proposed}$) + β2*(O&M cost $_{proposed}$) …*(1)*

U $_{existing}$ = ln[p/(1-p)] = (β1*(Purchase cost $_{exisitng}$) + β2*(O&M cost $_{existing}$) ..….*(2)*

Choice= ($U_{proposed}$)/(($U_{proposed}$)+ ($U_{existing}$)) ...…………………………………….*(3)*

Where,

"ln" is the natural logarithm,

"p/(1-p)" is the odds

"$U_{proposed}$ and $U_{existing}$" are utility values under the proposed and existing scenarios.

7.2. Scenario Classification – UEFV Demand

A sensitivity analysis on the utility equations (Table 8) for the year 2030 was carried out to understand the impact of capital and O&M costs on the choice shift from ICE to EFVs. The business as usual (BAU) scenario is derived without altering the purchase cost and considering the current fuel hike rate per annum. The existing fuel hike per annum is three percent for cities Ahmedabad and Surat and 1.2% for Delhi.

The scenarios have been developed based on the subsidy and fuel hike parameters directly related to the purchase and O&M costs. The provision of subsidies will reduce the purchase cost of the vehicle and shall attract more EFV operators. Currently, a subsidy of ₹ 40,000 (20% of vehicle cost) is offered on selected modes of freight 3-wheeler under FAME II and ₹ 32,000 (15% of vehicle cost) under Delhi EV Policy [33]. No subsidy is offered at the state level on E-freight 3-wheeler in Gujarat and at any level for E-LCVs. Based on this market understanding, for the sensitivity analysis, subsidies in a combination of 20% (only central subsidies) and 35% (state and central subsidies) are considered for both freight 3-wheelers and LCVs. Simultaneously, the O&M cost of ICE was increased with fuel hikes to attract more ICE users to EFV. Fuel hike per annum of double the existing values (six percent for Ahmedabad and Surat and 2.4% for Delhi) and 10% scenarios are considered for sensitivity analysis.

Thus, four scenarios are considered against the BAU scenario.

Scenario 1: 35% subsidy on purchase of new EFVs

Scenario 2: 20% subsidy on purchase of new EFVs

Scenario 3: 20% subsidy on purchase of new EFVs and double fuel hike

Scenario 4: 20% subsidy on purchase of new EFVs and 10% fuel hike

It shall be noted that the provision of subsidies and fuel hikes together will have socio-economic implications on the economy at a macro level, an understanding of which is beyond the scope of this research. The shift obtained in each scenario is applied to the growth of vehicles in respective markets identified in the case cities to find the on-ground electric freight vehicles by 2030; the summary is given in Table 9. The electric freight vehicles are also given as the percentage of the total on-ground freight vehicles.

Table 9: Scenario summary across cities

Scenario	Growth	Ahmedabad		Surat		Delhi	
		3-Wheeler	LCV	3-Wheeler	LCV	3-Wheeler	LCV
Business as Usual (BAU) scenario	% shift in 2030	51%	35%	43%	20%	67%	32%
	EFVs on road by 2030	497	40	335	184	2680	1826
	EFVs as % of total vehicles on the road	**19%**	**4%**	**11%**	**5%**	**21%**	**19%**
Scenario 1: 35% subsidy	% shift in 2030	54%	48%	93%	50%	78%	44%
	EFVs on road by 2030	514	49	688	354	2951	2261
	EFVs as % of total vehicles on the road	**20%**	**5%**	**22%**	**10%**	**23%**	**24%**
Scenario 2: 20% subsidy	% shift in 2030	53%	43%	80%	36%	66%	32%
	EFVs on road by 2030	508	45	651	317	2655	1826
	EFVs as % of total vehicles on the road	**20%**	**4%**	**21%**	**9%**	**21%**	**19%**
Scenario 3: 20% subsidy + double fuel hike	% shift in 2030	53%	44%	82%	37%	67%	32%
	EFVs on road by 2030	508	46	653	319	2680	1826
	EFVs as % of total vehicles on the road	**20%**	**4%**	**21%**	**9%**	**21%**	**19%**
Scenario 4: 20% subsidy + 10% fuel hike	% shift in 2030	54%	46%	86%	41%	73%	35%
	EFVs on road by 2030	514	47	673	346	2,829	1,937
	EFVs as % of total vehicles on the road	**20%**	**5%**	**22%**	**10%**	**22%**	**20%**

From Table 9, it can be deduced that in the BAU scenario, Delhi will have nearly 20% EFVs, whereas Ahmedabad and Surat will have only 5-10% EVFs. The impact on subsidies is found to have a positive shift to EFVs in all three case cities, whereas fuel hike scenarios did not have any effect. The fuel hike is found to be inelastic towards the shift to EFVs as the increase in fuel hike would compensate for the decrease in battery prices, thereby still of the need for subsidy allocation. NITI Aayog targets to achieve 30% EVs across all modes by 2030 [2], and for that, the government will have to provide subsidies at least to reduce the capital cost of electric vehicles or attract demand from ICE vehicles to EVs by raising CNG prices. It shall be observed from Table 9 that these efforts will not be enough as on-ground EVFs will still not reach the target across all scenarios for the case cities of Ahmedabad, Surat, and Delhi.

7.3. Economic and Environmental Benefits

Apart from the savings in the treatment of the vehicular emissions by shifting from ICE to EV, as TCO analysis shows, savings are also made from vehicle O&M cost as well. Together, these are considered as benefits to society due to the electrification of UFVs. The costs and benefits of the selected scenarios are analysed for the lifetime of the vehicle. The project's cost is the subsidies being proposed to be provided for the adoption of EFVs in the scenarios. The benefits are being analysed for the vehicle maintenance, fuel, and emission savings For all the cities across scenarios, the minimum benefits to cost ratio is 1.15 and goes as high as 5.56, i.e. the economic benefits of electrification are two to five times the expenditure on subsidies.

8. CONCLUSION

The transition to EFVs will improve air quality and reduce GHG emissions depending on the renewable components of the power grid. The paper identifies six factors that act as enablers and barriers to the faster adoption of EFVs, as summarised below.

- **(i) Technological suitability -** The choice of EFV models with the required operational range and payload is limited in the existing market. The payload, battery size, and content of the vehicle were understood to be well within the current operational requirements even with the constrained model choices. The primary survey in the three case cities deduces that, on average, 20–30% of the owners are aware of EFVs, but the novelty perception over its operation is still a barrier. The battery prices are evolving and are currently given a warranty period of three years; the uncertainty over costs of replacement is found to be a barrier for the potential buyers of EFVs.
- **(ii) Charging infrastructure and locations -** Overnight home charging is constrained because of the non-availability of secured parking places. Charging facilities at the markets are yet to be created and necessary institutional measures are to be put in place.
- **(iii) Operational economics -** The operating economics is met under the existing vehicle models and no subsidy considerations. Observed trends suggest that

diesel and CNG prices are increasing rapidly and prices of the batteries are decreasing. This trend continues, the costs of conventional fuel vehicles will become costlier than that of EVs. However, this is not adequate to bring absolute cost parity for quite some time. Hence, given the anticipated environmental and climate benefits, fiscal incentives for the purchase and operations of electric vehicles is necessary.

(iv) Fiscal incentives - Subsidies granted by the national and state governments bring capital cost parity between CNG/Diesel and UEFVs. The TCO analysis shows that shifting to UEFV is economically viable as there is a vast cost advantage for UEFV due to cost savings in energy and maintenance.

(v) Financing possibility - Commercial banks do not extend loans for the purchase of EVs. The loans advanced by the financial arms of the EV manufacturers charge exorbitant rates of interest making an adverse impact on the EV economies. Institutional financing of the EFV procurement is still primitive as the resale asset value is not known, and the resale market has not come into operation. Policy measures to encourage commercial banks to advance loans to EV buyers need to be initiated.

(vi) Awareness of UEFV - Lack of awareness among the UFV operators leads to unfounded apprehensions such as the ability of EVs to manoeuvre steep gradients, low speed, fire risk, etc. Therefore, knowledge dissemination and live demonstrations need to be organised.

The potential shifts to EFVs are identified based on the utility maximisation theory, whereby user perceptions are recorded based on the influencing factors impacting the choice of EFVs. The scenarios are classified by subsidy and fuel hike combinations. The potential shift in all the case cities is found to increase with greater subsidy allocations having a direct and positive impact on the capital cost. The fuel hike is found to be inelastic to the potential shift to EFVs. The economic benefits of electrification are found to be two to five times the expenditure on subsidies.

The perceived shift to EFVs is expected to increase with the better cost advantage over ICE vehicles and the provision of an enabling ecosystem by the government through additional incentives and market prices. Electrification of freight vehicles should therefore be considered as an opportunity to improve the efficiency of the existing supply chains and as imperative to achieving India’s commitment to combatting climate change.

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