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IDENTIFYING DRIVERS FOR ENERGY TRANSITION IN TRANSPORT SECTOR IN KOLKATA THROUGH FASTER ADOPTION OF ELECTRIC MOBILITY

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Abstract

Purpose – Kolkata's motor vehicle fleet has grown rapidly in recent years resulting in consequent increase in energy consumption and pollution by the transport sector. The number of registered vehicles in the city increased from 14.42 lakhs in 2013 to 23.17 lakhs in 2022[1]. Energy transition in the sector including adoption of environment friendly energy efficient technologies and measures is urgently required in Kolkata. One of such options of electric vehicles (EV) is a viable and cleaner way offering large potential for fuel savings and curbing pollution from the sector. However, new technologies do not get adopted on their own; they need to be pushed and facilitated by various drivers. This research aims to examine the different factors that are key to a faster uptake of energy efficient option like EV and lead to energy transition in Kolkata's transport sector.

Design/methodology/approach – A survey of one hundred and fifty-eight respondents from eleven relevant entities (national and state government, private sector, energy experts, NGO, media and think tanks) are carried out. After satisfying all the necessary tests of reliability of the survey, the data is subjected to the Principal Component Analysis (PCA) to determine the critical drivers for faster EV adoption in the city.

Findings – The study's results indicate that there are six clusters of drivers to promote EVs in Kolkata. They are: i) favorable policies & stakeholder coordination, ii) robust and smart EV infrastructure facility, iii) technology innovation, iv) awareness building & environmental consciousness, v) pilot projects and vi) financial instruments.

Practical implications – Reducing conventional fuel consumption and carbon footprints in the

[1] https://vahan.parivahan.gov.in/vahan4dashboard/

transport sector by shifting to energy efficient options is extremely urgent, not only in Kolkata, but all cities suffering from environmental degradation due to vehicular pollution. This study offers relevant information and directions for policy makers and other relevant stakeholders for achieving the same.

Keywords: Energy Transition, Energy Efficiency, Electric Vehicles, Drivers, Sustainable transportation

1. Introduction

Cities, accounting for more than 80% of global gross domestic product, also account for a phenomenal share of global energy consumption. Urban areas house 55% of world's population, consume 78% of global energy and emit more than 60% greenhouse gas (GHG) emissions (UN, 2022). However, earth's capacity to absorb the GHG emissions is already exhausted and under the Paris Climate Agreement (2015), several countries and cities across the globe have pledged to reduce the energy and carbon intensity of their economies by 2040 – 2050. This will only be possible through an accelerated energy transition (ET) away from fossil fuels through uptake of energy efficient technologies. Cities, responsible for such high energy consumption, have a major role in the global energy transition (C40, 2022).

The transport sector is one of the major sources of emissions in large urban areas (Inci et. al, 2022). A detailed analysis of data obtained for select cities has indicated that the transport sector is one of the major energy consumers in a city (ACEEE, 2017), resulting in consequent emissions. Kolkata, the capital city of West Bengal, is no exception. Increasing fossil fuel consumption and vehicular air pollution due to growing travel demand and high growth of motorized vehicles is a crucial problem in the city. Increasing number of vehicles with less than 6% of effective road space (Chakrabartty et. al. 2014) has led to high automobile density, disproportionately low percentage of road network, congestion, accidents, and effect on air quality. Kolkata was found to be the second most polluted cities in India after Delhi in terms of Particulate Matter (PM) 2.5 (Health Effects Institute, 2022).

In urban regions, road transport electrification through replacing internal combustion engine (ICE) vehicles with new technologies like electric vehicles (EV) seems to be a promising step towards envisaging urban sustainability (Kumar et al, 2020, Hagem et. al, 2023). EVs are considered a viable option for a sustainable urban transportation system by decreasing oil dependency and pollution, as well as providing possible health and environmental advantages (Buekers et al 2014). Their widespread adoption will result in drastic reduction in CO_2 emissions and air pollution (Gass et al, 2014) and will help emerging economies meet their climate goals. Apart from the environmental benefits, when compared to ICE vehicles, EVs have several advantages of lower operating costs, less interior noise and vibration, better low-speed acceleration, zero tailpipe emissions, etc. (Bhatti et. al, 2021). EVs can get rid of gasoline, and achieve zero-emission during the usage stage which has become the most promising way to achieve carbon reduction in the transportation sector (Xiong et. al., 2023).

In the past few years, Kolkata has been

considering EV deployment across the city. During 2017-19, the city implemented one of India's first electric bus project by procuring 80 e-buses facilitated by FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) subsidy of Department of Heavy Industries (DHI), Government of India[2]. However, the penetration of EVs is very slow in Kolkata. As of December 2022, only about 4,000 battery operated vehicles (BOV) are registered in Kolkata Municipal Corporation (KMC) area. This is just about 0.17% of the registered vehicles in the city[3].

In order to promote electric mobility, the Department of Power, Government of West Bengal announced its Electric Vehicle Policy in June 2021 (EV Policy, WB, 2021). It proposes formulating an EV accelerator cell, setting up citywide charging infrastructure, mandating charging infrastructure in new residential buildings, offices, parking lots and shopping malls, financial incentives, and other parameters. However, faster implementation of the EV Policy and transition to electric mobility is not a very easy task. It encompasses various factors, enormous initiatives, and actions by all relevant stakeholders. Thus, to make the transition from conventional ICE to EVs successful, it is necessary to identify the important drivers that may push an accelerated adoption of EVs (Palit et. al, 2022). It is also crucial to identify the relevant stakeholders for undertaking the actions with regard to the respective drivers.

In the recent past, researchers have explored various challenges and factors for EV deployment, however, most of them have concentrated on cases in developed economies; very few studies have analyzed the context of developing countries (Inci et al, 2022, Palit et. al, 2022). Furthermore, focused analysis of the parameters for promoting electric mobility in Kolkata has not been explored yet. In this context, this study analyses the key drivers and the relevant stakeholders for a successful and faster uptake of EVs in the city. The task is carried out through a questionnaire survey and Principal Component Analysis (PCA) method. This research is expected to facilitate policymakers and relevant stakeholders undertake measures leading to accelerated deployment of EVs in Kolkata thereby achieving increased energy savings and environmental benefits.

The outcomes of this study are not only limited to Kolkata, they are also applicable to other cities. Thus, this research provides significant implications for undertaking strategies and decisions regarding faster adoption of electric vehicles in urban areas.

2. Literature review

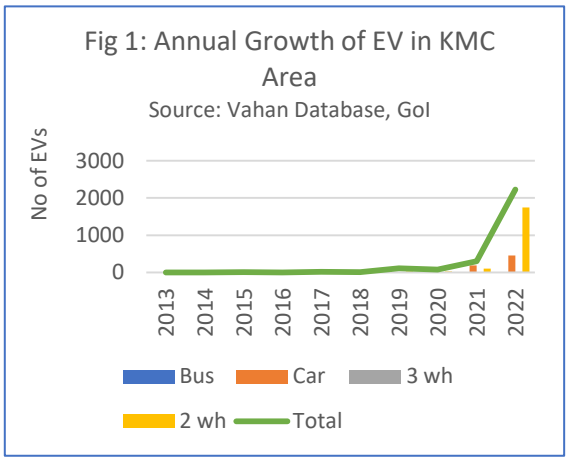
2.1 EV scenario in Kolkata

The transportation system in Kolkata is currently heavily reliant on conventional fuels. A variety of conventional ICE vehicles including buses, private vehicles, motorbikes, taxis, three-wheelers, and small/ medium size trucks are the most used modes of transportation in the city. Ridesharing services such as Uber, Ola and InDrive have also become very popular in the recent past. All these vehicles are mostly driven by fossil fuels (petrol and diesel) with consequent release of vehicular pollution. The three wheelers strictly run

[2] Report entitled Framework for Clean and Green Transportation in Kolkata, submitted to West Bengal Biodiversity Department by Radicl Action, 2017

[3] https://vahan.parivahan.gov.in/vahan4dashboard/

on LPG. In addition to ICE vehicles, trams and metro operate in the city.



In order to combat the increasing pollution from the transport sector, the environment friendly EV technology is a suitable option for the bus, four-wheeler, and two-wheeler segments. Following the procurement and successful operation of 80 e-buses during 2017-2019, West Bengal Transport Corporation (WBTC) has plans to procure another 2,500 electric buses (under FAME II) in order to promote electric public transport. However, the total EV uptake in the city is yet to leapfrog; share of EVs in 2022 was about 0.4% of the total on road vehicles. The annual mode-wise registration of EVs during 2013-22 is presented in Figure 1 (Vahan, 2023).

The objective of West Bengal's EV Policy 2021 is to encourage EVs to enable transition to environment friendly cities with major emphasis on technology innovation, demand creation and charging/ battery swapping infrastructure. The other focus areas include EV awareness building and innovative pilot projects showcasing sustainable mobility. It has an ambitious target of having 10 lakh EVs, combined across all segments of vehicles and 1 lakh charging stations across the state by 2026. However, as of March 2023, the number of total EVs in West Bengal is only 61,602, of which 42,581 are electric 3-wheeler/ e-rickshaws and the remaining 18,021 constitute electric cars, electric 2-wheeler, and electric buses (Vahan, 2023). The electric 3-wheeler/ e-rickshaws are mostly operating in small towns and the sub-urban areas. To address environmental issues, all 3-wheeler in Kolkata are mandated to use LPG since 2009. The number of electric vehicles registered in Kolkata is 3,978. Details are included in Table 1.

As seen in Table 1, of the registered electric vehicles in WB, more than 50% of the electric cars, 20% of electric 2-wheeler and 97% of the e-buses are in Kolkata. So, Kolkata is like an EV hub of the State. However, the share of EVs in the total respective modes vs the conventional fuel vehicles shows that the penetration of EVs in the city is miniscule. Except buses, more than 99% of the vehicles are using conventional fuels.

Table 1 – EVs in West Bengal and Kolkata

EVs	Total Registered EVs (March 2023)		Mode-wise Share of EV in total registered EVs (%)		Share of EVs plying in Kolkata of total EVs in West Bengal (%)	% Share of EV in respective mode (example: share of EV cars of total cars)	% Share of Conventional Fuel vehicles (example: share of non-electric cars in total cars)
Modes	West Bengal	Kolkata	West Bengal	Kolkata	Kolkata	Kolkata	Kolkata

Car	2,285	1,179	3.71	29.64	51.60	0.26	99.74
2-wh	13,098	2,625	21.26	65.99	20.04	0.57	99.43
Bus	122	119	0.2	2.99	97.54	2.29	97.71
3 wh	43,581	24	70.75	0.6	0.06	0.09	All 3 wh run on LPG
Goods & Others	2,516	31	4.08	0.78	1.23	0.1	99.9
Total	61,602	3,978	100	100	6.46	-	-

Source: Vahan 2023

Hence, fast implementation of the EV Policy and accelerated EV uptake has become urgent need of the city. However, it cannot be achieved by a single initiative or a single organization; entities and stakeholders from different segments of the society need to act collectively towards the various drivers needed for achieving the targets. Policy makers, regulators, original equipment manufacturers (OEMs), financial institutions, urban local bodies (ULB), electricity suppliers, energy experts, NGOs, Media and very importantly, the potential users are the key players in this endeavor.

2.2 Identification of the key drivers for successful adoption of EVs

A review of the literature available on various factors for EV adoption indicate that faster EV deployment does not depend on any one factor; it is a mixed bag containing many drivers. Factors like favorable government policies and adequate charging infrastructure are indicated as amongst the key ones for faster implementation of electric mobility (Coffman et al, 2017, Guno et al, 2021, Melander et al, 2022, Inci et al, 2022). Innovations in EV technology and charging systems (Melander et al, 2022, Xiong et al, 2023, Zhang et al, 2016, Choi et al, 2022, Liao et al, 2017) and financial and fiscal incentives for EV adoption (Jenn et al. 2018, Hagem et al, 2023, Aasness et al, 2023, Helveston et al, 2015) are also stated to be imperative to faster EV adoption. In addition, several researchers (Austmann, 2021, Melander et al, 2022, Guno et al, 2021, Choi et al, 2022, Inci et al, 2022) have indicated the importance of EV awareness building and environmental consciousness as significant factors for deploying the technology.

From the available literature, a list of the various driving factors leading to implementing electric mobility is prepared (Table 2). It is observed that the various drivers identified for a faster EV uptake can be broadly grouped under four categories – i) policy/ regulatory drivers, ii) technological drivers, iii) financial/ economic drivers and iv) social/ informational drivers.

Table 2: Drivers for EV adoption

Type	Divers	Author
Policy/ Regulatory Drivers	Regulations on deployment of public charging infrastructure	Coffman et al, 2017
	Relevant government policies towards faster EV uptake	Guno et al, 2021
	Policy on Regulations, subsidies, and environmental zones	Melander et al, 2022

	Policy incentives for adoption of electric and hybrid cars and recharge stations	Inci et al, 2022
	market regulation, and adequate charging infrastructure.	Costa et al, 2020
Technological Drivers	Innovations in EV technology and infrastructure	Melander et al, 2022
	Improving driving range and density of charging stations	Xiong et al, 2023
	EV technology improvement, charging station density	Zhang et al, 2016
	building charging infrastructure	Choi et al, 2022
	Reduce charging time and increased range	Liao et al, 2017
Financial Drivers	Financial incentives for encouraging EV	Coffman et al, 2017
	Solve financing issues	Guno et al, 2021
	Subsidies	Melander et al, 2022
	Toll waiver, municipal incentives	Zhang et al, 2016
	Subsidies for purchases of EVs and chargers, investments in public charging infrastructure	Hagem et al, 2023
	Providing subsidies	Choi et al, 2022
	Subsidize parking of electric cars, sufficient tax subsidies	Inci et al, 2022
	incentive policies	Costa et al, 2020
	Subsidies	Helveston et al, 2015
	Incentives adopted in Oslo: • User privileges like toll exemptions, access to bus lanes and free or reduced public parking • Fiscal incentives like exemption from registration tax and VAT, Reduced tax on vehicle insurance, Exemption from change in ownership tax • Lesser Electricity tax (€0.0162/kWh), compared to road use tax & CO2-tax of €0.491/litre & €0.126/litre for Gasoline and €0.362 &€0.145/litre for Diesel respectively	Aasness et al, 2023
Social/ Informational/ Drivers	Education/ publicity to reduce technological, operational, and infrastructure-related uncertainties	Melander et al, 2022
	Public acceptance of technology	Guno et al, 2021
	Research on psychological factors for adopting EVs	Austmann, 2021
	Consciousness about environmental impacts	Choi et al, 2022
	Awareness about environment and EV merits, break barriers like lack of EV experience and drivers' lack of information	Inci et al, 2022
	environmental concern and EV product-related determinants such as ease of use, perceived risks, and relative advantage	Roemer et al, 2022
	digital promotion and environmental concerns. Combat lack of awareness, mainly driven by misinformation about the potential adverse effect of EVs on the environment	Almansour, 2022

2.3 Identification of the key stakeholders for successful adoption of EVs

In order to achieve a faster EV deployment through the different drivers, initiative, participation, and collaboration amongst the relevant stakeholders

representing different entities and their coordination is mandatory. Various stakeholders include government policy makers, municipalities, citizens, electricity suppliers, ICE & EV manufacturers, RE producers, fossil fuel producers (Talantsev, 2017). E-businesses, media and digital marketing companies, can also play a positive role in providing relevant information and promoting the use of EVs for the greater good (Almansour, 2022). Commitments, efforts, and synergy between multiple stakeholders (Cao et al, 2021, Chaturvedi et al, 2022) play a key role in pushing the different drivers of faster EV adoption.

3. Research Method

This study is based on a quantitative questionnaire survey on the applicable drivers for faster EV uptake in Kolkata followed by conducting Principal Component Analysis (PCA) of the information gathered from the survey. Following the above comprehensive literature review of previous studies on EV drivers (Table 2), relevant drivers and respective stakeholders for faster uptake of EVs in Kolkata is formulated and pilot tested with twenty experts (policy makers and sector specialists) with at least fifteen years of working experience in the subject). The aim of the pilot testing was to ascertain and refine the EV drivers formulated for Kolkata. Based on the opinions from the experts of the pilot test, eighteen drivers are confirmed. They are grouped under four categories – i) policy/ regulatory drivers, ii) technological drivers, iii) financial/ economic drivers and iv) social/ informational drivers. The drivers and their respective stakeholders are presented in Table 3.

Table 3: Drivers for faster EV adoption in Kolkata

Policy Drivers		**Stakeholders**
RDT1	Accelerated implementation of WB EV policy and establishment of 'Govt EV Accelerator Cell'	Transport Dept, Power Dept, CESC, OEMs
RDT2	Set targets, formulate framework, and prepare action plans for faster uptake of EVs through regular & compulsory inter-departmental stakeholder meetings and knowledge sharing	KMC, Transport Dept, CESC, Power Dept, OEMs, fuel stations
RDT3	Designate EV parking slots at concessional rate in public & private parking areas (shopping malls, railway stations, airport, large Residential Buildings / Complexes, Institutional & Public Buildings) - amendment in building bye laws accordingly	Transport Dept, Power Dept, Real Estate Owners, Railways, Airport Authority, OEMs, CESC, KMC
RDT4	Designate land/ area for developing citywide EV charging infrastructure & battery swapping facilities and facilitate charge-point operators wrt their faster permissions, contract settlement and other issues	Transport Dept, Power Dept, KMC, SUDA, CESC, Kolkata Police
RDT5	Regulations on minimum share of EVs while procuring public transport vehicles (public & office buses, government vehicles, vehicle aggregators (Uber/ Ola/ food deliveries like zomato, swiggy etc)	Transport Dept, Power Dept, Aggregators, Energy Consultants
RDT6	Policies regarding recycling/ re-use/ disposal of EV batteries	Environment Dept, Transport Dept, OEMs, KMC
Technological drivers		
TDT1	Availability of increased EV variants for all modes (2,3,4 wheelers, bus, etc), their & after sales service/ repair centres & robust EV charging stations	OEMs, Repair & Service Centres

TDT2	Smart digitally operated charging stations (including RE powered green charging stations) with availability of real time information along with UPI apps & smart mobility card	Charge Point Operators, CESC, Transport Dept, OEMs, Energy Consultants, FIs
TDT3	Standardized batteries & infrastructure to facilitate battery swapping and charging of all types of EVs across charging stations	OEMs, RE Experts, Transport Dept, Power Dept, CESC, Ministry of Power
TDT4	Innovative Pilot Projects & their 3rd Party survey showcasing energy and cost savings (ex - explore wireless EV charging, using RE for battery charging, etc)	OEMs, RE Experts, Transport Dept, Power Dept, Energy Consultants
Financial/Economic Drivers		
EDT1	Cheaper bank loans, cheaper insurance, grants & subsidies, lower road & others taxes, lower TOD tariff, toll waiver etc for EVs and removal of subsidies from conventional fuels	Financial Institutions, Insurance Companies, DHI, Transport Dept
EDT2	Regulations on concessional parking charges for EVs in municipal & privately operated parking lots	KMC, Vendors
EDT3	Concessional lease rental (for land), favourable tariff rules & clear payment modalities for EV Charge-point Operators	CESC, OEMs
EDT4	Further research, innovation and collaboration with relevant organizations on EVs and grants for the same	Finance Dept, Transport Dept, Research Labs, WBPCB
Social/ Informational/ Cultural drivers		
SDT1	Education/ Awareness Programs (for all stakeholders & citizens) & Information dissemination (through print & social media) on EVs - variants & cost, charging/ battery swapping facilities, savings, subsidies/ grants, resale potential etc	Media, Academia, Transport Dept, NGOs, Charging Station Operators, FIs
SDT2	Information dissemination of demonstrated fuel/ cost savings from pilot projects thereby removing perceived risks of performance uncertainty of EVs	Media, Academia, Transport Dept, NGOs, CESC
SDT3	Training & capacity building towards developing skilled labours for repair/ maintenance of EVs	OEMs, NGOs, Energy Consultants, Transport Dept
SDT4	Green reputation and good image - Intent of vehicle owners & STUs to adopt EVs leading to increased conservation of fossil fuels	Public & private vehicle owners

The relevant stakeholders needed to expedite EV uptake in Kolkata were also confirmed from the pilot test. They include representatives from different public and private bodies, NGOs, media and think tanks. The entities include: Department of Transport, Department of Power, Kolkata Municipal Corporation (KMC), State Urban Development Agency (SUDA) – West Bengal, West Bengal Pollution Control Board (WBPCB), Department of Environment, Railways, Airport Authority, Department of Finance, Research Labs, Ministry of Power, Department of Heavy Industries (DHI), Calcutta Electric Supply Organization (CESC), EV Manufacturers (OEMs), Vendors, Aggregators (like Ola, Uber and others), Energy Consultants, Kolkata Police, Real Estate Owners, Charge Point Operators, Financial Institutions (FIs), Repair & Service Centers, Renewable Energy (RE) Experts, Media, Academia, NGOs, Public & private vehicle owners, fuel stations and Insurance Companies.

In the next step, to confirm the importance and significance of these eighteen drivers for accelerated EV uptake in Kolkata, the questionnaire was developed for taking opinion from relevant stakeholders. Two hundred experts from 11 types of entities working on transportation, energy and environment sectors at relevant government and private organizations in Kolkata and other cities were identified. The questionnaire was sent to the two hundred experts having extensive understanding of electric vehicles and its implications. The experts were requested to rank the drivers on a 5-point Likert scale (with severity between one and five). Of

the two hundred stakeholders, one hundred and fifty-eight experts (79%) provided comprehensive and usable feedback. A summary profile of the survey respondents from the eleven entities are provided in Table 4.

Table 4: Questionnaire Survey Respondents

SN	Profession	Share (%)
1	Academician/ Think Tanks	10
2	Central Government	9
3	Consumers	10
4	Energy Consultant	12
5	FI/Bilateral Agency/ Donor	7
6	Legal/ media	3
7	NGO	8
8	Private Sector	12
9	OEM	7
10	State Government	16
11	Urban Local Body	6
	Total	100

The information received from the one hundred and fifty-eight questionnaires was analyzed using the statistical tool of SPSS. First, the reliability of the survey was carried out by determining the Cronbach's alpha coefficient and then the authenticity of the data was verified through the KMO and Bartlett's test. After confirming the reliability and authenticity of the survey data, PCA is carried out using the 'Dimension Reduction' feature in SPSS. PCA is a general name for the technique that uses sophisticated underlying mathematical principles to transform several possibly correlated variables into a smaller number of variables called principal components.

4. Results and Discussions

4.1 Reliability test

Cronbach's Alpha measures the internal consistency amongst variables in a survey. It ranges from 0 to 1 and the higher the value, the higher is the internal consistency (Cronbach, 1951). Cronbach's alpha test for this study is 0.841 which indicates high internal consistency between responses and confirms suitability of the five-point Likert scale method adopted for this analysis.

4.2 KMO and Bartlett's test

After confirming reliability of the survey, the authenticity of the data was verified through the KMO and Bartlett's test. The value in this study is 0.651 (Table 5) which is more than the recommended minimum value of 0.500 (Osei-Kyei et al, 2017). In addition, Bartlett's test of sphericity at 0.000 is statistically significant thereby supporting the factorability of the correlation. The result of the Bartlett test of Sphericity at less than 0.0 indicates that a high significant relationship among variables under study (Arokodare M A, 2021). Thus, the data gathered from the questionnaire survey is suitable for factor analysis.

Table 5: KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.651
Bartlett's Test of Sphericity	Approx. Chi-Square	372.154
	Df	153
	Sig.	.000

4.3 Factor analysis of drivers for energy transition in transport sector in Kolkata

Using the information gathered from the questionnaire survey, first, the mean, standard deviation and ranks of the drivers are determined (Table 6). This was

followed by the PCA and Cattel scree test. The scree plot indicates six components having eigenvalues greater than one and accounting for 72% of the total variance. A varimax rotation with Kaiser Normalization method is applied to the components and the rotation is converged in 14 iterations. Figure 2 presents the scree plot, Table 6 presents the Mean, SD and Ranking of Drivers and Table 7 presents the total variance.

Table 6: Mean, SD and Ranking of drivers

Drivers	Mean	Std. Deviation	Rank
RDT1	4.08	.774	4
RDT2	4.08	.825	3
RDT3	4.22	.543	8
RDT4	3.88	.715	1
RDT5	4.22	.733	8
RDT6	4.14	.752	7
TDT1	4.12	.769	6
TDT2	3.90	.859	2
TDT3	4.36	.772	12
TDT4	4.30	.611	11
EDT1	4.60	.532	17
EDT2	4.10	.759	5
EDT3	4.64	.523	18
EDT4	4.36	.595	13
SDT1	4.56	.499	16
SDT2	4.28	.570	10
SDT3	4.42	.496	14
SDT4	4.54	.501	15

Figure 2

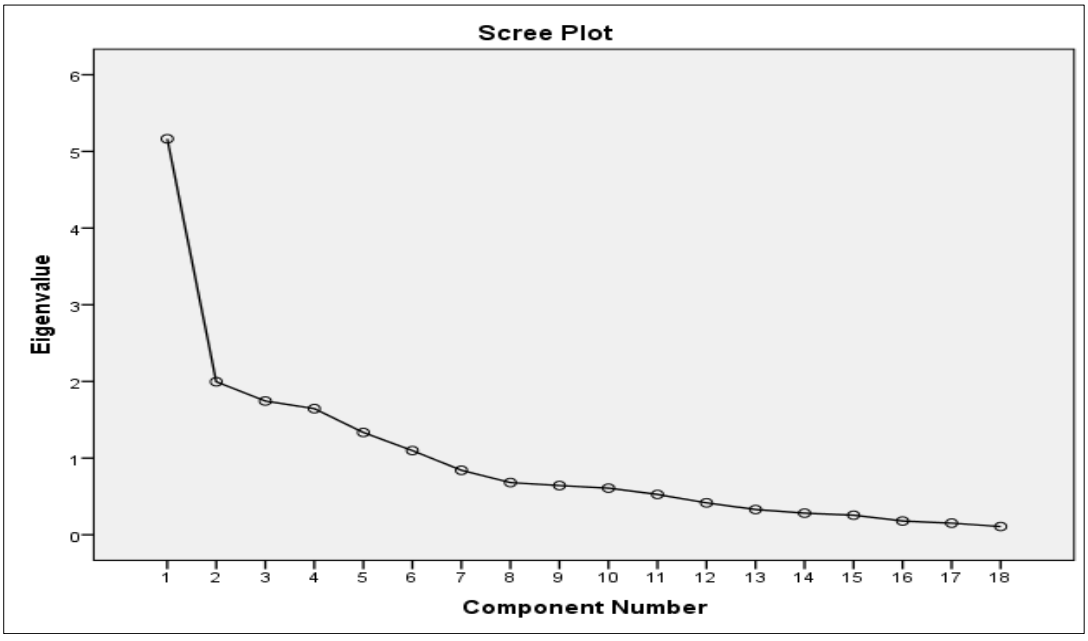


Table 7: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.164	28.691	28.691	5.164	28.691	28.691	2.845	15.808	15.808
2	1.996	11.087	39.778	1.996	11.087	39.778	2.358	13.099	28.907
3	1.744	9.688	49.466	1.744	9.688	49.466	2.101	11.671	40.578
4	1.645	9.138	58.604	1.645	9.138	58.604	2.070	11.498	52.076
5	1.334	7.411	66.015	1.334	7.411	66.015	1.809	10.048	62.124
6	1.098	6.101	72.117	1.098	6.101	72.117	1.799	9.993	72.117

4.4 Principal components extracted from the factor analysis

The rotated component matrix (Table 8) indicates that the eighteen drivers are distributed amongst the six components having eigenvalues more than 1. The six components can be grouped into six distinct categories/ themes (included in rightmost column of Table 8). Each of the six categories include mix of technological, policy, social/informational and financial drivers (Table 8).

Table 8: Rotated component matrix

	Drivers	**Component**						**Categories/ Themes**
		1	2	3	4	5	6	
RDT1	Accelerated implementation of WB EV policy and establishment of 'Govt EV Accelerator Cell'	.822						Favourable Policies & Stakeholder Coordination
EDT2	Regulations on concessional parking charges for EVs in municipal & privately operated parking lots	.744						
RDT5	Regulations on minimum share of EVs while procuring public transport vehicles (public & office buses, government vehicles, vehicle aggregators (Uber/ Ola/ food deliveries like zomato, swiggy etc)	.729						
RDT6	Policies regarding recycling/ re-use/ disposal of EV batteries	.559						
RDT4	Designate land/ area for developing citywide EV charging infrastructure & battery swapping facilities and facilitate charge-point operators wrt their faster permissions, contract settlement and other issues		.840					Robust & Smart EV Infrastructure Facility
RDT3	Designate EV parking slots at concessional rate in public & private parking areas (shopping malls, railway stations, airport, large Residential Buildings/ Complexes, Institutional & Public Buildings) - amendment in building		.686					

	bye laws							
TDT2	Smart digitally operated charging stations (including RE powered green charging stations) with availability of real time information along with UPI apps & smart mobility card		.508					
TDT1	Availability of increased EV variants for all modes (2,3,4 wheelers, bus, etc), after sales service/ repair centres & robust EV charging stations			.779				Technology Innovation
EDT4	Further research, innovation, and collaboration with relevant organizations on EVs and grants for the same			.745				
TDT3	Develop Standardized batteries & infrastructure to facilitate battery swapping and charging of all types of EVs across charging stations			.629				
SDT1	Education/ Awareness Programs (for all stakeholders & citizens) & Information dissemination (through print & social media) on EVs - variants & cost, charging/ battery swapping facilities, savings, subsidies/ grants, resale potential etc				.832			Awareness Building & Environmental Consciousness
SDT3	Training & capacity building towards developing skilled labours for repair/ maintenance of EVs				.658			
SDT4	Green reputation and good image - Intent of vehicle owners & STUs to adopt EVs leading to increased conservation of fossil fuels				.646			
RDT2	Set targets, formulate framework, and prepare action plans for faster uptake of EVs through regular & compulsory inter-departmental stakeholder meetings and knowledge sharing				.552			
TDT4	Innovative Pilot Projects & their 3rd Party survey showcasing energy and cost savings & innovation (ex - explore wireless EV charging, using RE for battery charging, etc)					.793		Pilot projects
SDT2	Information dissemination of ease of performance and demonstrated fuel/ cost savings from pilot projects thereby removing perceived risks of performance uncertainty of EVs					.727		
EDT1	Cheaper bank loans, cheaper insurance, grants & subsidies, lower road & others taxes, lower TOD tariff, toll-waiver etc for EVs and removal of subsidies from conventional fuels						.800	Financial Instruments
EDT3	Concessional lease rental (for land), favourable tariff rules & clear payment modalities for EV Charge-point Operators						.743	

These six components account for 72% of the total variance and share of loading of these six components vary between 15.8% to 9.9. Hence, as per this analysis, all these themes containing the eighteen drivers are significant for faster EV implementation in Kolkata. The six themes and the drivers included under the categories by the factor analysis are:

i) Favorable Policies & Stakeholder Coordination – Accelerated implementation of WB EV policy and establishment of 'Govt EV Accelerator Cell' with the maximum loading (0.822) in this category is very urgent. Other motivators like concessional parking charges for EVs (loading of 0.744) and regulations on minimum share of EVs while procuring public transport vehicles (buses, government cars, vehicle aggregators) with loading of 0.729 have a strong likelihood to enhance uptake of EVs in the city. The fourth driver under this theme regarding policies on recycling/ re-use/ disposal of EV batteries (loading – 0.559) can be focused on subsequently.

ii) Robust & Smart EV Infrastructure Facility - citywide EV charging infrastructure with battery swapping facilities and facilitating charge-point operators is identified as the most important driver for fast EV uptake in the city (highly loaded - 0.840). Designated free parking slots in public & private parking areas (shopping malls, railway stations, airport, large Residential Buildings/ Complexes, Institutional & Public Buildings, and necessary amendment in building bye laws with loading of 0.686 can be adopted immediately. The option of RE powered green charging stations with availability of real time information along with UPI apps & smart mobility card (0.508) need urgent consideration by the Government.

iii) Technology Innovation – it is indicated that availability of increased EV models and after-sales service/ repair centres (loading - 0.779) is imperative for faster adoption of the EV technology. Further research and innovation (0.745) on EVs and standardized batteries to facilitate battery swapping (0.629) are important factors too.

iv) Awareness Building & Environmental Consciousness – Continuous education and publicity on EVs (0.832) are extremely vital for increasing knowledge and removing uncertainties about EVs. Training & capacity building towards developing skilled labors for repair/ maintenance of EVs (0.658) and green reputation, good image, and environmental consciousness (0.646) emerged as important drivers. Regular and compulsory inter-departmental stakeholder meetings and knowledge sharing is a key factor too (loading - 0.552).

v) Pilot projects – Innovative Pilot Projects, their 3rd Party survey showcasing energy and cost savings (0.793) and information dissemination of their performance results are key factors for faster EV uptake (0.727)

vi) Financial Instruments - Cheaper bank loans, cheaper insurance, grants & subsidies, lower road & others taxes, lower TOD tariff, toll-waiver etc for EVs and removal of subsidies from conventional fuels (0.800), Concessional lease rental (for land), favorable tariff rules & clear payment modalities for EV Charge-point Operators (0.743)

The six broad themes, the drivers under each theme and the relevant stakeholders for implementing each of these drivers are included in Table 9. This analysis indicates that there are several critical factors for

uptake of EVs, and most of them need to be undertaken concurrently. For their implementation, all the levant stakeholders need to fulfill their respective responsibilities in a coordinated and collaborative manner for a successful and accelerated adoption of electric mobility in the city. Pushing one or two drivers in a piecemeal manner will not lead to fast deployment of the technology.

Table 9: Categories, Drivers, and Stakeholders for EV uptake in Kolkata

Categories	Drivers	Stakeholders
Favourable Policies & Stakeholder Coordination	Accelerated implementation of WB EV policy and establishment of 'Govt EV Accelerator Cell'	Transport Dept, Power Dept, CESC, OEMs
	Regulations on concessional parking charges for EVs in municipal & privately operated parking lots	KMC, Vendors
	Regulations on minimum share of EVs while procuring public transport vehicles (public & office buses, government vehicles, vehicle aggregators (Uber/ Ola/ food deliveries like zomato, swiggy etc)	Transport Dept, Power Dept, Aggregators, Energy Consultants
	Policies regarding recycling/ re-use/ disposal of EV batteries	Environment Dept, Transport Dept, OEMs, KMC
Robust & Smart EV Infrastructure Facility	Designate land/ area for developing citywide EV charging infrastructure & battery swapping facilities and facilitate charge-point operators wrt their faster permissions, contract settlement and other issues	Transport Dept, Power Dept, KMC, SUDA, CESC, Kolkata Police
	Designate EV parking slots at concessional rate in public & private parking areas (shopping malls, railway stations, airport, large Residential Buildings/ Complexes, Institutional & Public Buildings) - amendment in building bye laws accordingly	Transport Dept, Power Dept, Real Estate Owners, Railways, Airport Authority, OEMs, CESC, ULB
	Smart digitally operated charging stations (including RE powered green charging stations) with availability of real time information along with UPI apps & smart mobility card	Charge Point Operators, CESC, Transport Dept, OEMs, Energy Consultants, FIs
Technology Innovation	Availability of increased EV variants for all modes (2,3,4 wheelers, bus, etc), their after sales service/ repair centres & robust EV charging stations	OEMs, Service Centres
	Further research, innovation, and collaboration with relevant organizations on EVs and grants for the same	Finance Dept, Transport Dept, Research Labs, WBPCB
	Develop Standardized batteries & infrastructure to facilitate battery swapping and charging of all types of EVs across charging stations	OEMs, RE Experts, Transport Dept, Power Dept, CESC, Min of Power
Awareness Building & Environmental Consciousness	Education/ Awareness Programs (for all stakeholders & citizens) & Information dissemination (through print & social media) on EVs - variants & cost, charging/ battery swapping facilities, savings, subsidies/ grants, resale potential etc	Media, Academia, Transport Dept, NGOs, Charging Station Operators, FIs
	Training & capacity building towards developing skilled labours for repair/ maintenance of EVs	OEMs, NGOs, Energy Consultants, Transport Dept
	Green reputation and good image - Intent of vehicle owners & STUs to adopt EVs leading to increased	Public & private vehicle owners

	conservation of fossil fuels	
	Set targets, formulate framework, and prepare action plans for faster uptake of EVs through regular & compulsory inter-departmental stakeholder meetings and knowledge sharing	KMC, Transport Dept, CESC, Power Dept, OEMs, fuel stations
Pilot projects	Innovative Pilot Projects & their 3rd Party survey showcasing energy and cost savings & innovation (ex - explore wireless EV charging, using RE for battery charging, etc)	OEMs, RE Experts, Transport Dept, Power Dept, Energy Consultants
	Information dissemination of ease of performance and demonstrated fuel/ cost savings from pilot projects thereby removing perceived risks of performance uncertainty of EVs	Media, Academia, Transport Dept, NGOs, CESC
Financial Instruments	Cheaper bank loans, cheaper insurance, grants & subsidies, lower road & others taxes, lower TOD tariff, toll-waiver etc for EVs and removal of subsidies from conventional fuels	FIs, Insurance Companies, DHI, Transport Dept
	Concessional lease rental (for land), favourable tariff rules & clear payment modalities for EV Charge-point Operators	CESC, OEMs

5. Conclusions

The transportation sector accounts for about a quarter of the world's energy-related direct CO_2 emissions (Choi et al, 2022). Considering the adverse impacts of growing fossil fuel consumption on the environment, deployment of a low carbon energy efficient transportation system is gradually gaining more attention worldwide and many countries are considering EVs as a suitable option. Kolkata is no exception to this trend. However, the uptake rate in the city is still very slow.

EVs are not diffusing as anticipated, despite being both financially and environmentally a better solution for human mobility (Almansour, 2022).

This study examined the drivers for a faster uptake of EVs in Kolkata for the first time. Based on the literature review and expert opinions, eighteen crucial factors and the respective stakeholders for their uptake are identified through quantitative questionnaire survey and PCA. PCA extracted and categorized the drivers into six components having distinct themes - i) favorable policies & stakeholder coordination, ii) robust and smart EV infrastructure facility, iii) technology innovation, iv) awareness building & environmental consciousness, v) pilot projects and vi) financial instruments. Each theme contains a mix of technological, policy, social/informational and financial drivers. These six components account for 72% of the total variance and share of loading of these six components vary between 15.8% to 9.9%. Hence, all these themes containing the eighteen drivers are significant for faster EV implementation in Kolkata.

This analysis indicates the crucial drivers under different themes need to be taken up concurrently. In this regard, all the relevant stakeholders need to collaborate for a successful and accelerated adoption of electric mobility in the city. Pushing one or two drivers in a haphazard manner will not lead to fast deployment of the technology.

This research can be expected to be a foundation for additional future research

towards the adoption of a more energy efficient transportation modes in Kolkata and other cities.

6. Implications and Further Studies

This study has various implications. It develops an approach to identify and examine the key drivers of EVs adoption for Kolkata for the first time. The proposed framework will assist the future researchers, policymakers, and other stakeholders to determine key factors for successful implementation of EVs in other cities.

Although numerous research studies have been conducted towards assessment of the drivers, barriers, and critical success factors of successful EVs adoption over the past several years, most of the works have focused on the first-world or industrialized countries like the USA, Europe, China, South Korea etc., very few papers focused on the developing nations (Inci et al, 2022, Palit et. al, 2022). This research has explored the valuable insights of EV adoption in a developing country city through identification of the key factors that influence their faster uptake leading to energy transition in the transport sector. This research has been designed in a way that will help policymakers to deploy EVs in Kolkata effectively and efficiently.

The findings of this study offer important implications for the policymakers and other stakeholders to improve environmental sustainability in Kolkata which can eventually improve the quality of life by minimizing harmful elements of pollution.

Despite its contributions and the use of existing approaches for assessing sustainable initiatives, this study has limitations. The study focused on only one energy efficient technology in the transport sector, that of EV. Considering the diversity of the transport sector, and the inter-relationships between different modes of vehicles, there is a need for similar studies to be conducted for other low carbon energy efficient technologies like Fuel Cell vehicles powered by green Hydrogen.

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