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Identification and SWOT analysis of ecological and security issues of battery electric vehicles

Sanjeev Kumar* and Amit Pal

Department of Mechanical, Production & Industrial Engineering, Delhi Technological University, Delhi, India

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Abstract. Environmental sustainability is critical; else, the whole planet would face climatic disasters in the near future. A transportation system based on electric vehicles is assumed to be capable of providing long-term mobility. However, despite several attempts by national and international authorities, a great aim could not be met in India or the rest of the globe. Existing electric cars have a number of limits and obstacles. This report highlighted significant environmental and safety-related constraints that contribute to the low adoption rate of BEVs in India. A SWOT analysis was also carried out to identify the important elements influencing the future of BEV penetration in India.

Keywords: BEVs; environmental and safety barriers; environmental pollution; safety hazards

1. Introduction

Beginning with human development, the rapid expansion of economic activities resulted in a sharp increase in global energy consumption (Senpong and Wiwattanadate 2022). Fig. 1 shows that many countries anticipate more than doubling their energy consumption in the near future (Statistical Review of World Energy 2021, 2021). For the accomplishment of various economic as well as welfare activities, energy is generally obtained by burning different types of fossil fuels, which results in CO_2 emissions. Traditional transportation systems obtain propellant energy by burning fossil-based petroleum such as diesel and gasoline in IC engines, which emit significant amounts of harmful greenhouse gases when burned. With the contribution of tailpipe emission of the IC engine based transportation, environmental pollution has reached such a critical level that the entire world must take the necessary steps to reduce it, or else a slew of negative environmental issues will appear on the face of our planet. Fig. 2 depicts the IEA's estimate of the increase in CO_2 emissions over the last three decades (IEA 2021). Emissions from the transportation sector have become a worldwide issue, due to enhanced greenhouse gases, air pollution, particularly local air pollution, ozone layer depletion, global warming, increased suspended particulate matter and other hazardous chemicals in the atmosphere, all of which make the environment excruciating for humans and other living things (Sharma and Sahoo 2022). The stock of global fossil fuels is assumed to reduce at a very low level. Due to these drawbacks, the operation of the conventional transportation system, based on the burning of fossil fuel is facing

*Corresponding author, Ph.D. Student, E-mail: ersanjeevkumar124@gmail.com

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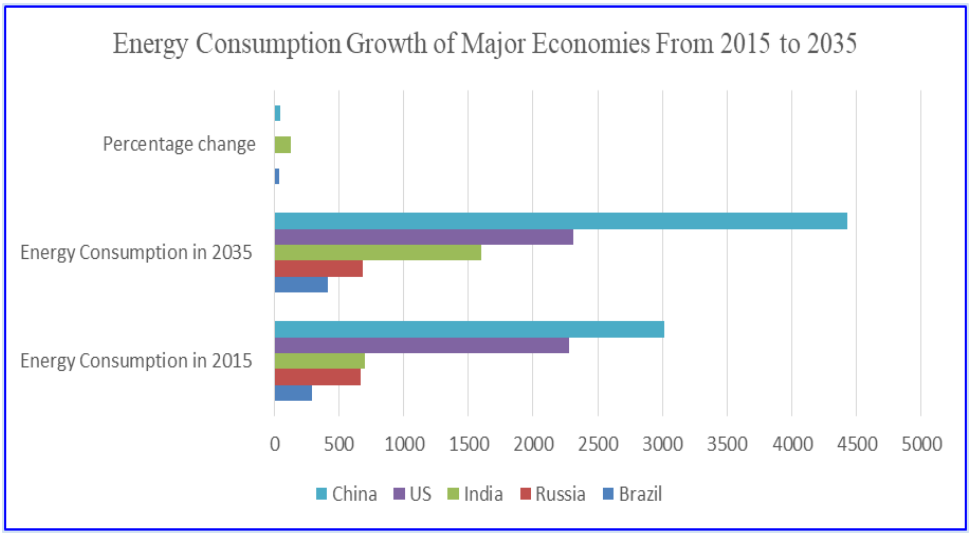

Fig. 1 Energy consumption Growth of major Economies from 2015 to 2035
Source: *Statistical Review of World Energy 2021*

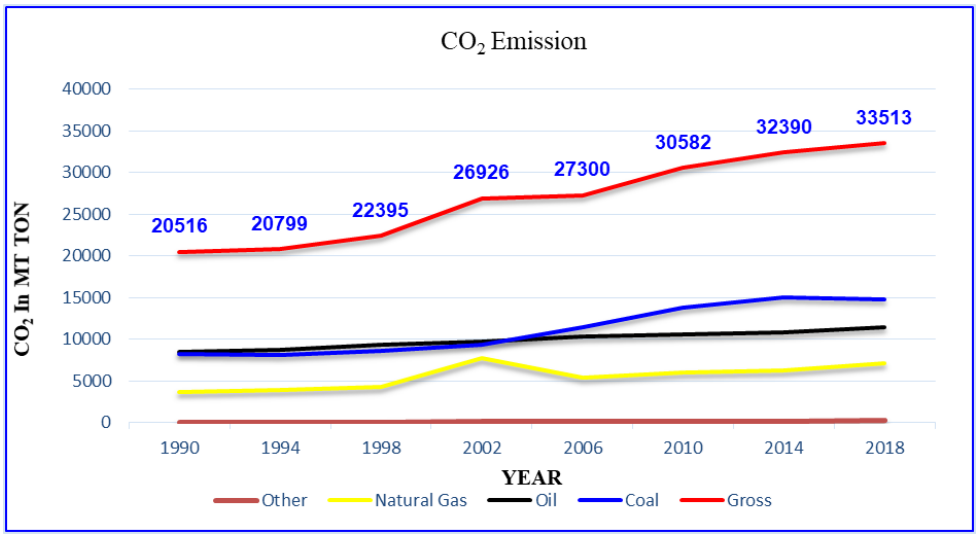

Fig. 2 Year wise CO2 Emission from different fossil fuel
Source: *IEA*

severe challenges and experts warned repeatedly for these issues (Leach *et al*. 2020). Therefore it can be concluded that environmental sustainability is critical; otherwise, the entire world will face climate disasters in the near future. (Yang *et al*. 2021).

Hence it is the need of the hour to convert the present transportation system into a sustainable system so that the global threat of greenhouse gas emissions and burning of fossil fuels can be

reduced. Several changes and advancements of technologies in the design of IC Engine or innovation of alternate fuel are being attempted throughout the world (Said *et al.* 2022). These technologies include CRDi, MPFI, GDI, VCR, mixing of biodiesel, use of CNG, fuel cell technology, solar powered vehicle, and the electrical vehicle have been introduced time to time to curb the menace of burning fossil fuel and reduce exhaust emissions (Alagumalai 2014, Sharma *et al.* 2018).

Among various alternative and renewable energy sources e.g., biofuels, biomass, wind, tidal, and solar energy are being explored extensively. The vegetable oil derived biodiesel is successfully being used in blended form with diesel in internal combustion engine in various industrial and agricultural fields (Sharma 2021). Biomass-derived producer gas can be used as IC engine fuel in dual or single fuel mode to save fossil-based diesel and reduce exhaust emission (Sharma 2020). All the alternatives have some potential and limitations, hence there is a need of ranking the available alternatives so that policymakers can focus on the best. MCDM like Intuitionistic Fuzzy Number, TOPSIS and AHP approach can be applied to obtain the best alternative e.g., power source for vehicles (Pal *et al*. 2020).

At the moment, the level of pollution has exceeded the global threshold value, making it difficult to meet pollution standards for conventional vehicles, forcing us to find a zero-emission alternative fuel for the current transportation system; otherwise, the accumulation of pollutants such as greenhouse gases causes significant environmental damage. A transportation system based on electric vehicles is thought to be capable of providing long-term mobility. According to CEEW India's report, 30% of total vehicle sales can be made up of BEVs, which will open up new business opportunities and provide environmental benefits such as reduced greenhouse gas emissions, reliance on petroleum fuel, and more job opportunities.(Soman *et al*. 2020). Also according to the NEMMP in 2012 targets for 2020 were set for seven million electric and hyb rid vehicles (NEMMP 2012) and Government of India has the intention to achieve the target of 100% electric vehicle in the country (CSR 2017). Union Government of India launched th e FAME scheme with the provision of granting incentives for procuring electric vehicles in t wo-phase i.e., Phase I from 2015 to 2019 and Phase II initiated in 2019 will go up to 2022 (*Electric Vehicle Industry in India*). According to the reports, a total number of 400,000 electrical vehicles are registered in India, as of date (*Bussiness Standard*). Due to the high sale of Tata Nexon BEV nearly 110% yearly growth is estimated in 2021(*AUTOCAR*, 2021). NITI-RMI estimated a 599 million demand for vehicles in India and that is 369 million by CEEW (Soman *et al.* 2020). If its approximate average value of 500 million is taken, then 150 million of Electrical vehicle is being estimated in 2030 which can be achieved with nearly 80% increase in the sale of electrical vehicles.

Hence various efforts have been initiated by national and international agencies to achieve the remarkable target. Though there are several limitations and challenges for present electricity-based vehicles. In this paper, crucial environmental and safety-related barriers are identified which are responsible for the low adoption rate of BEVs in India. In Section 2 of this paper literature review is given, in Section 3 research methodology, section 4 includes identified barriers with explanation and SWOT analysis, section 5 conclusion, and lastly references.

2. Literature review

Battery Powered Electric vehicles or BEVs are powered solely by an electric motor, which uses

electrical energy stored in a battery and is plugged in to recharge. BEVs are equipped with large batteries to provide a reasonable driving range per charge. Although BEVs are zero vehicular emission vehicles, there are certain issues remain which have to be overcome for their successful inclusion in the market of the transportation system in India as well as the rest of the world. The major barriers reported in the literature are the initial cost of BEVs, charging infrastructure, and charging time along with certain other barriers (Kumar and Pal 2021, Pal *et al*. 2021). Along with the technical constraints social concerns have equal importance for launching a new product like electrical vehicles (Egbue and Long 2012). Human beings make decisions based on reasonable assessments of inputs and potential outcomes. The behaviour of an individual is a reflection of whatever is received by him as the social standard of behaviour. To evaluate these factors various techniques have been applied to evaluate the impact of these factors on the diffusion of BEVs into the road transportation system. (Ajzen 2011).

External environmental conditions have the crucial impact on traction battery operations. When the temperature and voltage are too high, solid electrolyte interface film can deposit and oxygen evolved adjacent to the cathode which leads to more electrode scrounging lateral reactions and thus causing much intricate electrochemical reactions (Maleki *et al*. 1999). During charging, discharging, and operation of the battery system, flow of Li-ions take place due to which huge amount of heat produced as an outcome of the chemical energy and Joule heat (Lu e *et al*. 2007). The severe climatic condition in which the system has to operate imparts the major impacts on inside instabilities in batteries due to its influence on electrochemical reactions (Voitic *et al*. 2015). Heat and harmful gases evolved regularly due to which fire hazards and battery estrangement occur and these are a major concern of human safety for the operation of equipment like BEVs (Chen *et al*. 2021, Larsson *et al*. 2017). There are various supportive and challenging factors for the inclusion of BEVs in the market of India. To establish the circumstantial interactions between these factors MCDM technique like DEMATEL-ISM model can be applied (Shashank *et al*. 2020). Today Government agencies are encouraging all stakeholders to the adoption of BEVs but the results are not as per the expectations due to various potential barriers and their interdependency (Tarei *et al*. 2021).

Discarding the used Li-ion batteries created grave ecological contamination of intrusion of noxious heavy metal and poisonous gas like hydrogen fluoride, which must be considered as the severe hazardous for environment and human safety and other living thing leading to ecological imbalance (Balasubramaniam *et al*. 2020). With the view of the importance of traction battery system in electrical vehicle, the production of Li-ion batteries is crucial to initiate the manufacturing of BEVs in India because almost all BEVs brands installed Li- ion batteries (Sanjeev and Pal 2021, Pal *et al*. 2021).

By SWOT analysis internal and external factors responsible for the success of a product can be estimated. The factors which offer challenges and open the opportunities for the inclusion of BEVs into the road transportation system of Lithuania were identified and these factors were utilized to obtain the strength, weakness, opportunity, and threats for the Battery Electrical vehicle system (Raslavičius *et al*. 2015). In Brazil, electrical vehicles have a tough challenge with ethanol. Hence the factors affecting the diffusion of electrical vehicles (LDEV) into the market of Brazil from the area of environment, social, political, innovation, and performance of the electrical vehicle are necessary to identify. These factors were used for SWOT (Strength, Weakness, Opportunity, and Threat) analysis. SWOT is an abbreviation of Strength, weakness, opportunity, and threat which tells the four characteristics of a business(Costa *et al*. 2020). Any business has certain internal and external factors which are responsible for its success or failure and at a strategic level, it is

necessary to recognise them for the future of the business. In SWOT analysis criteria for internal a nd external evaluation are used. Internal considerations are used to assess the organization's str ength and weakness while external factors are used to detect opportunities and threats. It was fu rther explained that the SWOT analysis is a versatile tool for comparative analysis and simpler to understand along with an effective way of understanding a business's booster and adversary (Madurai Elavarasan *et al*. 2020).

With this literature review, it was concluded that there are certain barriers including environmental and human safety related, which are responsible for the low adoption rate of BEVs in India as well the rest of the world. Hence the identification of these barriers is necessary so that they can be addressed by all stakeholders and target of conversion of the transportation system of India into the electrified system which will be emission-free and human safe.

3. Research methodology

After the exhaustive literature review, several barriers were shortlisted. The discussion was made with the various experts working in the automobile industries, automobile parts manufacturers and academia of engineering/technological universities and well-educated car owners of the Delhi region in India to identify the significant barriers among the barriers obtained from the literature review. These experts were asked to give a mark to every barrier from '1' to '5'. Then the barriers that obtained an average mark greater than '3' were selected. These barriers are compiled in a table. After that SWOT analysis was performed using the compiled barriers.

3.1 Environmental and safety related barriers of BEVs in India

3.1.1 Discussion with experts

The discussion was made with the various experts working in the automobile industries, automobile parts manufacturer and academia of engineering/technological university and well-educated car owners of Delhi region in India were contacted to discuss the barriers obtained from the literature review. These experts were asked to give the mark to every barrier from '1' to '5'. Then the barriers that obtained the average mark greater than '3' are selected. Details of discussion made with the experts are given in Table 1.

3.1.2 Identification of barriers

There are so many barriers due to which the adoption of battery electrical vehicles into the Indian market is slow. Some of these barriers were identified from the literature and listed in Table 2.

3.1.3 SWOT Analysis

There are several factors upon which the success or failure of a business or a new product in the market depends. SWOT analysis is utilized to exhibit such factors whether internal or external responsible for the success or failure of a product. (Raslavičius *et al*. 2015). In the present work SWOT analysis was performed to the identified parameters. For SWOT analysis experts were asked about the parameters. Most of the experts agreed upon that the Energy efficiency of BEVs, Emission of Greenhouse gases, and Government support are the strength of BEVs while newer technology, charging time, and Scarcity of charging outlets are a weakness of BEVs. Further, they

Table 1 List of Experts

S. No.	Name of the Company	Designation	Highest Qualification	Area of Expertise
Expert 1	Trivium Power Engineers Ltd F 73 Sec 11 noida	Manager, Sales and Service	B. Tech.	Thermal Power Generation.
Expert 2	Hans Hyundai, B-5, Phase-I, Badli Ind Area, Delhi	Service Advisor	Engg Graduate	Automobile Services
Expert 3	SMS India Pvt Ltd, Udyog vihar, Gurugram	AGM	B. Tech., MBA.	Production and Project Management
Expert 4	Auto Sunvisor India Ltd, Udyog vihar, Gurugram	General Manager	B. Tech.,	Automobile Industries
Expert 5	Ministry of Medium and small Industries, Government of India.	Joint Director	M. Tech., MBA	Manufacturing and Industrial Policy
Expert 6	Delhi Skill and Entrepreneurship University, Delhi	Assistant Professor	M. Tech.,	Power generation,
Expert 7	Delhi Skill and Entrepreneurship University, Delhi	Assistant Professor	Ph. D.	IC Engine, Biofuel
Expert 8	Public works department	Office Administration	Post Graduate	Car Owner
Expert 9	Directorate of Education, Delhi	School Teacher	M. A. (Psychology)	Car Owner
Expert 10	Public Works Department, Delhi	Assistant Engineer	B. Tech.	Road Infrastructure

Table 2 Barriers for the adoption of BEVs

Barrier	Description	Reference
Energy Efficiency of BEVs	Efficiency of Electrical vehicles is much higher in comparison of IC Engine vehicles.	(Raslavičius *et al*. 2015); (Costa *et al*. 2020); (Kumar Sanjeev and Pal Amit 2021)
Emission of Greenhouse Gases	Emission from BEVs is zero but emission from generation of electric power depends upon the fuel used in power plants.	(Raslavičius *et al*. 2015); (Costa *et al*. 2020); (Kumar Sanjeev and Pal Amit 2021)
Newer Technology	From customer point of view BEVs technology is in its initial phase and possibility of variations are there.	(Costa *et al*. 2020); (Egbue and Long, 2012); (Ruiz *et al*. 2018); (Tarei *et al*. 2021)
Charging Time	Average charging time of battery after discharge is much higher relative to filling of petroleum fuel in IC Engine vehicles.	(Egbue and Long 2012); (Yang *et al*. 2015); (Mahmoudzadeh Andwari *et al*. 2017); (Kwade *et al*. 2018)
Dependency on Fossil Fuel	Dependency on fossil fuel can be reduced on adoption of BEVs if electricity generation is based upon renewable energy	(Egbue and Long 2012); (Costa *et al*. 2020); (Ruiz *et al*. 2018); (Raslavičius *et al*. 2015); (Matsumoto *et al*. 2018); (Tarei *et al*. 2021)
Harmful chemical in Battery pack	Battery cell is packed with chemicals which are major concern of human safety and environment pollution.	(Maleki *et al*. 1999); (Lu *et al*. 2007); (Kumar Sanjeev and Pal Amit 2021)
Disposal of Battery	As the battery pack contains hazardous chemical and heavy metals hence its disposal is a cause of great concern.	(Egbue and Long 2012); (Ruiz *et al*. 2018); (Costa *et al*. 2020); (Tarei *et al*. 2021)
Scarcity of Charging Outlet	In India installation of charging station is in its initial phase and till now very less.	(Egbue and Long, 2012); (Ruiz *et al*. 2018); (Costa *et al*. 2020); (Tarei *et al*. 2021)
Utilization of Renewable Resources	Electricity required can be produced in power station located in remote areas utilizing renewable resources.	(Egbue and Long, 2012); (Ruiz *et al*. 2018); (Costa *et al*. 2020); (Goel *et al*. 2021)
Government support	For any business success government intention towards it is very important. Presently Government of India is supporting adoption of BEVs.	(Egbue and Long, 2012); (Ruiz *et al*. 2018); (Costa *et al*. 2020); (Tarei *et al*. 2021); (Kumar Sanjeev and Pal Amit 2021)
Thermal Hazards	Heat is produced from the battery in a normal condition also which could be the major cause of the fire, if not dissipated properly.	(Maleki *et al*. 1999); (Lu *et al*. 2007); (Goel *et al*. 2021); (Kumar Sanjeev and Pal Amit 2021)
Electrical Hazards	High voltage electricity is supplied in traction batteries for propulsion of BEVs which could be hazardous for human safety.	(Maleki *et al*. 1999); (Lu *et al*. 2007); (Goel *et al*. 2021)

agreed that Dependency on Fossil fuel and Utilization of Renewable resources are the opportunity and Disposal of Battery, Use of harmful chemicals in the Battery pack, Thermal Hazards, and Electrical Hazards are a threat to the adoption of BEVs. This analysis is shown in Table 3.

Table3 SWOT Analysis

• **STRENGTH**	• **WEAKNESS**
1. Energy Efficiency of BEVs	1. Newer Technology
2. Emission of Greenhouse Gases	2. Charging Time
3. Government support	**3.** Scarcity of Charging Outlet
• **OPPORTUNITY**	• **THREAT**
1. Dependency on Fossil Fuel	1. Disposal of Battery
2. Utilization of Renewable Resources	2. Use of harmful chemical in Battery pack
	3. Thermal Hazards
	4. Electrical Hazards

4. Conclusions

- Twelve barriers to the adoption of BEVs were identified from the literature followed by a discussion with experts.
- SWOT analysis was performed to the identified parameters.
- The energy efficiency of BEVs, Emission of Greenhouse gases, and Government support are the Strength of BEVs while newer technology, charging time, and Scarcity of charging outlets are a Weakness of BEVs.
- Dependency on Fossil fuel and Utilization of Renewable resources are the opportunity and Disposal of Battery, Use of harmful chemicals in the Battery pack, Thermal Hazards, and Electrical Hazards are the threats to the adoption of BEVs.

5. Future scope

Every research shows the way of further investigations and innovations. As already discussed in this paper that there are more challenges which can be explored from existing literature and discussions with the market experts. Further other multi criteria decision making tool like DEMATEL, AHP and ANP can be utilized for ranking the influence level of a particular challenge, which can be helpful for the policy makers.

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Abbrevitions

AHP - Analytic hierarchy process
ANP – Analytical Network Process
BEVs – Battery Electric Vehicles
CNG, - Compressed Natural Gas
CRDi, Common Rail Direct Injection
CSR- Corporate Social Responsibility
DEMATEL- Decision Making Trial and Error Laboratory
CEEW - The Council on Energy, Environment and Water
FAME – Faster Adoption and Manufacturing of Hybrid and Electric Vehicles
GDI, - Gasoline Direct Ignition
IC engines – Internal Combustion Engines
IEA - International Energy Agency.
ISM- Interpretive Structural Modelling
LDEV - Light Duty Electric Vehicle
Li-ion- Lithium Ion
MCDM – Multi Criteria Decision Making
MPFI, - Multi Point Fuel Injection
NEMMP – National Electric Mobility and Mission Plan
NITI - National Institution for Transforming India
RMI - Rocky Mountain Institute
VCR - Variable Compression Ratio
SWOT - Strength, Weakness, Opportunity, and Threat
TOPSIS - Technique for order performance by similarity to ideal solution