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Feasibility Study of Electric Vehiclesin Indian Cities

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Abstract:*Pollution has been an area of concern in almost all major metropolitan cities. The increasing usage of motor vehicles and the emissions from these has been one of the prime reasons for deterioration in air quality in these cities. The local authorities have therefore been trying to encourage people to reduce the usage of personal vehicles and increase the usage of public transport. The city buses in this context play an important role as they are the lifeline of the public transport system of the city. However, these buses are diesel buses that consume more than 50 liters of diesel per day and emit toxic gases. It is therefore important to replace these buses with a more environment friendly option such as Electric Vehicles (EV) India has been progressive and the policy decisions have been in the right direction towards adoption and implementation of the concept of EVs. The biggest challenge in making it operational is providing better understanding of this new technology, its benefits and the policy around it to policy implementers, such as State Road Transport Undertakings (SRTUs) and also creating the infrastructure to manage the day to day operation and maintenance of the fleet.*
Keywords;*Battery Management System, Electric Vehicles, Pollution, Public Transport, Word 5*

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I. Introduction

Pollution has been an area of concern in almost all major metropolitan cities. The increasing usage of motor vehicles and the emissions from these has been one of the prime reasons for deterioration in air quality in these cities. The local authorities have therefore been trying to encourage people to reduce the usage of personal vehicles and increase the usage of public transport. The city buses in this context play an important role as they are the lifeline of the public transport system of the city. For the purposes of my study, I tried to deep-dive into the existing system in two major cities of India – Bengaluru and Delhi.

Table 1: General comparison of Delhi and Bengaluru

City	Area (km²)	Population (2018 estimate)	Density of Population (persons per km²)	Modes of Public Transport
Delhi	1,484	28,980,000	12,591	• Buses by Delhi Transport Corporation (DTC) • Delhi Metro by Delhi Metro Rail Corporation (DMRC) • Autos • Taxis • Circular city railways • E-rickshaw
Bengaluru	709	12,476,000	4381	• Buses by Bangalore Metropolitan Transport Corporation (BMTC) • Namma Metro by Bengaluru Metro Rail Corporation Ltd (BMRCL) • Autos • Taxis

(Table created using information from:http://indiapopulation2018.in/population-of-delhi-2018.html)

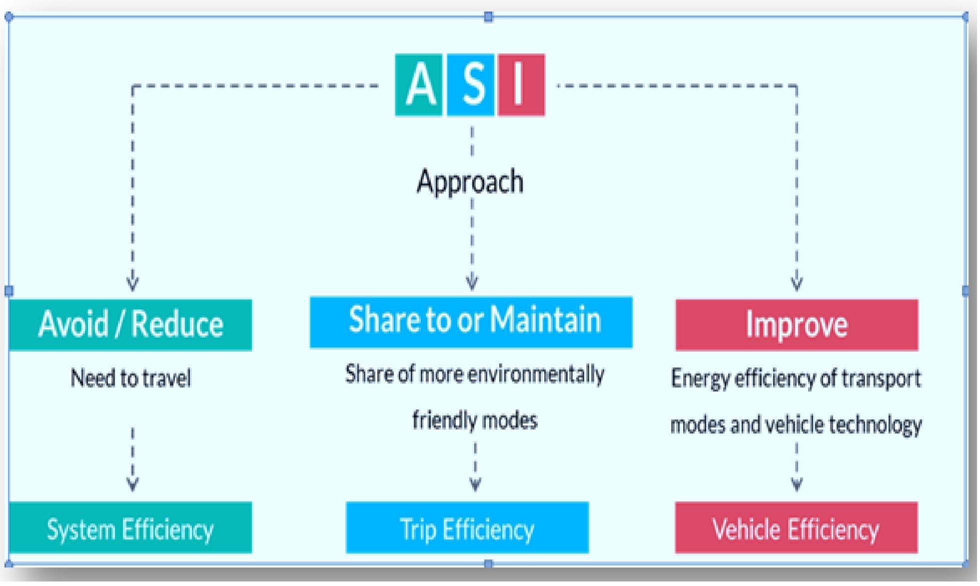
Bengaluru currently has a fleet of 6000 city buses each of which runs on an average for about 200km/day. All 6000 buses put together run for 12 lac km/day. These buses are diesel buses and consume more than 50 liters of diesel per day (@ 3.2 Km/liter) and emit toxic gases. The average life of a bus is 10 years and the average age of the buses in the Bengaluru fleet is 7 years. Therefore, in the next couple of years these buses will have to be replaced. Is there a possibility of using a more environment friendly option such as using Electric Vehicles (EV)? Can the city be equipped to handle the logistics and maintenance if the fleet is converted to EV? Can we address the safety and cost aspects associated with EV technology with an effective Battery Management System (BMS) and thorough implementation of standard operating procedures? [1]

The number of registered motor vehicles in India has increased from 29.4 million in 1991 to 159.4 million in 2011, and this growth is continuing at an increasing rate. It has been projected that in comparison to 2011 levels, the passenger travel demand from urban areas will double by 2021 to 1,448 Billion Passenger Kilometers (BPKM) and triple by 2031 to 2,315 BPKM. [2][3]

If the growth in the transport sector continues at this rate and the share of private vehicles remains the same, the annual use of crude oil is likely to double by 2021 and almost quadruple by 2031. The dependency on diesel economy will increase CO2 and Particulate Matter (PM) emissions at similar rates and increase the rates of illnesses. According to a study by World Bank (2013) India loses about 1.2% of Gross Domestic Product (GDP) due to air pollution. [4]

II. AVOID-SHIFT-IMPROVE (ASI) FRAMEWORK

An effective way of finding alternative mobility solutions and sustainable transportation systems is by using the ASI framework.



(Source: Sustainable Urban Transport Project, n.d.)

Figure 1:The ASI Framework

The Avoid/Reduce component of the framework focuses on ways and means to avoid or reduce travel by improving the efficiency of the transport system. It is important to address energy use and emissions in the transportation sector by reducing the need to travel and reducing trip lengths by managing travel demands and integrating land-use planning. Initiatives such as parking reform and road pricing, advanced traffic signal control, real-time travel information, virtual mobility programs etc. enable better planning and lead to avoiding unnecessary travel.

The Shift component encourages movement towards environment-friendly and energy-efficient modes of transport. Promoting non-motorized modes such as walking and cycling and increased usage of public transport can help reduce emissions and congestion and improve access and travel time. Affordable and easily accessible public transport system plays and important role in encouraging people to shift.

The Improve component focuses achieving higher vehicle and fuel efficiency through technology improvements or advancements. It promotes setting up stringent standards for fuel economy and adaptation of advanced vehicle technology such as clean diesel freight vehicles, Plug-in Hybrid Electric Vehicles (PHEVs), etc.]. It also aims at optimizing the transport infrastructure.

The ASI framework encourages transport strategies that improve the efficiency of the transport system while being sensitive towards climate change. The system aims at providing mechanisms that are efficient and environment friendly.

A shift towards public transport will be more effective if we also shift towards alternate mechanisms such as EVs. This shift combined with ASI framework can have a multiplier effect. However, it is also important to simultaneously understand the drive cycle for battery sizing so that the electric buses are cost-effective.

Policies such as the National Electric Mobility Mission Plan (NEMMP), Faster Adoption and Manufacturing of Electric Vehicles in India (FAME), Smart City Mission and other similar schemes are will encourage the city bus corporations to acquire and build electric bus fleets.[5]

III. ELECTRIC VEHICLE TECHNOLOGY

For the purposes of study, the conventional IEVs have been categorized into Diesel and CNG and EVs have been categorized into hybrid (HEVs) and battery (BEVs).

Although the external design features of the Battery Electric bus are similar to those of an ICE bus, the internal design is quite different among ICEV, HEV and BEV buses. The diesel and CNG buses have almost similar components; these are very different from hybrid and battery buses. For example, the fuel tank is not present in BE buses. The diesel and CNG buses operate on one energy source whereas the hybrid bus has both fuel tank as well as battery pack with an electric motor.

The BEVs can contribute towards reducing overall Greenhouse Gas (GHG) emissions (IEA 2012). The BEVs can be powered by electricity from renewable sources. The fuel that is burnt in IEVs can be burnt more efficiently in thermal plants to produce electricity.

While BEVs are an energy efficient and environment friendly alternative, their prices are very high as compared to IEVs. This is due to battery costs, complex design, nascent technology and charging infrastructure. On the other hand while diesel and CNG buses may cost less as compared to BEVs. Their maintenance cost is high due to high number of moving parts. These parts may require frequent oil changes, filter replacements, periodic tune ups etc. The maintenance requirement for hybrid buses can be similar, or higher, than those of diesel and CNG buses.The Lithium-Ion Batteries (LIBs) that are used in electric buses require minimal maintenance.Major costs in the total cost of operations of BE buses are depreciation and financing costs (interest on loan). Similarly, major costs in the total cost of operations of ICE buses are fuel costs. [6][7][8]

IV. MAJOR COMPONENTS OF ELECTRIC VEHICLE

An EV comprises of the following major parts:

4.1 Traction Battery

The electric vehicles are powered by lithium ion batteries. An EV’s battery pack consists of groups of batter modules each of which are created by combining many individual cells. A typical pack is in 300-400 volt range. These are extremely heavy (more than 1,000 lbs.) and are often placed low, under the vehicle floor, to produce a low center of gravity and improve handling performance. The size of a pack is determined by the number of kilowatt-hours (kWh) of energy that it can hold. A typical EV pack may hold around 60-150 kWh.

4.2 Battery Management System (BMS)

The individual cell temperatures and voltages in the lithium ion pack are monitored through the Battery Management System (BMS). The BMS ensures that during charging the cells have the same voltage level (usually within 0.01 volts). Without a BMS, a cell may get overcharged leading to a potential fire or explosion or may underperform during discharge leading to quick drain out of other modules. The BMS keeps your EV safe.

4.3 Controller

The EV controller is an electronic microprocessor which acts like a brain. It takes pressing of accelerator or brake pedal as an input and turns them into signals that travel along CAN/BUS communication line to the inverter which provides power to the motor.

4.4 Inverter

The more recent electric vehicles operate with brushless DC (BLDC) motors or AC motors which operate on alternating current. The inverter in the EV takes direct current from the battery and changes it into alternating current that is used to power the BLDC motor. The speed of the motor is determined by the frequency of the AC current. The motor has a position sensor which allows the inverter to time its current impulses and keep it spinning. The controller gives command to the invertor which converts it into signals for the motor. Therefore the efficiency and reliability of the EV depends on the robustness of the motor.

4.5 Traction Motor

The brushless DC (BLDC) motor is more efficient and has a higher speed than the traditional DC motors. It is therefore used in almost all modern EVs. A BLDC motor includes a rotor that has four to eight permanent magnets and spins in the center of the motor. The stator is surrounded by a series of electric coils which get energy from the invertor in such a way that they become electromagnets. Some EVs use a single motor which powers either the front or the back wheels while some use two – one powering the front wheels and the other the rear wheels. The motor temperatures are kept under check by air cooling or liquid cooling.

4.6 Regenerative Braking

The EVs capture the energy which is normally lost to heat during braking. When brakes are applied, the motor operates as a generator and simultaneously produces electricity along with slowing down of the vehicle. The electrical energy thus produced can be applied towards recharging of the battery. the battery, helping to recharge it slightly. “Regenerative braking can add more than 20% to the vehicle range during stop-and-go driving in the city”. (Tesla Motors Club)

4.7 Chargers and Charging

Recharging is most crucial part of entire EV eco system. Small EV cars have on board charger which is compatible with home circuit. The EV buses need higher level of charging with more powerful electric circuit. Ideally, the EV buses should be charged in a system that enables atleast 50 KM of charging in one hour of charging**.** [9]

V. THE BATTERY ELECTRIC VEHICLE MECHANISM

The BEV mechanism can be understood through the following components:

5.1 Body design

It is important that a BEV has an aerodynamic shape to save energy and have good speed. The design also needs to consider aspects of vehicle safety. Also, as heavier battery packs are required to increase the drive range, it is important to optimize design such that other components of lighter weight can be used.

5.2 Electric propulsion system

Electric motors, which are also called traction motors, produce mechanical energy from electrical energy to propel the vehicle. These can be of two types DC induction and Permanent Magnet-based motors (PM-DC). The PM-DC motors use high-energy permanent magnets for magnetic field generation. However, these are becoming unattractive because of large size requirement of the magnets and their supply vulnerability. Now days, there is also a new generation of motors called the Switched Reluctance Motor (SRM). This motor does not have brushes or permanent magnets but is driven by reluctance torque which is generated from misalignment between the stator and rotor. The mechanical design of the motor is less complex as compared to an induction motor as power is delivered to the stator rather than the rotor which does not have any windings or permanent magnets. However, the electrical design of this motor is complex as it needs to continuously switch between power receivers.

5.3 Power accessories

The auxiliary systems are dependent on the main battery pack for the necessary power. In order to, powerful microelectronic devices such as are necessary. These microprocessors, microcontrollers and Digital Signal Processors (DSPs) help in implementing modern control strategies and are a part of the power accessories.

5.4 Battery charging

The batteries used in EVs should be able to store more energy per unit volume or weight of the battery in order to get higher mileage per charge. It should also be safe and reliable with a long cycle life, low cost. As a single battery system may not provide all features, the performance mix is optimized according to EV variant.

VI. HYBRID ELECTRIC VEHICLE

The propulsion system of HEV has a conventional ICE and a battery with a traction motor connected to the driveshaft. These can be further classified as:

- parallel Hybrid Electric Vehicle (p-HEV): It can use both ICE and battery propulsion systems either simultaneously, or separately (ICE propulsion for acceleration and high speeds and electric propulsion at steady cruising speeds).
- series Hybrid Electric Vehicle (s-HEV): The ICE generates energy, which is converted to electricity used to propel the vehicle as well as to charge the battery.
- series–parallel HEV: A series–parallel HEV: It has a powertrain designed in such a way that it can act as an s-HEV and/or a p-HEV at multiple driving modes. [10][11][12]

VII. BATTERY AND CHARGING INFRASTRUCTURE

The choice of battery materials depends on the type EV. For instance, in an all-electric vehicle or a parallel Hybrid Electric Vehicle (p-HEV), it is important to attain higher range (mileage) per charge. Therefore, it becomes important to use electrode materials which ensure high charge-storing capability and are able to maintain this parameter consistently over a significant number of charge–discharge cycles to provide a higher battery life. As the battery component cost is the maximum among all EV components, it is important that the electrode material used in it retains its structure and properties over a prolonged period and is resistant to the chemicals and materials used in fabricating electrolytes and battery pack casing, container, etc. so it can provide high stability for a longer period.

Another important battery parameter is its safety. It is important that electrolyte has higher voltage tolerance so as to minimize the risk of battery catching fire or exploding. It should also be chemically stable with respect to the electrodes. The electrolyte to be able to form a passivating Solid–Electrolyte Interface (SEI) protective layer, which prevents unwanted side reactions and provides chemical stability at high discharge rate. Low cost of batteries is also important.

VIII. BATTERY TECHNOLOGIES FOR EV

Going with the desired parameters of stability and security along with low cost, following are the two types of rechargeable batteries that have been successfully used in EVs:

- Nickel (Ni)-based aqueous batteries
- Lithium-ion batteries

In conventional fuel vehicles, lead-acid batteries have been most successful as they cost less and have safe operations. However, these are low energy density batteries and therefore are more feasible for the starting–lighting– ignition needs of petrol/diesel based vehicles rather than being used in EVs. Therefore, Ni-based or LIB system are much is use as these display significantly higher energy density.

8.1 Ni-based aqueous battery system

These batteries are mainly made up of three materials, nickel cadmium, nickel zinc,and nickel–metal hydride. These batteries have nickel hydroxide as cathode, potassium hydroxide as the electrolyte and Cd, Zn or an alloy as anode. The anode is different in the above systems and is Cd, Zn and a complex metal alloy (a mix of rare earths, nickel, zirconium, aluminum, etc.), respectively. The Ni-based batteries are either toxic, show poor performance or may lead to short circuits due to growth of dendrites. The innovation to overcome these disadvantages led to the emergence of Lithium-ion battery.

8.2 Lithium-ion battery (LIB)

LIBs are currently the most widely used battery system in EVs. These batteries display high voltage, high stability and a good cycle life. It has compound of Li and transition metal oxides (or phosphates) as a cathode a carbon-based anode and organic solvents with Li salts as electrolyte. Lower safety and high costs are major challenges in the LIB system. [13] [14]

IX. BATTERY MANAGEMENT SYSTEM

A Battery System works within certain defined operating parameters such as temperature, voltage, structural changes during charge–discharge etc.

Higher temperatures may lead to thermal runaway of the battery. This means that the electrolyte and electrode materials may decompose leading to production of oxygen gas and combustible gases which react with oxygen to cause fire or explosion. At temperatures below the operating parameter, the battery may underperform due to decrease in diffusivity of Li ion. If the battery is over discharged beyond the tolerance limit, it may lead to a structural change of the material and display a lower voltage.

All of these conditions are safety hazards and therefore the Battery Management System (BMS) becomes important. The BMS enables real-time monitoring and control of LIB cells in a pack and ensures that each cell in the LIB pack or module functions within the defined parameters. [15]

X. CHARGING INFRASTRUCTURE AND TECHNOLOGY

Plug-in EVs like BEVs and PHEVs require physical connections with Electric Vehicle Supply Equipment (EVSE) at the charging station. The HEVs are charged using ICE and regenerative which converts the vehicle’s kinetic energy into electric energy and charges the battery. In conventional vehicles, this energy is wasted as heat.

In order to enable large scale penetration of EVs it is important to set up a robust charging infrastructure. The governments are promoting clean transportation as a policy and incentivizing EV manufacture and purchase which has led to expansion of the EV market. The electric bus market is forecast to grow at a CAGR of 28% and reach approximately 34,000 units by 2020. As a result, the share of EV-Charging (EVC) stations is expected to grow from more than 1 million units in 2014 to more than 12.7 million units in 2020. [16] [17]

The EVs run on electrical energy which is a result of chemical reactions in its batteries. Charging is the conversion of electrical energy into chemical energy so that it can be stored in batteries.

There are two types of charging technologies:

10.1 Conductive charging

Conductive charging requires a physical connection between the EV and EVSE at the charging station. It is the most popular option for accessing grid electricity. The automotive standard voltage plugs and sockets are the interface between the on-board sockets and the distribution lines.

The components required for conductive charging are connector, electrical connection cable, power supply from the grid and GPRS to locate charging stations. A connector is used to establish connection between the electrical circuits and the EV so that the battery can be charged.

10.2 Inductive or Contactless charging

Inductive charging uses an electromagnetic field created by placing an induction coil within a charging station to enable the exchange of energy between the EV and the charging station. A second induction coil is placed on the EV. This coil takes power from the electromagnetic field and converts it into an electrical current that is used to charge the battery of the EV. There is no physical contact between the EV and energy source.

The components required for inductive charging are induction coils, a local electricity distribution network connection, GPRS to locate charging stations, a charging point display to monitor the state of charge of the battery and an access tag to restrict access. There is minimum human intervention as the charging process is controlled by smart controllers.

Although the cost of Inductive charging is significantly higher than that of conductive charging, it has several advantages over conductive charging. [18]

- Easy to operate
- Driver does not have to exit the bus to start charging
- Safeguards the vehicle from thefts and severe environments as all charging components are encapsulated in the vehicle or under the ground

XI. IMPACTS AND BENEFITS OF EVs

11.1 Air Quality

Electric buses have zero tail-pipe emissions and therefore are beneficial in urban areas where local air pollution is a concern. Introduction of electric buses is more favorable in regions where the grid has a major share from renewable energy. When the electric buses are charged using electricity generated by renewable energy it ensures reduction in demand for fossil fuel demand and use of cleaner technologies and fuels.

11.2 Noise Pollution

Electric buses are mostly quieter than diesel buses by 17 decibels (dB). Diesel buses operate at 70 dB, whereas electric buses operate at about 60 db. Since loudness is measured on a logarithmic scale, this means that electric buses are half as loud as diesel buses. Such a significant reduction in noise can have a significant impact on well-being.

11.3 Energy Security

The average crude oil import of India is 74%. As there is heavy dependence on import, the increasing and fluctuating crude oil prices therefore pose a severe threat to India’s energy security. Using alternate solutions such as EVs will reduce the demand of crude oil and therefore the import. [19]

11.4 Jobs

EV sector provides various direct and indirect jobs. Vehicle manufacturing, batteries, chargers and other EV-related accessories lead to direct job creation.

XII. POLICY LANDSCAPE

12.1 National Electric Mobility Mission Plan (NEMMP) 2020

NEMMP2020 is an initiative by the Department of Heavy Industries (DHI) with an aim to fast-track the manufacturing and introduction of EVs in India so as to make it a significant player in the global EV market.

It has the potential to reduce CO_2 emissions and dependence on crude oil. The vision statement of NEMMP brings out the focus on encouraging reliable, affordable and efficient adoption of EV technology through government and industry collaboration. The target is to sell 6–7 million EVs in India by 2020.

12.2 Faster Adoption and Manufacturing of Electric Vehicles (FAME)

In order to provide financial incentives to support NEMMP, the FAME scheme was introduced. The scheme is intended to promote the development and uptake of EVs in India. Phase-1 of the scheme commenced in April 1, 2015. It has been implemented over a 2-year period with an overall allocation of INR 795 crores which was primarily used for implementing demand incentives. The cities covered under FAME include all metros - Delhi NCR, Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad and Ahmedabad, all cities with populations greater than 1 million and cities of the North-Eastern states. The scheme covers vehicles of all types and sizes (from hybrid to fully electric).

12.3 National Auto Fuel Policy, 2003, Auto Fuel Vision & Policy, 2025

The National Auto Fuel Policy 2003 specifies the fuel standards to be implemented in the country. Currently, the fuel standards implemented adhere to BS III standards and there has been talk of implementing BS V fuel standards. A move from BS III to BS V would lead to a reduction in sulfur content and PM2.5 emissions.

12.4 The National Green Tribunal (NGT)

The NGT is a specialized body to address challenges related to environmental protection and conservation of forests and natural resources from a multidisciplinary approach. The NGT has been intervening with respect to vehicle air pollution cases, including restriction of old vehicles and restriction on the number of vehicles.

12.5 The Bureau of Energy Efficiency (BEE)

The BEE under the Ministry of Power is the nodal agency known for implementing energy labeling program for most consumer durables in India. In early 2014, the BEE notified Corporate Average Fuel Consumption Standards (CAFC) for passenger cars (Ministry of Power, GoI 2015). The nature of the design was based on kilometers/liter and matched the US CAFE Standards. The scheme would direct all car manufacturers to attain a fleet average of 54.5 miles per gallon (23 km/L) by 2025 progressively.

12.6 Atal Mission for Rejuvenation and Urban Transformation – AMRUT

The AMRUT scheme focuses on urban infrastructure development. Under this scheme, the central government intends to spend INR 1 lakh crores during its tenure (2014–2019). It will provide a boost to adoption of EVs under its aim of developing infrastructure. [20]

XIII. Conclusion

BEVs emit minimal quantities of GHGs with the use of clean renewable sources such as solar and wind energy. They have highest well-to wheel efficiency and are less expensive as compared to HEVs. Although the battery limitations lead to a lower range in BEVs (distance covered in-between charges) and the vehicle cannot be used for long-range transportation, their impact in the environment outweigh these cons. The governments is promoting clean transportation as a policy and incentivizing EV manufacture and purchase which has led to expansion of the EV market.

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