Feasibility of Electric Bus Operation in Urban Areas, Case Study- Delhi

Pintu Saini
Research Associate, Dept. of Transport Planning, SPA Delhi
&
Dr. P. K. Sarkar
Prof. Dept. of Transport Planning, SPA Delhi
Source: Author
The total number of registered motor vehicles in India has increased rapidly over the past decade.
From 55 million in 2001 to 142 million in 2011.
The CAGR of registered motor vehicles was 10% against a population CAGR of 2% during 2001–2011.
Of the total registered vehicles, two wheelers and cars contributed approximately 83% in 2012 (Ministry of Road Transport and Highways 2012b).
Existing Issues

- Air pollution
- Congestion
- Noise pollution
- Health impacts
- Delays
- Accidents/fatalities
- Impacts on global atmosphere
- Encroachments

Source: Compiled by Author
Air pollution is one of the major problems every city around the world is facing these days.

Phenomenon of rapid motorisation leading to emissions

Research has estimated that 3283 Indians died per day due to outdoor air pollution in India in 2015, making the potential number of deaths due to outdoor air pollution in India in 2015 to 11.98 lakh.

Source: Global Burden of Disease (GBD), a comprehensive regional and global research program including 500 researchers representing over 300 institutions and 50 countries
Referred from: Airpocalypse- Assessment of Air Pollution in Indian Cities

Graphic Source: Author
Buses, being the traditional and predominant mode, must be explored for electrification.

Source: Compiled by Author
**China**
China is pioneering in electric buses. China homes around 1,70,000 electric and hybrid electric buses. Most of the buses are provided by BYD.

**U.S.**
Most of the E-buses are provided by Proterra followed by New Flyer and BYD. In 2015, More than 80 Battery-Electric buses were operating in the U.S. 72% are Proterra. Others OEMS: New Flyer and BYD.

**Gothenburg, Sweden**
The bus is provided by Volvo. The bus is based on the fast charging or opportunity charging system. The route is on test run for results evaluation.

### Electric Buses Distribution Worldwide

<table>
<thead>
<tr>
<th>Region</th>
<th>BYD</th>
<th>Proterra</th>
<th>Volvo</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>98%</td>
<td>2%</td>
<td>0%</td>
</tr>
<tr>
<td>Others</td>
<td>98%</td>
<td>2%</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Electric buses v/s Hybrid electric worldwide

- **Purely Electric:** 13%
- **Hybrid:** 87%

### Total E Buses (2015) - 173000

Source: Global EV Outlook 2016, International Energy Agency

<table>
<thead>
<tr>
<th>Bus Cost (Cr)</th>
<th>Range (kms)</th>
<th>Battery Type</th>
<th>Battery Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYD</td>
<td>3 Cr</td>
<td>Li-Ion</td>
<td>324 Kwh</td>
</tr>
<tr>
<td>Proterra</td>
<td>5 Cr approx.</td>
<td>Li-ti-Ion</td>
<td>8 x 368v</td>
</tr>
<tr>
<td>Volvo</td>
<td>--</td>
<td>Li-Ion</td>
<td>250 Kwh</td>
</tr>
</tbody>
</table>

Charge:
- 250+ in 5-6 hrs charge
- 53 kms in 10 min charge
- 6-7 km in 3-4 min charge

Source: Compiled by Author
Trials in Indian Cities

**Bangalore**
- Electric bus trial in Bangalore in 2014.
- One Bus was put on trial provided by BYD.
- Trial period of 3 months.
  - Bus Cost-3 Cr App.
  - Range- 250+ kms

**Delhi**
- One Bus was put on trial provided by BYD.
- Trial period of 4 months.
  - Bus Cost-3 Cr App.
  - Range- 250+ kms

**Manali-rohtang Road**
- Bus provided by BYD and Ashok Leyland
- for 1-day trial period each
  - Ashok Leyland Bus:
    - Bus Cost-1.9 Cr App.
    - Range- 120 kms

Similar trials have taken place in cities like
Hyderabad- BYD Bus
Rajkot- BYD Bus
Chandigarh-TATA motors & BYD Bus
Chinese Manufacturer BYD have been successful in conducting trails in many Indian cities.

Source: Compiled by Author from various sources
Being a capital city, must set example of innovative practices

Pollution levels

- City has witnessed worst pollution levels.
- Among various reasons, pollution from transport sector also dominates.
- Delhi, having a larger modal share of buses can have notable emission savings after adoption of E-buses.

Successful Trials

- Successful trials of electric bus in Delhi have provided evidences of its success.

Fits Operational Requirements

In Delhi, a bus covers around 200 kms/day

BYD bus can cover around 250+ kms/charge

One charge per day will fulfill operational needs and will also battery swapping will not be required.

Source: Author
Looking at successful trials, **BYD bus** is selected for the present study.

**Bus Cost** - 3Cr

**Range** - 250+ kms/charge

**Charging time** - 5-6 Hours

Looking at global practices, there are 2-3 types of charging types.

For the current study, **overnight/one time charging option is considered**.

This is due to BYD bus charging system and also due to its less costs.

*Source: Author*
Life Cycle Analysis

Life cycle analysis involves comparison of-

<table>
<thead>
<tr>
<th></th>
<th>CNG Bus</th>
<th>Electric Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus type</td>
<td>Low floor AC bus</td>
<td>Low floor AC bus</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Tata</td>
<td>BYD</td>
</tr>
<tr>
<td>Life span of bus</td>
<td>7.5 lakh kms or 12 Years</td>
<td>4000 charging cycles or 12 years</td>
</tr>
<tr>
<td>Seating capacity</td>
<td>31</td>
<td>31</td>
</tr>
</tbody>
</table>

**Total Kms operated in a year per bus**-

- Kms covered per bus per day- 200 kms
- Average operational days in a year- 340
- Total kms covered in a year= 200 x 340= **68,000 kms**

Source: DTC, 2017
<table>
<thead>
<tr>
<th>Year</th>
<th>CNG Bus Cost of Bus</th>
<th>Total Operatio nal Costs for 68,000 kms</th>
<th>Total Maintenance Costs for 68,000 kms</th>
<th>Total Expenditures</th>
<th>Total Earning for 68,000 kms</th>
<th>Net Operating Income</th>
<th>Total Capital Cost</th>
<th>Total Operational Costs for 68,000 kms</th>
<th>Total Maintenance Costs for 68,000 kms</th>
<th>Total Expenditures</th>
<th>Total Earning for 68,000 kms</th>
<th>Net Operating Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>7000000</td>
<td>7000000</td>
<td>-7000000</td>
<td>2390000</td>
<td>2390000</td>
<td>-2390000</td>
<td>7000000</td>
<td>7000000</td>
<td>7000000</td>
<td>7000000</td>
<td>7000000</td>
<td>-7000000</td>
</tr>
<tr>
<td>2017</td>
<td>2016</td>
<td>3023960</td>
<td>1013880</td>
<td>3023960</td>
<td>3023960</td>
<td>-3023960</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>3132760</td>
<td>4184829</td>
<td>2161992</td>
<td>4184829</td>
<td>4184829</td>
<td>-4184829</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2019</td>
<td>3453101</td>
<td>4586665</td>
<td>2383596</td>
<td>4586665</td>
<td>4586665</td>
<td>-4586665</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2020</td>
<td>3625382</td>
<td>4802416</td>
<td>2502776</td>
<td>4802416</td>
<td>4802416</td>
<td>-4802416</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2021</td>
<td>3806277</td>
<td>5282120</td>
<td>2627915</td>
<td>5282120</td>
<td>5282120</td>
<td>-5282120</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2022</td>
<td>3996217</td>
<td>5660711</td>
<td>2759311</td>
<td>5660711</td>
<td>5660711</td>
<td>-5660711</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2023</td>
<td>4195654</td>
<td>6150487</td>
<td>2897276</td>
<td>6150487</td>
<td>6150487</td>
<td>-6150487</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2024</td>
<td>4405063</td>
<td>6762234</td>
<td>3042140</td>
<td>6762234</td>
<td>6762234</td>
<td>-6762234</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2025</td>
<td>4624942</td>
<td>7392247</td>
<td>3296247</td>
<td>7392247</td>
<td>7392247</td>
<td>-7392247</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2026</td>
<td>4858815</td>
<td>7757750</td>
<td>3531595</td>
<td>7757750</td>
<td>7757750</td>
<td>-7757750</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2027</td>
<td>5098232</td>
<td>8206650</td>
<td>3776650</td>
<td>8206650</td>
<td>8206650</td>
<td>-8206650</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Financial analysis between electric bus and CNG bus provides net operating income as negative.
Net operating income for electric bus is less negative than CNG due to less maintenance cost of bus.
Financial analysis suggests the need of intervention for costs reduction for electric bus to make it feasible.

Source: Authors Analysis
### Economic Analysis

#### Health cost savings

<table>
<thead>
<tr>
<th>Name of Pollutants</th>
<th>Emissions from CNG Buses (g/km)</th>
<th>Health cost (Rs. per Kg)</th>
<th>Emissions for 68000 km (in kg)</th>
<th>Total Health cost savings (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td>719</td>
<td>2.52</td>
<td>48892</td>
<td>123147</td>
</tr>
<tr>
<td>CO</td>
<td>1.77</td>
<td>1.05</td>
<td>120</td>
<td>126</td>
</tr>
<tr>
<td>Nox</td>
<td>5.35</td>
<td>248.13</td>
<td>364</td>
<td>90270</td>
</tr>
<tr>
<td>CH4</td>
<td>1.455</td>
<td>57.93</td>
<td>99</td>
<td>5732</td>
</tr>
<tr>
<td>SO2</td>
<td>0.71</td>
<td>71.29</td>
<td>48</td>
<td>3442</td>
</tr>
<tr>
<td>PM</td>
<td>0.4928</td>
<td>1993.07</td>
<td>34</td>
<td>66789</td>
</tr>
<tr>
<td>HC</td>
<td>0.88</td>
<td>15.43</td>
<td>60</td>
<td>923</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,90,428</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Fuel cost savings

- CNG Bus mileage (km/kg): 2.6
- CNG Price(Rs/Kg): 30
- Fuel Efficiency (Rs/Km): 30/2.6=11.5
- Annual kms operated per bus: 68000
- Total Fuel cost savings (Rs.): 7,84,615

### Total savings

<table>
<thead>
<tr>
<th>Number of buses</th>
<th>CO2 Savings (ton)</th>
<th>Health Cost savings (Lac)</th>
<th>Fuel Cost savings (Lac)</th>
<th>Total Savings (Lacs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48</td>
<td>2.90</td>
<td>7.84</td>
<td>10.74</td>
</tr>
<tr>
<td>100</td>
<td>4889.2</td>
<td>290.42</td>
<td>784.61</td>
<td>1075.03</td>
</tr>
</tbody>
</table>

- Economic analysis shows that after applying all the benefits, operating costs are recovered, but capital cost of the bus is making total income as negative.
- This shows for the feasibility of the overall system, strategy has be adopted for reducing the cost of the bus.

Source: Authors Analysis with reference from various literature
Stakeholder Perception Survey

Bus Manufacturers
- BYD
- Ashok Leyland
- Volvo
- Tata

Bus Operators
- DTC
- DIMTS Cluster operators

Bus Users
- Bus users

Bus Manufacturer Survey
- Manufacturer survey revealed the need of government policies and incentives for easy introduction in market.

Bus Operator Survey
- Operators survey revealed the need for bus cost reduction, govt. incentives and electricity subsidisation for feasible operation.

User Survey
- Users survey revealed their willingness for adoption of electric buses for Delhi.
- Survey revealed that more than 75% of the users are ready to use the buses even if the fares are increased by 33%.

Source: Authors Analysis
1. Electricity Subsidization
2. Bus Cost becomes half
3. Fare increment by 33%
4. Bus cost equal to normal AC bus
5. Installation of solar based charging system

**Effects of Bus Cost Subsidisation**

- Procurement cost (Rs/km)
  - CNG Bus: 700000
  - Electric Bus: 300000
  - After Subsidy: CNG Bus 0, Electric Bus 234000

- Operational Costs Rs/km
  - CNG Bus: 44.47
  - Electric Bus: 46.02
  - After Subsidy: CNG Bus 37.52

- Fuel Efficiency Kms/Rs.
  - CNG Bus: 0.08
  - Electric Bus: 0.07
  - After Subsidy: Electric Bus 0.14

Source: Authors Analysis
1. **Tax Exemption** as done in various countries
   - Exemption from *acquisition tax* and from the *excise tax* in *China* for electric cars
   - *France* began offering in 2013 *purchase incentives* of 6300 euros for BEVs and PHEVs
   - Cars emitting zero CO2 at the tailpipe are exempt from paying *registration tax* in *Netherlands*.

2. **Battery Technology Improvement**
   - Current recommendations by transport minister have emphasized on the *use of Lithium ion battery for buses earlier used for aviation sector*.
   - *MoU* between *ISRO and BHEL* to help develop low-cost lithium ion batteries.
   - *ISRO* have *developed batteries costing Rs 5 lakh*, about a tenth of the imported ones which was 55 lakh.
Fare Increment

Willingness to Pay Higher
- 1 rupee per km: 18%
- 1.25 rupee per km: 27%
- 1.5 rupee per km: 5%
- Not ready to pay: 50%

Use of Solar Energy

Taking a case of 25 buses, if those are being put on solar instead of charging using electricity, costs are-

Using Electricity
- Unit cost: 10.66 Rs.
- For 25 years:
- Total costs: 94.8 Cr

Using Solar
- For 10,00,000 WaH = 4.5 Cr
- For 10,000 units
- i.e. 1,00,00,000 WaH = 4.5 x10 = 45 +0.5 (Annual Maintenance)
- Total Cost = 45.50 Cr (52% less)

For a period of 25 years, total saving of around 49.3 Cr for 25 buses

Over the life time of the solar system, there will be a savings of around 1.20Cr per Bus.

For 100 buses, savings of around 120 Cr. over the life time
Scenario 3+4+5, where fare increment, cost of bus equal to normal bus and adoption of solar strategies are adopted, is most desirable as it is having lowest rate of returns an Highest BCR.
1. Bus cost reduction through subsidy and battery technology advancement.
2. Cost reduction through tax exemptions will be a great move.
3. Making operation feasible by electricity subsidization.
4. Fare increment can be done and is acceptable to a certain level for making operation feasible.
5. Adoption of solar system will provide significant cost and emission savings in long term.
• Bus operation data from Delhi Transport Corporation (DTC), 2016
• IEA. (2016). *Global EV Outlook*.
• MoEFCC, G. (2016). *Air Pollution in Delhi-An Analysis*. ENVIS Centre CPCB.