Piloting Zero-Emission Buses
Best Practices and Data Analysis

Nov 12, 2020

Currently applied in the 100 e-bus trial implementation assignment in Jakarta, Indonesia
Agenda

• Importance of Data Driven Approach
• E-bus deployment planning
• E-bus trial data requirements
• E-bus route planning data requirements
• E-bus charging infrastructure data requirements
• Summary
Why is Data Driven Approach important

- Thoughtfully designed pilots to answer critical and outstanding questions
- Build confidence among decision-makers
- Understand the investment plans clearly
- Inform a broader strategy of electrification
E-bus deployment planning

Technical Feasibility Study

- Understanding/Survey the technologies
- Route Selection, TCO Modelling
- Preliminary Charging Strategy, Preliminary Market Study

Business Case

- Business Case and Financial Modelling
  - Design of service schedules, Depot Selection
- Discussion with operators
- Finalizing of charging Strategy, locations and electrical supply
  - Requirements
  - Feedback
- Finalizing of tender documents
E-bus technology

- Powertrain
- Charging & Support Infra
- Electrical Supply & Grid Impact

- Range & Routes
- Operational Schedule
- Energy Demand & Supply
- Energy Access
Approach for trial runs

Need for Data Collection
Approach for trial runs

- Route Selection
- GPS Data (Speed, stops, elevation)
- Battery Data (Energy Consumption, SoC)
- Monitoring & Evaluation

- Running Schedules
- Charging Profiles
Data collection

**Route length**

**GPS data**
Date, time, latitude, longitude, speed, and elevation

**Bus data**
Start and end time of active service, if available: avg time spent at bus stops

**Bus stop position**
Latitude and longitude data
Route profiling

Energy consumption and charger requirements on different routes in the city
Route profiling
## Performance Evaluation

<table>
<thead>
<tr>
<th>Data Item</th>
<th>Bus Type 1</th>
<th>Bus Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total mileage (in kms)- Daily</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of the bus – How much time was it used for?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Consumption- Daily (kWh/km)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Speed including stops (kmph)</td>
<td></td>
<td></td>
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<tr>
<td>Kms between road calls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total maintenance cost ($/km)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Data driven approach for route selection

<table>
<thead>
<tr>
<th>Passenger ridership (pax/bus/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route Length</td>
</tr>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>CPKM vs EPKM (Cost per km vs Earning per km)</td>
</tr>
<tr>
<td>Replacement Ratio (The ratio of the daily kms traveled and the actual range in kms provided in a single charge of the battery)</td>
</tr>
<tr>
<td>TCO at Route Level</td>
</tr>
<tr>
<td>Common origin/destination points</td>
</tr>
<tr>
<td>Dead kms</td>
</tr>
</tbody>
</table>
BRT routes: ridership and number of buses
BRT routes: daily kms vs. BEB range

Based on 324 kWh
BRT routes: replacement ratio
# BRT routes: TCO/km comparison

Diesel and electric (big battery) buses

<table>
<thead>
<tr>
<th>BRT Route</th>
<th>Big Battery Electric Bus* (USD)</th>
<th>Diesel Bus (USD)</th>
<th>TCO % Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.40</td>
<td>1.06</td>
<td>32%</td>
</tr>
<tr>
<td>2</td>
<td>1.54</td>
<td>1.13</td>
<td>36%</td>
</tr>
<tr>
<td>3</td>
<td>1.25</td>
<td>0.98</td>
<td>28%</td>
</tr>
<tr>
<td>4</td>
<td>1.27</td>
<td>0.99</td>
<td>28%</td>
</tr>
<tr>
<td>5</td>
<td>1.38</td>
<td>1.05</td>
<td>31%</td>
</tr>
<tr>
<td>6</td>
<td>1.10</td>
<td>0.89</td>
<td>24%</td>
</tr>
<tr>
<td>7</td>
<td>1.31</td>
<td>1.01</td>
<td>30%</td>
</tr>
<tr>
<td>8</td>
<td>1.14</td>
<td>0.91</td>
<td>25%</td>
</tr>
<tr>
<td>9</td>
<td>1.47</td>
<td>1.09</td>
<td>35%</td>
</tr>
<tr>
<td>10</td>
<td>1.28</td>
<td>1.09</td>
<td>17%</td>
</tr>
<tr>
<td>11</td>
<td>1.37</td>
<td>1.04</td>
<td>32%</td>
</tr>
<tr>
<td>12</td>
<td>1.30</td>
<td>1.01</td>
<td>29%</td>
</tr>
<tr>
<td>13</td>
<td>1.29</td>
<td>1.00</td>
<td>29%</td>
</tr>
</tbody>
</table>
BRT routes: TCO/km comparison
Findings with big battery (324 kWh)*

- TCO for electric bus is higher than the diesel buses by about 29% (average).
- The average TCO for electric bus is $1.32/km while for the diesel bus the average TCO is $1.02/km

*Based on analysis of full data set provided by TJ
# BRT routes: TCO/km comparison

## Diesel and electric (medium battery) buses

<table>
<thead>
<tr>
<th>BRT Route</th>
<th>Medium Battery Electric* Bus (USD)</th>
<th>Diesel Bus (USD)</th>
<th>TCO % Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.20</td>
<td>1.06</td>
<td>13%</td>
</tr>
<tr>
<td>2</td>
<td>1.32</td>
<td>1.13</td>
<td>17%</td>
</tr>
<tr>
<td>3</td>
<td>1.07</td>
<td>0.98</td>
<td>9%</td>
</tr>
<tr>
<td>4</td>
<td>1.09</td>
<td>0.99</td>
<td>10%</td>
</tr>
<tr>
<td>5</td>
<td>1.19</td>
<td>1.05</td>
<td>13%</td>
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<tr>
<td>6</td>
<td>0.94</td>
<td>0.89</td>
<td>6%</td>
</tr>
<tr>
<td>7</td>
<td>1.12</td>
<td>1.01</td>
<td>11%</td>
</tr>
<tr>
<td>8</td>
<td>0.97</td>
<td>0.91</td>
<td>7%</td>
</tr>
<tr>
<td>9</td>
<td>1.26</td>
<td>1.09</td>
<td>16%</td>
</tr>
<tr>
<td>10</td>
<td>1.10</td>
<td>1.09</td>
<td>1%</td>
</tr>
<tr>
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<td>1.17</td>
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<td>1.01</td>
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</tr>
<tr>
<td>13</td>
<td>1.11</td>
<td>1.00</td>
<td>11%</td>
</tr>
</tbody>
</table>
BRT routes: TCO/km comparison
Findings with medium battery (180 kWh)*

- TCO for electric bus is higher than the diesel buses by about 11% (average).

- The average TCO for electric bus is $1.13/km while for the diesel bus the average TCO is $1.02/km

*Based on analysis of full data set provided by TJ
Factors to consider for slow vs. fast charging

Data driver approach

- How many additional kms required? (Range Extension)
- Headway of the schedule? (Understand the time available for charging)
- OEM’s charging products (Power rating)

→ How many times need to be charged
→ Number of fast vs. slow chargers
→ Location of Chargers
Charging requirements

Daily Utilization vs Range

Total Kms

Range

Charging requirements
Charging strategies

Bus Schedule

Option 1: Fast
Option 2: Slow Charging
Charging strategies based on distance

Source: UITP and Manufacturers
Comparison of cost implications

Cost Estimates for E-Bus (Over Life span)
- Contingency
- Operating Cost
- Maintenance cost
- Energy cost
- Battery replacement
- Charging
- CAPEX bus

Cost Estimates for Diesel Bus (Over Life span)
- Contingency
- Operating Cost
- Maintenance cost
- Energy cost
- CAPEX bus

* Draft Numbers subject to revision
Summary

• Data Analysis will help in designing successful pilots and scaling-up
• Clear understanding of technology and cost implication upfront will be beneficial for city governments, transit agencies, operators, utility companies and relevant stakeholders
• Will lead to a collaborative approach and clear definition of roles and responsibilities
Thank you for your attention

Terimah Kasih Banyak!

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