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Implementation of Electric Buses for Public Transportation in Jakarta

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Abstract: **- Transportation sector which is the main contributor of air pollution in Jakarta. Effective public transportation presents an opportunity not only to alleviate the trend towards individual vehicle ownerships but also helps limiting city-level pollution. PT. Transjakarta is the backbone of the capital's public transportation service with exponential increase in ridership since its inception. Implementation of Battery Electric Buses (BEBs) is an opportunity for Transjakarta that would potentially reduce more than 50% of the pollution generated by vehicle emission along with reduction in oil imports. PESTEL framework and supply chain analysis is done to determine the effect of external and internal environment on the adoption of BEBs in Jakarta.**
This exploratory research will use qualitative methodology to analyse the data and determine the barriers for the adoption of electric buses. High upfront cost of buses and development of charging infrastructure along with grid stability issues are identified as main barriers. The objective is to provide a solution to overcome the barriers based on cost benefit analysis, charging strategy and innovative business models considering technological advancement and local operational requirements.

Keywords: BEBs, Business models, Charging strategy, Cost benefit Analysis, Business models, GHG emissions

I. INTRODUCTION

Indonesia's decarbonization policies to address greenhouse gas (GHG) emissions and drive new economic opportunities, while improving the quality of life of the citizens in the cities, will be based on three key pathways; energy–generation, energy-utilization, and transportation sectors. The long-term prospects for energy generation as well energy utilization does not look great based on PLN high carbon grid and latest electricity procurement plan (RUPTL) for the 2019-2028 period which is still firmly dependent upon coal. However, Indonesian government is concerned about increasing air pollution, GHG emissions and oil imports. In an approach to ensure sustainable transportation system in the city, PT Transjakarta, the backbone of public transportation in Jakarta has prepared a 10-year plan to replace conventional buses by electric buses by 2030.

Company Profile

Transjakarta is the first Bus Rapid Transit (BRT) transportation system in Southeast and South Asia that has been operating since 2004 in Jakarta, Indonesia. It has 260 bus stops spread across 13 BRT corridors with the longest BRT path in the world (251.2 km). The buses run in dedicated lanes, of BRT corridors as well as on feeder routes and ticket prices are subsidized by the regional government.

Business Problem

Electrification of buses requires additional investment for operators as electric buses are approximately 2-3 times expensive than conventional buses. One of the outcomes of increase in investment is increase in fare but ticket prices are governed by public service obligations and hence, cannot be increased. Hence, implementation of electric buses is challenging without government supporting policies and incentives.

II. BUSINESS SITUATION ANALYSIS

The PESTEL Framework

Political Factor: Presidential regulation 55/19 discusses the development of electric vehicle industry in Indonesia. However, there is no specific regulation for adoption of electric buses for public transportation.

Economic Factor: GDP of Indonesia in the last five years (2015-2019) reached an average of 5.04% per year. However due to current conditions of COVID-19 pandemic Indonesia's GDP will drop. Asian Development Bank has also released its forecast that Indonesia's GDP in 2020 will drop to 2.5% (adb.org) on April 3, 2020. However, these predictions are only temporary and economic factors in long term are positive.

Sociocultural Factor: Indonesia being the fourth most populated country in the world with a relatively young population who is concerned about falling air quality and welcoming towards BEBs.

Technological Factor: Technology is still developing and with time the cost of BEBs will reduce with reduction in battery cost and increase in battery life. Cost of the charging infrastructure will also reduce in future along with time

required for charging.

Environmental Factor: BEBs would potentially reduce more than 50% of the pollution generated by vehicle emission in Jakarta and also help in meeting the commitments of emission reduction as per Paris agreement.

Legal Factor: Legal factors for vehicle certification, charger's installation etc. are in place but the process of approval is time consuming and needs improvement.

Supply Chain Analysis

One of the major challenges for electric automotive industry is to evolve a sustainable supply chain. Except Chinese makes like BYD and Yutong, all other BEB manufacturers have comparatively small production numbers and are limited to specific geographies.

Presence of a local manufacturer, Mobil Anak Bangsa (MAB) is a positive factor for Indonesia. Although, it is difficult to achieve cost effectiveness in comparison with the established Chinese players but secondary benefits like no import duty, employment for local people and ease of part replacement cannot be ignored. Joint ventures between local manufacturers and more experienced foreign companies like Build Your Dreams (BYD) can further help in evolvement to competitive supply chain for Indonesia.

III. RESEARCH METHODOLOGY

Research methodology uses both primary and secondary sources to collect the data and gather the information. The primary sources were obtained through interview and discussions with Head of Electric Bus Division, Transjakarta and General Manager, PLN. The secondary sources are based on desk research and articles about electrification of buses.

Data Analysis

As per the data collected from Transjakarta, 2217 conventional buses excluding micro buses are registered till Sep. 2019. As electric buses are not cost-effective solution for micro buses so far, these are not considered in analysis. In the next 10 years, all these buses are to be replaced with electric buses. High capital cost of electric buses, development of charging infrastructure and ensuring electric grid stability with mass adoption of electric buses are the main barriers identified during interview. However, training and maintenance requirement, operational challenges and range issues along with policies for the end use of batteries are also important. In the short term (pilot testing), it is planned to procure 100 electric buses. Two of these buses are already undergoing trial run and three are expected to reach by the end of this year. Remaining 95 buses will arrive in 2021.

Cost Benefit Analysis

In order to find most suitable solution for the replacement of electric buses, analysing the costs of e-buses compared with those of diesel buses considering the buses' total cost of ownership (TCO) is required. For electric buses, TCO refers to the overall costs of procuring and operating a bus over its useful lifespan, and is a reasonable metric to compare the costs of different bus technologies.

Buses on BRT corridors travel 250 km per day. Buses stop for 15-20 seconds at bus stops whilst passengers board and deboard the bus and for around 2-6 minutes at the end of the route prior before restarting operations. For the analysis of 12 m BRT buses, following types of e-buses each with different charging configurations are selected and compared with diesel buses:

- 490 kWh depot charged BEBs with 130 kW charger per bus.
- 110 kWh opportunity charged BEBs using 30 kW charger per bus for depot charging and 400 kW chargers for opportunity charging at the end of route.
- 60 kWh flash charged BEBs using 30 kW charger per bus for depot charging and 600 kW chargers for flash charging at bus stops.

Buses on non-BRT corridors travel 200 km daily. For non-BRT routes following configurations are considered:

- 350 kWh depot charged BEBs with 110 kW charger per bus.
- 110 kWh fast charged BEBs using 30 kW charger per bus for depot charging and 400 kW chargers for fast charging at terminals.

For BRT corridors fast charged BEBs are not considered as charging time for fast charged BEBs is 20-30 minutes while buses on BRT corridors run continuously with a time lag of 5-10 minutes in peak hour. During non-peak hours, which is generally 2-3 hours, approximately 30% buses return to the depots. 12m buses are considered for initial analysis as these are common for BRT as well as non-BRT routes. Also, electric buses are more cost effective for 12m size in comparison to longer18m buses and smaller 8m buses. Apart from this, various international manufacturers are producing 12m electric buses.

Results of TCO calculations for BRT routes considering unsubsidized fuel cost for diesel buses and adding pollution cost for different alternatives is as tabulated below:

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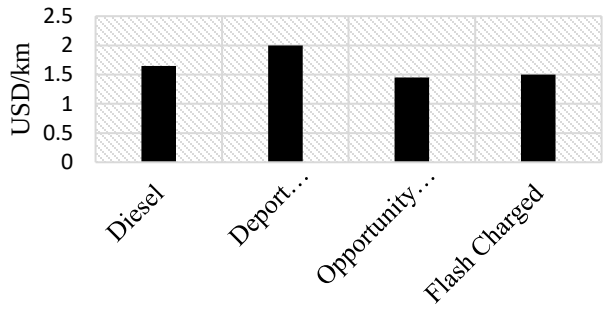

Fig. 1(a): TCO of Alternatives for BRT buses

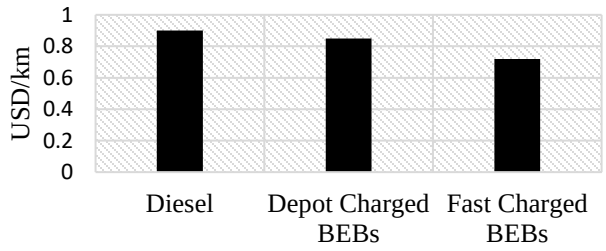

Fig. 1(b): TCO of Alternatives for non-BRT buses

Results obtained from TCO calculations are clearly indicating a trend towards BEBs. Fast charged BEBs are the best option for non-BRT routes where daily distance travelled in 200 km. Opportunity charged at the end of route is best suited for BRT routes where continuous service is required with daily distance of approximately 250 km and more. However, these results are indicating a positive trend only if cost of emission released by diesel and CNG buses in comparison with BEBs is taken into calculation. In order to determine the value of emission, all the parameters which can generate emission from well to wheel are considered and fuel consumption data is collected from Transjakarta. In the similar approach values for GHG emission for electric buses are calculated based on IEA electricity grid emissions and values are compared as shown in graph below:

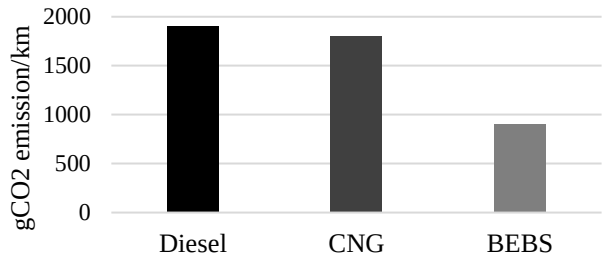

Fig. 2: Comparison of CO2 emission for diesel, CNG and BEBs

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From the graph it is clear that 12m BEBs can reduce GHG emission by around 50% compared to conventional diesel and CNG buses. When the cost of emission is considered in calculation, BEBs are not only cost effective but also helps in achieving goal 11 of sustainable cities and communities of United Nations Sustainable Development Program, Envision 2030.

IV. BUSINESS MODELS

Operating lease from manufacturers

An operating lease generally run for a short period of time, during which the operators or transit agencies gets to use the BEBs in return for rental payments. However, these payments do not cover the full cost of the buses and hence, additional components, like buses maintenance contracts are also part of operating lease. Although, all the risks and advantages of ownership are kept on the side of the leasing company, this option is most suitable for pilot testing (2-3 years) when transit agency/operators want to test electric buses under local operational conditions and are not sure about the requirements for the electrification of buses.

Best option for Transjakarta for pilot testing is operating lease in present pandemic situation. The results obtained from pilot testing shall be used to refine technical specifications for electric buses which will be helpful for the procurement of BEBs in future.

Battery Lease from manufacturers

One of the attractive ways of lowering capital costs of BEBs is battery leasing. It brings the capital costs of an e-bus closer to the level of a diesel city bus. The payments for the battery are included in fixed service agreement for the life time of battery or may be shorter depending upon the requirements. The savings in operational cost can be used for paying the battery lease.

This way, operators could not only purchase more electric buses but also reduce the risk around battery life and end use of battery. This option is most suitable for Transjakarta to accelerate the adoption of electric buses after pilot testing till there is uncertainty about battery life and end use of batteries.

Capital leases from third party or manufacturer

This option is considered a low-cost financing tool for operators and is often cheaper than the upfront purchase of an electric bus. The leasing company which remains the owner of the asset for a specified time can offer better condition than operator. In a capital lease agreement, transit agency/operator manages and operates the buses and after a specified period becomes their owner. The lease can be paid from operating revenue. A third-party financial institute can act as a debt financier or can procures and leases the buses to operators, with an option for bus operators to purchase the

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bus after a set number of years. This option is best suited for long term and it is scalable for procurement of large number of buses with lower upfront expenditure. Government can play an important loan in development of third-party financing. Many big manufacturers like BYD and Pare also provided this facility in collaborating with financing companies to accelerate the purchase of electric buses.

V. BUSINESS SOLUTION

In the present situation of pandemic, it is advisable to start the electrification of buses with minimum infrastructure development. Hence, it is advisable to opt for operating lease of 100 depots charged, 12m BEBs with battery capacity of 350 kWh. This is most effective solution for pilot testing as depot charging requires infrastructure installation only at depot. Also, there are no issues with respect to electricity supply and grid stability as the buses are overnight charged when the demand is low. Risk associated with battery replacement and uncertainty regarding end use of battery can be mitigated by operating lease.

These buses should be tested on various routes BRT and non-BRT routed of Transjakarta to get the information about following parameters:

- Range including variations based on route, passenger load, and AC requirements
- Vehicle Availability Rate due to maintenance, repair, and unavailability of charging infrastructure
- Charging Time and Energy Consumption including variations based on ambient temperature
- Driver and Public Satisfaction factors related to comfort, noise and air quality

However, these buses are not suitable for BRT corridors after 3 years of service when SOC (state of charge) of batteries will be dropped to 80%. For non-BRT corridors where daily travel requirement is 200 km only these buses are suitable even after SOC dropped to 80%. As the business model selected is operating lease, this will not create any problem in future. The data collected from pilot run will help Transjakarta to develop technical requirements for procurement of buses for various corridors in future.

Selection of right charging strategy and business model considering local requirements can help to resolve the barriers for adoption of electric buses. As the technology for BEBs is still developing it is very necessary for Transjakarta to stay updated with latest developments in the field and modify their requirements with the technological advancements. Most suitable solution in short, medium and long term for implementation of electric buses in present situation is as tabulated below. However, it is necessary to have a flexible approach for adoption of electric buses which can be modified with the changing technology and operational requirement

Table 1: Most appropriate solution to overcome barriers for implementation of e-buses in Jakarta

Barriers Description Short Term

Barriers	**Description**	**Short Term (2020 -2023)**	**Medium Term (2024-2026)**	**Long Term (2027-2030)**
	High Capital costs	Operating lease	Battery leasing	Capital lease
	Unclear second life options			Government regulation for end use of battery
	Falling battery price			Extended warranty
Charging Infrastructure	High capital cost	Bundling the price of the charger with bus during the tendering process.	Standardization of chargers to ensure interchangeability.	
	Land and space restrictions	Select type of bus and charging strategy considering space availability. Develop underground charging facilities if feasible.		Relocate bus stops or terminals
Electricity grid	Grid stability	Check grid stability in advance before procurement of buses. Solar panels can be used for meeting peak demand.		
Operations	Range and flexibility	Select battery capacity considering SOC, temperature and operational risks.		

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Vol 5, Issue 10, October 2020

	Issues		
	Lack of trained manpower and drivers	Provide training and set operational and maintenance procedures.	
Government support	Lack of government policies	Discuss with government to set clear and time bound targets and indirect incentives like	
Financing	Lack of financing institute	Bus manufacturers can act as leasing agencies.	Government guaranteed loans/ debt financing.

VI. MANAGERIAL IMPLICATIONS OF TRANSJAKARTA IN FUTURE

Electric mobility is still an evolving technology with significant scope for improvement in future. In view of this Transjakarta should select a business model that will play an important role in achieving financial, economic and operational sustainability.

After the pilot testing phase (short term), number of electric buses will increase significantly in medium and long term and hence, business strategy of Transjakarta will play a crucial role in electrification of buses. Some of the important managerial implications for Transjakarta include:

- Ridership assessment and route planning
- Infrastructure and operational planning
- Fleet selection and standardization of technical requirements
- Participate in tariff fixation to ensure operational efficiency
- Manpower training for drivers and others maintenance and technical people
- Developing standard operational and maintenance procedures
- Ensuring proper operation of electric buses and charging infrastructure
- Monitoring physical and financial performance of BEBs

CONCLUSION

Implementation of electric buses for public transportation is an excellent strategy considering reduction in oil imports, GHG emissions and for making Jakarta a sustainable city. Selection of right business strategy and innovative business models along with formulation of a long-term infrastructure and procurement plan can help in replacing conventional buses with BEBs.

In order to replace conventional buses with electric buses, coordination among various key stakeholders is necessary. Following key points are recommended to various stakeholders:

- Government to set clear targets for adoption of e-buses and form policies on reuse of batteries. Apart from that government shall provide fiscal and non-fiscal benefits to accelerate the transmission.
- Transjakarta to standardize technical requirements of e-buses and form a multilayer procurement policy considering charging strategy and business models.
- PLN shall work for standardization for charging stations and ensuring grid stability with mass adoption of e-buses.
- Operators shall work with manufacturers and look for the opportunity of operating, battery and capital lease with manufacturers which can help in reducing upfront cost.

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