Sustainable development impact of implementing electric taxis in Jakarta: A cost-benefit analysis

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Abstract. Due to issues in global warming in the world, the application of replacing fossil fuels to electricity is important to reduce air pollution, especially in the metropolitan area. In 2016, total emissions in Indonesia increased from 11th to 10th in the world and were the highest in ASEAN, so this became the focus in order to reduce emissions. What issues make efforts to change from conventional taxis to electric taxis an important measurement to achieve targets in energy-saving and reduce emissions because electric taxi has the potential to resource savings and to improve urban air quality. This study was conducted to diagnose the potential application of electric taxis by conducting a feasibility study, social impact, and environmental analysis in the implementation of the electric taxis to measure sustainability aspects. In the calculation process, the maintenance cost is estimated to be fixed. The results of this study from the cost-benefit analysis are expected to be able to contribute to the government and the private sectors for decision making towards increasing sustainability in Indonesia.

1. Introduction
The progress of a country can be seen from the factor of vehicle ownership and housing. Vehicles are strongly related to transportation. Transportation is one of the basic economic and social growth in a country. In Indonesia, the transportation sector creates many opportunities to employ people, for example, as drivers. The transportation sector, especially online transportation, can absorb a lot of labor, for example, such as motorbikes, catches, and online taxis. In addition, online transportation supports or provides services between goods and food, which means it has a positive impact on other businesses. Transportation also contributes to connecting people, which is a positive impact. In its negative impact, transportation certainly impacts air pollution, accidents, traffic jams, and noise.

Transportation is one source of GHG emissions and the main principle of air pollution, especially in urban areas. Transportation accounts for around 14% of global GHGs [1]. Increasing the amount of transportation is usually characterized by increasing urbanization, thereby increasing the demand for transportation itself, especially in developing countries like Indonesia. Based on the WHO, the GHG index in Indonesia accounts for around 9.2% of the world's GHGs. The GHG level of the transportation sector in Indonesia is high, especially in urban areas such as Jakarta, which reaches 24.71% [2]. To reduce GHG levels, one of them is changing the mode of transportation from conventional to electric transportation.

Under normal circumstances, electric vehicles do not produce GHG emissions or air pollution. Even if electrical energy sources are not obtained from combustion such as hydroelectric power, nuclear power plants or renewable sources, the use of electric vehicles will increasingly have a
positive impact on the environment and energy transfer [3]. The transition from conventional vehicles to electric vehicles is very difficult to implement because investing in electric vehicles requires a large investment fund. The reason is the price of electric vehicles that are more expensive when compared directly with the prices of conventional vehicles and fossil fuels.

It is reflecting on the difficulty of making a transition where the government must take the lead in starting the transition. At present, the private sector in Indonesia has begun the transition to electric vehicles, especially in public transportation. The establishment of a more sustainable urban mobility in Jakarta City has begun to be implemented by the private sector. The private sector sells transportation services with a taxi fleet. The launch of the Electric Taxi fleet starts in October 2018 with 19 fueling stations. From the implementation of electric taxis, it is expected to become more competitive, technically, financially, and environmentally. The public or other private parties may not be fast enough to accept this change. In this case, this allows the government to collaborate with the private sector, or the government can take the initiative to make the transition from conventional vehicles to electric vehicles to official vehicles in government.

Taxis in urban areas generally have characteristics of longer daily trips and longer distances than private cars. Private cars are usually only in the parking lot most of the day, so it does not affect greenhouse gas emissions. In terms of the time to stop on the road, taxis tend to be far longer than other vehicles, which will lead to taxis that will be much greater, causing an increase in greenhouse gas emissions and air pollutants compared to other vehicles. The distance traveled by taxi per day is much longer than a private car that usually sits in a parking lot most of the day. Based on these things, the environmental impact arising from conventional taxis will be disproportionately higher when compared to comparable private vehicles [4].

Based on that information, this study was conducted to diagnose the potential application of electric taxis by conducting a feasibility study, social impact, and environmental analysis in the implementation of the electric taxis to measure sustainability aspects in Indonesia. The paper is organized as follows. Section 2 describes the literature review and previous researchers about electric taxis. Section 3 describes the method to collect data and assumptions. Section 4 describes the results and discussion about feasibility and cost-benefit. Section 5 discusses some are concluding marks.

2. Literature Review

The application or transition from conventional vehicles to electric vehicles is basically to implement sustainable pillars that are expected to have a positive impact on human life. From an economic perspective, there is research on life cycle costs and the optimal capacity of batteries that have been carried out in China [5] and the US [6]. Then there is the research about scheduling that has been done in Taiwan by mixing conventional taxis and electric taxis [7]. From an environmental perspective, there is research on solar electricity production and the conversion of conventional taxis into electric taxis in Chile [8] and research on the magnitude of the impact of carbon dioxide resulting from the transition from conventional taxis to electric taxis in Brazil [9]. Research that examined the eco-environment as a result of the shift towards electric taxis has been done in Beijing [10] and Seoul [4].

Previous studies conducted on electric taxis mostly came from countries with high levels of greenhouse gas emissions except for Chile. When viewed regionally, these studies are in the American, European, and East Asian regions. China and the USA rank first and second for the world's greenhouse gas emissions index, while Indonesia ranks increased from 11th to 10th in the world and first ranks in the Asia Pacific [11].

Based on sustainability pillars, namely from the economic, social, and environmental aspects, which focus on renewable energy. Then seen from the aspect of developing countries and geographical regions of Indonesia where Indonesia really needs public transportation that is environmentally friendly and policy aspects where the ranking of GHG emissions in Indonesia continues to increase. Thus, an assessment of the feasibility study is needed to see as good an impact caused both economically, socially, and environmentally in Indonesia in making the transition to electric vehicles, especially in Jakarta City.
3. Method
Conventional taxis and electric taxis are the targets chosen in this study. This study uses face-to-face interviews with taxi drivers in gathering the required data. Conventional taxis that are used as objects are taxis with Toyota Vios models. The electric taxis used as the object are taxis with the BYD e6 A/T model. The data is obtained from face-to-face interviews and secondary data (Table 1.). The result from face-to-face interviews is mileage per day, trips per day, operational time per day, and maintenance cost per month. The secondary data are the initial investment is obtained for 30 cars, fuel capacity, price of fuel, and fuel used per km.

Table 1. Data obtained from interviews and secondary data.

| Explanation                             | Toyota Vios          | BYD e6 A/T           |
|-----------------------------------------|----------------------|----------------------|
| Investments for 30 units (IDR)          | 6,600,000,000        | 11,325,000,000       |
| Fuel Capacity                           | 42 liters            | 75 kWh               |
| Mileage (km/day)                        | 210                  | 210                  |
| Trips per day                           | 6                    | 7                    |
| Operational Time (hour/day)             | 16                   | 16                   |
| Maintenance Cost (monthly)              | 2,923,000/unit       | 20,000,000/unit      |
| Average Tariff per Trip (IDR)           | 170,000              | 197,000              |
| Fuel used per km                        | 0.09 liter           | 0.3 kWh              |

In addition to primary data from face-to-face interviews and secondary data, there are several assumptions. It is assumed there is no Value Added Tax (VAT) on Luxury Goods for electric taxis because they are still in the pilot project category and are assumed to be free from import duties. Besides, income tax is assumed to be pessimistic with a value of 20%, and the differentiation for taxis is 10% per year.

For data processing, this study calculates earnings after tax (EAT) to be able to facilitate the calculation of the Payback Period (PP). The Payback Period value is obtained by interpolating from the difference in investment value and earnings after tax per year. The final point of the interpolation results will be a minimum period to reach the Payback Period. Average Rate Return (ARR) is used to see the value of returns using the average value of EAT and the average value of the investment. This transition project will be considered feasible to be implemented if the ARR results show a positive value.

4. Result and Discussion
Table 2. shows the results of the calculations obtained by EAT for five years with a degree of freedom of 20% for conventional taxis and electric taxis. The interpolation results show that the transition project for electric taxis will reach the Payback Period of 3.489 years (Figure 1.). Table 3. shows the Average Rate of Return, Net Present Value (NPV), Profitability Index (PI), and Internal Rate Return (IRR) for both conventional taxis and electric taxis. ARR for implementing electric taxis in Jakarta City is 4.12% or equal IDR 2,211,291,506. The NPV for implementing electric taxis in Jakarta City is IDR 4,441,776,499. The relationship between cost and benefit in the implementation of electric taxis showed positive results with a PI of 1.34. The results show the IRR obtained a positive value with a value of 30.01.

Basically, it needs an assessment of the impact of the transition of conventional vehicles to electric vehicles, which is done by assessing the feasibility study. There are three feasibility assessments in this paper, namely: economic impacts, social impacts, and environmental impacts. The economic impact can be seen from the assessment of the feasibility study by knowing the value of the Present Net Value (NPV) and sensitivity factors to the comparison between conventional taxis and electric taxis. The calculation of electric vehicles is assumed not to apply Value Added Tax (VAT) for Luxury Goods and import duties. The economic impact on conventional vehicles is still considered feasible if
the Value Added Tax (VAT) on the cost of Luxury Goods and vehicle import duties are eliminated. Under the policy scenario, the impact of the transition to electric taxis has a positive economic impact.

**Table 2.** Earning after tax for conventional and electric taxis.

| Year | Conventional Taxis | Electric Taxis |
|------|---------------------|---------------|
| 2020 | 4,828,992,000       | 5,804,352,000 |
| 2021 | 6,277,689,600       | 7,545,657,600 |
| 2022 | 8,223,773,376       | 9,884,811,456 |
| 2023 | 10,855,380,856      | 13,047,951,122|
| 2024 | 14,437,656,539      | 17,353,774,992|

**Figure 1.** Payback Period for (a) Conventional Taxis and (b) Electric Taxis by interpolating from the difference in investment value and EAT per year.

**Table 3.** The results of calculations on conventional and electric taxis feasibility.

| Value  | Conventional Taxis | Electric Taxis |
|--------|---------------------|---------------|
| ARR    | 2,045,497,027       | 2,211,291,506 |
| NPV    | 3,189,628,464       | 4,441,776,499 |
| PI     | 1.33                | 1.34          |
| IRR    | 29.01               | 30.01         |

The sensitivity factor (Figure 2.) is obtained through an interpolation process based on the effect of increased processing costs due to inflation and the effect of investment on NPV. Sensitivity values are seen in positive and negative NPV, where a positive Degree of Freedom factor is found at 30%. The sensitivity factor on a positive NPV with the Degree of Freedom 30% will affect the company's cash value, which refers to the Internal Rate Return (IRR). The sensitivity value obtained is based on the zero points of net cash received by the company, the Degree of Freedom limit cannot be less than 20% if it exceeds the assumption then it is assumed that electric taxis in Indonesia are not feasible to be implemented. Whereas the sensitivity factor on negative NPV with a Degree of Freedom value of 31%, can be seen in Figure 2. This provides an explanation of the economic impact based on a Degree
of Freedom sensitivity value of more than 20%, which is declared feasible in the implementation of electric taxis in Jakarta City.

**Figure 2.** Sensitivity factors in positive and negative NPV for electric taxis.

Social impacts have a significant effect if the government provides incentives for exemptions and import duties. However, the social impact on the community can also be seen from environmentally friendly electricity, and also reduces the costs of refueling. It is known that the current price of electricity is IDR 1,026 per kWh while the price of fossil fuels is IDR 6,450 per liter, conventional vehicles will cost IDR 580.50 per kilometer, and electric taxis will spend IDR 153.90 per kilometer. In the scenario of conventional taxis and electric taxis traveling 210 kilometers per day, the cost savings incurred by electric taxis are 3.77 times more than conventional taxis. Conventional taxis will cost IDR 121,905 at a distance of 210 kilometers, while electric taxis will only cost IDR 32,319. This will provide a good social impact on electric taxi users in Jakarta City, which can save up to 73.48% per day, which should be spent on conventional taxis.

It is assumed that in one day, 30 conventional vehicles are operating with a distance of 210 km per vehicle and assuming each vehicle consumes 1 liter of fuel every 11.11 kilometers. Table 4. shows the environmental impacts that occur based on the level of pollution generated by vehicle fumes per day from emission load estimation in Indonesia [12]. If electric vehicles operate in Indonesia with a total of 30 vehicles, it will reduce SO$_2$ and NOx air pollution by 2.47% per day.

**Table 4.** The environmental impact obtained from each conventional vehicle per day.

| Category        | CO (g/km) | HC (g/km) | NOx (g/km) | CO$_2$ (g/km) | SO$_2$ (g/km) |
|-----------------|-----------|-----------|------------|---------------|---------------|
| Motor Cycle     | 0.088     | 0.037     | 0.77       | 152.972       | 0.021         |
| Car (Gasoline Fuel) | 0.252     | 0.025     | 15.12      | 437.062       | 0.197         |
| Car (Diesel Fuel)  | 0.018     | 0.001     | 1.85       | 30.517        | 0.233         |
| Bus             | 0.069     | 0.008     | 24.74      | 119.890       | 1.933         |
| Truck           | 0.053     | 0.011     | 28.10      | 91.552        | 1.302         |
| Total           | 0.480     | 0.083     | 70.58      | 831.992       | 3.686         |
5. Conclusion
In a small effort to improve urban air quality in Indonesia, investigate the economic feasibility of the transition from conventional taxis to electric taxis in Jakarta City. This study uses an approach to replace current conventional taxis into electric taxis. The transition to the public transportation sector will be relatively easy if the government can provide incentives in the form of free import duty for the procurement of electric taxis by private sectors.

In the cost-benefit analysis for the transition to electric taxis, it gives a significant economic impact on the cost of purchasing a vehicle based on the given scenario. On the benefits side, the increase in social benefits is seen from the reduction or more cost savings incurred up to 73.48% in the use of electric taxis compared to conventional taxis (gasoline fuel). Improving air quality in Jakarta City is one of the benefits to the environment. From the environmental side, it is reducing air pollution by 2.47% per day (SO$_2$ and NOx) in the implementation of 30 electric taxis. The results show the implementation of electric taxis in Jakarta City has a positive impact on aspects of sustainability in terms of economic, social, and environmental. The policy that can be taken by the government is to collaborate with certain private sectors to be able to provide free import duty for the procurement of electric vehicles that are used as public transportation.

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References
[1] Santos G 2017 Road transport and CO$_2$ emissions: What are the challenges? Transport Policy 59 71–4
[2] Center for Data and Information Technology ESDM 2017 Study on the Use of Local Emission Factors (Tier 2) in the Energy Sector GHG Inventory (Jakarta: Center for Data and Information Technology ESDM)
[3] Aziz M, Huda M, Budiman B A, Sutanto E and Sambegoro P L 2018 Implementation of Electric Vehicle and Grid Integration 2018 5th International Conference on Electric Vehicular Technology (ICEVT) (Surakarta) pp 9–13
[4] Kang SC and Lee H 2019 Economic appraisal of implementing electric vehicle taxis in Seoul Research in Transportation Economics 73 45–52
[5] Deyang K, Dan M and Minmin W 2016 A Simulation Study of Upgrading Urban Gasoline Taxis to Electric Taxis Energy Procedia 104 390–5
[6] Hu L, Dong J, Lin Z and Yang J 2018 Analyzing battery electric vehicle feasibility from taxi travel patterns: The case study of New York City, USA Transportation Research Part C: Emerging Technologies 93 91–104
[7] Lu C-C, Yan S and Huang Y-W 2018 Optimal scheduling of a taxi fleet with mixed electric and gasoline vehicles to service advance reservations Transportation Research Part C: Emerging Technologies 93 479–500
[8] Girard A, Roberts C, Simon F and Ordoñez J 2019 Solar electricity production and taxi electrical vehicle conversion in Chile Journal of Cleaner Production 210 1261–9
[9] Teixeira A C R and Sodré J R 2016 Simulation of the impacts on carbon dioxide emissions from replacement of a conventional Brazilian taxi fleet by electric vehicles Energy 115 1617–22
[10] Shi X, Wang X, Yang J and Sun Z 2016 Electric vehicle transformation in Beijing and the comparative eco-environmental impacts: A case study of electric and gasoline powered taxis Journal of Cleaner Production 137 449–60
[11] Janssens-Maenhout G, Cippa M, Guizzardi D, Muntean M, Schaaf E, Olivier J G J, Peters J A H W, Schure K M 2017 Fossil CO$_2$ and GHG emissions of all world countries (Luxembourg: Publications Office of the European Union)
[12] Novianti S and Driejana 2010 The influence of factor emission characteristics in transport-induced nitrogen oxides (NOx) emission load estimation (Case study: karees area, bandung) *Jurnal Teknik Lingkungan* **16** 185–98