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Analysis of Electric Bus Utilization for Urban Transport using Bus Route, Passenger Demand and Fuel Consumptuion (Blok M-Kota Corridor Case)

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ABSTRACT

Buses as a means of public transportation can greatly reduce traffic problems in urban areas through the use of, among other things, innovative techniques and technologies. The development of innovative technologies increasingly oriented towards the electrification of vehicle propulsion systems is expected to lead to the reduction of harmful emissions, increased vehicle efficiency, improved performance, reduced fuel consumption, and reduced noise. This study aims to determine the comparison of Transjakarta electric buses with conventional buses owned by Transjakarta, identify and evaluate the condition of the electric bus side. This study uses quantitative methods. The results of the study show a comparison of the operational cost calculation as indicated by the calculation of direct costs and indirect costs. The unit price for a bus/km for a diesel bus is Rp. 51,796, on the electric bus Rp. 224,991, and BBG buses for Rp. 82,227. where in the comparison of BOK diesel buses are cheaper than electric buses and CNG. The most expensive cost is the replacement of spare parts, especially the price of the battery which needs to be replaced every 10 years. 3,876, while bbg buses require much cheaper, which is Rp. 630. The calculation results of the electric bus battery consumption on the use of 1 route with a distance of 30.8 on weekdays on average 11.5% while on weekends it is 9.5%. At the kWh consumption, the electric bus requires the consumption of kWh per trip with a distance of 31.4 km is 23.57 kWh. From this value, it is known that the efficiency is 1.3 km/1 kWh. In charging the battery, the average battery charging time on the electric bus is 134 minutes or about 2.23 hours.

Keywords: electric bus; vehicle operating cost; comparison of electric bus; battery charging time; transjakarta.

INTRODUCTION

Transportation is one of the main needs of the community in an area, namely to support daily activities. Public transportation can be divided into several types, including air transportation, sea transportation, land transportation, one of which is buses. Buses as a means of public transportation can greatly reduce traffic problems in urban areas through the use of, among other things, innovative vehicle drive system techniques and technologies. The development of innovative technologies increasingly oriented towards the electrification of vehicle propulsion systems is expected to lead to: reduction of harmful emissions, increased vehicle efficiency, improved performance, reduced fuel consumption, reduced noise, and potentially lower maintenance costs. One of the public transportation that is currently the mainstay of the people of the capital city of DKI Jakarta is the Transjakarta Bus. Transjakarta is currently reviewing various aspects of switching from oil-fueled (BBM) and gas-fueled buses to electricity. One of them is in terms of operational costs. This step is the company's commitment to support efforts to handle air pollution and emissions in DKI Jakarta through battery-based electric motorized vehicles (KBLBB) which shows in Government regulation No. 55 of 2019 concerning the Acceleration of Battery Electric Motorized Vehicles (Battery Electric Vehicles) and refers to the Instruction DKI Jakarta Governor Number 66 of 2019 concerning Air Quality Control in Jakarta and is the mandate of PT. Jakarta Transportation in Regional Strategic Activities (KSD) number 71 concerning air pollution control with

plans for implementing environmentally friendly transportation modes. Transjakarta buses have undergone many changes, both rapidly and gradually. These changes include improvements in terms of facilities, fleet, routes. The purpose of the change is to improve service to passengers. This electric-fueled bus has several advantages compared to conventional buses, such as not causing pollution, relatively low maintenance costs. With a battery that can be recharged for a maximum of 4 hours, this electric bus can go up to 250 kilometers.

Transportation planning is something that is necessary and must be carried out in every decision making. Good decision making will have an impact on the influence of well-implemented urban transportation. Transportation conditions in urban areas greatly influence the condition of many vehicles passing through the urban transportation system. The urban transportation system will influence the basic concept of transportation problems in the future (Syaiful S et.al, 2023; Syaiful S et.al, 2022; Syaiful S et.al 2021).

RESEARCH METHODS

The location where this research is located is in corridor 1 with the Blok M - Kota route, where the route is a route that is passed by the Transjakarta electric bus. The study was carried out for 6 months starting from January 2022, the research location is shown in Figure 1.

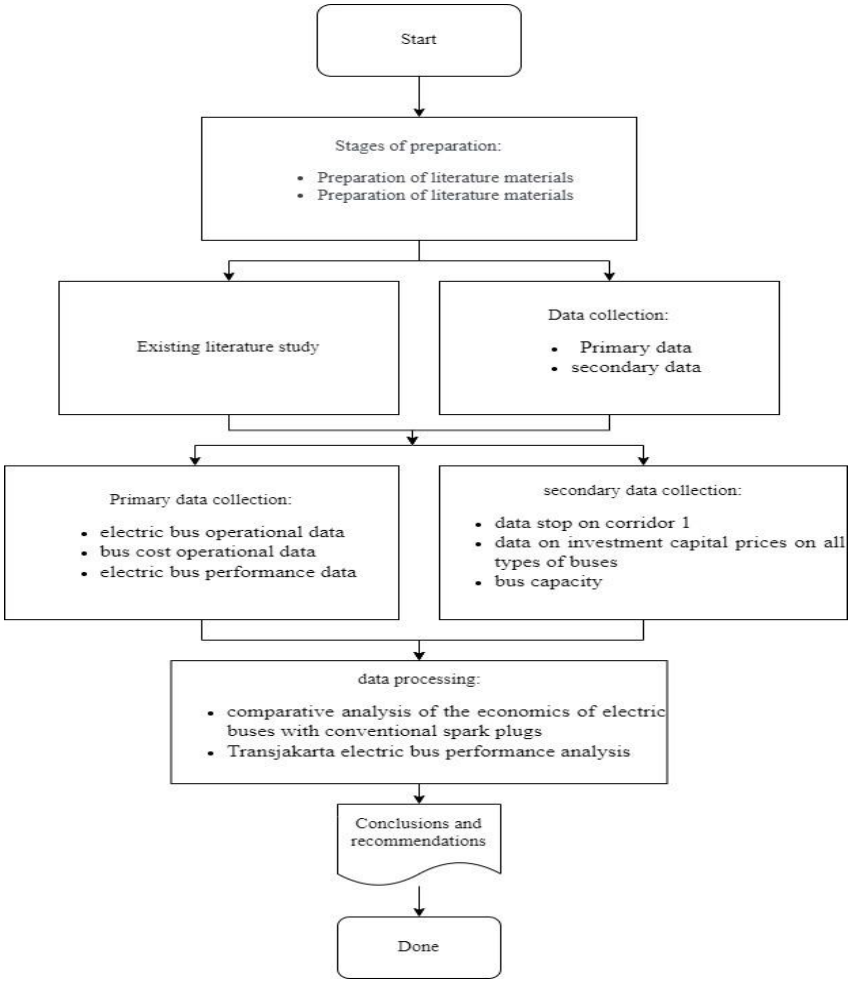

Figure 1. researcher flow chart

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Data Analysis

The largest manufacturer of 12m electric buses is BYD and the largest fleet is located in Shenzhen which started using electric buses in January 2011 and now operates about 1,300 full electric buses produced by BYD and Wuzhoulong basically. Shenzhen is by far the largest fleet of electric buses worldwide while Zhengzhou is operating since 2011 a fleet of 10 electric buses which was expanded to 110 units by the end of 2013. Zhengzhou is operating since 2011 10 Yutong electric buses with a length of 12m and a passenger capacity of 60 people. These buses do not have air conditioning, resulting in limited use of the unit during the hot summer months. At the end of 2013 100 new units were acquired with AC. Under standard traffic conditions the electric bus has a range of 120 km with an overnight charge time of 8 hours. New buses and charging stations allow fast charging with a duration of 2.5 hours. (Grutter Consulting, 2015).

Table 1. Comparison of energy consumption of electric buses with diesel buses

Type of Bus	Electric Bus	Diesel Bus
Energi Consumption	100 kWh/100 km	40 l/100 km

Source: Zhengzhou Bus Communication Company, 2014

RESULTS AND DISCUSSION

Vehicle Operating Expenses (BOK)

Vehicle Operating Costs (BOK) are costs that are economically incurred due to the operation of a vehicle under normal conditions for a particular purpose. Vehicle Operational Costs (BOK) in this study uses the Technical Guidelines for the Implementation of Public Transportation in Urban Areas in Fixed and Regular Routes in the form of a Decree issued by the Directorate General of Land Transportation (SK.687/AJ.206/DRJD/2002).

Table 2. Operational Cost of Diesel Bus

Cost component	Cost (Rp)
1. Direct Costs	
a. Cost of depreciation	184.000.000
b. Capital Interest	1.656.004
c. bus crew salaries and allowances	6.700.000
d. Diesel cost	3.876
e. Tire Cost	1.300.000
f. battery cost	1.200.000
g. Small Service	815.180
h. Large maintenace	7.660.180
i. Addition of engine oil	1.755,32
j. Bush Cleaning	2.400.000
k. STNK	4.390.000
Amount	**210.126.995**
2. Indirect Cost	

a. Employee fees other than bus crew	38.496.000
Grand Total	**248.622.995**
Grand Rp/Km	**51.796**

Based on the BOK calculation data in table 4.3 the direct cost of the diesel bus is Rp. 210.126.995 and the indirect cost is Rp. 38.496.000. total direct and indirect costs of Rp 248,622,995. So the unit cost of the bus/km is IDR 51,796.

Table 3. Operational Cost of Electric Bus

Cost component	Cost (Rp)
1. Direct Costs Biaya langsung	
a. Cost of depreciation Biaya Penyusutan	400.000.000
b. Capital Interest Bunga Modal	45.000.004
c. Backup Battery Charge	579.058.000
d. bus crew salaries and allowances	6.700.000
e. Charging Fee	1.172
f. Tire Cost	1.901.000
g. Bush Cleaning	2.400.000
h. Service	1.145.000
i. STNK	1.457.000
Amount	**1.037.662.176**
2. Indirect Cost	
a. Employee fees other than bus crew	38.496.000
Grand Total	**1.079.158.176**
Grand Tota Rp/Km	**224.200**

Based on BOK calculation data on electric buses, direct costs are Rp. 1,037,662,176 and indirect costs are Rp. 38,496,000. total direct and indirect costs amounted to Rp 1,079,158,176. So the unit cost of the bus/km is IDR 224,200.

Tabel 4. Operational Cost of BBG Bus

Cost component	Cost (Rp)
1. Direct Costs	
a. Cost of depreciation	296.000.000
b. Capital Interest	33.300.004
c. bus crew salaries and allowances	6.700.000
d. Diesel cost	630
e. Tire Cost	1.300.000
f. battery cost	1.875.000
g. Small Service	2.400.000

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h. Large maintenace	7.616.000
i. Addition of engine oil	1.755,32
j. Bush Cleaning	2.400.000
k. STNK	4.600.000
Amount	**356.193.389**
2. Indirect Cost	
a. Employee fees other than bus crew	38.496.000
Grand Total	**394.689.389**
Grand Total Rp/Km	**82.227**

Based on BOK calculation data on gas-fueled (BBG) buses, direct costs are Rp. 356,193,389 and indirect costs are Rp. 38,496,000. total direct and indirect costs of Rp. 394,689,389. So the unit cost of the bus/km is IDR 82,227.

Fuel Comparison Per km

Comparison of the cost of raw materials per 1 kilo meter, it can be seen that gas-fueled (BBG) buses in this case Zhongtong require lower costs when compared to electric and diesel buses. For a kilometer distance, the Zhongtong bus costs Rp. 630, the BYD bus costs Rp. 1,172, while the diesel bus, namely Scania, is much higher, at Rp. 3,876. Gas fuel consumption is indeed much cheaper where 1 lsp zhongtong bus can reach 1.4 km. In Figure 2.

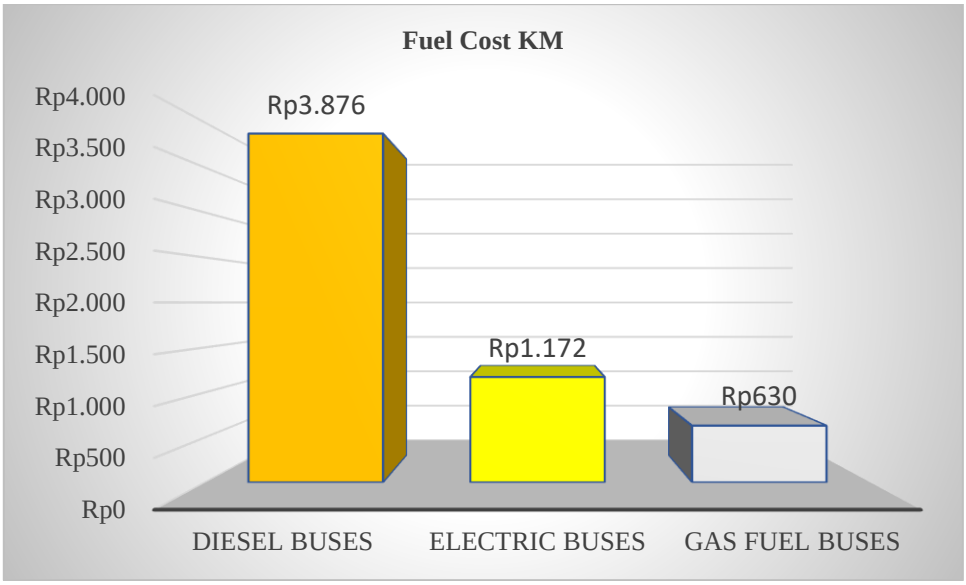

Figure 2. Comparison diagram of fuel cost per kilometer

Fuel Ratio Per Ritage

Comparison of the cost of material talent per trip with a distance of 25.8 km, it can be seen that gas-fueled (BBG) buses in this case Zhongtong require lower costs when compared to electric and diesel buses. At a distance of 30.8 km, Zhongtong costs Rp. 19,404, the BYD bus costs Rp. 36,082 while the diesel bus, Scania, costs Rp. 119,381 for fuel. Gas fuel consumption is indeed much cheaper where 1 lsp zhongtong bus can reach 1.4 km. In Figure 3.

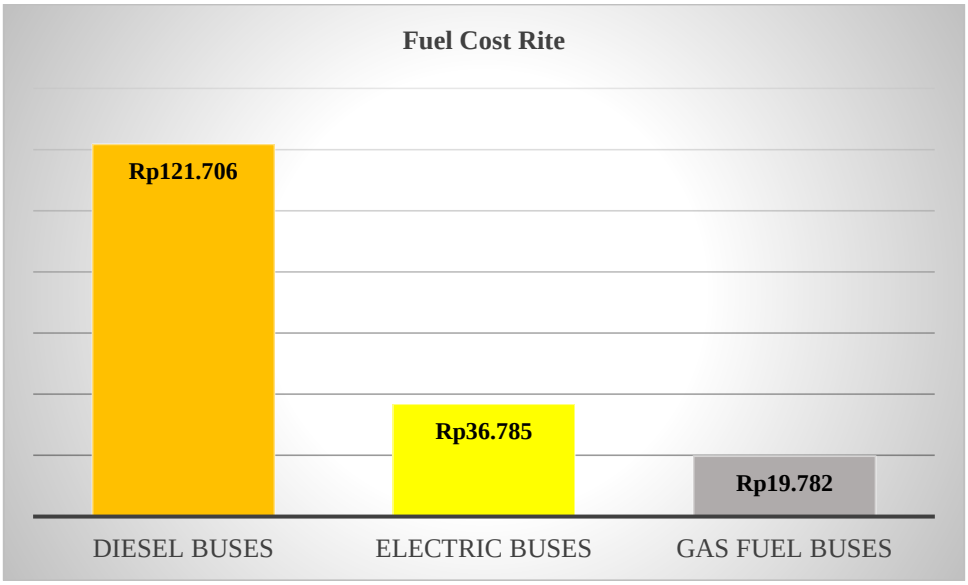

Figure 3. comparison of rit fuel costs

Electric bus performance analysis

Battery consumption

In collecting trip kWh data on 31,1,2,3,4,5,6 January and February 2022. The surveyor conducted a survey on the bus, following the bus through the departing and returning routes. Surveyors take a bus from Terminal Blok M via the departing route and then after arriving at the City Stop using the same bus that will depart via the return route to Blok M.

To ensure that the bus can run until it reaches its destination, it is also necessary to monitor the condition of the battery during the trip with a distance per trip of 31.4 km. On Monday when the bus travels to the departure of Blok M to the city the battery is not fully charged 82%, and on the return trip with the remaining battery 71% On Tuesday when the bus travels to the departure of Blok M to the city the battery is not fully charged 85% , and rit home with 73% battery remaining. On wednesday when the bus travels to the departure of Blok M to the city the battery is not full 86%, and it is back home with 75% battery remaining. On thursday when the bus travels to the departure of block m to the city the battery is not full 86%, and it is running back home with 73% battery remaining. On Friday when the bus travels to the departure of Blok M to the city, the battery is not fully charged at 85%, and it is running back home with 73% battery remaining. And the average battery consumption on electric buses on weekdays per trip is 11.8%. On a high battery consumption, namely on Thursday 13% with conditions there are traffic jams at several points. The amount of battery consumption for the Transjakarta electric bus during the trip on weekdays can be seen in Figure 4.

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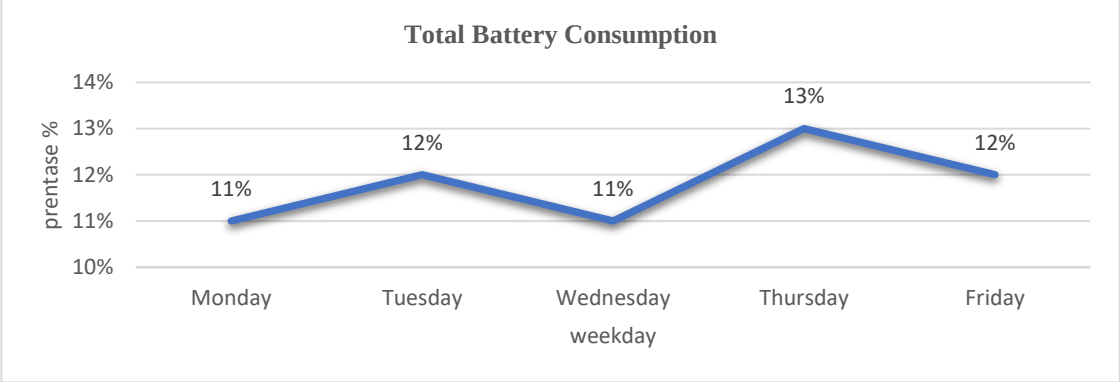

Figure 4. Weekday total battery consumption

On weekends, namely Saturdays, when the bus travels to block m departing to the city, the battery is not full 85%, and returns home with 76% battery remaining. On Sunday Hours when the bus travels to the departure block m to the city the battery is not 90% full, and it is running back home with 80% battery remaining. And the average battery consumption on electric buses is 9.5% on weekends. The amount of battery consumption for the Transjakarta electric bus during the trip on weekends can be seen in figure 5 below.

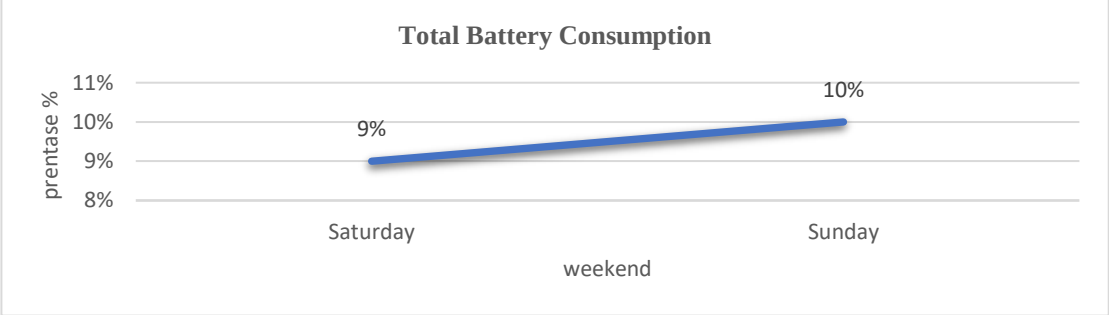

Figure 5. Total weekend battery consumption

Travel kWh consumption

Based on a field survey on weekdays or weekday routines Blok M – Kota, the electric bus runs a distance of 31.4 km, the kWh issued on Monday is 13 kWh, on Tuesday trips it is 16 kWh, on Wednesdays it is 16 kWh, on Tuesdays it is 16 kWh. Thursday 16 kWh. and on Friday the issued kwh is 13 kWh. Consumption kWh The total battery consumption of the Transjakarta electric bus during the trip on weekdays can be seen in the picture.

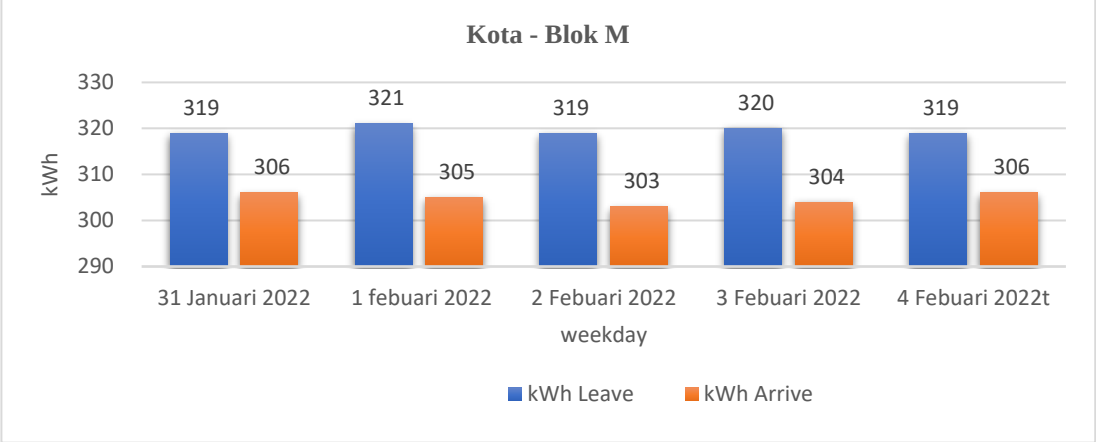

Figure 6. Blok M Diagram – Kota weekday

On weekends or weekend rit blocks m - city, the kWh issued on Saturdays is 12 kWh, on Sunday trips it is 13 kWh. kWh consumption The total battery consumption of the Transjakarta electric bus during the trip on weekends can be seen in figure 7 below.

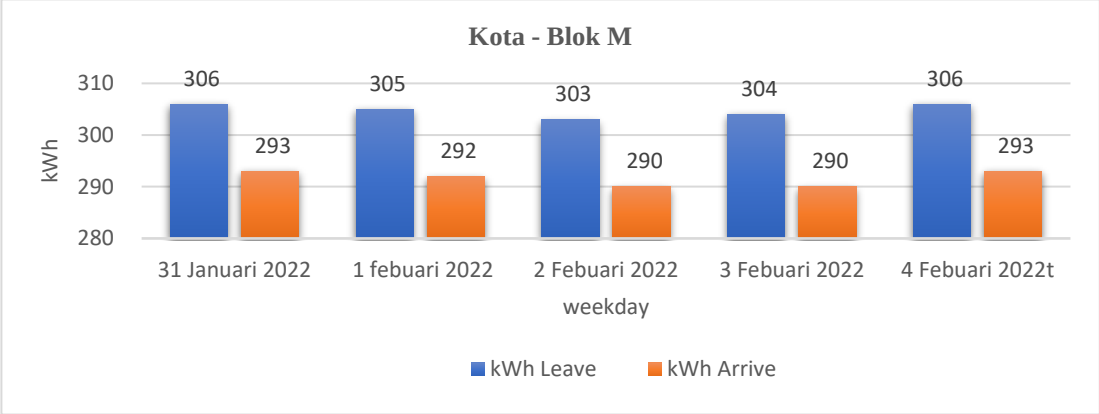

Figure 7. Block M Diagram – City weekend

Based on data on the number of kWh consumption on the Blok M - Kota trip and Kota - Blok M trip, the Monday trip was 26 kWh, the Tuesday trip was 29, the Wednesday trip was 29, the Thursday trip was 30 kWh, and on Friday it was 30 kWh. 26 kWh. And trips on weekends, Saturday trips are 25 and on Sundays are 26 kWh. The total consumption of kWh per trip with a distance of 31.4 km is 23.57 kWh. From this value, it is known that the efficiency is 1.3 km/1 kWh.

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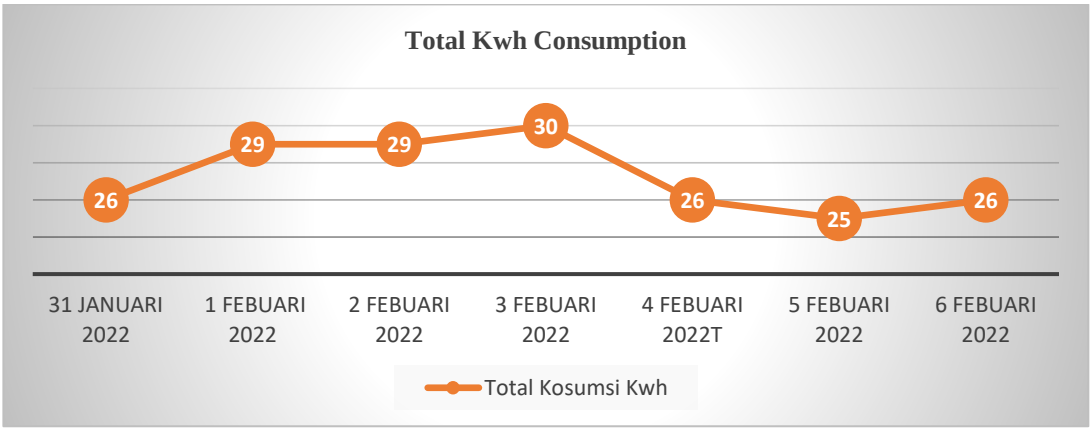

Figure 8. Total kWh consumption

Charging Duration Analysis

Charging is a different "recharging" paradigm from gas stations. Refueling vehicles at gas stations usually only takes about 10 minutes to fill our gas tank, with a fairly short time at least it's enough for just a restroom or buying drinks, buying food at fast food restaurants. So it's just a short stop to refuel, then get back on the road as fast as you can. So it's unthinkable to spend a long time at the gas station. Charging electric vehicles at SPKLU takes quite a long time. Charging an electric vehicle takes anywhere from 15 minutes to several hours. Therefore, there needs to be a change in mindset. The electric car driver's mindset needs to plan charging time to do other things while charging the vehicle. This includes shopping, eating at a restaurant, maybe watching a movie, a business meeting and so on.

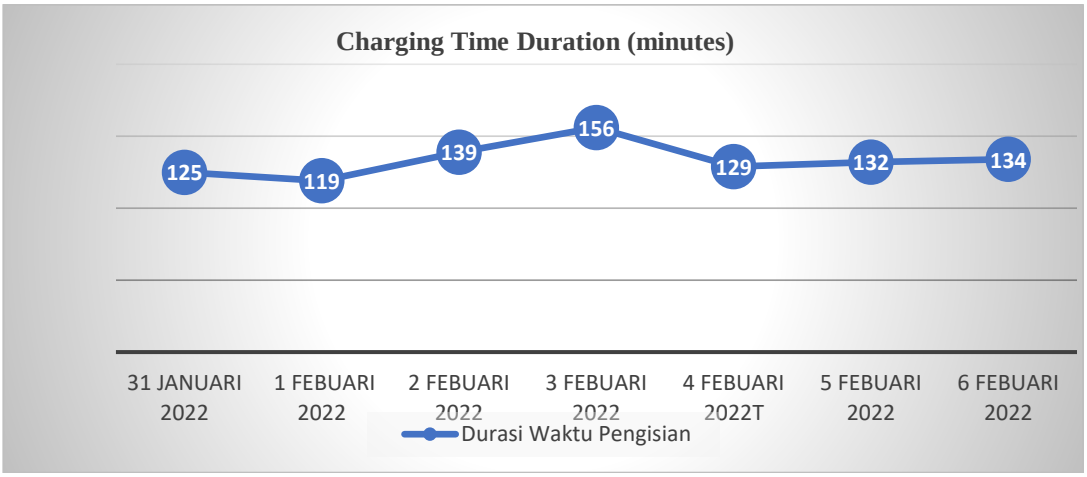

Figure 9. Battery charging duration

The charging process is carried out when the bus returns to the pool after operating, on Monday when the battery condition arrives to 25% and the charging process to 100% is carried out for 125 minutes, on Tuesday when the battery condition arrives at 28% and the charging process to 100% is carried out for 119 minutes, on wednesdays the charging process is carried out for 139 minutes with the remaining 28% battery when it arrives and the charging process is up to 100%, on thursday when it arrives the battery condition is 23% and the charging process is up to 100% taking 156 minutes, and on the day Friday when it arrives the battery condition is 33% and the charging process is up to 100% by taking 129

minutes of charging time, while on Saturday when it arrives the battery condition is 30% and the charging process is up to 100% with 132 charging time, and on Sundays Charging takes 134 minutes. the average battery charging time on the electric bus is 134 minutes or about 2.23 hours.

CONCLUSION

Based on the results of the analysis and discussion, it can be concluded, as follows, cmparison of the calculation of BOK indicated by the calculation of direct costs and indirect costs. The unit price for a bus/km for a diesel bus is Rp. 51,796, on the electric bus Rp. 224,991, and BBG buses for Rp. 82,227. where in the comparison of BOK diesel buses are cheaper than electric buses and CNG. The most expensive cost is the replacement of spare parts, especially the price of batteries that need to be replaced every 10 years. Based on the results of the comparative analysis of electric buses and conventional buses Rp./km where electric buses cost Rp. 1,172, diesel buses cost Rp. 3,876, while bbg buses require much cheaper, which is Rp. 630. The results of the calculation of the electric bus battery consumption on the use of 1 route with a distance of 30.8 on weekdays on average 11.5% while on weekends 9.5%. At the kWh consumption, the electric bus requires the consumption of kWh per trip with a distance of 31.4 km is 23.57 kWh. From this value, it is known that the efficiency is 1.3 km/1 kWh. When charging the battery, the average battery charging time on the electric bus is 134 minutes or about 2.23 hours.

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