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ESTIMATING POWER NEEDED TO FUEL ELECTRIC PARATRANSITS IN BANDUNG

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Abstract

This is the preliminary finding of a study elaborating the total energy consumption when paratransits in Bandung are altered into electric and the scenario to fulfill it. Therefore, there are lots to be done further concerning result of this initial research, of which will be discussed in another publication. In this paper calculation was done to find out the volume of power needed to fuel electric paratransits in Bandung. Steps carried out include computing total energy consumption for all paratransits, clustering stations from classified routes established by local Department of Transport, and estimating the electricity demand in every clustered station. Data used for this study was acquired from *Badan Pusat Statistik Kota Bandung* and *PT PLN DJA APD Jawa Barat and Banten*. A total demand of 61.12 MWh per month will surface to charge the total of 5,521 paratransits from 38 available routes in 15 clustered stations under the assumptions that all paratransits only make 6 return travels per day, operate 30 days per month, and use batteries with 50% State of Charge.

Keywords: transportation; electric paratransit; in town; electricity demand; feasibility study.

I. INTRODUCTION

Functioning in a small yet busy city, Bandung transportation is excessively active while on the other hand pollution it produces is too much. These facts make Bandung a potential project site for electric car initiative. Despite its pricey purchase cost [1], electric vehicle (EV) provides solution to lower pollution level and operation as well as maintenance costs reduction [2-5]. Best when applied for mass transport [6] for the sake of more pollution cutback, electric vehicle conversion then could be suitable when implemented to paratransit.

Existing research on Indonesian paratransit mainly discuss about general problems surrounding paratransit [7-9], tariff, service and customer perception [9, 10], the effect of air pollution it creates [11, 12], driver welfare [13-15], routes and programming [16-19], paratransit stop design [20], and feasibility on fleet addition [21]. On Bandung paratransit in particular, main

research were done related to user satisfaction [9, 22, 23] and feasibility of electric paratransit initiative [24] which emphasizes on cost rather than energy implication.

As the pilot of a more comprehensive research, this paper is limited only to find out total electricity should be made available by the government to guarantee full operation of paratransits when they are converted into electric in Bandung. Conversion could cover retrofitting the available paratransit into electric or procure a full brand new electric vehicle for paratransit. How the demand would be satisfied is beyond the scope of this paper.

II. METHODOLOGY

This study was done according to simple steps illustrated in Figure 1. With single aim of giving rough estimation of energy demand when paratransits in Bandung turned electric, these following factors are not taken into account in all calculations performed. It has to be born in mind that this study assumes all routes to have the

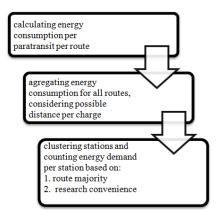* Corresponding Author.Tel: +62-22-2503055
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Figure 1. Methodology of this study

same topology, hence using average energy consumption. It is known that topology, traffic, driving style and temperature are of factors affecting energy consumption in EV [25]. In reality, routes topology probably a lot differs, resulting bias from the calculated energy consumption, either too high or even too low. Moreover, it was presumed that electric paratransits are retrofitted into electric using electric motor that still fulfills the function of their old internal combustion engines and fueled using lead acid batteries. Furthermore, regardless distance of each route, all routes are supposed to travel 6 returns per day. Actually, they can travel less and often, more. This will affect the concrete total energy consumption as well. To provide a glimpse of what is paratransit, Figure 2 displays the multicolored paratransits in Bandung whose colors define routes [26].

Using basic retrofitted paratransit in [24], presuming power consumption of retrofitted paratransit would be 500 Wh/mile, lead acid battery energy of 31,680 Wh and battery State of Charge (SoC) of 50%, maximum distance that can be obtained per charge is approximately 51 km. There are 5,521 paratransits available in Bandung, accommodating 38 routes with route distances range from 7 to more than 24 km one way [27].

For each route, first thing done was calculating kilometer traveled per day for each vehicle, which is 6 returns or equals to 12 times one-way distance. Using 1 mile = 1.61 km, we got energy consumption of 310.56 Wh/km. Considering vehicle load which is about to carry 15 people, this number is in line with other research where a Smart ED of 2 passengers consumes 0.17 Wh/km [28] and another passenger vehicle consumes an average of 0.62 MJ/km [29] or 172.22 Wh/km when air conditioner is off. By multiplying this energy consumption per kilometer with total distance traveled per day, energy consumption per day per vehicle was found. Multiplying again this number

with the quantity of paratransit per route, energy consumption of all paratransits per route per day then is resulted. To find total energy consumption for all paratransit, energy consumptions of all paratransits from all routes were aggregated.

Next step was clustering the avalaible routes to classify paratransits in which route should be charged in which station. Clusters are set in compliance with route and station convenience, and rough observation of paratransit in which route usually be mostly parked in or near which station. Routes, distance of each route, total energy consumption and alternative clustering are recapped in Table 1.

III. RESULTS AND DISCUSSION

Total energy needed per day to run all retrofitted paratransits in Bandung is 2,037,397.824 Wh. This makes 61.12 MWh per month. Albeit an official yet confidential data obtained from PT PLN APD Jawa Barat and Banten [30] which seems like a safe supply for the charging needs, it does not mean that charging process can be done anywhere at any time. Mapping should be done in defining which nearest main distributing point can supply the power and at what time slot charging should be done to make sure electricity is sufficiently available, hence preventing blackout. This will be covered in another paper.

As this is a paper that leads to a feasibility study and not analyzing present application, scenario concerning number of paratransits involved in this electrification project can actually later be extrapolated. This is critical to define which number will match Bandung capability in providing electricity to support e-paratransits. Extrapolation can be executed concerning degree of electrification covering which routes should be involved, number of altered paratransits per route, work hours, number of travels and State of Charge (SoC).

Lessening routes number will decrease the power demand. From road topology point of view, this would be wise if implemented to routes that have hilly road topology. Hilly road calls for higher energy consumption than estimated, hence higher energy demand. For shorter routes (10 km and below), e-paratransit application would be convenience as charging can be done after 2-time returns. Cutting the number of paratransits to be converted to electric will cut the total energy consumption as well. Not to mention reducing the number of work hour and travels per day. In contrast, lowering or increasing SoC will not have significant effect to total energy consumption. To charging process, the action

Table 1.
Total energy consumption and proposed stations clustering

No.	Route*	Distance* (km)	Σ Distance/way /station (km)	Σ Vehicles /route (units)	Σ Vehicles /station (units)	Energy consumption /12 way or a day (Wh)	Σ Energy consumption /station/day (Wh)	Clustered station name
1	Abdul Muis – Cicaheum via Binong	16.30		369		60,746		
2	Abdul Muis – Cicaheum via Aceh	11.55	48.15	100	595	43,044	179,441.57	1. Abdul Muis
3	Abdul Muis – Elang	9.75		101		36,336		
4	Abdul Muis – Mengger	10.55		25		39,317		
5	Abdul Muis – Dago	9.30		273		34,658		
6	Stasiun Hall – Dago	10.00	39.90	52	526	37,267	148,696.13	2. Dago
7	Dago – Riung Bandung	20.60		201		76,770		
8	Abdul Muis – Ledeng	16.00		245		59,628		
9	Cicaheum – Ledeng	14.25	50.05	214	584	53,106	186,522.34	3. Ledeng
10	Margahayu – Ledeng	19.80		125		73,789		
11	Cicaheum – Ciroyom	17.00		206		63,354		
12	Cicaheum – Ciwastra – Derwati	17.00	50.10	200	556	63,354	186,708.67	4. Cicaheum
13	Cicaheum – Cibaduyut	16.10		150		60,000		
14	Stasiun Hall – Sadang Serang	11.00	29.10	150	350	40,994	108,447.55	5. Sadang Serang
15	Sadang Serang – Caringin	18.10		200		67,454		
16	Stasiun Hall – Ciumbuleuit via Eykman	9.80	18.10	60	100	36,522	67,453.63	6. Ciumbuleuit
17	Stasiun Hall – Ciumbuleuit via Cihampelas	8.30		40		30,932		
18	Stasiun Hall – Gede Bage	21.00		200		78,261		
19	Stasiun Hall – Sarijadi	10.20	39.70	75	330	38,013	147,950.78	7. Stasiun Hall
20	Stasiun Hall – Gunung Batu	8.50		55		31,677		
21	Pasar Induk Caringin – Dago	19.85		140		73,975		
22	Panghegar Permai – Dipatiukur – Dago	19.35	63.55	155	420	72,112	236,833.06	8. Dipati Ukur
23	Bumi Panyileukan – Sekemirung	24.35		125		90,746		
24	Ciroyom – Sarijadi	11.75		97		43,789		
25	Ciroyom – Bumi Asri	8.35	46.70	115	497	31,118	174,037.82	9. Ciroyom
26	Ciroyom – Cikudapateuh	12.90		125		48,075		
27	Antapani – Ciroyom	13.70		160		51,056		
28	Sederhana – Cipagalo	16.05		276		59,814		
29	Sederhana – Cijerah	8.90	33.95	67	398	33,168	126,522.14	10. Sederhana
30	Sederhana – Cimindi	9.00		55		33,540		
31	Ciwastra – Ujungberung	13.40	35.70	32	232	49,938	133,043.90	11. Ciwastra
32	Cijerah – Ciwastra – Derwati	22.30		200		83,106		
33	Cisitu – Tegallega	13.95	13.95	82	82	51,988	51,987.74	12. Cisitu
34	Elang – Gede Bage – Ujungberung	22.45	47.50	115	450	83,665	177,019.20	13. Elang
35	Cibogo – Elang	7.00		35		26,087		
36	Cicadas – Elang	18.05		300		67,267		
37	Cicadas – Cibiru – Panyileukan	13.65	13.65	200	200	50,870	50,869.73	14. Cibiru
38	Cibaduyut – Karang Setra	16.60	16.60	201	201	61,864	61,863.55	15. Cibaduyut
	TOTAL	547.00	547.00	5,521	5,521	2,037,397	2,037,397.82	

*Data is taken from [27]

Figure 2. Paratransit colors interpret its specific route [26]

will only affect charging schedule since the charging should be done earlier and shorter (when SoC is smaller) or later and longer (when SoC is bigger).

From 38 routes, it was created 15 charging stations based on rough observation of majority paratransit settled on the stations when not in operation, and distance of paratransit parking and owner dwellings. Table 1 lists all that proposed charging locations. Actually, this kind of clustering might not be effective since there will be lots of efforts to put it into realization. The problem is when not in use paratransits are usually parked within the close proximity of the owners, which are often located far from the stations. Therefore, if paratransits are charged in the stations, then to be brought home to the owners, the energy reserved for the next run the day after will be lessened. There are two proposed ways to overcome this. First, build a station where people can park their paratransit as well as charge them. Even though this is one manifestation of government interference, the cost would be massive, for building and security officer for instance. Or instead, conduct a survey to map locations of each paratransit park lot, and subsequently create new locations for charging station and its new capacity as oppose from the old charging stations clustered above. This can be solved by providing a battery exchange, a big wide warehouse where batteries are charged to be readily used later.

This is just a convenience clustering that actually needs to be further investigated. The ideal should incorporate detail process comprising mapping paratransit parking locations, mapping electricity supply at potential or designated charging hours, matching number of charging needs with charging supply, and last but not least, interviewing stakeholders.

As transportation is the main contributor for air pollution in Bandung [31], and shifting to environmentally safe fuel and vehicle can be the way out [32] [33], paratransit electrification could be the answer to Bandung's circumstances. Beside, global condition creates a more conducive movement for electric vehicle application [34].

In accordance to fund in creating start-up fleet, government should do its best to establish a funding policy for this matter [2]. Be it the government, private sectors or other possible third parties. As considering cost to procure one electric paratransit could reach IDR 500 million, or IDR 450 million via retrofitting [24], sum of money should be provided would be huge. This cost falls mostly for batteries, which need to be replaced approximately once a year when lead acid is used. This cost will decline due to mass electrification since for example, battery price will decrease from bulk buy [3, 35]. Nevertheless, it still involved so much money. Further discussion about this is not within the reach of this paper.

Another option of charging stations is battery exchange or battery swapping stations. When battery is low, paratransit could visit a battery exchange station to have its empty battery be replaced with the fully loaded one. Nonetheless, as the consequence, a big warehouse containing stacks of battery should be provided. This will bring new obligations like land acquisition, building construction, operational management and security. Since the two alternatives in really have their own advantages and disadvantages, both can be executed according to circumstances of the future charging station locations.

IV. CONCLUSION

Paratransit electrification in Bandung yields a power demand of virtually 62 MWh per month that should be met by energy provider, which in this case is Indonesian Government through PLN (name of Indonesian national electricity company). Even the demand seems can be sufficiently fulfilled, careful planning should be conducted to ensure the demand will be satisfied without disturbing other industry. The planning will embrace obtaining real data on energy demand for paratransit electrification in Bandung. Field survey would be crucial in acquiring data to design and map places of charging stations taken into account paratransit parking and electricity availability at certain charging hours.

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