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ECONOMIC VALUATION OF HYPOTHETICAL PARATRANSIT RETROFITTING

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Abstract

This paper describes a feasibility analysis of conventional and retrofitted paratransits, comparing economic performance of conventional paratransit with those using lead acid and lithium batteries. Research object is Dago-Kalapa paratransit in Bandung, West Java, travelling the distance of 11 km in town, under 8 peak hour operation. After calculating the estimated annual cost and benefit; net present value (NPV), payback period (PBP), and internal rate of return (IRR) then were quantified to provide feasibility description of those three paratransits. In addition, a sensitivity analysis regarding discount rate, gasoline price, and battery price is given to offer broader sense of factors embraced. It is found that both gasoline and lead acid paratransit have big NPVs with only slight differences, while lithium paratransit has negative NPV. This phenomenon applies to their PBPs and IRRs as well. Only when gasoline costs reaches IDR 15,000 will electric paratransit prevails over conventional one. Thus, it can be inferred that at the moment, paratransit runs with gasoline is still the most cost effective compared to its counterparts. However, starting retrofitting from now is endorsed due to its environmental benefit.

Keywords: feasibility; paratransit; conventional; electric; Bandung; Indonesia.

I. INTRODUCTION

Paratransit, or usually called ‘angkot’ by locals, is the most common means of urban transport in Indonesia. Paratransit armada is mostly possessed by private individuals [1], and run on determined routes but not determined schedule [2]. Paratransit provides ease of access while on the other hand, generates high emission [3]. Emission comes from the fossil fuel used by the paratransit. This condition is coupled by the fact that paratransit fleet mainly consists of old vehicles, resulting in poor exhaust system of the vehicles. Beside emission, some noted public outcries associated to public image of paratransit include traffic jam [3], traffic accidents, and its low quality of service.

In Bandung and in most Indonesia’s cities and towns, paratransit is the main medium of commuting [4]. Though not always 24 hours available to serve the commuters, paratransit’s departures during the day are quite frequent [5]. Moreover, it offers relatively cheaper fare compared to other transportation methods. Fare is set based on distance. Passengers pay directly to the driver rather than using ticket. Since price is the main consideration factor for customers to decide which public transport they would like to use [6], paratransit market is always available. Paratransit by far is community’s favorite choice.

To tell apart one route from another, paratransits are differentiated by colors, and in some locations, numbers. Using vans or minibus, its capacity ranges from twelve to fourteen passengers, driver not counted. At peak hours, paratransit can load up to twenty two passengers per return and only five during off peak hours [1]. Many ideas have been proposed to improve Bandung’s paratransit condition. Some studies propose rerouting, new pools for paratransit, and paratransit reduction to eliminate traffic jam; and others recommend the use of renewable energy to substitute fossil fuel as an effort to suppress air pollution [1, 4-7]. This paper will only discuss the economic viability of paratransit retrofitting as an endeavor to reduce fossil fuel usage and minimize pollution by applying alternative energy to fuel paratransit. In the national level it

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complies with Presidential Decree Number 5/2006 which states that in 2025 oil consumption should be only 20% in Indonesian total energy mix [8].

In the meantime, electric vehicle is gaining popularity as a transportation device that emits a very low level of emission, if not zero [9]. When generated from renewable energy, electricity offers bigger benefit as fuel, even when compared to direct use of biomass [10] and CNG [11]. Many suggested that if applied as mass transport, electric vehicle will generate significant reduction of local and global emission, not to mention oil usage, traffic noise, and traffic jam [12]. Nevertheless, due to the current battery capacity, distance range will be narrow. Consequently to date, electric vehicles are more suitable for everyday travel and city commuting [12].

Studies [12-15] have been done to compare performance of gasoline and electric vehicles. Most of them emphasize the benefit of electric vehicle over gasoline cars in term of minimizing pollution and vehicle operational cost. Therefore, exploring electric vehicle for future application would be beneficial. Continual and thorough study should be done to endorse implementation as well as creating capacity building and public awareness. In Indonesia researches on electric vehicle have been done by several research institutions and industry. As seen in local media, some research products and prototype of electric vehicle have been made by public.

This paper will elaborate the economic feasibility of converting the conventional paratransit into electric. There are two electric paratransits that are about to be investigated, one uses lead acid battery and the other uses lithium. Lead acid is deemed obsolete at this time, nonetheless considering its modest price and some improvements made related to resistance, weight and cost [16], the possibility of its application still exists. Lithium is included to provide the ideal condition of electric paratransit. The type of lithium battery investigated for this study is lithium iron phosphate ($LiFePO_4$). Due to its advantages over lead acid in terms of weight, size, and capacity, lithium is more widely used for current electric and hybrid vehicles available in the global automobile market. Paratransit is elected for this study for some basis. Paratransit is a popular public transport and available in massive amount. Moreover, it operates almost all day, therefore using large amount of gasoline which is the core of our energy and pollution problem. Most importantly, paratransit business is very open to government interference. For those reasons, it is expected that if paratransit electrification plan is executed, reduction of emission and fossil fuel usage would be massive and the benefit would be clear.

II. Methodology

Figure 1 explains steps done in this research. For studying the feasibility of retrofitted paratransit, the cost needed to alter conventional paratransit into electric paratransit using lead acid and lithium battery is quantified. Cost covers the retrofitting cost plus operation and maintenance cost. Retrofitting cost incorporates price of vehicles, batteries and retrofitting workshop. Operation and maintenance cost comprises of gasoline price, charging cost, and common maintenance cost. After daily operation cost was calculated and aggregated to ten years, net present value (NPV), internal rate of return (IRR), and payback period (PBP) then were counted. Below is formula for NPV:

$$\text{NPV}\ (i) = \sum_{t=0}^{N} \frac{Rt}{(1+i)^t} \qquad (1)$$

where t represents number of calculation years, which in this case is 10; i is discount rate and Rt is cash flow of annual revenue and disbursement. IRR can be determined using extrapolation to find in what exact discount rate NPV would be zero. Furthermore, payback period is counted by dividing the initial capital with annual profit in present value. All calculations were executed using built in formulas based on equation above in MS Excel. End result is presented in Table 1. NPV is in IDR, IRR is in % and payback period is in year.

The calculation was done by presuming 8% of roughly estimated inflation, averaged from year 2000-2013 inflation data from Badan Pusat

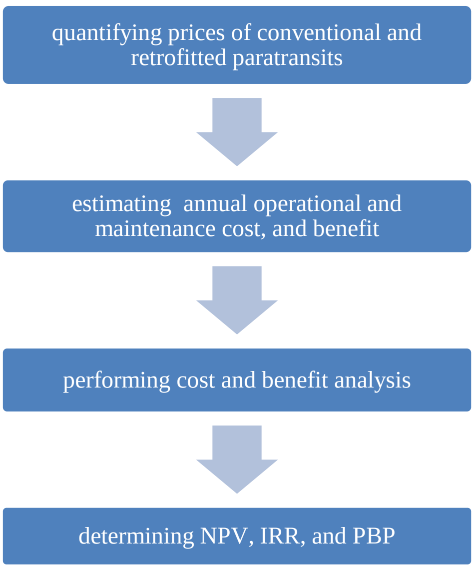

Figure 1. Research methodology

Statistik [17], 10 years vehicle useful life according to Bandung Mayor Decree 2002/1714 [18], and 13% discount rate following loan interest rate of Bank BNI (PT Bank Negara Indonesia) [19], an Indonesian leading national bank. It is further assumed that paratransit operates 30 days per month, 10 months per year considering some days off that usually employed by paratransit owners spent on overhaul, repairing and mere holidays. NPV, IRR, and PBP were computed to gain economic parameters to evaluating the financial performance of those three paratransit. As widely known, NPV, IRR, and PBP are the most common ways to assess the performance of future investment. Please note that some data and calculations will not be revealed in this paper. Please contact the author when you need one. Calculation basis are as follows:

- Working hours per day = 8, working days per month = 30, working days per year = 300.
- Kalapa - Dago paratransit fare is assumed IDR 5,000 fixed. As authors could not get the valid established fare from the authorities, fare is inferred from articles [20] and [21].
- Price of gasoline is IDR 6,500, needed gasoline per 4 hour operation = 10 liters.
- Maintenance cost is calculated in accordance with Keputusan Direktur Jenderal Perhubungan Darat SK. 687/AJ.206/DRJD/2002 for conventional paratransit and adjusted for retrofitted paratransit.
- Vehicle used is Mitsubishi Colt T120SS 1300 cc and the same MPI 1.5 L for conventional paratransit, price of new vehicle is about IDR 90,000,000.
- Assumed resale value of 10 year vehicle = IDR 30,000,000.
- Electric motor used is FBI-4001 144 V.
- Distance that can be travel with such vehicle weight and 50% state of charge battery per charge ≈ 51 km.
- Battery replacement is done per year considering the available cycles of the batteries.

For lead acid:

- Lead acid battery used is NS2200 6 V 220 Ah produced by PT Nipress Tbk., weighted 25 kg each cell, hence 24 cells per vehicle with total weight of 600 kg.
- Battery replacement price = IDR 36,000,000.
- Assumed battery resale value = IDR 2,640,000.
- Price for retrofitted paratransit using lead acid = IDR 202.41, assumed resale value = IDR 6,000,000.
- Energy needed to charge using 25 A charger is 3.6 kVA. In PLN (Indonesian state electricity company) tariff list, this falls into Cluster 4 for Industry (3,500 VA – 14 kVA) [22], IDR 1,112 per kWh.
- Energy to charge one electric paratransit per day = 3.6 kVA x 3.667 hours = 13.201 kWh.
- Cost per charge = 13.201 kWh x IDR 1,112 per kWh = IDR 14,679.51 bringing monthly charging cost of IDR 14,679.51 x 30 = IDR 440,385.36.

For lithium ion:

- Lithium battery used is 3.2 V 220 Ah. For 144 V, total cells used are 45.
- Battery replacement price = IDR 225,720,000.
- Assumed battery resale value = resale of lead acid battery = IDR 2,640,000. Actually the predicted salvage value of lithium battery can be higher or lower than that of lead acid, depending on valuable components it still has at the end of its economic life [23]. For this study however, the salvage values are assumed similar.
- Price for retrofitted paratransit using lithium ion IDR 392.13, assumed resale value = IDR 6,000,000.
- Energy needed to charge using 60 A charger is 8,640 VA. In PLN (Indonesian state electricity company) tariff list, this falls into Cluster 4 for Industry (3,500 VA – 14 kVA) [22], IDR 1,112 per kWh.
- Energy to charge one electric paratransit per day = 8.64 kVA x 1.833 hours = 15.837 kWh.
- Cost per charge = 15.837 kWh x IDR 1,112 per kWh = IDR 17,610.74 bringing monthly charging cost of IDR 17,610.74 x 30 = IDR 528,322.32.

III. RESULT AND DISCUSSION

Using the above assumptions and data, economic performance valuation of three paratransit schemes has been done. Result is shown in Table 1. NPV is in IDR and payback period in years. It can be seen that conventional paratransit has the best performance of all. Lead acid paratransit comes after and retrofitted paratransit with lithium is the worst. Lithium has negative NPV since the cost it bears is ultimately high. Majority of lithium paratransit cost is generated from battery replacement. Cost of one replacement is more than IDR 200,000,000. Since replacement must be done once a year due

Table 1.
Estimated financial performance of three kinds of paratransit

Scenario	Paratransit types		
	Lead acid	Conventional	Lithium ion
NPV	296,026,974.43	407,056,330.83	-1,090,727,925.02
IRR	44.09%	90.81%	-
Payback period	2.27	1.10	-

Table 2.
Feasibility when gasoline price is IDR 13,000

Scenario	Paratransit types		
	Lead acid	Conventional	Lithium ion
NPV	228,495,089.12	123,010,209.27	-979,356,140.28
IRR	40.24%	42.10%	-
Payback period	2.49	2.38	-

Table 3.
Feasibility when gasoline price is IDR 13,500

Scenario	Paratransit types		
	Lead acid	Conventional	Lithium ion
NPV	228,495,089.12	106,563,427.48	-979,356,140.28
IRR	40.24%	38.48%	-
Payback period	2.49	2.60	-

to battery cycle, annual cost of operation becomes large. While income gained from daily operation cannot compete with the escalating disbursement, lithium cash flow eventually produces minus NPV. Therefore, IRR and payback period for paratransit with lithium battery cannot be counted due to its very big accumulation of annual disbursements. Conventional paratransit has big NPV because the income is far bigger than the annual cost which comes mostly from gasoline consumption.

To test the effect of some factors incorporated in the feasibility calculation, Table 2 to Table 9 below consecutively show sensitivity analysis concerning gasoline price, discount rate applied, battery price discount, and paratransit fare increase. Table 2 and 3 list the new values of NPV, IRR, and payback period of those three paratransits due to change on gasoline price. It can be seen that NPVs of lithium paratransit are still negative. However, paratransit with lead acid battery outweighs paratransit with gasoline when gasoline price is at least IDR 13,500, an increase of more than 200% from current price which is IDR 6,500. This happens because when gasoline price escalates, operational cost of the conventional paratransit automatically escalates resulting in lower annual cash flow as on the other hand, revenue does not increase. In regard with revenue upsurge, when fare is increased to IDR 7,000 and IDR 10,000 from IDR 5,000 at the moment, as can be seen in Table 4 and 5, there is no significant improvement to the financial performance of electric paratransit. Yet in the real world, when condition is still in status quo, increasing fare that much is unlikely to happen.

Furthermore, when discount is reduced to become 5% and enlarged to become 20% from the previous 13% as described in Table 6 and 7, no crucial improvement takes place in term of lead acid and lithium feasibility. Both electric paratransit still cannot overcome the conventional paratransit. These same conditions are also applied to battery price cut in Table 8 and 9. Even though battery price is reduced with 50% and 60% markdown for lead acid and lithium, conventional paratransit still wins the race. Nevertheless, it is good to note that the bigger the markdown, the better the financial performance of electric paratransit will be. NPV of lithium paratransit is better albeit the value still does not make lithium paratransit feasible. Likewise, lead acid performance also gets better. In contrast, performance of conventional paratransit remains the same since it is not affected by battery price. It should be noted that price reduction will only apply for bulk buy. Therefore, as long as retrofit is done solely, price reduction would be hard to get.

Table 4.
Feasibility when paratransit fare is IDR 7,000

Scenario	Paratransit types		
	Lead acid	**Conventional**	**Lithium ion**
NPV	517,958,448.68	626,281,732.14	-689,892,780.72
IRR	69.98%	146.26%	-
Payback period	1.43	0.68	-

Table 5.
Feasibility when paratransit fare is IDR 10,000

Scenario	Paratransit types		
	Lead acid	**Conventional**	**Lithium ion**
NPV	952,153,488.02	1,060,476,771.49	-225,697,741.38
IRR	112.85%	234.82%	-
Payback period	0.89	0.43	-

Table 6.
Feasibility when discount rate applied is 5%

Scenario	Paratransit types		
	Lead acid	**Conventional**	**Lithium ion**
NPV	438,413,673.21	569,929,949.43	-1,366,621,194.63
IRR	40.24%	86.99%	-
Payback period	2.49	1.15	-

Table 7.
Feasibility when discount rate applied is 20%

Scenario	Paratransit types		
	Lead acid	**Conventional**	**Lithium ion**
NPV	126,132,602.85	221,934,367.37	-777,157,979.31
IRR	40.24%	86.99%	-
Payback period	2.49	1.15	-

Lithium actually has a number of advantages over lead acid. It has lighter weight and higher energy density than lead acid [24-29], Isastia even mentions that lead acid's energy density and specific energy is one fourth of lithium's [30]. Other studies find that lead acid's lifetime is far shorter, moreover, it is easier to get and the most attractive factor is that it is cheaper than lithium [30-35]. This makes cost of ownership for lithium then is higher to at least twice than that of lead acid. Lithium on the other hand, has serious protection risk and more expensive [26], [36] despite the fact that it is the most promising battery available for electric vehicle [37]. Lead acid technology is mature, the battery has been marketed for over 100 years [38] although at the moment lithium is the most sought for electric vehicle [39]. Nevertheless, even though it is widely applied for electric vehicle at the beginning of EV development, lead acid's range is shorter and its performance is poorer than lithium's [37], [40]. Lead acid cheap price and mature technology trades off its low energy density [35]. Amount of energy produced, weight, life time, charging time, distance per unit energy, and other aspects. Weinert states whereas both kind of batteries will develop in the future, for the time being, taken into account the performance of lithium batteries, the cost of ownership is very high [36], hence shifting to lithium from lead acid is not recommended from financial perspective.

The weakness of this study is that passenger quantification is based on busy hours, where number of passenger is assumed as 22 per return or paratransit seats are full. While in fact number of passengers is not always that big. However, although this income seems too optimistic, even when we assume it as half of the current income, the NPV value is still positive; hence this investment is feasible to execute. This applies for lead acid case as well. This scenario seems to support the existing mode of paratransit and does not endorse the electrification or paratransit. However, when looking into the real matter, both conventional and lead acid options actually are

Table 8.
Feasibility when battery prices are 50% discounted

Scenario	Paratransit types		
	Lead acid	Conventional	Lithium ion
NPV	327,175,779.88	336,818,372.58	-360,628,209.22
IRR	50.63%	86.99%	-
Payback period	1.98	1.15	-

Table 9.
Feasibility when battery prices are 60% discounted

Scenario	Paratransit types		
	Lead acid	Conventional	Lithium ion
NPV	346,911,918.03	336,818,372.58	-236,882,623.00
IRR	52.66%	86.99%	-
Payback period	1.90	1.15	-

profitable, thus supporting electrification using lead acid is good to be considered. Their NPV are close, lead acid's payback period is half that of conventional's, but that does not mean that lead acid is not profitable. For lithium, since its NPV is negatively huge, unless there is interference from the donor to settle this value in the ways of providing the battery or probably increasing the paratransit fare to improve its income, it is better to be left off of this discussion. Exception can be given when lithium battery replacement price is available below lead acid's. For starting annual income of IDR 132,000,000 from the passenger, the paratransit owner is clearly cannot afford it. Not to mention the escalating price in the years to come. Fare raise, if exists due to inflation or other enablers, will not be able to compete with the raise of lithium ion battery. On lead acid battery, recycling technologies are available, has been commonly used and more technologies are proposed [41-43]. Consequently, when capital cost is ready, there is no stopping in implementing lead acid retrofitting for paratransit. Electric vehicle is created to reduce fossil fuel and eradicate emission [44-46]. As a result, although only allows short range, electric vehicle application will provide great benefit compared to conventional vehicle [15], even greater when the electricity used is generated from renewable energy. Predicted to have more than 10% growth before 2025 [47], nowadays electric vehicle selling are supported almost everywhere. This fact is supported by some reported enhancements related with electric vehicle, such as battery [11]. All these information opens the possibility of cheaper vehicles in the future, hence wider application of electric vehicle.

Regarding efforts to advocate the implementation of EV nationally, government involvement is a must. Support can be given in the forms of EV purchase incentives, parking fee waiver, special policy to attract investment in EV industry [48], and making available charging infrastructure. However, first step should be to release regulation on EV usage on road.

IV. Conclusion

Retrofitting paratransit into electric paratransit using lead acid battery is endorsed, while lithium is not, until the price is competitive. Further investigation can be done taken into account reduced price of batteries and motors due to bulk buy. This will provide more benefit since the price will be remarkably cheaper. Considering peak and off peak hour would be a plus point as well, since income from the passenger may increase during peak hours. From sensitivity analysis, increase of gasoline price will benefit the application of electric paratransit, particularly lead acid, as they will improve the economic performance of the retrofitted paratransit. Finally, based on the financial performance of proposed paratransit electrification, as long as capital is available to support for battery price discount, electric paratransit retrofitting can be executed promptly in Indonesia. Depart from the discussion presented, this paper hence of its accord recommends government support to facilitate early EV implementation in terms of realizing friendly business climate, releasing policies benefitting future EV industries and EV owners, and providing early establishment of charging facilities.

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