Operational Cost Comparison of Alternative Fuel Vehicles for Public Transportation

Jose Gabriel E. Mercado and Edwin N. Quiros

Mechanical Engineering Department, College of Engineering, University of the Philippines Diliman, 1101, Quezon City Philippines

Abstract – *This paper presents the operational cost analysis of different alternative fuel vehicles used for Public Utility Jeepneys (PUJ's) in Metro Manila. Four models were generated using data from the UP-SM North Jeepney route. Model A used actual data gathered from the on-road tests conducted. Model B did not consider the downtime days to normalize the daily net income. Model C kept the costs not related to fuel and maintenance, jeepney fare, and data influence by the preference of the driver, constant. Model D assumed only jeepney type varied, without accounting for any preference for any preference mentioned in Model C. For all models, in terms of Fuel Cost (PhP) per Passenger-km, the Electric Jeepney is 35-49% more economical and has 1%-36% higher net income vs Diesel Jeepney. However, the LPG jeepney is less economical by 8%-18% vs Diesel Jeepney in Models A – C but more economical by 4% in Model D due to higher cost of Diesel fuel. In terms of Net Income (PhP) per Passenger-km, LPG Jeepney has 10% lower income vs Diesel Jeepney in Models A&B but has 5% higher income in Models C&D as considered days are the same, thereby minimizing differences in the number of passengers that affects both parameters.*

Keywords—jeepney, alternative fuels, operational cost analysis

I. INTRODUCTION

The Philippines' Public Utility Jeepney (PUJ) or more commonly known as the Jeepney is one of the cheapest and most popular mode of transportation in the country. Considered as the symbol of Filipino's creativity and ingenuity, PUJ's were derived from US Military jeeps and are usually assembled using shop fabricated bodies and chassis, then fitted with second hand engines. As of 2010 there are 210, 840 registered jeepney units with franchises, with about 50, 085 units plying in Metro Manila [1], They account for around 74 million passenger-km travelled in Metro Manila annually [2] and 80% of total Passenger Kilometer travel for the whole country [3] despite its original purpose to serve feeder routes to the bigger transport modes (buses and light rail ways). Moreover, most are still using old and dilapidated diesel engines that account for 15% of the particulate matter emissions in Metro Manila [4]. Most of these jeepneys are 10-20 years old [1] and with the advancement in alternate vehicle technologies, call for a cleaner environment, and the push for a "Jeepney Modernization Program" [5], different alternative fuel jeepneys (Electric, Diesel-Electric Hybrid, LPG, Euro-4 Compliant Diesel Engines) are now proposed to replace the current fossil fueled jeepneys.

The use of electric-based vehicles in public transport fleets has been the trend in the past few years globally. In Metro Manila, electric jeepney fleets are running commercially on some routes. One of which is operating in Makati Central Business District since 2008 and another has been operating since 2014 plying the SM North-Katipunan Avenue special route. One constraint of an electric jeepney, however, is the high initial cost. This is expected to decrease over the years due to projected reduction in components [6].

LPG jeepneys have been viewed as alternative to the diesel jeepney as early as 2004 but only a

handful of jeepneys in Metro Manila have adopted this. LPG retrofitted engines are usually based on gasoline engine platform, thus requiring cheaper maintenance compared to diesel engines. This conversion to LPG from gasoline engine commonly results to fuel economy penalties [7]. There were reports of drivers using LPG converted taxis complaining of body pains such as headaches, back pains, cough, dizziness, etc. [8,9]. Although no scientific and direct link to the conversion, this gave jeepney operators and drivers doubts in adopting the technology.

Diesel engine technology advancements such as high pressure direct injection systems provide better fuel atomization for complete burning, thus giving better fuel economy and higher power output. Adopting Euro-4 Diesel Engines together with Euro 4 fuel quality standards is expected to contribute to emission reductions. However, Euro 4 diesel jeepneys are expected to have higher maintenance costs compare to old diesel jeepneys because of sensitivity of its parts and a stringent required fuel purity.

The main objective of this paper is to show and compare the performance of diesel and alternative fuel vehicle jeepneys. Relevant data such as revenue, costs, and income were collected and used in the comparison and analysis. Four models were made to see different effects of certain parameters. Each model had a specific assumption in order to make fair comparisons and analysis based on the data obtained from the on-road tests.

This study is part of the Phase 1 of the Fuel Efficiency in Road Transport Program of the Philippine Department of Energy (DOE) in partnership with University of the Philippines National Engineering Center (UP NEC). The results of the study may be used in support of developing programs and strategies for the DOE and related government agencies for an effective implementation of alternative fuels and technology program in the country. The approach used in this study may also be adopted for future studies with similar objectives in other location within the Philippines.

II. METHODOLOGY

For this study, three in-use jeepneys of operators belonging to transport group PasangMasda and PHUV were used for the U.P. Diliman-SM North route. The Diesel Jeepney, shown in Figure 2-1, and the LPG jeepney, shown in Figure 2-2 were owned by PasangMasda. Meanwhile, the Electric Jeepney, shown in Figure 2-3 was owned by PHUV. Due to limited availability, the three units used were based on what was provided by the said group from their fleet.

Figure 2-1 Diesel Jeepney owned

Figure 2-2 LPG Jeepney

Figure 2-3 Electric Jeepney

The on-road test was designed to run for 72 days. The schedule of the transit operation was from 6:00 AM to 7:30 PM, Monday to Saturday. All drivers of the test vehicles followed normal work breaks (meals, snacks) of drivers of other PUJ's operating in the route. Daily operational characteristics such as daily vehicle operation information (operation cost and revenue) and passenger station origin-destination were collected by as surveyor as shown in Figure 2-4. Designated stops for the route are strictly followed by the drivers. The route is classified as short urban type with length 6.75 km from SM North Edsa to UP Diliman and 6.5 km from UP Diliman to SM North Edsa with a total length of 13.25 km (roundtrip) as shown in Figure 2-5. Typical one-way trip duration was 17 to 30 minutes with

an average of 23 minutes. The average speed was approximately 17kph with an idle time ranging from 26% to 46% of the total duration, with an average of 36%.

Figure 2-4. A surveyor aboard one of the test vehicles

Figure 2-5. Map of East and Westbound Route with Stops

III. DATA ANALYSIS AND DISCUSSIONS

Four models were made in order to see different effects of selected parameters to the operational costs using the three fuel types.

Model A used actual data gathered from the on-road tests conducted. This model reflected actual conditions and showed all the revenues and costs incurred during the testing period.

Model B did not consider the downtime days to normalize the daily income & costs, as there were significant differences between jeepney types as seen in Model A.

Model C was a simulation that kept the following variables constant – costs not related to the fuel and maintenance/ repair, jeepney fare, and data that were influenced by the preference of the driver. Load Factor was still retained as a variable as passenger preference may be influenced by the jeepney type.

Model D was another simulation that assumed only jeepney type varied, without accounting for any preference mentioned in Model C. Thus, all parameters were kept constant except for those directly related to the jeepney type – Fuel Cost and Maintenance/Repair Costs.

MODEL A.

Data on actual number of passengers and distance travelled were used to calculate performance parameters. The length of the route was 13 km with 6.75 km from SM North to UP and 6.5 km from UP to SM North. Data for Model A is shown in Table 1A and 1B below.

The Test Period indicates the total number of testing days. In some of these days, the test vehicle was down due to some repairs needed. These are shown in "Downtime Days". Testing days that fell on a Sunday or a holiday were considered as "No Operation Days". Thus, both these days were deducted from the Test Period get the "Days Considered".

The Gross Income was computed from the total fare collected by the drivers during operation. The Operating Costs recorded were fuel costs/charging costs, terminal fee, dispatcher's fee, and repairs and maintenance. Net Income over the entire testing period is calculated by

$$\text{Net Income} = \text{Gross Income from Fares} - \text{Total Operating Costs}$$

This also assumed that the driver is the operator of the PUJ thus there is no "boundary" (payment made by the driver to the operator of the jeepney) as part of the costs incurred.

Average daily parameters were also calculated to get a fair comparison regardless of the differences in the length of testing period. The Gross Income, Operating Costs, and the Net Income were all divided by the total testing days (Considered Days plus Downtime Days) to get the average Daily Gross Income, Daily Operating Costs, and the Daily Net Income respectively.

$$\text{Daily Gross Income} = \frac{\text{Gross Income}}{\text{Considered Days} + \text{Downtime Days}}$$

$$\text{Daily Operating Costs} = \frac{\text{Total Operating Costs}}{\text{Considered Days} + \text{Downtime Days}}$$

$$\text{Daily Net Income} = \frac{\text{Total Net Income}}{\text{Considered Days} + \text{Downtime Days}}$$

Table 1A. ECONOMIC MODEL A

Type	**Diesel**	**LPG**	**Electric**
Plate Number	*UVH 491*	*ZTS 904*	*ZZI 169*
Passenger Capacity	*20*	*20*	*16*
Operational Data			
Testing Period Start	01/29/13	01/28/13	01/28/13
Testing Period End	04/10/13	05/15/13	04/09/13
Test Period (Days)	72	108	72
Considered Days	52	37	41
Days of No Operation	16	41	29
Downtime Days	4	30	2
Total Passengers	24,110	15,616	11,061
Load Factor	0.6347	0.5981	0.6374
Total Distance Travelled (km)	8713	6063.31	4807.17
Total Fuel Consumed, (liters) [1]	1294.16	1282.68	1421.4
Gross Income (PhP)	**211,646.69**	**131,047.97**	**94,331.00**

Table 1A. ECONOMIC MODEL A *(cont'd)*

Type	Diesel	LPG	Electric
COSTS			
Fuel/Energy Cost[2] (PhP)	52,196.47	37,624.49	15,635.40
Terminal Fee	15,260.00	7,405.00	7,910.00
Dispatcher's Fee (PhP)	4,450.00	5,854.00	5,720.00
Maint./ Repair Costs (PhP)	6,325.00	7,633.00	3,507.00
Total Operating Costs (PhP)	**78,231.47**	**58,516.49**	**32,772.40**
NET INCOME (PhP)	**133,415.22**	**72,531.48**	**61,558.60**
AVERAGE PERFOMANCE INDICATORS			
DailyGross Income (PhP)	3,779.41	1,955.94	2,193.74
Daily Operating Costs (PhP)	1,396.99	873.38	762.15
DailyNet Income (PhP)	2,382.41	1,082.56	1,431.60

[1]kWh for EJeep
[2]Electrical energy cost for Ejeep, assumed value is 10.66 Php per kWh

For a better and normalized comparison, the Fuel Cost, Operating Cost, and Net Income parameters were viewed on a passenger-kilometer basis. This simply means that the parameters would be viewed by how much they cost to transport one passenger by one kilometer, as shown by the following formula:

$$\text{Fuel Cost (Php per passenger} - \text{km)} = \frac{\text{Fuel Cost (Php)}}{\text{Number of Passengers x Total Length of Route (km) x Load Factor}}$$

$$\text{Net Income (Php per passenger} - \text{km)} = \frac{\text{Net Income (Php)}}{\text{Number of Passengers x Total Length of Route (km) x Load Factor}}$$

The Load Factor reflected the average percentage of passengers riding the vehicle per trip and was obtained from the passenger data. The resulting computation for Fuel Cost per Passenger-kilometer and Net Income per passenger-kilometer is shown in Table 1B:

Table 1B. Performance Indicators per Passenger-Km

	Diesel	LPG	Electric
Fuel Cost (PhP)	52,196.47	37,624.49	15,635.40
Net Income (PhP)	133,415.22	72,531.48	61,558.60
Total No. of Passengers	24,110	15,616	11,061
Load Factor	0.6347	0.5981	0.6374
Total Length of Route (km)	13.25 km	13.25 km	13.25 km
Fuel Cost per Passenger-Kilometer (PhP)	**0.25743023**	**0.30402629**	**0.16737348**
Net Income per Passenger-Kilometer (PhP)	**0.65799681**	**0.58609370**	**0.65897115**

Model A shows that in terms of **Fuel Cost (Php) per Passenger-km**, the Electric Jeepney is 35% more economical and the LPG is 18% less economical, both in comparison with the Diesel Jeepney. In terms of **Driver income**, the Diesel Jeepney has the highest **daily gross income** among the three, 55% higher than the LPG Jeepney and 40% higher than the Electric Jeepney. In terms of the **Net Income per Passenger-km**, the Diesel Jeepney is 12% higher than the LPG Jeepney but it is 15% less than the Electric Jeepney. Looking at the **Operating expense per passenger-km** the Diesel Jeepney is 22% less expensive to operate than LPG Jeepney but 10% more expensive to operate than Electric Jeepney.

MODEL B

Table 2 shows the second Model.

Table 2A - ECONOMIC MODEL B

Type	**Diesel**	**LPG**	**Electric**
Plate Number	*UVH 491*	*ZTS 904*	*ZZI 169*
Passenger Capacity	*20*	*20*	*16*
Operational Data			
Testing Period Start	01/29/13	01/28/13	01/28/13
Testing Period End	04/10/13	05/15/13	04/14/13
Test Period (Days)	72	108	72
Considered Days	52	37	41
Days of No Operation	16	41	29
Downtime Days	4	30	2
Total Passengers	24,110	15,616	11,061
Load Factor	0.6347	0.5981	0.6374
Total Distance Travelled (km)	8713	6063.31	4807.17
Total Fuel Consumed, (liters) [1]	1294.16	1282.68	1421.4
Gross Income from Fares (PhP)	**211,646.69**	**131,047.97**	**94,331.00**
COSTS			
Fuel/Energy Cost [2](PhP)	52,196.47	37,624.49	15,635.40
Terminal Fee	15,260.00	7,405.00	7,910.00
Dispatcher's Fee(PhP)	4,450.00	5,854.00	5,720.00
Maint./Repair Costs(PhP)	6,325.00	7,633.00	3,507.00
Total Operating Costs (PhP)	**78,231.47**	**58,516.49**	**32,772.40**
NET INCOME (PhP)	**133,415.22**	**72,531.48**	**61,558.60**
AVERAGE PERFOMANCE INDICATORS			
DailyGross Income (PhP)	4,070.13	3,541.84	2,300.76
Daily Operating Costs (PhP)	1,504.45	1,581.53	799.33
DailyNet Income (PhP)	2,565.68	1,960.31	1,501.43

[1]kWh for EJeep
[2]Electrical energy cost for Electrical Jeepney, assumed value is 10.66 Php per kWh

The Average Performance Indicators per passenger-km is not affected by the changes made and are still the same as the one for Model A as shown in Table 1B. Hence it showed the same results for the said parameters. In terms of **Fuel Cost (Php) per Passenger-km**, the Electric Jeepney is 35% more economical and the LPG Jeepney is 18% less economical, both in comparison with the Diesel Jeepney. In terms of the **Net Income per Passenger-km**, the Diesel Jeepney is 12% higher than the LPG Jeepney but it is 15% less than the Electric Jeepney. Looking at the **Operating expense per passenger-km,** the Diesel Jeepney is 22% less expensive to operate than LPG Jeepney but 10% more expensive to operate than Electric Jeepney.

Model C

The simulated testing period is 72 days and fare is set at 11 pesos per passenger per trip. Maintenance costs were simulated using actual market prices and assuming advisable preventive maintenance behavior. This model uses the same Load Factor used in the first two models.

Table 3A - ECONOMIC MODEL C

Type	**Diesel**	**LPG**	**Electric**
Plate Number	*UVH 491*	*ZTS 904*	*ZZI 169*
Passenger Capacity	*20*	*20*	*16*
Assumed Operational Data			
Test Period (Days)	72	72	72
Operating Days	72	72	72
Rest Days	0	0	0
Downtime Days	0	0	0
Total Passengers	18,279	17,225	14,686
Passenger-km	121,101	114,117	97,293
Total Number of trips per day	20	20	20
Total Distance Travelled, (km)	9540	9540	9540
Liters/km, kWh/km	0.148532	0.2115478	0.2956833
Price per liter, Price per kWh (PhP)	43	29	10.66
Total Fuel Cost (PhP)	60,930.83	58,526.82	31,029.01
Load Factor	0.6347	0.5981	0.6374
Gross Income from Fares (PhP)	**201,072.96**	**189,478.08**	**161,542.66**
COSTS			
Fuel/ Energy Cost [2] (PhP)	60,930.83	58,526.82	31,029.01
Terminal Fee	26,640.00	26,640.00	26,640.00
Dispatcher's Fee (PhP)	1,800.00	1,800.00	1,800.00
Maint./Repair Costs (PhP)	**11,750.00**	9,250.00	**6,000.00**
Total Operating Costs (PhP)	**101,120.83**	**96,216.82**	**65,469.01**
NET INCOME (PhP)	**99,952.13**	**93,261.26**	**96,073.65**

Table 3A . ECONOMIC MODEL C *(cont'd)*

Type	Diesel	LPG	Electric
AVERAGE PERFOMANCE INDICATORS			
Daily Gross Income (PhP)	2,792.68	2,631.64	2,243.65
Daily Fuel Cost (PhP) [1]	846.26	812.87	430.96
Daily Net Income (PhP)	1,388.22	1,295.30	1,334.36

As with Models A and B, the Fuel Cost, Operating Cost, and Net Income parameters were viewed on a passenger-kilometer basis. This is to present a normalized comparison among the performance of the three technologies. This is summarized in Table 3B.

Table 3B. Performance Indicators per Passenger-Km

	Diesel	Auto-LPG	Electric
Fuel Cost (PhP)	60930.83	58526.82	31029.01
Net Income (PhP)	99,952.13	93,261.26	96,073.65
Total No. of Passengers	18,279	17,225	14,686
Load Factor	0.6347	0.5981	0.6374
Total Length of Route(km)	13.25	13.25	13.25
Fuel Cost per Passenger-Kilometer (PhP)	**0.39636174**	**0.42874489**	**0.25017589**
Net Income per Passenger-Kilometer (PhP)	**0.65019959**	**0.68319599**	**0.77460768**

Model C shows that in terms of **Fuel Cost (Php) per Passenger-km**, the Electric Jeepney is 37% more economical and the LPG Jeepney is 8% less economical both in comparison with the Diesel Jeepney. In terms of the **Net Income per Passenger-km**, the LPG Jeepney is 5% higher and the Electric Jeepney is 20% higher both comparing to the Diesel Jeepney.

MODEL D

The simulated testing period is 72 days and fare is set at 11 pesos per passenger per trip. Maintenance costs were simulated using actual market prices and assuming advisable preventive maintenance behavior.

Table 4A - ECONOMIC MODEL D

Type	Diesel	LPG	Electric
Plate Number	*UVH 491*	*ZTS 904*	*ZZI 169*
Passenger Capacity	*20*	*20*	*20*
Assumed Operational Data			
Test Period No. of Days	72	72	72
Operating Days	72	72	72
Rest Days	0	0	0
Downtime Days	0	0	0
Total Passengers	17,954	17,954	17,954
Passenger-km	118,945	118,945	118,945
Total Number of trips per day	20	20	20
Total Distance Travelled, (km)	9540	9540	9540
Liters/km, kWh/km	0.148532	0.2115478	0.2956833
Price per liter, Price per kWh (PhP)	43	29	11
Total Fuel Cost (PhP)	60930.829	58526.819	31029.007
Load Factor	0.6234	0.6234	0.6234
Gross Income from Fares (PhP)	**197,493.12**	**197,493.12**	**197,493.12**
COSTS			
Fuel/ Energy Cost [2] (PhP)	60930.72	58526.64	31029.12
Terminal Fee	26640	26640	26640
Dispatcher's Fee (PhP)	1800	1800	1800
Maint./ Repair Costs (PhP)	11,750.00	9,250.00	6,000.00
Total Operating Costs (PhP)	**101,120.72**	**96,216.64**	**65,469.12**
NET INCOME (PhP)	**96,372.40**	**101,276.48**	**132,024.00**
AVERAGE PERFOMANCE INDICATORS			
Daily Gross Income (PhP)	2,742.96	2,742.96	2,742.96
Daily Fuel Cost (PhP)[1]	846.26	812.87	430.96
Daily Net Income (PhP)	1,338.51	1,406.62	1,833.67

As with the previous models, the Fuel Cost, Operating Cost, and Net Income parameters were viewed on a passenger-kilometer basis. This is to present a normalized comparison among the performance of the three technologies. This is summarized in Table 4B.

Table 4B – Performance Indicators per Passenger-Km

	Diesel	Auto-LPG	Electric
Fuel Cost (PhP)	60930.83	58526.82	31029.01
Net Income (PhP)	96,372.40	101,276.48	132,024.00
Total No. of Passengers	17,954	17,954	17,954
Load Factor	0.6234	0.6234	0.6234
Total Length of Route (km)	13.25	13.25	13.25
Fuel Cost per Passenger-Kilometer (PhP)	**0.4108612**	**0.39464902**	**0.20923003**
Net Income per Passenger-Kilometer (PhP)	**0.64984639**	**0.68291193**	**0.89024387**

Model D shows that in terms of **Fuel Cost (Php) per Passenger-km,** the Electric Jeepney is 49% more economical and the LPG Jeepney is 4% more economical both in comparison with the Diesel Jeepney. In terms of the **Net Income per Passenger-km**, the Diesel Jeep is 5% less than the LPG Jeepney and 37% less than the Electric Jeepney.

VII. CONCLUSION AND RECOMMENDATIONS

Overall the best jeepney to use in this route in terms of both fuel cost and net income per passenger-km is the Electric Jeepney. LPG Jeepney would be an overall better option vs the Diesel Jeepney on equalized data as considered days are the same, thereby minimizing difference in the number of passengers that affects both parameters. If basing on actual data alone, although lower in fuel cost per passenger-km, LPG Jeepney also has lower net income vs. Diesel Jeepney.

Based on scope and limitations discussed in this project, further analysis needs to be done to have a more comprehensive comparison and conclusion. This may include expanding the study, i.e. using different routes, accounting for related logistics of the jeepney types, and considering total life cycle monetary cost of ownership of the jeepneys.

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