A Consolidated Economic Analysis of Alternative Fuel for Public Utility Jeepneys

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***Abstract*— This paper presents the economic analysis of a two-phase Philippine study of different alternative fuel vehicles used for Public Utility Jeepneys (PUJ's) that are plying two separate Metro Manila urban routes. Two economic models were generated using data for the two routes and in both models, in terms of fuel economy (fuel cost in Pesos per Passenger-Km) versus the Diesel Jeepney, the Electric Jeepney is 35%-46% more economical, while the LPG Jeepney is 2%-51% less economical. In terms of Net Income per Passenger-Km, trend is the same, as the Electric Jeepney has 10-31% higher net income, whereas the LPG Jeepney has 0.19-8% lower net income.**

***Index Terms*— alternative fuel, diesel, economic analysis, electric, LPG**

I. Introduction

The Philippines' Public Utility Jeepney (PUJ) is one of the cheapest and the most popular mode of transportation in the country. Considered as the symbol of Filipino's creativity and ingenuity, PUJ's are derived from US military jeeps and are usually assembled using shop fabricated bodies and chassis, then fitted with second hand engines. PUJ's account to around 74 million passenger-kilometers travelled in Metro Manila annually [1] 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 [2],[3]. With the advancement of alternative vehicle technologies, call for a cleaner environment, and the push for a "Jeepney modernization program"[4], different alternative fuel vehicle options – Electric, Diesel-Electric Hybrid, LPG, Euro-4 Compliant Diesel Engines, are being proposed to replace the current fossil fueled jeepneys.

Relevant data including revenue costs, expenses, and incomes were gathered and used in the comparison of the options. Two economic models were made. Each had a set of assumptions to simulate both realistic and ideal scenarios.

This study is a part of the Fuel Efficiency in Road Transport Program of the Philippine Department of Energy (DOE) as technical support.

The specific objectives of this paper are as follows:

a) To provide economic analysis for the on-road tests of the following: Electric Jeepney, LPG Jeepney, and Diesel Jeepney.
b) To identify operational issues, if any, and provide recommendations

II. Methodology

This study was divided into two phases, with Phase 1 having a less severe stop-and-go driving condition than Phase 1 because of more on-road stretches of relatively constant speed sections.

PUJ's from a transport cooperative using routes that fit Phase 1 and Phase 2 conditions were used. These PUJ's have passed inspection for roadworthiness and exhaust smoke opacity compliance conducted at the North Motor Vehicle Inspection Center of the Philippine Land Transportation Office.

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, and 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 a surveyor. Designated stops for the route were strictly followed by the drivers .The total length of the route for the first phase was 13.25 km round-trip with 6.75 km from SM North Edsa to UP Diliman and 6.25 km from UP Diliman to SM North Edsa. For Phase 2, the selected route was SM North Edsa to Litex via Commonwealth Avenue, with route length of 20.8 km round-trip, with roughly similar westbound and eastbound route lengths of 10.4 km each.

The full tank method of refueling was used in the measurement of the daily fuel consumption for the Diesel and LPG Jeepneys. Likewise, kWh used to charge Electric Jeepneys were measured as their fuel consumption.

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III. Data analysis and discussions

Model A.

The first model (Model A) utilizes actual data gathered from the on-road tests conducted. This model reflects actual conditions and shows all the revenues and expenses of the operator during the testing period. Data on actual number of passengers and distance travelled were also used to calculate performance parameters.

The Test Period indicates the total number of testing days. In some of these days, the test vehicle was down due to 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. Costs included in the Total Operating Expenses were fuel costs/charging costs, terminal fee, dispatcher's fee, and repairs and maintenance. Net Income over the entire testing period is calculated by

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

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 expenses incurred.

Average daily parameters were also calculated. The Gross Income, Operating Expenses, and the Net Income were all divided by the sum of Considered Days plus Downtime Days to get the average Daily Gross Income, Daily Operating Expenses, and Daily Net Income. The data are shown in Table I-II

$$\text{Daily Gross Income} = \text{Gross Income}$$

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

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

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

Table I
Data for Phase 1 (Model A)

Type	Diesel	LPG	Electric
Plate Number	*UVH 491*	*ZTS 904*	*ZZI 169*
Passenger Capacity	*20*	*20*	*16*
Operational Data			
Test Period, Days	72	108	72
Considered Days	52	37	41
No Operation Days	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)	8,713	6,063.31	4,807.17
Total Fuel Consumed (L)[1]	1,294.16	1,282.68	1,421.4
Gross Income (Php)	211,646.7	131,047.97	94,331.0
EXPENSES (Php)			
Fuel/Energy Cost	52,196.47	37,624.49	15,635.40
Terminal Fee	15,260.00	7,405.00	7,910.00
Dispatcher's Fee	4,450.00	5,854.00	5,720.00
Maint./Repair Expenses	6,325.00	7,633.00	3,507.00
Total Operating Expenses	78,231.47	58,516.49	32,772.40
NET INCOME	133,415.22	72,531.48	61,558.60
AVERAGE PERFOMANCE INDICATORS (Php)			
Daily Gross Income	3,779.41	1,955.94	2,193.74
Daily Operating Expenses	1,396.99	873.38	762.15
Daily Net Income	2,382.41	1,082.56	1,431.60

Table II
Data for Phase 2 (Model A)

Type	Diesel	LPG	Electric
Plate Number	*UWK 720*	*UUB 169*	*AAZ4219*
Passenger Capacity	*24*	*24*	*20*
Operational Data			
Test Period, Days	31	50	60
Considered Days	21	44	41
No Operation Days	5	6	8
Downtime Days	5	0	11
Total Passengers	4,991	10,819	11,061
Load Factor	0.6959	0.6974	0.6826
Total Distance Travelled (km)	3,072	8,068	4,901
Total Fuel Consumed (L)[1]	435.09	1,738.93	985
Gross Income (Php)	61,273.8	134,394.0	95,683.5
EXPENSES (Php)			
Fuel/Energy	12,466.27	41,459.20	10,500.1

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Cost			
Terminal Fee	1,120	1,645	2,034
Dispatcher's Fee	4,260	10,663	4,710
Maint./Repair Expenses	6,825	7,633	3,507
Total Operating Expenses	24,671.27	61,100.2	20,751.1
NET INCOME	36,602.53	73,293.8	74,932.4
AVERAGE PERFOMANCE INDICATORS (Php)			
Daily Gross Income	2,356.68	3,054.40	1,840.06
Daily Operating Expenses	948.895	1,388.64	399.06
Daily Net Income	36,602.53	73,293.8	74,932.4

For a better and normalized comparison, the Fuel Cost and Net Income 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 formulas:

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

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

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

The Load Factor reflected the average percentage of passengers riding the PUJ per trip and was obtained from the passenger data. The resulting computation for Fuel Cost per passenger-km and Net Income per passenger-km is shown in Table III-IV:

Table III
Normalized Data for Phase 1 (Model A)

	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	13.25	13.25
Fuel Cost, Php per passenger-km	0.25743023	0.3040262	0.1673734
Net Income, Php per passenger-km	0.65799681	0.5860937	0.6589711

Table IV
Normalized Data for Phase 2 (Model A)

	Diesel	LPG	Electric
Fuel Cost (Php)	12,466.27	41,459.20	10,500.1
Net Income (Php)	36,602.53	73,293.8	74,932.4
Total No. of Passengers	4,991	10,819	11,061
Load Factor	0.6959	0.6974	0.6826
Total Length of Route (km)	20.8	20.8	20.8
Fuel Cost, Php per passenger-km	0.17255947	0.2622614	0.0933767
Net Income, Php per passenger-km	0.5066562	0.4670193	0.6663908

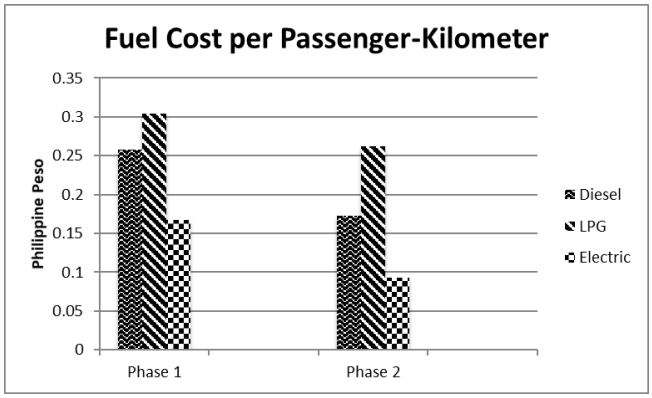

Fig. 1. Fuel Cost per Passenger-Kilometer of the three PUJ types in Phase 1 and Phase 2 using Model A.

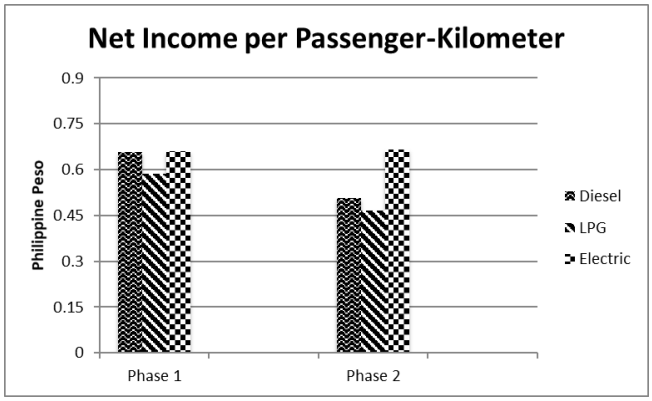

Fig. 2. Net Income per Passenger-Kilometer of the three PUJ types in Phase 1 and Phase 2 using Model A.

Model B.

The second model (Model B) was an equalized model, where only the daily fuel cost and maintenance were variable and all other parameters were kept constant. It was assumed that all PUJ's have fixed daily expenses and have covered the same number of trips. The simulated testing

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period was 72 days. Phase 1 had 20 trips per day, with a fare of 11 pesos per passenger per trip, while Phase 2 had 14 trips per day, with a fare of 15 pesos per passenger per trip. Maintenance expenses were simulated using actual market prices and assumed recommended preventive maintenance frequency was followed. Load Factors from Model A were used in this model.

Table V
Data for Phase 1 (Model B)

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
Considered Days	72	72	72
No Operation Days	0	0	0
Downtime Days	0	0	0
Total Passengers	18,279	17,225	14,686
Total Trips per Day	20	20	20
Load Factor	0.6347	0.5981	0.6374
Total Distance Travelled (km)	9,540	9,540	9,540
Liters/km, kWh/km (Electric)	0.1485320	0.2115478	0.295683
Price Php per liter, Price Php per kWh	43	29	11
Total Fuel Cost (Php)	60,930.829	58,526.819	31,029.01
Gross Income (Php)	211,646.69	131,047.97	94,331.00
EXPENSES (Php)			
Fuel/Energy Cost	60,930.829	58,526.819	31,,029.01
Terminal Fee	26,640	26,640	26,640
Dispatcher's Fee	1,800	1,800	1800
Maint./Repair Expenses	11,750	9,250	6,000
Total Operating Expenses	101,120.83	96,216.82	65,469.01
NET INCOME	99,952.13	93,261.26	96,073.65
AVERAGE PERFOMANCE INDICATORS (Php)			
Daily Gross Income	2,792.68	2,631.64	2,243.65
Daily Operating Expenses	1,404.46	1,336.34	909.29
Daily Net Income	1,388.22	1,295.30	1,334.36

Table VI
Data for Phase 2 (Model B)

Type	Diesel	LPG	Electric
Plate Number	*UWK 720*	*UUB 169*	*AAZ4219*
Passenger Capacity	*24*	*24*	*20*
Assumed Operational Data			
Test Period, Days	72	72	72
Considered Days	72	72	72
No Operation Days	0	0	0
Downtime Days	0	0	0
Total Passengers	18,279	17,225	14,686
Total Trips per Day	14	14	14
Load Factor	0.6959	0.6504	0.6826
Total Distance Travelled (km)	10,483.2	10,483.2	10,483.2
Liters/km, kWh/km (Electric)	0.141630	0.2155342	0.200979
Price Php per liter, Price Php per kWh	28.65	23.67	10.66
Total Fuel Cost (Php)	42,541.14	53,840.43	22,459.63
Gross Income (Php)	252,540	236,025	206,430
EXPENSES (Php)			
Fuel/Energy Cost	42,541.14	53,840.43	22,459.63
Terminal Fee	18,000	18,000	18,000
Dispatcher's Fee	2,160	2,160	2,160
Maint./Repair Expenses	11,750	9,250	6,000
Total Operating Expenses	74,451.146	74,564.432	48,619.630
NET INCOME	178,088.85	161,459.56	157,810.37
AVERAGE PERFOMANCE INDICATORS (Php)			
Daily Gross Income	3,507.5	3,278.12	2,867.08
Daily Operating Expenses	1,034.0437	1,035.631	675.272
Daily Net Income	2,473.4563	2,242.494	2,191.810

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As with Model A, the Fuel Cost, Operating Cost, and Net Income parameters were viewed on a passenger-kilometer basis.

Table VII
Normalized Data for Phase 1 (Model B)

	Diesel	LPG	Electric
Fuel Cost (Php)	60,930.829	58,526.819	31,029.01
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, Php per passenger-km	0.251570	0.256432	0.159462
Net Income, Php per passenger-km	0.68780	0.68103	0.82289

Table VIII
Normalized Data for Phase 2 (Model B)

	Diesel	LPG	Electric
Fuel Cost (Php)	42,541.14	53,840.43	22,459.63
Net Income (Php)	178,088.85	161,459.56	157,810.37
Total No. of Passengers	18,279	17,225	14,686
Load Factor	0.6959	0.6974	0.6826
Total Length of Route (km)	20.8	20.8	20.8
Fuel Cost, Php per passenger-km	0.17798904	0.2228005	0.117199
Net Income, Php per passenger-km	0.74511073	0.7436952	0.8234884

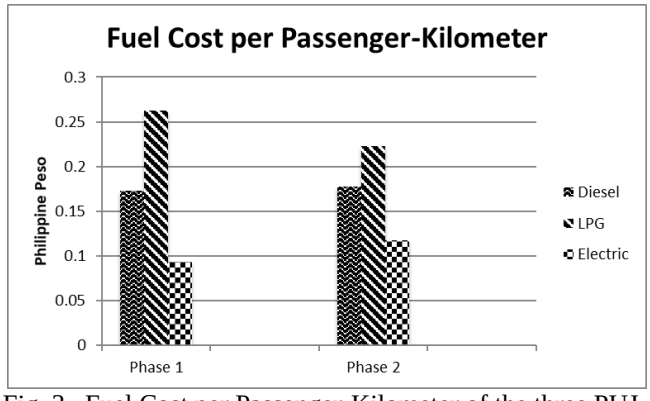

Fig. 3. Fuel Cost per Passenger-Kilometer of the three PUJ types in Phase 1 and Phase 2 using Model B.

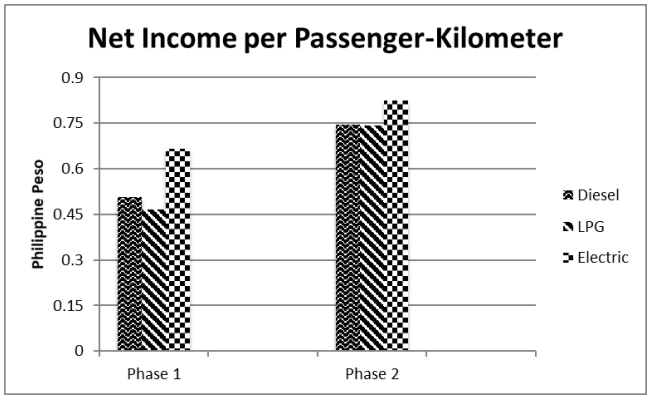

Fig. 4. Net Income per Passenger-Kilometer of the three PUJ types in Phase 1 and Phase 2 using Model B.

IV. Conclusion

In both Models A and B, the more economical PUJ to use for both routes in terms of fuel cost per passenger-km is the Electric Jeepney, followed by the Diesel Jeepney, and lastly by the LPG Jeepney. The same order of preference can be said in terms of net income per passenger-km.

The methodology applied may also be done using other route variations for a more thorough analysis. Note that other factors, such as performance and emission analysis, logistics for alternative fuel types (i.e. charging stations, LPG Refueling Stations, etc) must also be taken into account when selecting the proper PUJ type to use per route.

References

[1] Department of Transportation and Communications, Development of a Mega Manila Public Transportation Planning Support System (MMPTPSS). "Project Report. Mega Manila Public Transport Study", 2011
[2] Subida, R., Velas, M, Mcnamara, D, Integrated Environmental Strategies –Philippines Project Report/Metropolitan Manila: A Focus on the Transport Sector. ,2004
[3] Ronda, R.A., "Too Many Vehicles Slowing Down Traffic, Group Says," The Philippine Star, July 23 2012
[4] Republic of the Philippines Department of Transportation,"Omnibus Guidelines on the Planning and Identification of Public Road Transportation Services and Franchise Issuance" , 2017

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