Electric Tricycle Pilot Testing at the University of the Philippines in Diliman, Quezon City

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Abstract: The on-road test of the E-tricycles was conducted from June 22, 2015 to December 31, 2015. Each public transport E-tricycle was categorized as either high or low demand. Units used as public transport with low demand carried a daily average number of passengers from 22 to 60. The units traveled a daily average distance of 13 to 38 kilometers with daily average passenger-km of 16 to 106. The average kWh used per day is 3.51 with a maximum of 4.10 kWh and minimum of 2.29 kWh. The average duration of charging is 4 hours and 3 minutes. The computed average fuel efficiency is 8.97 km/kWh with maximum of 10.81 km/kWh and a minimum of 5.54 km/kWh. Category 2, with high demand carried a daily average number of passengers from 114 to 191. The computed average fuel efficiency is 7.99 km/kWh with maximum of 9.58 km/kWh and minimum of 6.64 km/kWh.

Keywords: electric tricycles, kilowatt-hour (kWh), kilometre, passenger-kilometer

1. INTRODUCTION

1.1 Background

The UP Diliman Chancellors Office, the Office of the Vice Chancellor for Community Affairs (OVCCA), and the E-tricycle management, agreed on the pilot-testing of several units of E-Tricycles (E-Trike) at the University of the Philippines, Diliman. The UP National Center for

Transportation Studies (UPNCTS) was tasked to conduct the research part of the pilot testing. The pilot testing is in line with the vision of the university to have a green environment system in the campus, thus eyeing electric vehicles to be part of the campus's transport system.

1.2 E-trike Production

The E-tricycle company has started its production of electric vehicles at their plant which is located in South Luzon. The EV engineers of the E-tricycle company were training their local counterparts in assembling the EVs. The company expects no less that standards imposed by their local EV subsidiary will be adhered by the Filipino technicians and local parts manufacturing partners.

Among the tests conducted by the E-tricycle company their EVs are vibration tests, slalom test, uphill and downhill run, water proofing and breaking capability.

With its partnership with a top lithium-ion battery manufacturer, the E-tricycle company extends full support in terms of their R&D departments to make sure the compatibility between E-tricycle's VCU technology and the battery is working seamlessly.

Furthermore, the company was expected to produce a minimum of 500 units per month or 6,000 units per year. It is preparing to increase its production capacity to 1,000 units per month or 12,000 units per year starting the third quarter of 2015.

1.3 Specifications of the E-trike

The E-trike units has specifications indicated in Table 1.1.

Table 1.1 E-trike Specifications (1/2)

Car Name		Passenger	
Model		68VM	
Dimension	Length	mm	3300
	Width	mm	1440
	Height	mm	1820
	Wheelbase	mm	2450
	Tread	mm	1285
	Ground Clearance	mm	130
Weight	Net Weight	Kg	450
	Passenger Capacity	Person	6+D
	Gross Weight	Kg	835
	Front Axle Load	Kg	235
	Rear Axle Load	Kg	600
Performance	Minimum Turning Radius	m	4.3
	Maximum Speed	Kph	50
	Mileage per Charge	Km	60 @ 20kph constant
	Gradeability	Degree	16

Main Battery	Type		Li-ion
	Nominal Voltage	V	55.2
Motor	Type		AC Induction Electric Motor
	Rated Voltage	V	AC 30
	Cooling System		Air Cooling
Other Devices	Drive System		Rear Wheel Drive
	Tire	Front	145/80-R13
		Rear	165/70-R14
Charger	Installation Mode		On-board
	Control System		Constant Current Control
	Input Voltage	V	Single-Phase AC 240
	Input Current	A	20

1.3 Objectives of the Study

The UP National Center for Transportation studies was tasked to formulate the protocol in testing the three wheeled vehicles. The following objectives were set:

1. to characterize operations parameters such as number of daily passengers carried, daily distance travelled, daily electricity kWh used, duration of charging, repairs and maintenance during testing;
2. to compute fuel efficiency (kWh/km), passenger-km/kWh;
3. to determine perception of both passengers and drivers of the E-trikes.

The pilot test of the E-trike was conducted at the University of the Philippines-Diliman campus from 22 June to 19 September 2015. Ten units of the E-trikes (or E-kots) were deployed to serve as a) service vehicles for the different offices of the university and b) public transport. The test was later extended up to December 31, 2015.

The perception survey interviews started on September 8 and ended on September 22.

1.4 Review of Related Studies

A study on alternative fuels entitled "Alternative Fuels Research Program (Phase 1), conducted by the National Engineering Center (UPNEC), in cooperation with the UP National Center for Transportation Studies (UPNCTS), UP Vehicle Research Testing Laboratory (UPVRTL) and the UP Electronics and Electrical Engineering Institute (UPEEEI), commissioned by the Department of Energy – Energy Utilization Management Bureau (DOE-EUMB), conducted on-road and laboratory tests to determine operations characteristics and fuel efficiency of electric jeepney, auto-LPG and diesel jeepney. The on-road tests of the jeepneys was conducted through the SM North – UP Campus route. The laboratory tests were conducted at the Department of Mechanical Engineering – Vehicle Research Testing Laboratory. The electric jeepney has a capacity of 16 and powered by lead acid batteries. The results of the study are still being evaluated before

releasing to the public. The average distance traveled on a single charge is 3.7 km/kwhr on a three battery bank swapping system. It can travel to as high a 4Km/KwHr and as low as 2.7Km/ KwHr. It was recommended that the e-jeep be used for public transport because of its low energy consumption, however, support infrastructure should be in place (e.g. battery swapping) for continuous operation.

2. E-TRIKE OPERATIONS

2.1 Preparation of the E-trike Drivers

On June 11, 2015, before the start of the on-road tests, the drivers of the E-trikes underwent orientation conducted by the E-tricycle company regarding safety and other administrative related tasks. They were also oriented on how to fill forms on the passenger trip data and charging logs.

The company's personnel demonstrated how to drive the three-wheeled vehicle as shown in Figure 1.

Figure 1. Personnel Showing the Different parts of the E-trike

The prospective drivers of the E-trike took turns test driving as shown in Figure 2.

Figure 2. A participant of the orientation taking his turn to drive the E-trike

2.2 Operations Characterization

There are two main categories of operations of the e-trikes. These are, (1) service for offices and (2) as a public transport. Figure 3 shows the map of UP Campus showing the routes taken by the different E-trike units.

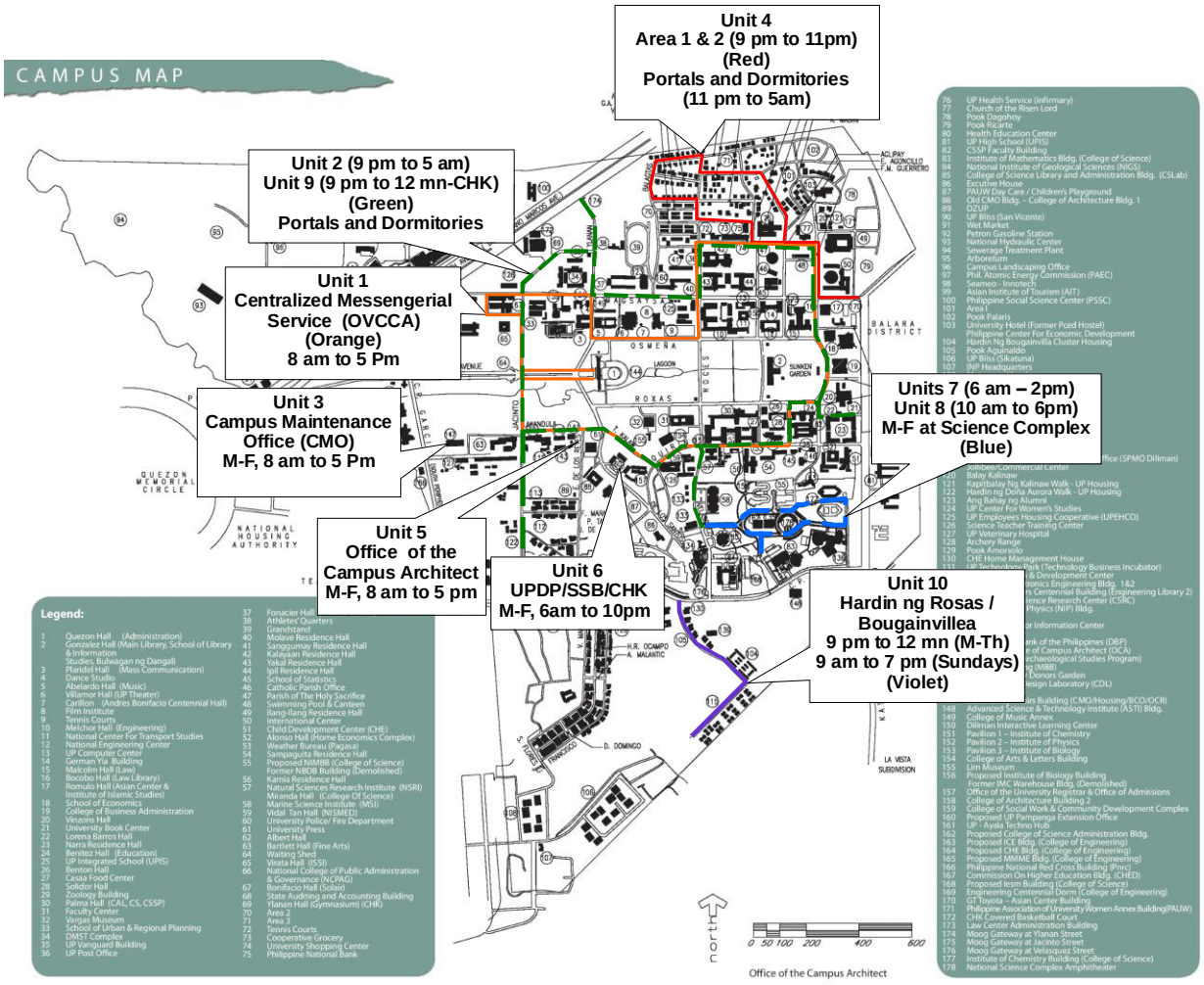

Figure 3. Map of Routes of E-trike Units inside UP Diliman

Units 1, 3, 5 and 6, which belong to the first category, are used to haul employees and cargoes, e.g. papers, documents, etc. to different locations inside the campus. Unit 1 follows a route (Orange Route) and a schedule when it is dispatched from the OVCCA (Quezon Hall). Units 3, 5 and 6 are on-demand basis when dispatched, i.e. no route and no schedule. These units which belong to the first category have their respective charging stations in the offices where they are assigned.

The second category plies a certain route with a prescribed headway. Units 5 and 6 are assigned to the Science Complex route (Blue Route) in which they are stationed at the parking area of the College of Science library to wait for passengers. The drivers were instructed to dispatch every 30 minutes, however, first passenger to board should not wait more than 10 minutes. This rule applies to the rests of the units, i.e. units 2, 4 and 9. Green route is marked dotted line to signify flexible route, i.e. unit takes the nearest route to reach destination of passenger. Unit 2 is stationed at the GT Toyota exit and is assigned to Area 1 and 2 from 9PM to 11PM, then transfers to the Green route from 11 PM to 5am. Units 4 and 9 also follow the Green route and are stationed at the Ylanan and Jacinto exits, respectively. Unit 10 operates at Hardin ng Bougainvilla and Rosas from 9PM to 12MN of Mondays to Thursdays and 9AM to 7PM on

Sundays. Table 2.1 shows summary of E-trike operations assignments, schedule, parking and charging stations.

Table 2.1 E-Trike operations assignments, schedule, parking and charging stations

Unit No.	Plate No.	Office/Route	Schedule of Operations	Parking and Charging Station
1	31	OVCCA/ Messengerial	M to F, 8 AM to 5 PM	Quezon Hall
2	18	Portals and Dormitories	M to F, 9 PM to 5AM	NCTS
3	32	CMO	M to F, 8 AM to 5 PM	Campus Maintenance Office
4	25	Area 1 and 2/ Portals and Dormitories	M to F, 9 PM to 5AM	NCTS
5	33	OCA	M to F, 8 AM to 5 PM	OCA
6	54	UPDP/SSB/CHK	M to F, 6 AM to 10 PM	UPDP
7	55	CS Complex	M to F, 6 AM to 2PM	EEEI
8	56	CS Complex	M to F, 10AM to 6PM	EEEI
9	57	Portals and Dormitories	M to F, 9 PM to 5AM	NCTS
10	58	On-Call (Overtime OUR/Library), Hardin ng Rosas/Bougainvilla	M to Th: 6 PM to 9 PM: On-Call (Overtime OUR/Library) 9 PM to 12 MN: Hardin ng Rosas/Bougainvilla Sunday: 9AM to 7PM: Hardin ng Rosas/Bougainvilla	EEEI/ UPDP

There have been changes in the schedule of operations from their original operations to maximize the use of E-trike units. These were:

1. Unit 2 originally served CHK players and the Green route at designated schedule. Due to limited number of units operating in the Green route, the said unit was later assigned solely to the Green route (Portals and Dormitories).
2. Unit 4 originally serves Area 1 and 2 from 9pm to 5am. It was shorten up to 11am due to scarce number of passengers. From 11 pm it transfers to the Green route to serve passengers going to and from portals and dormitories.
3. Unit 5 and 6 were originally operating up to Shuster St. near UPIS and College of Education. Due to complaints of TOKI drivers and operators, the route was cut short to cover only the Science Complex, i.e. from the Institute of Chemistry building, the units will proceed to NIMBB bldg. Then back to Velasquez St.
4. Unit 10 was originally operating from Monday to Friday from 9pm to 2am at Hardin ng Rosas/Bougainvilla. Due to requests of residents that a Sunday operation would be favourable since no shuttle jeepney operates on that day, an additional schedule of 9am to 7pm during Sundays was added to the E-trike's schedule. To compensate for the hours added, the Friday operation was removed.

2.3 Data Logging

To characterize the E-Trikes' operation, trip information are logged. The number of passengers, time start and end of trip, origin and destination, and initial and final odometer readings per trip are logged in designated forms. Figure 4 shows the odometer gauge (left), and driver recording the readings (right). There are times the passengers would be the ones recording the odometer readings.

Figure 4. Odometer Gauge (Left); E-trike driver recording odometer reading (Right)

To measure the kWh charged to the battery, a dedicated outlet in a charging station is assigned for every E-trike unit. The charging station has a submeter in which initial and final reading before and after charging are recorded in Form 5 (Appendix C). Figure 3 shows a submeter with a pair of outlets where the units are plugged in when charging.

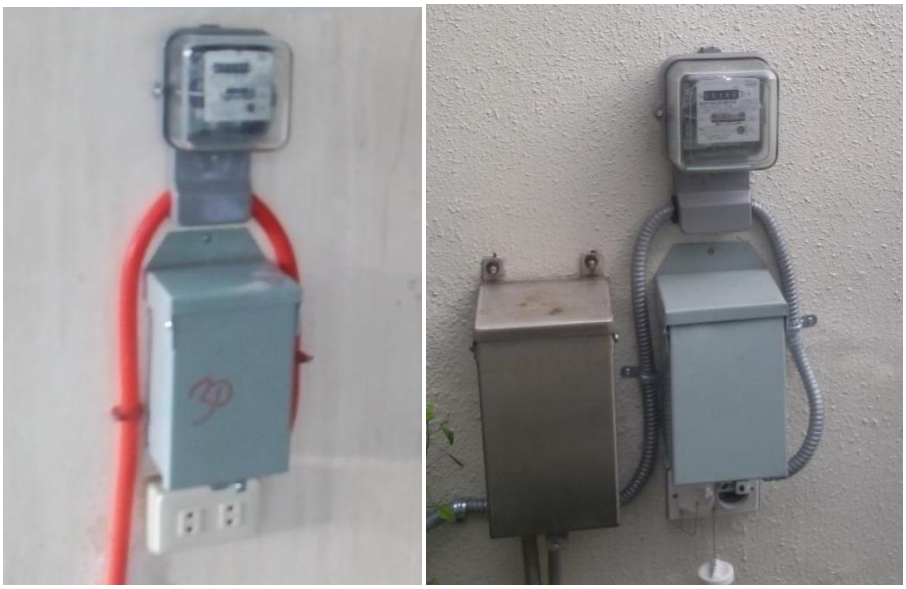

Figure 5. Submeters with a pair of outlets

To estimate the amount of kWh used corresponding to the distance covered by an E-trike, the "full tank (charge)" method is adopted. The drivers are advised to charge their units when it is almost drained. "Almost drained" was uniformly defined as – when the there is only one or two light indicators left (1 red or 1 red and 1green).

E-trike Units assigned at offices are charged after office hours. This allows them to be fully charged for the next day's operation. The E-trikes assigned at the CS complex and Hardin ng Rosas have to be charged at the middle of their operation since trips on this areas are more frequent.

2.4 Calibration of Odometer Gauges

To confirm integrity of the E-trikes' odometer gauges, five units were sampled and were run in the academic oval which has a known circumference of 2.2 kilometers. The test is done by marking a starting point in which an initial odometer reading is read. The three-wheeled vehicle then makes a complete run around the oval up to the starting point, after which a final odometer reading is recorded. Table 2.2 shows the odometer readings of the tests.

Table 2.2 Odometer Gauges Integrity Tests

Unit No.	Plate No.	Round	Initial Odometer Reading	Final Odometer Reading	Computed Distance	Average
2	18	1	2091.7	2093.9	2.2	2.2
		2	2093.9	2096.1	2.2	
		3	2096.1	2098.3	2.2	
4	25	1	2012.5	2014.7	2.2	2.2
		2	2014.7	2016.9	2.2	
		3	2016.9	2019.1	2.2	
5	33	1	1564.7	1566.9	2.2	2.2
		2	1566.9	1569.1	2.2	
		3	1569.1	1571.3	2.2	
7	55	1	2558.4	2560.6	2.2	2.2
		2	2560.6	2562.8	2.2	
		3	2562.8	2565.0	2.2	
9	57	1	1935.5	1937.7	2.2	2.2
		2	1937.7	1939.9	2.2	
		3	1939.9	1942.1	2.2	

The odometer readings of the tested units show integrity when compared to the known circumference of the academic oval.

2.5 Analysis and Computations

The parameters that are considered in the analysis are: passenger-kilometer/kWh and km/kWh. Other parameters such as (1) time of charging, (2) time and distance traveled before next charging and repairs and maintenance issues were also computed.

To obtain passenger-kilometer, the number of passenger boarding and alighting in the origin destination is multiplied by the distance (final minus initial odometer reading). The sum is lumped for every day of operations. Overall distance covered for the day is also computed by subtracting initial odometer reading before operations to the final odometer reading after operations.

The kilowatt-hour used charged is computed from the difference of kWh initial kWh reading before charging and the initial kWh reading after charging.

The daily trip characteristics were computed both for Category 1 and Category 2. 2.3.1. Daily Trip Characteristics

E-trike Category 1

Category 1 of E-trikes are used as service vehicles of different offices in the Campus. Table 2.3 shows daily trip characteristics and charging properties of E-trikes. This category of the units carried a daily average of number passenger from 10 to 40. The units traveled an daily average distance of 13 to 30 kilometers, with daily average passenger-km of 12 to 50. The average kWh charged per day is 3.17 (Max: 3.75, Min: 2.64) with average duration of charging of 4 hours and 49 minutes. The computed average fuel efficiency is 9.41 km/kWh (Max: 13.50, Min: 7.12).

Table 2.3 Daily Trip Characteristics and Charging Properties (Category 1 – Offices)

Unit No.	Statistical Parameter	Total No. of Passenger	Total Distance Traveled	Total Passenger Km	Total kWh Used	Duration of Charging	Fuel Efficiency (km/kWh)
1	Average	10.33	13.41	12.35	2.72	2:18	6.38
	Maximum	82.00	41.90	137.20	4.60	4:09	13.94
	Minimum	0.00	1.00	0.00	1.00	0:47	3.67
	Std Dev	17.57	7.95	24.38	1.06	0:58	3.03
3	Average	29.23	25.34	52.54	3.32	4:54	8.17
	Maximum	56.00	46.80	112.50	6.00	3:20	24.10
	Minimum	4.00	1.70	7.20	1.00	1:30	0.00
	Std Dev	14.88	9.37	27.71	1.09	5:30	4.70
5	Average	33.02	23.79	39.31	3.06	2:42	13.50

	Maximum	93.00	39.30	113.20	5.30	5:08	33.67
	Minimum	1.00	3.90	2.80	0.60	0:54	0.67
	Std Dev	19.18	6.61	24.19	0.83	0:48	7.93
6	Average	39.77	30.69	47.50	3.75	3:43	8.52
	Maximum	106.00	64.60	130.10	8.50	14:02	25.84
	Minimum	3.00	2.70	4.20	0.50	1:17	1.69
	Std Dev	22.93	13.23	26.02	1.40	2:27	4.15

Statistical Parameter	Total No. of Passenger	Total Distance Traveled	Total Passenger Km	Total kWh Used	Duration of Charging	Fuel Efficiency (km/kWh)
Average	28.09	23.31	37.93	3.21	3:24	8.97
Maximum	39.77	30.69	52.54	3.75	4:54	13.50
Minimum	10.33	13.41	12.35	2.72	2:18	5.70
Std Dev	12.62	7.23	17.90	0.43	1:09	3.27

E-trike Category 2

Table 2.4 indicates trip characteristics and charging properties of E-trikes with Category 2 usage – as public transport. This category of the units is further categorized to two, namely (a) high demand, (b) low demand. The data in Unit 10 is divided on the two categories since its operation during Sundays can be considered as high demand. Therefore Units 7, 8 and 10 (Sundays) are subcategorized as high demand and Units 2, 4, 9 and 10 (M-F) are low demand. Low demand E-trike characteristics are shown in Table 2.4 and the high demand in Table 2.5.

Category 2 with low demand carried a daily average number of passenger from 22 to 60. The units travels an daily average distance of 13 to 38 kilometers, with daily average passenger-km of 16 to 106. The average kWh charged per day is 3.51 (Max: 4.10, Min: 2.29) with average duration of charging of 4 hours and 3 minutes. The computed average fuel efficiency is 8.97 km/kWh (Max: 10.81, Min: 5.54).

Table 2.4 Trip Characteristics and Charging Properties
(Category 2 – Public Transport, Low Demand)

Unit No.	Statistical Parameter	Total No. of Passenger	Total Distance Traveled	Total Passenger Km	Total kWh Used	Duration of Charging	Fuel Efficiency (km/kWh)

2	Average	60.62	36.66	105.70	4.10	3:31	9.30
	Maximum	148.00	89.10	534.90	8.10	6:55	25.07
	Minimum	5.00	10.40	4.00	1.40	0:57	2.20
	Std Dev	29.39	13.71	86.58	1.34	1:00	4.00
4	Average	48.86	37.75	71.76	3.80	5:12	10.81
	Maximum	98.00	76.90	137.90	8.20	16:45	26.47
	Minimum	2.00	5.70	1.40	1.70	1:49	2.04
	Std Dev	24.84	13.31	39.12	1.44	3:53	4.67
9	Average	45.16	35.23	95.65	3.64	3:31	10.23
	Maximum	88.00	46.40	638.90	6.40	5:15	21.69
	Minimum	17.00	14.70	6.40	1.60	1:59	4.59
	Std Dev	18.90	7.38	109.96	0.97	0:51	3.29
10	Average	22.51	13.27	15.95	2.49	3:57	5.54
	Maximum	32.00	24.10	31.20	6.80	13:12	13.76
	Minimum	10.00	9.00	9.50	1.20	0:55	0.00
	Std Dev	4.67	2.92	5.54	1.20	10:44	3.43

Statistical Parameter	Total No. of Passenger	Total Distance Traveled	Total Passenger Km	Total kWh Used	Duration of Charging	Fuel Efficiency (km/kWh)
Average	44.29	30.73	72.27	3.51	4:03	8.97
Maximum	60.62	37.75	105.70	4.10	5:12	10.81
Minimum	22.51	13.27	15.95	2.49	3:31	5.54
Std Dev	15.94	11.68	40.15	0.70	0:47	2.37

Category 3, with high demand carried a daily average number of passenger from 114 to 191. The units travel an daily average distance of 34 to 45 kilometers, with daily average passenger-km of 60 to 112. The average kWh charged per day is 4.78 (Max: 5.60, Min: 3.77) with average duration of charging of 3 hours and 40 minutes. The computed average fuel efficiency is 7.99 km/kWh (Max: 6.64, Min: 9.58).

Table 2.5 Trip Characteristics and Charging Properties
(Category 3 – Public Transport, High Demand)

Unit No.	Statistical Parameter	Total No. of Passenger	Total Distance Traveled	Total Passenger Km	Total kWh Used	Duration of Charging	Fuel Efficiency (km/kWh)
7	Average	191.45	45.36	112.43	5.60	5:33	7.74
	Maximum	280.00	89.20	184.60	7.20	7:40	12.27

	Minimum	74.00	17.60	42.33	3.70	3:25	1.75
	Std Dev	58.51	13.04	33.00	0.74	0:53	1.48
8	Average	186.79	45.31	112.41	4.96	2:22	6.64
	Maximum	352.00	142.60	230.50	9.00	4:40	41.64
	Minimum	14.00	6.00	7.00	0.00	0:00	1.21
	Std Dev	83.36	22.82	48.82	2.72	1:14	8.30
10	Average	113.75	34.28	59.25	3.77	3:07	9.58
	Maximum	162.00	43.90	86.20	5.20	5:02	12.23
	Minimum	63.00	26.30	32.70	2.20	1:40	8.24
	Std Dev	54.09	9.01	27.49	1.50	1:26	1.84

Statistical Parameter	Total No. of Passenger	Total Distance Traveled	Total Passenger Km	Total kWh Used	Duration of Charging	Fuel Efficiency (km/kWh)
Average	164	41.65	94.70	4.78	3:40	7.99
Maximum	191	45.36	112.43	5.60	5:33	9.58
Minimum	114	34.28	59.25	3.77	2:22	6.64
Std Dev	44	6.39	30.70	0.92	1:40	1.48

2.6 Repairs, Maintenance and Accidents Encountered

Among the repairs conducted by the maintenance team of the E-tricycle company were: (1) turning signal not lighting, (2) no power, (3) passenger lighting not working (shorted due to water dripping from joint of roofing), and (4) battery not charging. The technicians have always been prompt in addressing issues on the operability of the electric vehicles.

The only road mishap encountered by the test vehicles was when Unit 6 was sideswept by a backing jeepney at the intersection of Osmeña Avenue and Roces Street. Figure 6 shows a scraped paint at the right side of the unit. The E-trike driver infers that the public utility jeepneys driver was not aware that his vehicle sideswept the E-trike that he did not bother checking whether he has indeed hit the E-trike.

Figure 6. Side of the E-trike Sideswept by a Public Utility Jeepney at Osmeña Avenue

2.7 Passenger Perception Study

A passenger perception survey was conducted to the main recipients of the E-kot service. The questionnaires were distributed to different offices in the campus, dormitories and nearby communities. Students, employees and residents of the UP Diliman community were the main respondents of the perception survey. Accomplished survey forms were later retrieved, encoded and processed.

The survey was designed to measure how the passengers, perceive the effectiveness of the E-kot as a public transport. It touches upon a number of features of the E-kot units, such as comfort, safety and travel time. The respondents gave an overall positive satisfaction on e-kot as they realize its advantages over other transport modes in the campus.

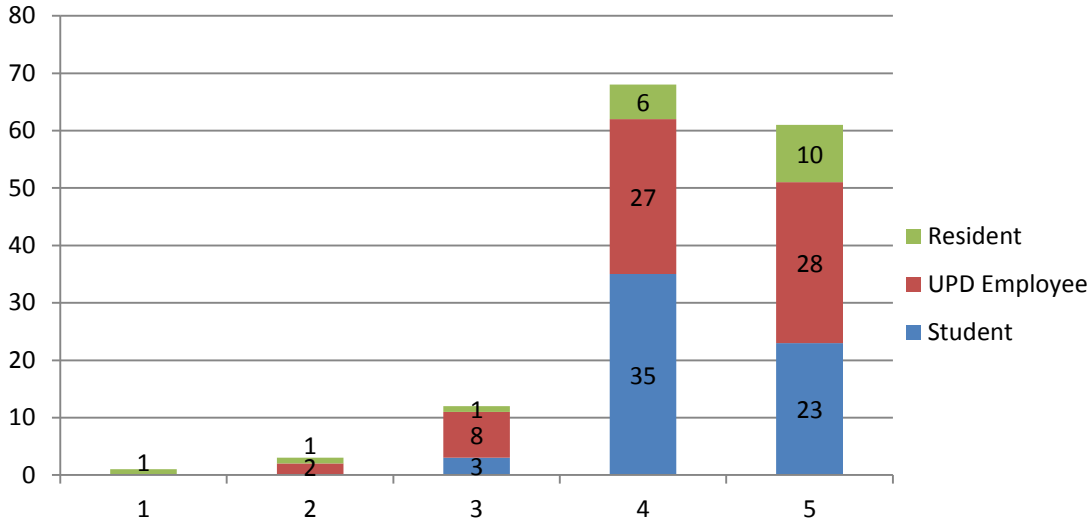

Figure 31. Overall satisfaction for the e-kot service.

Majority of the respondents are willing to pay 5 pesos for every e-kot ride as the respondent's main priority is its economic impact on their commuting (see Figure 32). Others even suggested that the rides would be free. This is evident as most of the respondents are students thus classified as non-income generating individuals

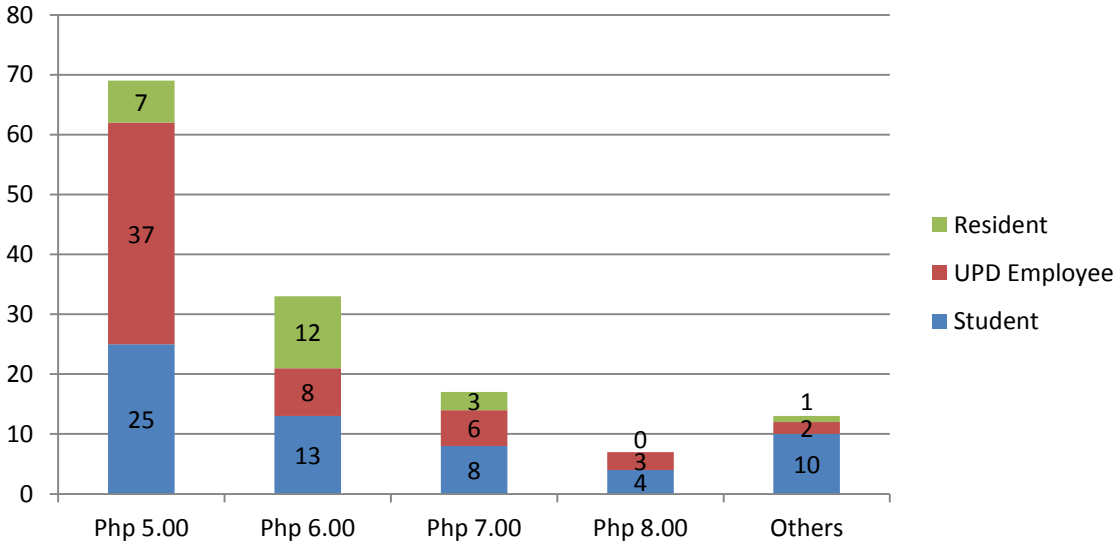

Figure 32. Willingness to pay for the e-kot service.

3. CONCLUSIONS AND RECOMMENDATIONS

The pilot testing of the E-trike was conducted with minimal repairs. The passengers of the E-trikes were successfully transported from their origin to their destinations. There were minimal cases of breakdowns reported. The E-tricycle company had been prompt in addressing issues regarding smooth operations of the units.

The E-trikes that were used as service vehicles of different offices in the Campus carried a daily average of passenger from 10 to 40 with a daily average total distance travelled of 13 to 30 kilometers. The daily average passenger-km was from 12 to 50 and the kWh used per day is 3.17 (Max: 3.75, Min: 2.64) with average duration of charging of 4 hours and 49 minutes. The computed average fuel efficiency is 8.97 km/kWh with a maximum of 13.50 km/kWh and a minimum of 5.70 km/kWh.

Units used as public transport with low demand carried a daily average number of passengers from 22 to 60. The units travelled a daily average distance of 13 to 38 kilometers with daily average passenger-km of 16 to 106. The average kWh used per day is 3.51 with a maximum of 4.10 kWh and minimum of 2.29 kWh. The average duration of charging is 4 hours and 3 minutes. The computed average fuel efficiency is 8.97 km/kWh with maximum of 10.81 km/kWh and a minimum of 5.54 km/kWh. Category 2 with high demand carried a daily average number of passengers from 114 to 191. They travelled a daily average distance of 34 to 45 kilometers, with daily average passenger-km of 60 to 112. The average kWh charged per day is 4.78 (Max: 5.60, Min: 3.77) with average duration of charging of 3 hours and 40 minutes. The computed average fuel efficiency is 7.99 km/kWh with maximum 9.58 km/kWh of and minimum of 6.64 km/kWh.

The conducted perception interview survey showed favourable responses from respondents in terms of comfort, safety and travel time. Respondents are willing to pay a fare of Php 5.00 for the E-kot ride. Majority of the respondents rated overall satisfaction of 4 and 5 (1 lowest, 5 – highest). Most of the respondents are in favour of making the E-kot a permanent transport in the Campus.

The results of the pilot testing of the electric tricycle in UP Diliman prove that the electric tricycle can be a viable transport mode in the campus. Such transport mode may well be used with similar route terrain at other school campuses.

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