

Application of Electric Motorcycles in Macau

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Abstract

The development of electric vehicles (EVs) has advanced rapidly over the past decades. Researchers and engineers have concentrated on the improvement of EV performance through the advances in batteries, motors, converters, controllers and relevant auxiliaries, with great successes. Now, it comes to the stage of commercialization! It is important to understand various cost issues and the business models relating to EV application. This paper aims to discuss the application and cost analysis of EVs and internal combustion engine (ICE) vehicles in Macau. Viability of EVs will be assessed by comparing the costs of an electric motorcycle (EM) with its comparable counterparts.

Keywords: BEV (battery electric vehicle), cost, LCA (Life Cycle Assessment), scooter

1 Introduction

With the growing concerns on price fluctuation, depletion of petroleum resources, global warming, environmental and health, there is fast growing interest in electric vehicles (EVs) in Macau and also a pressing need for researchers and power utilities to develop various infrastructures for EVs and strategies for adapting EVs. Being a city with small geographical size (29.9km²) limiting the travel range of vehicles, Macau has great potential for EV implementation [1] to [3].

With an urbanized city and limited land space, Macau has been faced with problems of road congestion and rapid growth in car population. Total length of public roads in Macau was 395km, and the motor vehicle density was 550 vehicles per kilometer. Motorcycles are not only widely used by private users but also business users. From Table 1, the total number of motorcycles is steadily increasing, with 115,623 licensed by the end of 2012, 53.2% of total number of vehicles in Macau. And it is straightforward to broaden the EV market in

Macau by first choosing electric motorcycles (EMs).

Air pollution is also another important concern. EVs provide low emission urban transportation. Even taking into account the emissions from power plants needed to fuel the vehicles, the use of EVs can reduce carbon dioxide (CO₂) emissions significantly. From the energy aspect, EVs are efficient and environmentally friendly [3] to [5]. Thus, EVs are promising green vehicles that can

Table 1: Number of Vehicles in Macau

Year	Total	Light Vehicles	Heavy Vehicles	Motor Cycles
2006	162,874	71,726 (44.1%)	5,780 (3.5%)	85,368 (52.4%)
2007	174,520	76,117 (43.6%)	6,107 (3.5%)	92,296 (52.9%)
2008	182,765	78,753 (43.1%)	6,288 (3.4%)	97,724 (53.5%)
2009	189,350	80,499 (42.5%)	6,285 (3.3%)	102,566 (54.2%)
2010	196,634	83,879 (42.7%)	6,363 (3.2%)	106,420 (54.1%)
2011	206,349	88,581 (42.9%)	6,570 (3.2%)	111,198 (53.9%)
2012	217,335	95,063 (43.7%)	6,649 (3.1%)	115,623 (53.2%)

reduce both energy consumptions and CO₂ emissions [3] and [4].

2 EVs in Macau

In November 2010, the Macau Government announced to promote “Green Vehicles” by offering tax incentives in acquisition of “energy efficient vehicles” [7]. During past three years, several public test rides and demonstrations of electric motorcycles (EMs), scooters, mini/mid-size sedans and buses were conducted by manufacturers from Europe, Japan, Taiwan and China.

The Macau Government approved in February 2012 to promote “Green Vehicles” by offering 50% tax reduction (with a limit of MOP60,000; €1 ≈ MOP10.66) in acquisition of energy efficient vehicles [8]. Three battery-powered EVs (BEVs) were imported to Macau, the first by the power company, the second by a car renting company (both in April 2010 and had been running in real-world for more than 43 months); the third was bought by Macau Government in September 2011.

A project was launched to investigate the performance of EV, specifically for sub-tropical environment of Macau. Due to the high

temperature and humidity, performance of EVs operated in Macau was yet to be understood. Previous experimental studies conducted in the US, Europe or Japan might not reflect the actual local real-road driving conditions. The EV performance study was a collaboration work between the University of Macau (UM) and a local electric power company, Companhia de Electricidade de Macau (CEM), aimed to understand issues relating to EV adoption [9].

3 Driving Tests and Performance Evaluation

The previous experimental works [3] aimed at the road testing of EVs and evaluation of fuel costs and CO₂ reductions when EVs are adopted in Macau area, via testing of an EV and compared with its comparable internal combustion engine (ICE) counterpart “i”. Road test also revealed that a fuel cost saving of more than 70.4% could be achieved when both the EV and ICEV were tested under same routes [3].

From Table 1, more than half (53.2%) of vehicles in Macau are motorcycles, in view of this, an EM was chosen in this experimental project, an ICE powered counterpart was also used as baseline for evaluation, test results are to be presented in



Fig. 1 Road Test (a) Test route; (b) Motorcycles being tested: ICE (left) and electric (right).

following sections.

4 Road Test Results

The concept of real driving conditions is emphasized in this test routes rather than collecting data synthesized from simulated conditions using a chassis dynamometer in the laboratory, as it would not have been the real driving conditions. Moreover, the road driving test was conducted with both an EM and gasoline-powered motorbike.

Both vehicles were tested for two laps and the sequence of driving was interchanged during the second lap in order to cancel the effects of different driving habit of drivers. The test was conducted on 8 December 2012, with frequent start-stops in downtown area during lunch hours, similar to those performed in [3]. Summary of primary results were shown in Table 2. Differences in distance travelled were due to location between the gas station and EV charging station.

Unit fuel costs (€1 ≈ MOP10.66) for the day of road test were listed in Table 2, fuel per unit distance and distance to be travelled per unit fuel were also calculated and tabulated in the same table for comparison. From the table, we can see that the fuel cost saving achieved was around 90.36%.

5 Costs to Consumer

It is the most expensive to pay upfront for acquiring an EM, but not the costs for operating and maintaining! To investigate the various costs and the future business models relating to EM application, it was proposed to evaluate the present value of life cycle cost (LCC) [6] of an EM and compare with ICE vehicle.

5.1 Upfront Costs and Taxes

In Macau, the motor vehicle tax was already included in the vehicle purchase price listed by a dealer (Table 3), but the owners are required to pay the vehicle circulation tax annually (Table 4), which will be waived for EVs in Macau.

5.2 Operating and Maintenance (O & M) Costs

Acquisition cost of EVs is high. However, EVs are much more efficient than ICE vehicles [3], their o & m costs are also much lower. Various maintenance and operating costs, e.g. engine oil (ICE only), tires and 12V batteries (ICE and

Table 2: Fuel cost and consumption

	EM	ICE
Fuel price (MOP)	1.283 per kWh	12.56 per Liter
Fuel consumption per distance travelled	0.0533 kWh per km	0.0564 Liter per km
Distance travelled per unit fuel	18.76km per kWh	17.72km per Liter
Fuel cost per distance travelled (MOP)	0.0684 per km (9.64%)	0.7088 per km (100%)

Note: €1 ≈ MOP10.66

Table 3: Price of vehicles

	MOP (Taxed)
Ebubu (electric)	30,000
Yamaha (49c.c. ICE)	19,900

Table 4: Operating and maintenance costs

	ICE (MOP)	EM (MOP)
Engine oil (every 6,000km)	400	-
Tires (every 12,000km)	1,000	1,000
Routine maintenance (every 9,000km)	500	500
Battery (12V) (every 36,000km)	400	400
Annual vehicle circulation tax	500	-
Fuel (per km)	0.0684	0.7088

auxiliaries for EM) for ICEV and EM are compared in Table 4.

5.2.1 Forecast of gasoline price

Historical quarterly price of gasoline from Q4/2008 to Q4/2011 [10] to [11] was used to forecast the future gasoline price from 2013 to 2021, using equations (1-3) below, as y is the forecast for period t :

$$y_t = a + bt \quad (1)$$

where

$$b = \frac{n \sum ty - \sum t \sum y}{n \sum t^2 - (\sum t)^2} \quad (2)$$

and

$$a = \frac{\sum y - b \sum t}{n} \quad (3)$$

Similarly, historical yearly electricity prices [10] to [11] from 2007 to 2011 were used to forecast the future electricity price from 2013 to 2021, using the same decomposition approach. Parameters a , b and forecasting accuracy were to be further investigated and analyzed in the future. Results of forecasted prices of gasoline and electricity are shown graphically in Fig. 2 and Fig. 3 respectively.

5.2.2 Present value of o & m costs

Expenditures for o & m are to be happened in

the future, for example, the monthly fuel consumption costs are to be settled monthly. When comparing the various costs, the present values of future expenditures are evaluated using equation (4):

$$P = \frac{F}{(1+i)^n} \tag{4}$$

where:

- P = present value of expenditure
- F = future expenditure
- i = interest rate (2.81% in 2012)
- n = interest compounding period

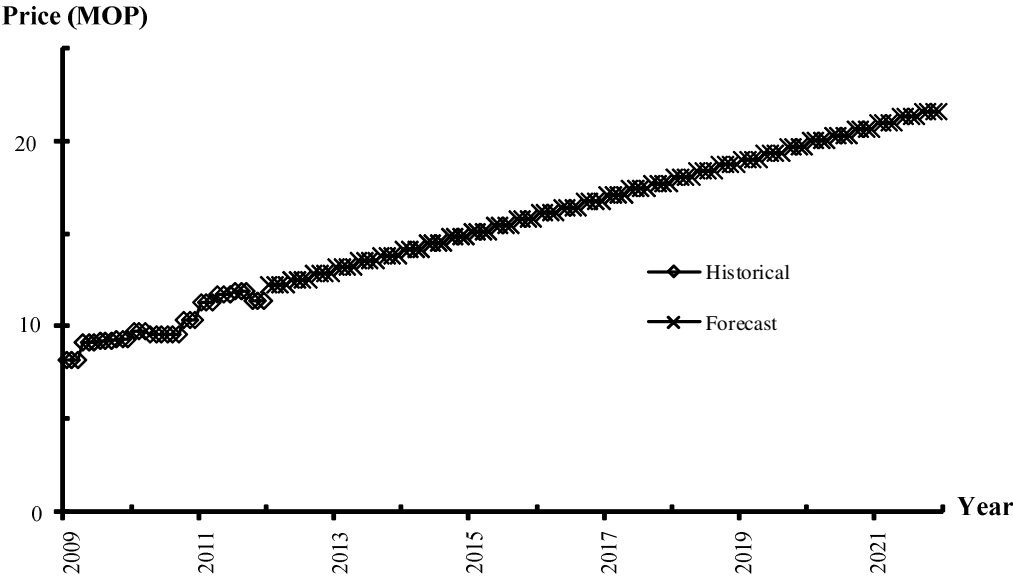


Fig. 2 Price of gasoline in Macau.

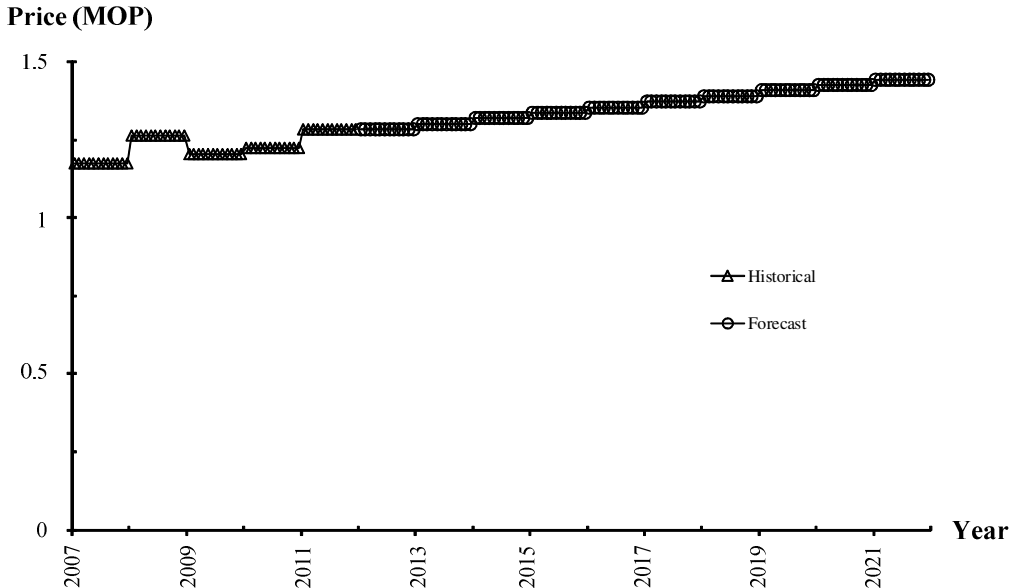


Fig. 3 Price of electricity in Macau.

5.2.3 Costs to Consumer

LCCs are the summation of all costs mention in sections 5.2.1 to section 5.2.2 (upfront cost listed in Table 3 and o & m costs tabulated in Table 4, since 2-cylinder scooter used for road test will be banned soon, so consumption of 0.033 Ltr per km will be used in LCC estimation), over the lifetime of the vehicles. By assuming both the ICEV and EM are to be used in Macau, and assuming a monthly driving range of 1,500km, all costs listed in Tables 3 and 4 incurred during operation were calculated and plotted in Fig. 4.

6 Conclusion

From Fig. 4, after 14 months of operation, the total costs of an ICE motorcycle will be €3,318 while it is higher than €3,294, the total costs of an EM. From Fig. 3, the break-even time for these two vehicles was estimated to be February 2014.

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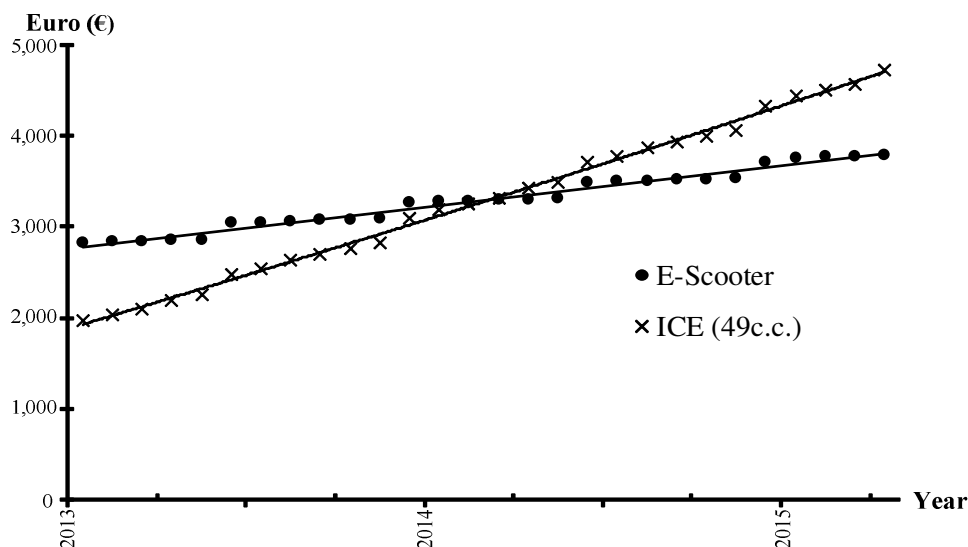


Fig. 4 Present values of LCC for 2 motorcycles.

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