Pilot Green Transport Fund

Final Report On
Trial of Hybrid Light Buses
for Green Public Light Bus Services
(Pokfulam Maxicab Company Limited)

(22 December 2020)

PREPARED BY:

Dr. Joe LO Ka Wah
Mr. Elvin NG Cheuk Yin
Mr. CHAN Ka Chun
Mr. Ricky CHONG Ka Ho

List of Monitoring and Evaluation Team Members

Dr. Joe K. W. LO (Team Leader)
Centre Manager
Jockey Club Heavy Vehicle Emissions Testing and Research Centre
Hong Kong Institute of Vocational Education (Tsing Yi)

Mr. Elvin C. Y. NG (Team Member)
Test Engineer
Jockey Club Heavy Vehicle Emissions Testing and Research Centre
Hong Kong Institute of Vocational Education (Tsing Yi)

Mr. K. C. CHAN (Team Member)
Technician
Jockey Club Heavy Vehicle Emissions Testing and Research Centre
Hong Kong Institute of Vocational Education (Tsing Yi)

Mr. Ricky K. H. CHONG (Team Member)
Executive Assistant
Jockey Club Heavy Vehicle Emissions Testing and Research Centre
Hong Kong Institute of Vocational Education (Tsing Yi)

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Final Report
(Trial Period: 1 April 2018 – 31 March 2020 for HV-1
and 1 September 2018 – 31 August 2020 for HV-2)

Executive Summary

1 Introduction

1.1 The Pilot Green Transport Fund (the Fund) is set up to encourage transport operators to try out green innovative transport technologies, contributing to better air quality and public health for Hong Kong. Pokfulam Maxicab Company Limited (Pokfulam Maxicab) was approved under the Fund for trial of two diesel-electric hybrid light buses (HVs) for green public light bus services.

1.2 Hong Kong Institute of Vocational Education (Tsing Yi) has been engaged by the Environmental Protection Department as an independent third-party assessor to monitor the trial and evaluate the performance of the trial vehicles. Pokfulam Maxicab assigned two liquefied petroleum gas (LPG) public light buses (GVs: GV-1 and GV-2) providing similar services as the conventional vehicles for comparing with the HVs.

1.3 This Final report summarizes the performance of the HVs in the 24 months of the trial as compares with their conventional counterparts.

2 Trial and Conventional Vehicles

2.1 Through the tendering procedures stipulated in the Subsidy Agreement, Pokfulam Maxicab procured two GMI Gemini GM6700GAREEV diesel-electric hybrid light buses (HVs: HV-1 and HV-2) for trial.

2.2 Key features of the HVs and the GVs are in Appendix 1 and photos of the vehicles are in Appendix 2. The vehicles were used for providing green public light bus services on Hong Kong Island, with HV-1 and GV-1 serving the green minibus (GMB) route no. 23/23M between Kennedy Town MTR Station and Chi Fu Fa Yuen in Pok Fu Lam, and HV-2 and GV-2 serving the GMB route no. 22/22S/22X between Pok Fu Lam Garden and Central (Exchange Square). According to the manufacturer, the HVs had a gross vehicle weight of 7,000 kg and a cylinder capacity of 2,776 cc.

3 Trial Information

3.1 HV-1 and HV-2 started their trials on 1 April 2018 and 1 Sep 2018 respectively, and each lasted for 24 months. Pokfulam Maxicab was required to collect and provide trial information including the HV odometer reading before refueling, the date of refueling, the refueled amount, cost and operation downtime associated with scheduled and unscheduled maintenances of the HVs. Similar sets of data from the GVs were also required. In addition to the cost information, reports on maintenance work, operational difficulties and opinions of the drivers and Pokfulam Maxicab were also collected to reflect any problems of the HVs.

4 Findings of Trial

4.1 Table 1 summarizes the statistical data of the HVs and the GVs. The average total operating costs of HV-1 and HV-2 were higher than those of the GV-1 and GV-2 by HK$0.75/km (29%) and HK$1.51/km (65%) respectively. The fleet average total operating cost of all two HVs was HK$1.13/km (46%) higher than that of the GVs. The average fuel costs of HV-1 and HV-2 were higher than those of the GV-1 and the GV-2 by HK$1.40/km (87%) and HK$1.98/km (146%) respectively. The fleet average fuel cost of the HVs was HK$1.68/km (113%) higher than that of the GVs. It was because the HVs consumed diesel and the GVs consumed LPG. The average unit price of diesel was higher than that of the LPG by over 300%.

Table 1: Key operation statistics of each vehicle (April 2018 – March 2020 for HV-1 and September 2018 – August 2020 for HV-2)

		HV-1	**HV-2**	**GV-1**	**GV-2**
Total mileage (km)		77,991	51,218	130,924	112,860
Fuel cost (HK$) [1]		234,887	170,851	207,743	158,381
Average fuel economy	(km/litre)	4.66	4.25	2.13	2.39
	(km/MJ)	0.129 [4]	0.118 [4]	0.090 [5]	0.101 [5]
Average fuel cost (HK$/km)		3.01	3.34	1.61	1.36
Fleet average fuel cost (HK$/km)		3.17		1.49	
Average total operating cost (HK$/km)		3.34	3.82	2.59	2.31
Fleet average total operating cost (HK$/km)		3.58		2.45	
Downtime (working day) [2] [3]		42	36	24	24

[1] The market rate was adopted for calculation.
[2] Downtime refers to the equivalent number of working days in which the vehicle is not in operation due to maintenance, counting from the first day it stops operation till the day it is returned to the operator.
[3] Maintenance due to traffic accident or incidents unrelated to the performance of the vehicle was not included for comparison.
[4] Assuming lower heating value of 36.13 MJ/litre for diesel fuel.
[5] Assuming lower heating value of 23.67 MJ/litre for LPG fuel.

4.2 During the 24 months of the trial, there were 5 scheduled maintenances for each of the HVs and 24 for each of the GVs. Also, there were 14 unscheduled maintenances for HV-1 and 11 for HV-2, while none for the GVs in this reporting period. The scheduled and unscheduled maintenances of HV-1 and HV-2 resulted in 42 days and 36 days of operation downtime respectively, while the GVs each had 24 days of operation downtime in this reporting period. There were 730 working days in the reporting period. The utilization rates of HV-1, HV-2 and the GVs were 94%, 95% and 97% respectively.

4.3 The drivers felt that the HVs produced less air pollutants. In the beginning of the trial, the drivers expressed that the HVs ran quieter than the GVs when they were not charging, but were noisy during charging and sometimes the drivers even could not hear passengers notifying him to get off the HVs at the next station. The situation was reported to the manufacturer and the following mitigation measures were taken to tackle the noise problem:

i) redesigned with tighter seams and changed to a thicker molded plastic to insulate the cabin from engine noise;
ii) lined the engine compartment with thicker sound insulation materials;
iii) re-routed the main cable and wiring harness from the underchassis to the onboard controller so that the void created by the cable entry could be sealed off from road surface reflection; and
iv) injected all steel tubings of the body frame with damping material to prevent building up of stationary wave.

The noise problem was fairly improved after the mitigation measures, and the drivers were satisfied with the performance of the HVs. it. In addition, the drivers felt that the HVs had comparatively lower acceleration rate, especially going uphill and sometime even on flat road.

4.4 Passengers had different opinions on the HVs. Some passengers felt that the HVs emitted less air pollutants and improved roadside air quality. They liked the HVs and supported replacing the existing GVs with HVs. However, compared with the conventional LPG light buses, some passengers still expressed dissatisfaction on the noise generated during charging.

4.5 Pokfulam Maxicab claimed that the performance of the HVs met the operational requirements and the HVs could help improve the roadside air quality. Therefore, they would encourage other transport operators to try out the hybrid light bus and believed that HVs could continuously provide GPLB services for a long time.

4.6 To remove the effect of seasonal fluctuations, 12-month moving averages were used to evaluate the trend of fuel economies of the HVs. In the 24 months of the trial, it was shown that their fuel economies were stable (HV-1 between 4.58 km/litre and 4.69 km/litre) and (HV-2 between 3.95 km/litre and 4.44 km/litre). It demonstrated that the engine of the HVs were still in normal working conditions and their fuel economies could be maintained through proper maintenance. No deterioration in the performance of the HVs' batteries were observed during the trial period.

4.7 Based on the total mileages of the HVs, the fuel economies of the GVs during the trial period and the carbon dioxide equivalent (CO_2e) emission per litre of LPG consumed[1], the relative CO_2e emission from the GVs could be evaluated for comparison purpose. The CO_2e emission from HV-1 was 46,429 kg while that from the GV-1 was 61,668 kg. Also, the CO_2e emission from HV-2 was 33,432 kg while that from the GV-2 was 36,093 kg. Therefore, there was a total reduction of 17,900 kg CO_2e emission (18 %) in the trial by using the HVs.

5 Summary

5.1 The drivers shared the view that the HVs ran quieter than the GV when they were not charging, but were noisy during charging in the beginning of the trial. Also, the drivers felt that the HVs had comparatively lower acceleration rate, especially during uphill and sometime even on flat road. However, they encountered fewer difficulties in driving the HVs when the trial went on, after the manufacturer had implemented multiple noise reduction measures to reduce the charging noise level. The noise problem was fairly improved after the mitigation measures, and the drivers were satisfied with the performance of the HVs. Eventually, Pokfulam Maxicab and the drivers were satisfied with the performance of the HVs.

5.2 Passengers had different opinions on the HVs. Some passengers felt that the HVs emitted less air pollutants and improved roadside air quality. They liked the HVs and supported replacing the existing GVs with HVs. However, compared with the conventional LPG light buses, some passengers still expressed dissatisfaction on the noise generated during charging.

5.3 Since the average unit price of diesel fuel consumed by the HVs was over 300% higher than that of LPG consumed by the GVs, the fleet average fuel cost and the fleet average total cost of the HVs were higher than those of the GVs by 113% (HK$1.68/km) and 46% (HK$1.13/km) respectively, even though the average fuel economies of HV-1 and HV-2 were higher than those of GV-1 and GV-2 by 43% and 17% respectively.

5.4 The utilization rates of HV-1, HV-2 and the GVs were 94%, 95% and 97% respectively.

5.5 The CO_2e emission from HV-1 was 46,429 kg while that from the GV was 61,668 kg respectively. Also, the CO_2e emission from HV-2 was 33,432 kg while that from the GV was 36,093 kg respectively. Therefore, there was a total reduction of 17,900 kg CO_2e emission (18 %) in the trial by using the HVs.

5.6 No deterioration in the performance of the HVs was observed during the trial period.

1 Guidelines To Account For And Report On Greenhouse Gas Emissions And Removals For Buildings In Hong Kong, http://www.epd.gov.hk/epd/sites/default/files/epd/english/climate_change/files/Guidelines_English_2010.pdf

Appendix 1: Key Features of Vehicles

1. Trial HVs

HV-1 and HV-2

Registration Mark	**EJ8882 (HV-1)** **LA4381 (HV-2)**
Make:	GMI
Model:	Gemini GM6700GAREEV
Class:	Public Light Bus
Gross vehicle weight:	7,000 kg
Seating capacity:	Driver + 19 passengers
Engine capacity:	2,776 c.c.
Battery Type:	Lithium iron phosphate
Year of manufacture:	2017

2. GVs for comparison

GV-1

Registration Mark	**LA4381 (Apr 2018)** **LG2081 (May 2018 – Oct 2018)**
Make:	Toyota
Model:	BZB40RZCMSCYY
Class:	Public Light Bus
Gross vehicle weight:	4,000 kg
Seating capacity:	Driver + 16 passengers
Engine capacity:	4,104 c.c.
Year of manufacture:	2003

Registration Mark	**TF9821 (Nov 2018 – Feb 2019),** **KM6985 (starting from Mar 2019)**
Make:	Toyota
Model:	BZB40RZCMSCYY
Class:	Public Light Bus
Gross vehicle weight:	4,000 kg
Seating capacity:	Driver + 16 passengers
Engine capacity:	4,104 c.c.
Year of manufacture:	2004

GV-2

Registration Mark	**RN9056**
Make:	Toyota
Model:	BZB40RZCMSCYY
Class:	Public Light Bus
Gross vehicle weight:	4,000 kg
Seating capacity:	Driver + 16 passengers
Engine capacity:	4,104 c.c.
Year of manufacture:	2002

Appendix 2: Photos of Vehicles

1. Trial HVs

HV-1 (EJ8882)

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<tr><td>Front view of HV-1</td><td>Rear view of HV-1</td></tr>
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<tr><td>Left side view of HV-1</td><td>Right side view of HV-1</td></tr>
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HV-2 (LA4381)

	
Front view of HV-2	Rear view of HV-2
	
Left side view of HV-2	Right side view of HV-2

2. GVs

GV-1 (LA 4381: Apr 2018)

	
Front view of GV-1 (LA 4381)	Rear view of GV-1 (LA 4381)
	
Left side view of GV-1 (LA 4381)	Right side view of GV-1 (LA 4381)

GV-1 (LG 2081: May 2018 – Oct 2018)

	
Front view of GV-1 (LG 2081)	Rear view of GV-1 (LG 2081)
	
Left side view of GV-1 (LG 2081)	Right side view of GV-1 (LG 2081)

GV-1 (TF 9821: Nov 2018 – Feb 2019)

	
Front view of GV-1 (TF 9821)	Rear view of GV-1 (TF 9821)
	
Left side view of GV-1 (TF 9821)	Right side view of GV-1 (TF 9821)

GV-1 (KM 6985: Starting from March 2019)

	
Front view of GV-1 (KM 6985)	Rear view of GV-1 (KM 6985)
	
Left side view of GV-1 (KM 6985)	Right side view of GV-1 (KM 6985)

GV-2 (RN9056)

	
Front view of GV-2	Rear view of GV-2
	
Left side view of GV-2	Right side view of GV-2