For Discussion on
30 March 2016

LEGISLATIVE COUNCIL
PANEL ON ENVIRONMENTAL AFFAIRS

Interim Findings of the Trial of Hybrid Franchised Buses

PURPOSE

This paper reports on the interim findings of the 2-year trial of hybrid franchised buses.

BACKGROUND

2. Franchised buses are a major source of roadside air pollution, particularly at busy corridors. Hybrid buses could emit less air pollutants and be more fuel efficient. To assess their environmental performance in local conditions, the Government has subsidized The Kowloon Motor Bus Company (1933) Limited ("KMB"), Citybus Limited ("CTB") and New World First Bus Services Limited ("NWFB") to acquire a total of six[1] hybrid double-deck buses for a 2-year trial. If the trial is successful, hybrid buses can be one of the environmentally friendly bus types to be considered by franchised bus companies when acquiring new buses, taking into account the feasibility and affordability for bus operators and passengers.

3. When seeking this Panel's support for the trial, we undertook to carry out an interim review one year after the start of the trial and to report back on the related findings.

THE HYBRID BUSES

4. The three franchised bus companies procured the hybrid buses through

[1] Among the six hybrid franchised buses, three are operated by KMB, two by CTB and one by NWFB. The allocations of the buses are made in consideration of their bus fleet sizes.

open tender. The chosen model is Enviro E500H Hybrid, which is a 3-axle double-deck bus produced by Alexander Dennis (Asia Pacific) Limited (ADL). The hybrid buses are equipped with an electricity-driven air conditioning system with sufficient cooling capacity for Hong Kong's conditions. Each of the hybrid buses costs about $5.5 million.

5. With implementation of Euro VI emission standards for heavy duty vehicles exceeding 3.5 tonnes in Europe on 31 December 2013, the hybrid double-deck buses supplied to Hong Kong are equipped with 6.7 litres engines that can meet Euro VI emission standards.

6. Before delivery, one of the hybrid buses was tested under the Millbrook bus test cycle[2] in the United Kingdom. In the absence of an exact diesel control bus with Euro VI engine and Hong Kong's tailor-made air-conditioning system, the test was performed without an air-conditioning system in operation. The test results showed that the Euro VI diesel hybrid bus outperformed ADL's 3-axle double-deck Euro V diesel control bus with a 8.9 litres engine by emitting about 89% less nitrogen oxides (NOx), better than the 80% based on the difference between the NOx emission limits of Euro V and VI emission standards, which is an indication of the NOx emission benefit of the hybrid drive-train. Another test[3] was conducted by Millbrook on the fuel saving performance of the hybrid bus and it showed that the hybrid bus had a fuel saving of about one-third over the diesel control bus.

THE TRIAL

7. The 2-year trial of hybrid franchised buses commenced progressively in November 2014. The commencement dates, trial routes and route characteristics for the hybrid buses concerned are at **Annex**.

8. To monitor and assess the performance of the hybrid buses, we have set up a task force, comprising representatives from the three franchised bus companies, the bus manufacturer, the Transport Department (TD), as well as

[2] The tests were conducted by Millbrook Proving Ground Ltd. in the United Kingdom using the Millbrook London Transport Bus (MLTB) drive cycle. The MLTB test cycle was developed by Transport for London and Millbrook Proving Ground Ltd for testing bus exhaust emissions.

[3] The tests for fuel consumption of the buses were conducted using the Standardised On-Road Test (SORT 1) cycle, which was developed by the International Association of Public Transport (UITP) for measuring fuel consumption of diesel buses.

three experts from the local academia.

9. During the trial, the performance of the hybrid buses would be compared with that of conventional 3-axle double-deck diesel buses operating on the same route and of Euro V standard. Since the diesel engines of the hybrid buses could meet Euro VI standard and the emission limits for NOx and particulate matters (PM) are 80% and 50% lower than those of Euro V respectively, due care will be made to estimate the emission benefits of their diesel-hybrid drive-train.

10. The performance of the hybrid buses and the control buses in the following five aspects are being monitored in the trial –

(a) fuel consumption;
(b) urea consumption rate[4];
(c) daily bus availability;
(d) total number of on road breakdowns; and
(e) NOx emissions.

11. Particulate matter (PM) emissions are not included in the monitoring because both the hybrid buses and the control buses are designed such that their PM emission level is close to the measurement instrument's measurement limits. We thus focus on NOx emissions when assessing the emission benefits of the hybrid buses.

INTERIM FINDINGS

12. A summary of the interim trial findings up to 30 November 2015 is below –

Monitoring Parameters	Hybrid Buses	Diesel Control Buses
Relative Fuel Consumption (as compared to diesel control bus)	1.034	1

[4] Both the hybrid buses and diesel control buses are using selective catalytic reduction devices (SCRs) to reduce NOx emissions. To support their operation, SCRs use a reagent, urea. Urea consumption rate has a bearing on their running costs.

Urea Consumption Rate (% of fuel consumption)	4.5	5.2
Daily Bus Availability (%) (Excluding outage unrelated to malfunctions of the buses[5])	82.6	94.9
Average Number of On-Road Breakdowns / Month	0.3	0.04

13. In respect of NOx emissions, the emission test has so far suggested an emission reduction contributed by the hybrid drive-train. An exact quantification will be made in the second half of 2016, when a Euro VI diesel bus would be available in Hong Kong for conducting emission tests in local real driving conditions.

14. The performance of the hybrid buses are evaluated below –

(a) Fuel Consumption

Overseas experiences suggest that hybrid buses could save about 30% fuel as compared with conventional buses. However, during the first year of the trial, the hybrid buses consumed on average 3.4% more fuel than the control buses. On an individual bus basis, the best performing hybrid bus delivered a fuel saving of 5.8% whereas the worst one used 14.7% more fuel. The hybrid buses operated on highway routes tend to use more fuel, while those on urban routes, having more frequent start-stop operations, could allow the hybrid buses to operate without running their diesel engines to save fuel.

Furthermore, the fuel efficiency of the hybrid buses was better in cooler months when the loading on the air conditioning system was lower. For example, the hybrid buses used on average about 12.9% less fuel than the control buses in January 2016; and the best performer used 25% less fuel.

As such, a hybrid bus's ability to save fuel depends to a large extent on how often it can run without its engine in operation. The following

[5] The outages could be for inspections for Certificate of Road Worthiness / Certificate of Fitness, monthly inspections, routine maintenance/checking, cleaning, emission tests by Portable Emission Measurement Systems (PEMS), etc.

considerations are also relevant:

(i) the air-conditioning system could consume up to 40% of the energy used by the hybrid buses in summer. The heavy energy demand would give little chance for their diesel engines to stop operation, which will significantly deplete the fuel saving capability of the hybrid buses;

(ii) owing to supply constraints, the air-conditioning system chosen for the hybrid buses, which has to be electricity-driven, could be of a less energy-efficient design as compared to that for the control buses; and

(iii) a mechanical fault at the intercoolers of the hybrid buses could increase the fuel consumption. The problems were rectified by the bus manufacturer from November to December 2015.

Taking into account of the above findings, the bus manufacturer has been working to improve the fuel efficiency of the hybrid buses by:

(i) replacing the compressors of their air-conditioning system by smaller ones, in order to better manage the air-conditioning load and allow the engines to stop more frequently;

(ii) fine-tuning the control of the air-conditioning compressor to improve energy efficiency of the air-conditioning system;

(iii) lowering the acceleration rate of the hybrid buses to match with that of the diesel control buses; and

(iv) widening the charging range of the battery to increase the amount of energy from regenerative braking that can be captured and stored in the battery

(b) Urea Consumption Rate

The overall average urea consumption rate was 4.5% of fuel consumption for hybrid buses, as compared to 5.2% for control buses. This was

relatively stable throughout the hot and cool months. The urea consumption rates of the hybrid buses did not show explicit variation patterns among the different kinds of routes.

(c) Daily Bus Availability

The 94.9% availability (excluding outage unrelated to malfunctions of the buses) of the control buses outperformed the 82.6% availability of the hybrid buses. The relative poor availability of the hybrid buses was more evident in the initial months of the trial and the performance started to improve from August 2015 onwards. The average availability from August to November 2015 improved to about 88.2% from 79.8% for the preceding period.

(d) Total Number of On Road Breakdowns[6]

The hybrid buses and control buses did not have major recurrent operational problem or on road breakdown in the period. As compared with the diesel control buses in respect of the total number of breakdowns, the control buses performed slightly better than the hybrid buses in the first year of trial. The average numbers of on road breakdown were 0.3 and 0.04 times per month for hybrid buses and control buses respectively. Despite the difference, both rates are considered to be at very low level and do not constitute significant impacts to bus operation.

(e) NOx Emissions

The emissions of hybrid buses and diesel control buses have been compared by using Portable Emission Measurement Systems (PEMS)[7]. The PEMS measurement results showed that the average NOx emission reductions of the hybrid buses as compared with the control buses was about 93%, which also exceeded the 80% difference between the respective Euro V and VI emission limits.

[6] Total number of on road breakdowns includes only failure of a passenger-carrying bus that necessitates passenger evacuation. Breakdowns for bus journeys on dead mileage are not included. Accidents are also not included.

[7] The first batch of PEMS tests was conducted from January to May 2015 during weekdays. During each test, about 4-5 round trips were measured to cover peak and non-peak periods.

As a 3-axle double-deck Euro VI diesel bus will arrive in Hong Kong in mid-2016, we plan to conduct another round of PEMS measurement to evaluate the NOx emission performance of the hybrid buses in the second half of 2016.

15. The Task Force will continue to monitor and assess the performance of the hybrid buses, in particular the improvement measures taken by the bus manufacturer in improving the fuel consumption performance. We aim to report the overall findings of the trial to the Panel in early 2017 upon completion of the 2-year trial period.

ADVICE SOUGHT

16. Members are invited to note the interim findings of the trial in paragraphs 12 to 14.

Environmental Protection Department
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Annex

Bus Routes, Commencement Dates and Route Characteristics of the Six Hybrid Buses under Trial

FBCs	Trial Route	Commencement Date	Route Characteristic
KMB	1A [Star Ferry – Sau Mau Ping (Central)]	11 November 2014	Urban
	104 [Pak Tin – Kennedy Town]	5 December 2014	Urban
	619 [Shun Lee – Central (Macau Ferry)]	13 November 2014	Highway + Urban
CTB	5B [Kennedy Town – Causeway Bay]	22 November 2014	Urban
	969 [Tin Shui Wai Town Centre – Causeway Bay (Moreton Terrace)]	6 December 2014	Mainly Highway
NWFB	8 [Chai Wan (Heng Fa Chuen) – Wan Chai North Temporary Public Transport Interchange]	22 November 2014	Urban