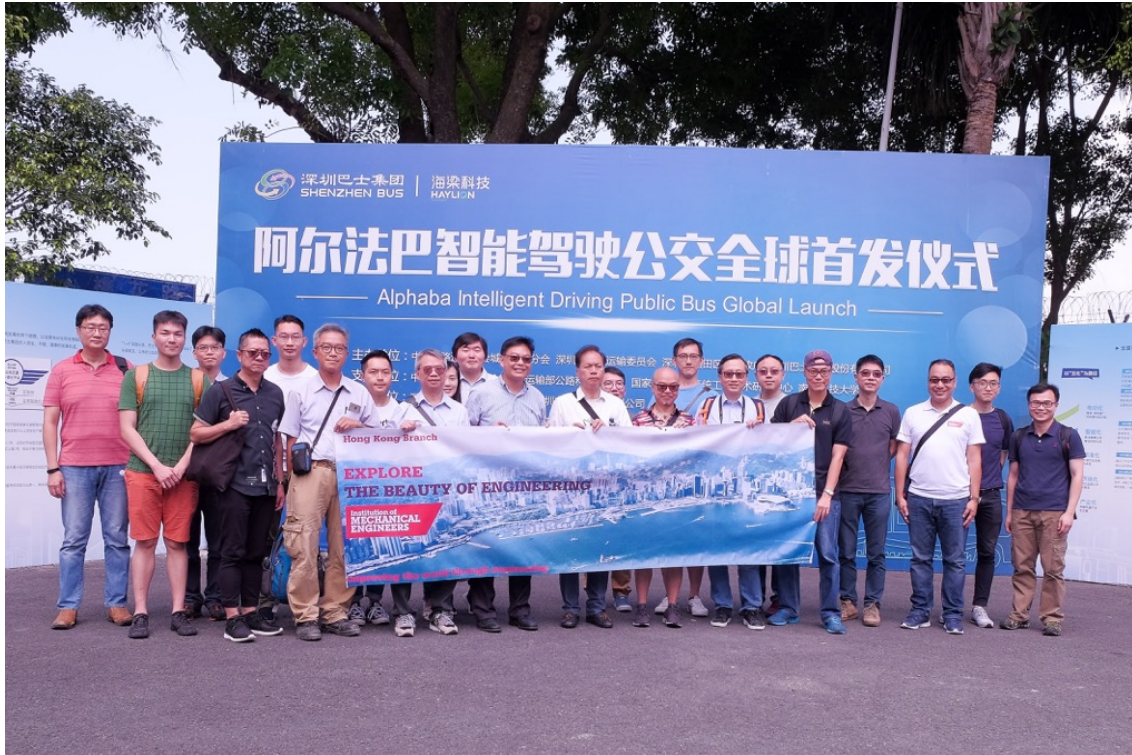


INSTITUTION OF MECHANICAL ENGINEERS HONG KONG BRANCH
TECHNICAL VISIT TO SHENZHEN BUS GROUP ON 21/7/2018



Institution of Mechanical Engineers Hong Kong Branch visited the autonomous bus trials in Shenzhen on 21/7/2018

Across the boundary of Hong Kong, the municipal of Shenzhen in Guangdong Province in the mainland China has always been a forerunner. Not only was it the first place in China to be “open door” embracing foreign direct investment under the Communist planned economy over four (4) decades ago, it is now the top five (5) most attractive municipals of China, listing itself in the same rank as Beijing and Shanghai. It has attracted top-end technology firms to establish research and development facilities and trail the latest technology in various sectors, including public transport.

Shenzhen is championing the transformation of the municipal public bus services at two (2) fronts, namely pure electric public bus fleets and autonomous buses. Shenzhen is the first city in the world with all public bus services being operated entirely by electric vehicles and it is also the first city in China to have autonomous buses on trial. There are three (3) franchised bus companies in Shenzhen, namely Shenzhen Bus Group (SBG), Shenzhen Eastern Bus and Shenzhen Western Bus, and they have been operating the majority of the nearly 1,000 bus routes in Shenzhen. Institution of Mechanical Engineers Hong Kong Branch (IMechE-HKB) was privileged to visit SBG on 21/7/2018 for sharing their experience of operating a pure electric bus fleet and understanding of the technology adopted for the autonomous buses.

The Chinese Autonomous Driving Solutions

Originated with the incorporation of Baoan County Shenzhen Towns Public Transport Company in 1975, SBG is a full licenced public transport operator in the Shenzhen municipal,

operating about 13,000 vehicles including municipal public buses, taxis and scheduled and chartered coaches by around 28,000 employees.

In parallel, autonomous driving has advanced from concepts in the late last century to road trials in the developed countries. While the legislations for governing autonomous vehicles on public roads is under development, designating autonomous vehicles to operate within predefined areas only enables trials to be carried out within the existing legal framework. France, Germany, Japan, the U.K. and the U.S.A. have had their autonomous people mover on test, and the Chinese version is “Alphaba”, which literally means “Alpha Bus”.

In February 2017, SBG co-championed the project of developing an autonomous bus system with Shenzhen Haylion Technology Co., Ltd. (Haylion), Information Technology Support Centre of Institute of Science and Technical Information of China, Shenzhen Traffic Police and other Chinese organisations. The “Alphaba” project has taken nine (9) months within 2017 to develop from kick-start to prototype launch in the following order:-

| Month | Milestone |
|----------|------------------------------|
| February | Project kick-started |
| March | Project objectives confirmed |
| April | Conceptual design commenced |
| May | Specification confirmed |
| July | Design freeze |
| August | Prototype production |
| November | Prototype tested |

Although currently the autonomous prototypes on road are manned on the driving seat in satisfying the legislation and insurance requirements, eventually “Alphaba” aims at the bus operations to be entirely driver-less; thus reducing the operating costs on drivers and management. Also, according to National Highway Traffic Safety Administration (NHTSA), 93 % of the total traffic accidents are human-caused. The autonomous drive of “Alphaba” may eliminate the human factors and improve traffic safety. In fact, with reference to the NHTSA statistics, computers are advantageous over human in driving safety as follows:-

| Performance | Computer | Human |
|--|------------------|------------------|
| Response Time [second] | 0.2 (base) | 1.2 (600 % base) |
| Safety Visual Distance [metre] | 500 m (base) | 50 (10 % base) |
| Continuous Permissible Driving Time [hour] | unlimited (base) | 4 (0 % base) |

Alpha Bus

The accumulated 14,000 km trails of the first generation of “Alphaba” (Alphaba 1.0) in Shenzhen have performed tests on detection of pedestrians and vehicles, by-pass of obstacles, give way, short distance emergency stop, autonomous stop approach and autonomous door operations. Currently, two (2) prototypes built by Dongfeng Motor Corporation and two (2) more built by Ankai Bus are running on the designated routes on the streets of ordinary traffic within Futian Free Trade Zone, where is right on the boundary with Hong Kong, while two (2) Swedish Scania-made 10 m full-sized pure battery electric municipal buses will be joining the Shenzhen trail. The similar semi-closed operating environment which is suitable for operation of autonomous buses like “Alphaba” may also be applicable to the airport aprons, industrial parks, college campuses, resorts and amusement parks.

Alphaba 1.0 is a pure battery electric people mover. Its batteries are capable to deliver 150 km of air-conditioned travel after 30 minutes of charging. Dimensioned 6.6 m by 2.3 m by 2.8 m in total length, width and height respectively, its test laden weight is 6.9 tones. Alphaba 1.0 is equipped with one (1) laser-based radar, one (1) infrared-based (IR) and one (1) camera at the vehicle front, plus ultrasound sensors on the rear bumper as well as dual antenna for global positioning. These commercial-grade sensors provide data to the Alphaba 1.0 computer for integration and processing, which results in commands to be given to the brakes, steering wheel and accelerator for their respective execution in order to manoeuvre the vehicle safely. Although Alphaba 1.0 is designed to a maximum road speed of 60 km/h and Level 4 automation according to Society of Automotive Engineers, its trail speed is capped at 30 km/h in order that it may have longer reaction time to command avoiding danger.

Inside the air-conditioned cabin which can accommodate maximum 19 passenger, eight (8) cameras capture the cabin condition and transmit the image signals to the remote control centre. The operator in the remote control centre may observe the passenger behaviours and intervene the operations of the vehicle accordingly. His observation will be assisted by the new technologies such as human pattern recognition and liquid detection for the detection of any anomalies in the vehicle, which are under development. Besides, Alphaba 1.0 has been programmed to react to certain predefined road situations, such as vehicle halts in case of collision.

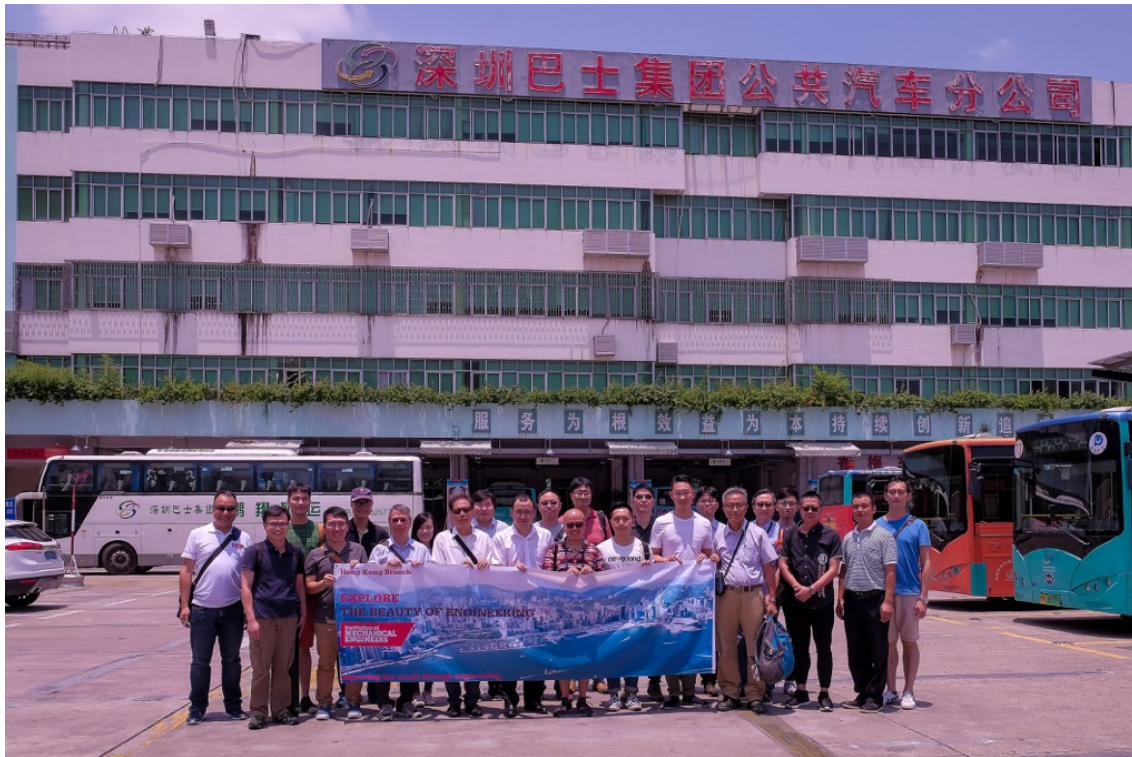
Commercialisation is a key aspect associated with the success of the Alphaba project. All the sensors, computers, power-train and components are commercial products readily available on the current market, and the equipment costs are endeavoured to minimise. The improved version of Alphaba 1.0, the second generation of Alphaba (Alphaba 2.0), has started trail in Hefei, the provincial capital of Anhui Province on 11/7/2018. Alphaba 2.0 is upgraded with double the number of lasers of Alphaba 1.0 at the front, in conjunction with the installation of a 360 degree radar on the roof, contributing the provision of more information to the computer for data integration and instructing more intelligent commands. Utilising the existing commercially available technological products, each Alphaba 2.0 prototype costs RMB 1.4 million.

In spite of the fact that Alphaba 2.0 has just started tests, its evolved version, the second-and-half generation Alphaba is expected to launch in September 2018.

Electric Transformation

SBG electrified its entire bus and taxi fleets in 2016, when the Chinese government subsidised qualified pure battery electric vehicles. At that time, the central government and the local government of Shenzhen subsidised RMB800,000 and RMB200,000 respectively towards the purchase price, which resulted in SBG only had to pay the remaining RMB800,000 for acquiring a BYD K8 bus at a purchase price of RMB1.8 million. Likewise, for a BYD e6 saloon for taxi, the government offered RMB79,000 towards the purchase price of RMB300,000. The aggressive subvention for pure electric vehicles in 2016 incentivised SBG to entirely transform its 7,000 municipal buses and one-third of the 15,000 taxis in Shenzhen from the conventional internal combustion engine (ICE) models to the pure battery electric equivalences.

SBG received its first batch of pure electric buses in 2010, and they have come to the age in compliance with the state regulation of retiring buses at the end of their eighth year of service. The withdrawn buses are bought back by the bus original manufacturer at their residual market value for recycle. Every year, SBG procures about 400 new buses to replace the retired units, whereas the subsidy received per new vehicle has dropped to RMB400,000 because half of the total price of an electric bus is the batteries and their management system.



IMechE-HKB visited the SBG pure battery electric bus charging operations in SBG largest fleet depot of Xianmei North on 21/7/2018

Electric Operations

The electricity cost for charging the buses is subject to the hour when the charging takes places. In Shenzhen, the electricity for industrial use is charged RMB0.20 per unit between 23:00 and 07:00, in comparison to RMB1.1 per unit during the daytime. Therefore, utilising the low tariff, SBG recharges its entire fleet from mid-night to dawn as much as possible.

Each of SBG 1,500 charging stations can charge four (4) to eight (8) buses, capable to deliver fast charging and slow charging. While each bus maintains about 37 % of its total power storage as reserve, the slow charging rate of 110 kW can fully recharge a bus in two (2) hours, sufficient for it to remain on service for 200 km. For certain long distance routes which demand the buses to travel over 200 km on a day, top-up charging is required during the day and the buses are fast charged at 180 kW. The delivery of the charging power of 550 volts voltage and 250 amperes current is through a nine (9) pin power cable for direct current (D.C.) charging, or seven (7) pin power cable for alternative current (A.C.) charging.

In spite of the vast number under its operation, SBG does not possess the chargers. Instead, it contracts the construction and operations of the charging facilities to an external service

provider. This service provider provides all infrastructure required to deliver sufficient electricity to charge the entire SBG bus fleet, including transformers, power cables, charging stations at the bus depots and the charging operators. In return, it charges SBG a service fee of RMB0.396 per kWh in addition to the average electricity cost of RMB0.504 per kWh, resulting in the cost of charging a bus at RMB0.9 per kWh. For the annual mileage of a bus in the SBG fleet at about 60,000 km and an average energy efficiency of 0.9 km per kWh, the annual energy cost is RMB60,000.

In fact, the Shenzhen government has encouraged the provision of the electric vehicle chargers by means of providing subsidies. According to the charger capacity, RMB600 per kW is subsidised to support the sourcing and construction of a D.C. charger, and RMB300 per kW of an A.C. charger. However, despite the importance of the power supply to the SBG charging stations in maintaining the municipal bus services, the power supply to the SBG depots are not uninterrupted. SBG needs to reschedule the charging operations of its fleet upon power supply suspension, usually being notified in advance.

Electric Consumers

Three (3) major bus models in the SBG fleet are Nanjing Golden Dragon NJL6859BEV (Skyworth), BYD K8 and BYD K9 in 8.5 m, 10.5 m and 12 m gross length respectively. 960 South Dragon vehicles are powered by the lithium-ion batteries supplied by Amperex Technology Ltd., while the 6,000-plus BYD units use the in-house BYD-made lithium-ion batteries. Both Skyworth and BYD have guaranteed the minimum battery efficiency of 85 %. In case of a battery system with its efficiency falls below the guarantee, they have pledged to replace the defective modules in the battery system to restore its efficiency to above the minimum level. Besides, other than the batteries, the instrumentation and control components are also warranted by the vehicle manufacturers.

The power consumption varies by season. For Skyworth and BYD K8, they consume about 0.9 kWh and 1.0 kWh per kilometre (kWh/km) respectively in winter months. In summer time, however, the power consumption may rise to 1.03 kWh/km and 1.09 kWh/km respectively. In comparison, the several BYD K9 buses in the Citybus and New World First Bus fleet in Hong Kong consume about 1.0 kWh/km in winter and up to 1.4 kWh/km in summer.

According to the experience of SBG, operating pure battery electric buses is more economical than their ICE counterparts. The average annual operating cost of a former type is about RMB200,000, whereas that of the latter type is RMB700,000. For the average maintenance cost, the pure battery electric bus is about RMB1/km, whereas the ICE bus is about RMB200/km which is substantially higher.

Remarks

Shenzhen is leading the world in respect of road passenger transport by means of electrifying all the public buses and putting autonomous buses on trial operations. Government policies, in the form of monetary and administrative incentives, are the key steer of new technologies to be applied to public passenger transport services. While the intelligent buses are on the horizon with the support from the government, operation of a sizable pure battery electric bus fleet for public passenger transport services has been proved to be technically viable with

over 7,000 units being operated by SBG. The SBG experiences may have offered the public transport industry a glimpse of the future mode of public transportation.



Certificate of appreciation was presented to SBG Deputy General Manager, Mr. Joseph Ma, in recognition of his arrangement for the technical visit

IMechE-HKB thanks Mr. Joseph Ma, SBG Deputy General Manager for his arrangement and hospitality in making the technical visit possible.

*** END ***

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By courtesy of Shenzhen Bus Group with compliment

IMechE Hong Kong Branch
Activity Sub-Committee
Technical Visit Group

TECHNICAL VISIT SHENZHEN BUS GROUP

Hong Kong Branch

Institution of
**MECHANICAL
ENGINEERS**

Date: 21 July 2018

Time: 08:30 to 13:30



Successful registrants will be informed.

North of the border of Hong Kong, Shenzhen is at the forefront of technologies. Not only is it the first municipal to be served by entirely pure electric buses in the mainland China and the world, it is also trailing the country's first autonomous bus for passenger service. Institution of Mechanical Engineers (IMechE) Hong Kong Branch is privileged to visit Shenzhen Bus Group, the operator of these pioneering and visionary vehicles, and appreciate their engineering, operations and experiences gained. Do join and understand the technologies for the future of automotive engineering and municipal bus transportation.

25 places are available for free of charge to IMechE members.

Registration and Enquiries

For registration, please scan the QR code or visit the IMechE webpage:

<http://nearyou.imeche.org/near-you/north-east-asia/hong-kong/events>

For more information please write to imeche@imeche.hk.org.