Submission
No 10

INQUIRY INTO PRIVATISATION OF BUS SERVICES

Organisation: SMART Infrastructure Facility, University of Wollongong

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Contribution from the SMART Infrastructure Facility at the University of Wollongong to the Inquiry into the privatisation of bus services

The SMART Infrastructure Facility welcomes the opportunity to contribute to the inquiry and thanks the members of the Committee for the invitation. This contribution focuses on the issue to be addressed by the inquiry: **(d) the transition to an electric bus fleet and supporting infrastructure**.

Introduction

The SMART Infrastructure Facility at the University of Wollongong (UOW) is one of the largest research institutions in the world dedicated to helping governments and businesses better plan for the future. SMART's work is augmented by collaborations with experts across UOW's Faculties in infrastructure-related fields such as energy generation and storage, water sustainability, environmental engineering, spatial geotechnics and digital innovation.

When the $62 million SMART building opened in 2011 as Australia's first multi-disciplinary applied infrastructure research and training facility, it represented a commitment by the Australian and NSW Governments to apply a more scientific approach to infrastructure planning. Since opening, SMART has built an international profile working with government agencies in Australia and around the world, and has developed a strong network of global collaborators. SMART brings together experts from fields such as rail, infrastructure systems, transport, water, energy, economics and modelling and simulation and provides 30 state-of-the art laboratories to facilitate this important research.

This contribution will focus on two categories of research and projects that have direct relevance to the inquiry, namely: (1) zero-emission bus fleet transition (including preliminary trial and transition plan), and (2) charging/refuelling solution (including supporting infrastructure planning and charging scheduling).

Zero-emission bus fleet transition

Our understanding

Zero-emission bus (ZEB) fleet transition aims to find the optimal bus replacement strategy and offers a mixed-type bus fleet operational strategy consisting of conventional buses and ZEBs during the transition. With given budget/investment and emission reduction target, the optimal bus fleet size and required charging/refuelling infrastructure should be determined in the planning horizon. Mathematical modelling, economic analysis and scenario-based approaches can be applied to exploring and evaluating various ZEB transition strategies. Research on this topic is expected to provide support for transport authority and bus operators to make economical decision on ZEB investment.

As the first step of ZEB fleet transition, a series of trials are able to provide preliminary understanding of ZEB related technologies and compare various options (e.g., battery electric bus, hydrogen electric bus) available in the market. Moreover, such trials play an important role in collecting various operational data, which will be used as input parameters into ZEB fleet transition models to develop corresponding ZEB fleet transition plan.

Our experience

UOW has been a key member organisation of the Low Carbon Living Cooperative Research Centre, the Future Fuels Cooperative Research Centre and the Port Kembla Hydrogen Hub, which would be pivotal to the decarbonisation of Australia's energy networks. SMART has successfully led and delivered the project Energy Efficiency Decision Making in the NSW Transport Sector on electric vehicle (EV) purchasing behaviour analysis and policy intervention investigation, and found that insufficient charging infrastructure was one of the major obstacles to EV uptake [1]. In this project, an interactive dashboard has been developed for government sector to visualise and analysis EV survey results, and further evaluate complex combination of EV features and incentives/interventions (video demo).

In middle 2020, as response to Transport for NSW's call for ZEB trial, SMART collaborated with multiple bus operators (e.g., Premier Illawarra, Transdev, Interline) and bus manufacturers (e.g., Yutong Australia, Foton Bus Australia) in NSW to prepare multiple ZEB trial plans.

Moreover, SMART was invited to join a five-month electric bus trial conducted by Nowra-based Premier Transport Group in the NSW South Coast with impressive performance [2]. This trial was conducted on route 737 (approximate 40km and 45mins single trip, mainly highway operation) connecting Bomaderry Station to Kiama Station via Beery and Gerringong return. Yutong E12 electric bus and overnight normal plug-in charging at depot were adopted. During the trial, very positive feedback was received from both bus drivers and passengers regarding multiple aspects (e.g., outstanding performance, quietness, acceleration, easy operation, quality of build, internal features). Regarding energy consumption during the trial period, the total operational cost of electric bus was 33.3% less than the cost of diesel bus. It is worthy of mentioning that a cheaper power plan (approximately 40% less) can be negotiated with electricity supplier, which would lead to further lower cost of running electric bus.

More recently, SMART is involved in a hydrogen powered electric bus trial in the Central Coast conducted and endorsed, respectively, by Red Bus Services and Transport for NSW. SMART is providing relevant experience and expertise to help collect trial data, conduct corresponding performance evaluation, and further propose ZEB fleet transition strategy.

[1] Pascal Perez, Bo Du, Rafael Benavent, Nam Huynh (2019). EV Purchasing Analysis – Promoting EV Uptake with Government Support. Project report prepared for Low Carbon Living CRC and NSW Office of Environment and Heritage.
[2] Australian Bus & Coach (2019), TfNSW-endorsed electric bus trial 'extremely impressive'. https://www.busnews.com.au/industry-news/1907/tfnsw-endorsed-electric-bus-trial-extremely-impressive.

In addition, SMART is partnering with Dion's Bus Service and Volvo to explore a zero-emission solution of the FREE Gong shuttle services – Gwynneville Keiraville (GK) shuttle and North Gong (NG) shuttle.

<u>Our suggestion</u>

Trial – In a short-term period, to demonstrate the advantages and disadvantages of ZEBs, proper ZEB trial should be conducted for multiple purposes: (1) A comprehensive performance evaluation framework should be developed, which consists various criteria such as energy consumption, traffic emission, noise pollution, charging/refuelling activities, passenger satisfaction. Performance evaluation on the ZEBs should be conducted based on the framework, and further compare ZEBs with conventional buses. (2) Survey questionnaire needs to be designed to understand the satisfaction of both bus drivers and passengers. (3) Trial data should be collected and processed to establish a ZEB related dataset to support further ZEB fleet transition. It is worth mentioning that, although each bus operator is allowed to propose individual trial plan, transport authority is suggested to firstly develop a trial masterplan with multiple trial categories (e.g., different types of ZEBs, trial routes in CBD vs suburb area, trial routes in long distance vs short distance, trial routes in different regions, trial routes with ZEBs vs conventional buses), and then let eligible bus operators propose detailed trial plan under a specific trial category. In this way, a series of trials can be implemented in a comprehensive and complementary format to cover different trial purposes. After the trial, all the relevant data should be merged into an integrated ZEB trial dataset as valuable input to support the development of further ZEB fleet transition plan.

Transition – In a long-term period, with well-established ZEB trial dataset, a multi-stage ZEB fleet transition plan should be developed for each bus operator with given financial investment budget and emission reduction target. With the planning horizon (e.g., 10 years to reach 100% ZEB fleet), a multi-stage ZEB replacement plan can be designed based on the existing conventional bus fleet condition to minimise the total cost. In the meanwhile, during the transition period, the optimal operation of mixed-type bus fleet (i.e., conventional buses and ZEBs) should be investigated to maintain the level of service for passengers.

Charging/refuelling solution

<u>Our understanding</u>

Given a bus network with bus fleet size and vehicle type, it is important to determine the optimal location and capacity of the charging/refuelling infrastructure in planning level, and then develop the corresponding schedule of charging/refuelling activities in operational level. Mixed-type charging/refuelling techniques should be considered, such as normal plug-in charging at depots or charging stations for overnight charging, fast charging at bus stops for en-route top-up charging, and refuelling station at depots and mobile station for en-route refuelling, for different features of bus routes/networks. Mathematical modelling and simulation, operations research and optimisation, and scenario-based approaches can be applied to exploring and evaluating various charging/refuelling solutions. Research on this topic is expected to provide support for transport authority to make economical investment on charging/refuelling infrastructure and for bus operators to make efficient operation of ZEBs with incorporation of charging/refuelling activities.

Our experience

Our empirical results generated from a well-to-wheel analysis suggest that, with the current electricity mix in Australia, battery electric vehicles perform better than other types of vehicles in terms of energy consumption. Emission wise, battery electric vehicles emit 40% less than fuel cell electric vehicles in Australia. In the long run, as more "green hydrogen" will be produced at a cheaper price, fuel cell electric vehicles will play a critical role in minimising emissions [3]. It is further evident from our research that the provision of sufficient charging and refuelling stations for battery electric vehicles and fuel cell electric vehicles, respectively, play a critical role to facilitate the uptake of zero-emission EVs. Therefore, proper investment and regulations on the charging/refuelling facilities need to be made [4,5].

Based on our conversation with local bus operators, charger providers and hydrogen suppliers, we found that deployment of charging/refuelling stations at a bus depot might be not an economical or efficient solution to all bus operators, especially those with small size of bus fleet or limited space at depot. In this case, heterogeneous types of charging/refuelling solutions should be considered case by case according to the bus fleet and served bus routes/networks. To address this challenging problem, SMART has conducted a series of research on the optimal location and capacity of mixed-type chargers (e.g., normal plug-in charger at depot for overnight charging, fast charger at bus stops for en-route top-up charging), and corresponding optimal schedule of charging activities with minimised impact on bus operation. It is evident from our research that, with only a few number of fast chargers required at selected bus stops in a bus network, bus drivers can maximise the utilisation of dwelling time at bus stops with high volume of boarding and/or alighting passengers to top up the battery efficiently without causing extra waiting time for passengers, which on the one hand leads to smaller size of battery to save energy consumption, on the other hand requires reduced number of normal plug-in chargers deployed at depot [6,7].

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[3] Mingyue Sheng, Ajith Viswanath Sreenivasan, Basil Sharp, Bo Du (2021). Well-to-wheel analysis of greenhouse gas emissions and energy consumption for electric vehicles: A comparative study in Oceania. **Energy Policy**. doi: 10.1016/j.enpol.2021.112552.

[4] Mingyue Sheng, Ajith Viswanath Sreenivasan, Basil Sharp, Bo Du (2021). Well-to-wheel analysis of greenhouse gas emissions and energy consumption for electric vehicles: A comparative study in Oceania. **Energy Policy**. doi: 10.1016/j.enpol.2021.112552.

[5] Mingyue Sheng, Le Wen, Basil Sharp, Bo Du, Prakash Ranjitkar, Douglas Wilson (2022). A Spatio-Temporal Approach to Electric Vehicle Uptake: Evidence from New Zealand. **Transportation Research Part D: Transport and Environment**. doi: 10.1016/j.trd.2022.103256.

[6] Hao Hu, Bo Du, Pascal Perez (2021). Integrated optimisation of electric bus scheduling and top-up charging at bus stops with fast chargers. **The 24th IEEE International Conference on Intelligent Transportation (ITSC)**, Indianapolis, IN, USA. doi: 10.1109/ITSC48978.2021.9564617.

[7] Hao Hu, Bo Du, Wei Liu, Pascal Perez (2022). A joint optimization model for charger locating and electric bus charging scheduling considering opportunity fast-charging and uncertainties. **Transportation Research Part C: Emerging Technologies**. Under review.

<u>Our suggestion</u>

Charging/refuelling infrastructure – In planning level, transport authority is suggested to develop a masterplan of charging/refuelling infrastructure deployment in NSW to maximise the utilisation of charging/refuelling resources rather than letting each bus operator build individual charging/refuelling facilities. Mixed-type charging/refuelling techniques (e.g., normal plug-in charger, fast charger, refuelling station, mobile refuelling station) should be considered to satisfy heterogeneous charging/refuelling demand in the large-scale bus network. Based on our previous trial experience, it is very important to integrate charging/refuelling activities with existing electrical grid and hydrogen supply network, and negotiate discount price with electricity/hydrogen suppliers.

Charging schedule – In operational level, bus operators may need to consider flexible and hybrid charging activities to minimise the charging cost during daily operation, and meanwhile to maintain a certain level of service and resilience. For example, for a bus network consisting of different types of bus routes (e.g., short distance vs long distance routes, high-patronage vs low-patronage routes), ZEBs with different battery capacities can be adopted in the bus network and served by different types of chargers (e.g., normal plug-in chargers and fast chargers) with flexibility of utilising en-route top-up charging at selected bus stops and overnight charging at bus deport or charging station. In the meanwhile, with diverse uncertainties during bus operation (e.g., traffic congestion, traffic accident, severe weather), it is important to reserve certain bus fleet resources and backup charging/refuelling facilities to maintain resilience of the ZEB system.

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