Research framing for a study examining the risks to bus operators' cost models during the transition to zero-emissions fleet

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Purpose

This extended abstract describes the need for research into changes in operating and capital cost risk - both magnitude and allocation - that will be bought about by the transition to battery electric bus fleet (Zero Emission Buses, ZEBs) in urban areas. The paper's purpose is to lay the theoretical foundation for qualitative interviews, which will in turn underpin the development of risk-based ZEB cost models. These models can in turn inform revised forms of service contracts where the identified risks are allocated to the parties best positioned to manage them.

Introduction

Within many countries urban bus services are provided under fixed term contracts by private operators (White, 2019). In the United Kingdom outside London the model is mixed with some services being operated without subsidy but, in the major urban areas, this looks set to change due to new legislation enabling universal bus franchising (Centre for Cities, 2024).

Generally, however, the suite of contracts used for bus franchising are designed to accommodate only minor changes in scope and cost, not major shifts such as fleet transition to a different technology. The scale of the changes needed for the ZEB transition is therefore likely to act as a contract disruptor, resulting in specific risks being allocated to parties ill-equipped to manage them, which will in turn affect contract costs and stability. These topics are discussed in more depth in the next section – the literature review - and at the end of this, a research question is developed to set out the next stages of the research.

Literature review

This section is divided into three subsections: fleet transition; battery technology and energy; and regulatory and procurement models.

Fleet transition

Public transport buses are suitable for migration to electric fleet as their operation is planned in advance and dominated by high mileage. Yet, the transition to ZEBs represents a fundamental change in the way in which bus operators and suppliers do business; a change for which many operators have no experience. Phasing out entire fleets of diesel buses and replacing them with battery electric is not likely to be economically feasible, and early retirement of working fleet could waste vast amounts of energy embedded in the manufacturing process (Bus Association Victoria, 2021).

The high investment costs of the electric vehicle drivetrain *could* be compensated for by reduced lifecycle costs through lower maintenance costs (Rogge et al., 2018), but as noted by Bus Association Victoria (2021), battery electric buses currently cost considerably more in capital than diesel models. In the UK this order of magnitude is of a rough factor of two - £500k versus £250k (Meek, 2024). There is also the issue of residual value – at the moment this is uncertain due to lack of knowledge of the secondary market for electric buses in the future (Zhou et al., 2023).

Furthermore, for bus operators who provide services under contract to the state, the decision as to whether to invest in electric fleet is not a stand-alone commercial one. The ZEB transition is often a public policy decision. In some countries capital subsidies are offered to operators to transition to electric fleet – e.g. in Hong Kong, France, Germany, and Poland (Wang et al., 2024). Without subsidies, operators in contestable markets are not likely to take long term lifecycle fleet costing decisions, as there is a possibility of them being left with stranded assets if they lose a contract (Laurie et al., 2022).

Battery technology and energy supply

Entering a new energy market will have an impact on how a bus operator's business is structured financially. The total cost of ownership is likely to change due to the lifespan of technologies such as batteries - battery refits may be needed within a contract life, and operators will be able to procure (and potentially sell) energy at different times of the day (Bus Association Victoria, 2021).

Battery life is crucial to service reliability. Forecasts at present range from four to ten years which makes the need for replacement during a franchise likely depending on the contract term (Abdullah, 2023). Should an operator on a seven year contract risk that the battery will operate perfectly for the life of the contract, and then the battery begin to degrade after five years, then this will affect operational performance potentially incurring punctuality and reliability penalties (Shehabeldeen and Mohamed, 2025). Such an operator would then have to invest capital in a replacement battery, despite not being guaranteed they will be able to continue to operate the service beyond a few more years.

Operating busy schedules on a full charge may also not be possible, necessitating a need to recharge or swap in another bus (Gao et al., 2017; Li, 2016). This uncertainty will be difficult to price into a tender. Moreover, the reliability, availability, and quality of energy play a pivotal role in ZEB deployment, and there is little surety about how energy delivery will be prioritised during times of shortages (Avenali et al., 2024a).

There is also the question of the additional costs of training maintenance staff and a potential safety premium when transitioning from a diesel to a high-voltage environment. Original equipment manufacturers (OEMs) will need to sign off on depot safety as a condition of warranty, and whilst staff training is usually a feature of new bus purchase agreements, high voltage systems require special training needs (Lipman and Rogers, 2023).

Regulatory and procurement models

Given the shifting landscape flexibility in contracts will be needed. Contracts will need to be allowed to dynamically evolve as circumstances change. Very few franchising studies, however, have explored the dynamic evolution of contracts (Cochet and Garg, 2008). Cruz and Marques (2013) distinguish between flexibility "in" and "on" projects - options "in" projects are imbedded into a system (endogenous), i.e., they consider that the infrastructure or regulatory landscape might change. Furthermore, the literature around franchising flexibility tends to focus on the commercial franchising of a retail brand rather than a regulated term concession to provide state services (Klick et al., 2006).

In bus service franchising, concessionaires are usually selected through auctions at which candidates submit bids for fixed terms. This combination of fixed-term concessions and auction-based does not induce an efficient selection of concessionaires. In more efficient contracts it might be necessary to isolate concessionaires from revenue uncertainty by automatically adjusting the concession term (Nombela and de Rus, 2004). Another problem is that bus contracts are often output based and many operators do not build flexibility into their contracts for fear of losing a bid, and thus suffer losses over the life of the contract (Hou and Neely, 2018). Moreover, transport transitions are often place-based phenomena, embedded in highly localised political, institutional, regulatory, physical, and economic contexts unfamiliar to bidders (Argyriou, 2023). The scale of potential disruption when moving to ZEBs may therefore make these contracts inherently unstable and necessitate new procurement models. Kapatsila et al., (2024) note that a key risk to the ZEB transition is 'inadequate procurement frameworks'

Several scholars have called for a revision to procurement models to facilitate the ZEB transition by laying out a different division of responsibilities between established and new stakeholders than is present in the current model, and mooting innovative regulation to promote cooperation, allocate risks correctly, and maintain a balanced supplier market Suggestions include capacity building on both operator and regulatory side, supply chain partnerships, asset ownership shifts, the establishment of asset leasing firms, and negotiated solutions (at least for the initial period of uncertainty until a model 'beds in' (see: Ashmore et al., 2021; Ashmore and Hensher, 2022; Ashmore, 2022; Åslund and Pettersson-Löfstedt, 2023; Avenali et al., 2024a; Hensher, 2022; Miles and Potter, 2014; Foecke et al., 2024; Hensher, 2021; Lowe, 2024; Jagiełło et al., 2023).

This short literature review has shown significant uncertainties in the ZEB fleet transition, battery charging and energy supply, and regulatory and procurement model. These are likely to cause significant cost shifts and unless better understood there remains a chance that future contracts will allocate risks incorrectly, increasing service delivery and public policy risk.

Research question

The uncertainties described make quantifying the risks and rewards of transitioning to an electric fleet difficult (Avenali et al., 2024b). Research is therefore needed to understand:

> *What will be the changes in operating and capital cost risk - both magnitude and allocation - bought about by the transition to ZEBs in urban areas, and to what degree to procurement models need to be modified to accommodate them?*

The study will break down into several key issues:

- The likely aspects of operating and capital cost which will be subjected to the greatest uncertainty
- Which risks will fall to the public and private sector respectively
- How the industry is likely to account for a shift in risk profile when pricing bids
- If a franchising agency is likely to recognise these potential risks and make allowances for them in contract crafting, bid assessment and cost variation provisions
- The possible impacts of the zero-emissions transition in terms of competition and monopolies.

The research will be of interest to regulators, operators, financiers, academics, and manufacturers, and aid the transition to battery electric fleet in urban areas.

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