Total Cost of Ownership Analysis of Battery Electric Buses for Public Transport System in a Small to Midsize City

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Overview

The deployment of battery-electric buses within the public transportation sector plays an important role in decreasing the exhaust gas emissions of transportation [1]. The introduction of technologies has accelerated quickly in the last decade, influenced by national energy policies and driven by environmental requirements more than by commercial considerations. However, there are currently various barriers to the widespread adoption of electric buses. A significant challenge is the relatively low energy density of batteries, which is directly related to a price issue on buses [2]. The recent development in battery technology has increased the potential of electric buses to be a viable solution for public transport.

This publication is constructing the Total Cost of Ownership (TCO) model including an analysis of CAPEX and OPEX and to assess public transport in one small-mid size city, Offenburg whether it is suitable for the transition to electric buses. The future development of costs is estimated and a projection based on learning curves will be carried out. This study intends to introduce a new future prospect by introducing the latest data based on the previous research [3]. Through the new TCO result, we want to find out how economical the operating cost difference is between the existing diesel bus and the current electric bus, and also to look into the future prospects for the economic feasibility of the electric bus in a small and midsize city.

Methods

The TCO (Total Cost of Ownership) has been identified as one of the main decision factors for the viability of investment for all types of buses [4, 5]. TCO considers all expenses linked to owning and operating public buses and is used to calculate the cost experienced during the entire life cycle [5, 6].
Although TCO has been calculated based on operational data and values from the literature, there is still uncertainty in the estimation of TCO. As those buses have not been manufactured yet in large-volume series, it is difficult to estimate the related costs precisely. Additionally, because their production is not mature enough when compared to conventional public buses, it is hard to estimate the technological development of alternative buses in terms of costs [7]. Especially, differences in the taxation policies of the energy in different countries make the overall cost calculation quite difficult [7], but in this study, they are not considered.

Results

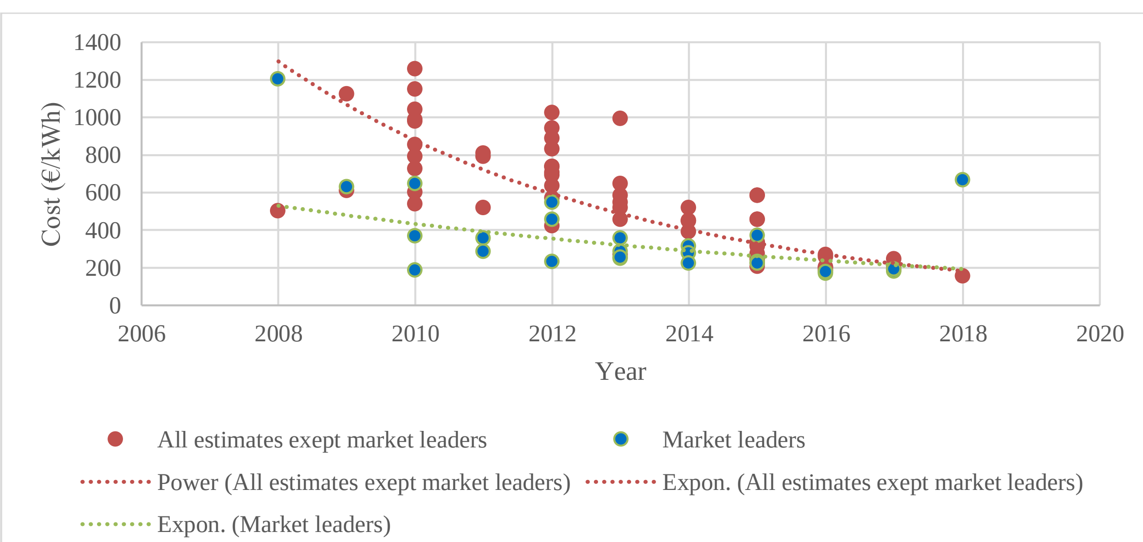

Figure 1. Battery prices changes between 2008 and 2018 (should be updated with the latest data) [3]

The high upfront costs of electric buses are still the single largest barrier holding back mass adoption of the technology. Many cities lack funding to support higher spending when faced with a technology choice for fleet replacement, but some are deliberately delaying the purchase decision because they know battery prices are falling, and they expect e-buses to be cheaper in the future. Figure 1 shows how battery prices have changed over the last decade. The battery prices found in the literature are much lower than the actual market price of the e-bus battery, even though it is meant to show the trend of changing battery prices. Those researches show that battery prices are falling to low prices, massively. Therefore, cost reductions of e-bus are expected to come mainly from the battery pack, as there is little scope to further reduce the price of the other components of the vehicle. [3]

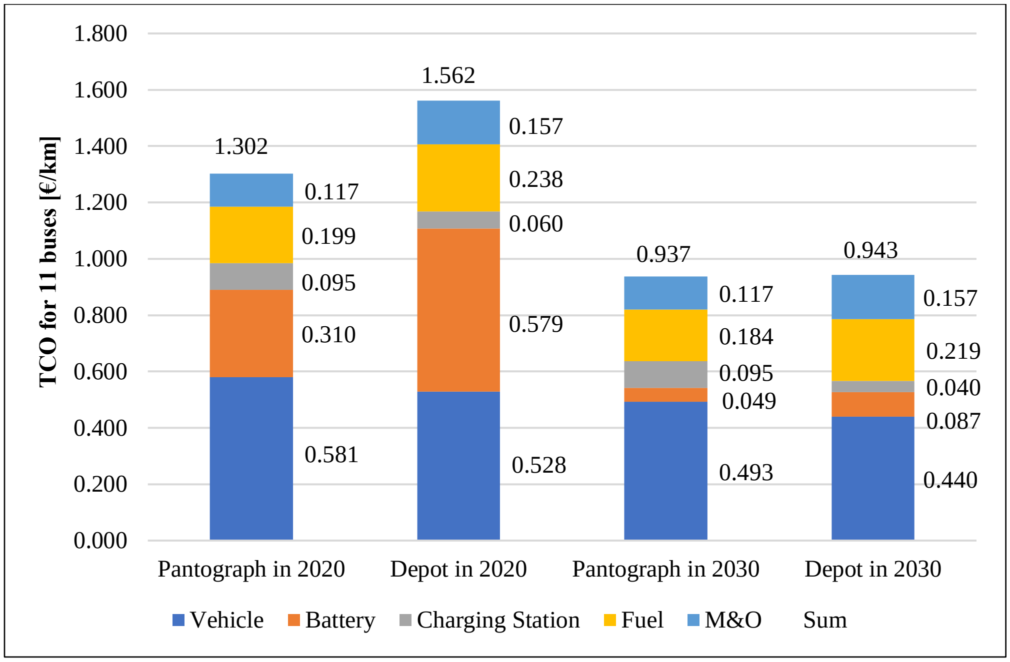

Figure 2. Battery electric bus TCO results for 11 buses scenario with two charging methods (should be updated with the latest data) [3]

Figure 2 represents that the pantograph bus scenario is more cost-effective than the depot bus. Although the pantograph bus price is higher than the depot charging bus due to the characteristics of opportunity charging, it requires smaller battery capacities that have lower prices. Additionally, it is possible to cover the route with less electricity, resulting in lower TCO.

In 2020, depot charging has a TCO value that is 0.26 €/km higher than pantograph charging. However, in 2030, the difference between the two models is only 0.005 €/km, due to fluctuations in battery prices. The pantograph batteries, which are just needed as a small capacity, save a lot of money as of 2020, but the cost of the battery will be lower in 2030, so the cost-saving effect according to the capacity is not significant.

In other words, it is difficult to determine the advantage of the depot and panto-graph models in terms of price based on the TCO results in 2030. However, the panto-graph model has more managing and planning aspects, because the lines have to match the pantograph availability. But it has the advantage, that the vehicles can be charged during the day, which will correspond better to PV feed-in, especially in the future with more renewable energy sources. [3]

Conclusions

Consequently, the TCO models can be used in finding economical solutions for a full emission-free bus introduction into the public transport system. In the study, the depot and pantograph charging electric bus models were compared with the diesel bus TCO. The results indicate that the short-range fully electric bus scenario with shared opportunity charging infrastructure is the most economical solution in 2030. [3]

However, the pantograph charging method is applicable under the assumption that several buses share the same station. In Offenburg's case, all 11 buses stop in front of the train station, so there was no difficulty in selecting the location of the Panto-graph charging station. Therefore, for the analysis of other cities, finding a bus station where a certain number of buses gather acts as an important key factor.

This study is also related to other small to midsize cities, as these generally have similar public bus lines and schedules. These public bus lines in small to midsize cities will gradually increase economic competitiveness with alternative powertrains compared with existing diesel buses.

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