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Analysis of passenger impacts of implementing electric buses in Denmark using smart card data

Jesper Bláfoss Ingvardson, DTU Management, jbin@dtu.dk
Otto Anker Nielsen, DTU Management, oani@dtu.dk

Abstract
Electric buses have been implemented in several Danish cities over the last years replacing conventional diesel buses. Previous studies have shown that electric buses can increase passenger satisfaction through increased comfort levels. Such results suggest that there could also be an effect in terms of increased ridership, however no studies have so far analysed this in detail. This study analyses the development in ridership over a 6-year period, covering cities in Denmark, which have replaced conventional diesel buses with electric buses. The study compares selected cities, which have made such replacement city-wide, to selected cities in a control group in which no changes were made. The analysis is based on primarily Rejsekort data, and the results compare ridership trends across cities dependent on the type of buses and level of service. Preliminary results of three of the case study cities show mixed ridership trends, but did not include controlling for service supply. Future work will include results for eight case study cities as well as a ridership model controlling for important service quality and supply data.

1 Introduction
Electric buses are being deployed in great numbers around the world replacing conventional diesel buses. This has a number of environmental benefits such as reduced CO2 emissions, local air pollution and noise. In addition, electric buses might have positive passenger impacts considering that they can be more comfortable than diesel buses due to less rapid accelerations and decelerations, less vibrations and less engine noise. Previous studies have shown that comfort is one of the most important parameters for passengers in terms of passenger satisfaction, equally important as service levels (*1*), and that comfort is a key parameter for using electric buses (*2*). Furthermore, the environmental aspect has been highlighted by passengers as reason for choosing public transport (PT) in general (*3*) and electric buses in particular (*2*), and it is an aspect that increases user satisfaction (*4*). Hence, the implementation of electric buses might have a positive influence on actual PT ridership. However, to the knowledge of the authors no studies have focused on the impacts on ridership of substituting conventional diesel buses with electric buses. Hence, this study will contribute to existing literature by analysing in detail the passenger impacts of implementing electric buses as replacement of conventional diesel buses. This will be achieved through using a large-scale dataset of passenger trips based on Rejsekort data covering the period from 2018-2024. The analysis will be

two-fold by i) comparing the development in ridership across bus lines and cities that deployed electric buses and those that did not, and ii) estimation of a statistical model that analyses the ridership trends as function of service quality and supply.

2 Background

Electric buses have replaced diesel buses in many Danish cities since 2019. The transition process happens gradually when tendering contracts are re-negotiated and often happens on a municipality level. Hence, some entire city areas have had electric buses implemented simultaneously, whereas others continue using conventional, old buses. This allows for comparing the ridership trends in different cities over time before/after introducing electric buses. We thereby compare ridership trends across cities of similar characteristics, which are served by either electric or conventional buses. In few cases tendering only affects certain bus lines in a city, thus resulting in service within city areas being a combination of electric and conventional buses. Similarly, some regional bus lines with conventional buses might still serve cities after the local buses have been switched to being electric. This will also be considered in the analysis. Finally, the city of Aalborg implemented a full Bus Rapid Transit system (BRT), which opened in September 2023. This special case of electric buses with a notably improved level of service will also be included in the analysis as a special case.

3 Approach and data

The study is based on smart card data (*Rejsekort*), which is a tap-in-tap-out Automated Fare Collection (AFC) system covering the entire country of Denmark with detailed OD-information including transfers. This data cover approx. 41% of trips conducted in PT in Denmark (2021, Movia), whereas the remaining passengers use monthly cards or other types of tickets. The study utilises data from 2018 to 2024 and focus on eight cities which had electric buses implemented during this period, two cities where electric buses only served the key lines (and in combination with light rail), and a control group of 10 cities that have continued using only conventional diesel buses, cf. Table 1. All cities have been selected such that no other major changes of the PT network took place in the given period. Note however that Aalborg had a full BRT system implemented during the study period with a notable increase in level of service. This corresponds to a further improvement in terms of both being electric and having notably reduced travel times for passengers and is thus part of the analysis as a special case.

All electric buses (inauguration year)	**Combination**	**Conventional buses only**	**City Characteristics**
Roskilde (April 2019), Slagelse (June 2021), Næstved (April 2022)		Hillerød, Helsingør, Køge, Holbæk	Cities in the Greater Copenhagen Region
Esbjerg (December 2021) Kolding (June 2022) Horsens (March 2023) Fredericia (June 2023)		Herning, Vejle, Randers, Silkeborg, Viborg, Holstebro	Provencial Cities
Aalborg (August 2022)	Odense, Aarhus		Larger cities

Table 1; List of cities included in the study, their city type, and which type of buses they are using.

4 Results

A preliminary analysis based on data from 2018 to 2023 focused on the ridership trends across the three cities of Roskilde, Næstved and Slagelse, which all had electric buses implemented citywide. The ridership trends were compared to the control group cities in East Denmark, namely Hillerød, Helsingør, Køge and

Holbæk. In addition, a comparison was done between the ridership trends of the specific electric bus lines to those being conventional within the city. The results for Roskilde are shown in Figures 1 and 2.

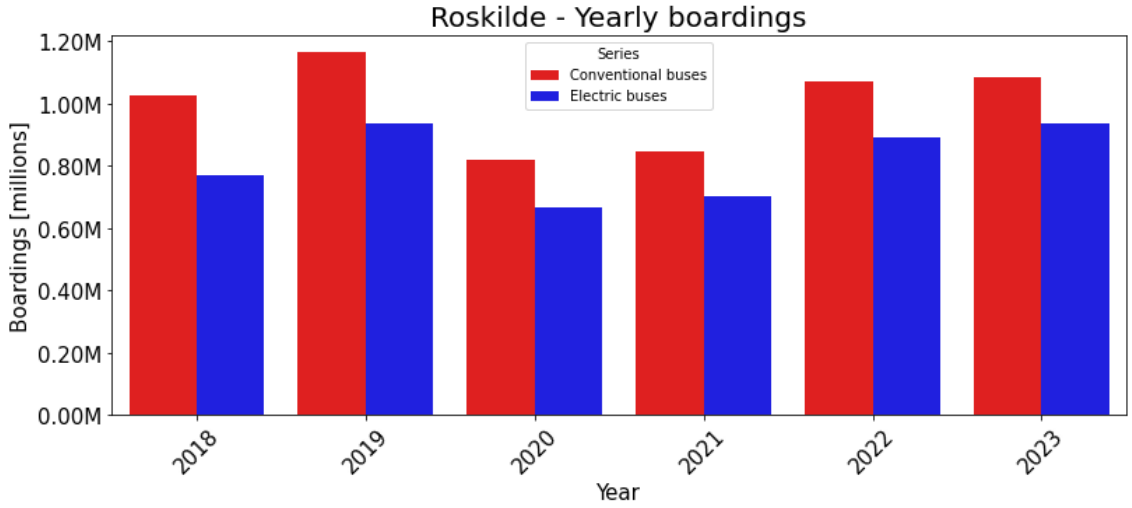


Figure 1; Yearly number of boarding passengers segregated for the bus lines that changed to being electric in 2019 (blue) and for those that continued being conventional throughout the entire study period (red). Note that in 2018 all bus lines were conventional, but the graph still shows the boardings for the two groups of bus lines separately.

The graph shows that throughout the entire six-year period conventional bus lines has had slightly more passengers than those bus lines that in 2019 changed to electric vehicles. However, possibly with the difference being smaller over the years. Hence, Figure 2 shows the indexed ridership. From here it can be seen that the bus lines that changed to being driven by electric vehicles from April 2019 generally has higher ridership than the remaining bus lines in Roskilde as well as the bus ridership in the control cities on Sjælland. Hence, this suggests that these bus lines were more attractive to passengers. Whether that is due to the vehicles used, or it has to do with other factors such general supply needs to be analysed in more detail.

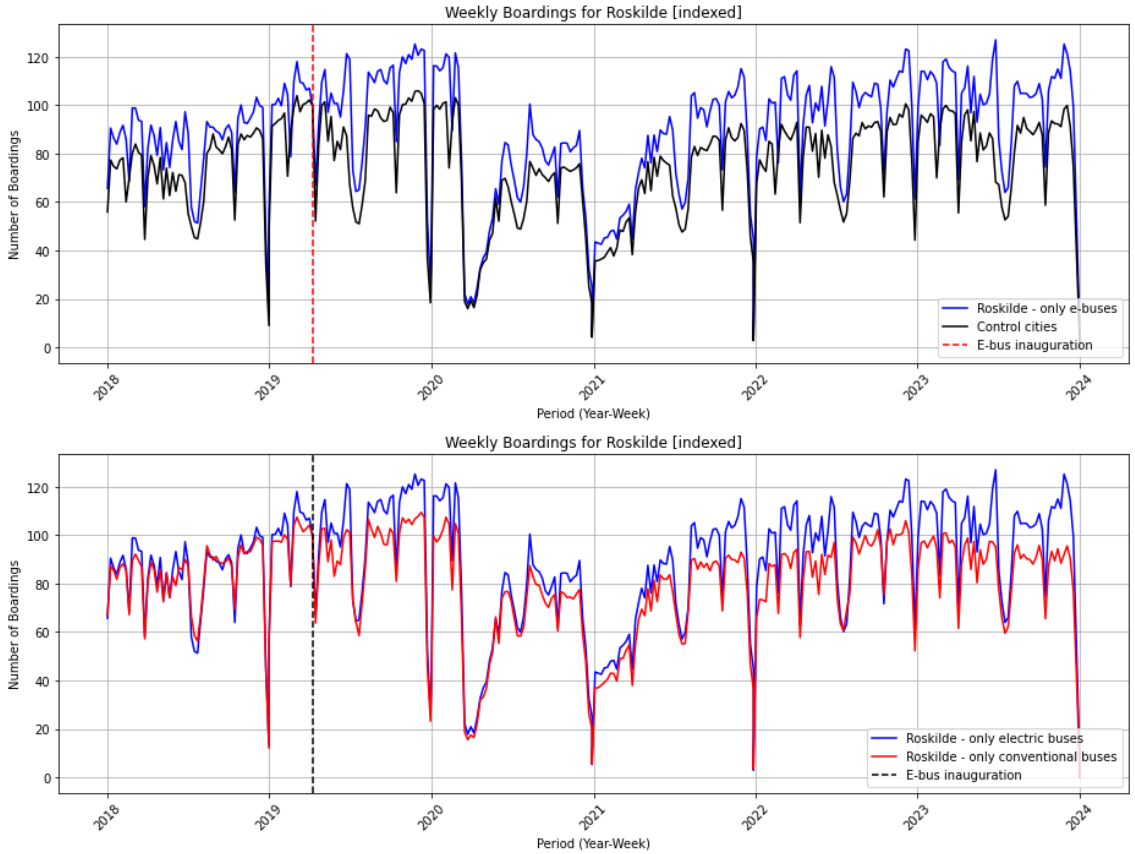
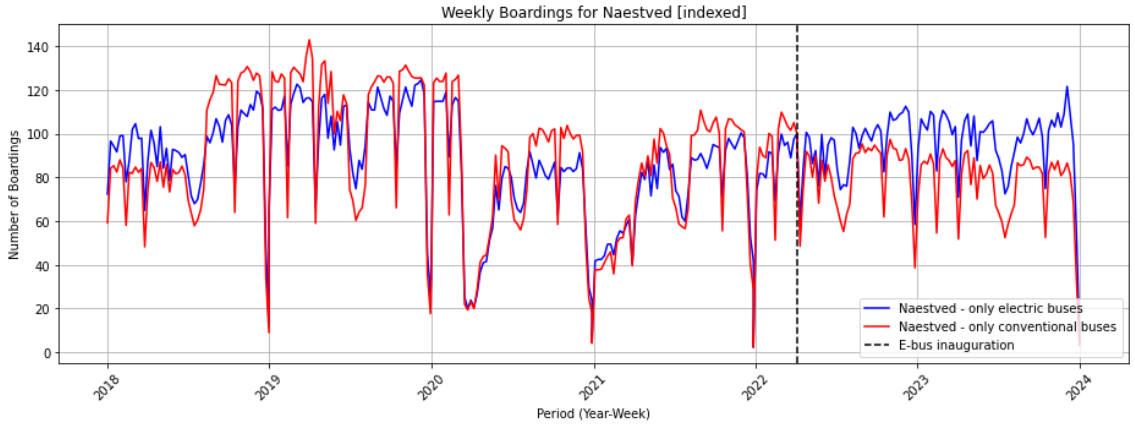


Figure 2; Ridership trends of Roskilde of e-buses compared to control cities (above) and e-buses compared to c-buses in Roskilde municipality (below).

The same analysis is shown for the cities of Næstved and Slagelse in Figure 3. The trends for these two cities are different. In Næstved an increasing ridership trend for the electric bus lines after the change of vehicles in 2022 can be seen. Hence, the ridership increased more for these bus lines when compared to the conventional bus lines. For Slagelse the results are opposite showing a decreasing trend for the bus lines changing to electric vehicles after the implementation in 2021, and this seems to be more negative than for the conventional bus routes in Slagelse.



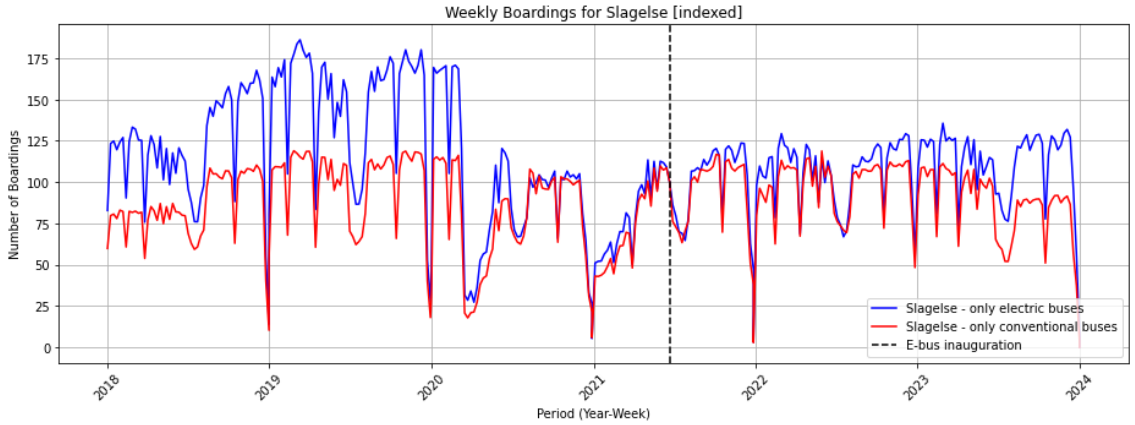


Figure 3; Ridership trend of e-buses compared to c-buses in Næstved (above) and Slagelse (below).

To summarise the results, an overview of the average ridership trends for the three cities are shown in Table 2, which shows the average indexed ridership for e-buses before and after implementation, as well as comparison values for the indexed ridership across the entire city and control cities. As can be seen, for Roskilde ridership of the buses that changed from conventional diesel to being electric increased slightly whereas for the city as whole ridership decreased, like for the control cities. Whether this can be contributed to the buses being electric cannot be concluded, but needs further analysis. For Næstved, ridership increased more for the bus lines changing to being electric compared to the city as a whole, but slightly less than for the control cities. On the other hand, in Slagelse the bus lines changing to being electric experienced a decreasing ridership trend, which was more negative than the city of Slagelse in general and the control cities during the same period. Hence, based on these numbers it is difficult to draw general conclusions.

	Before	After	Difference	Entire city	Control cities
Roskilde	87.1	88.4	+1.3	-3.5	-2.4
Næstved	85.5	95.8	+10.3	+2.3	+11.3
Slagelse	115.0	105.6	-9.4	-0.5	+11.9

Table 2; Overview of average ridership index during the evaluation period.

4.1 Future work

For the presentation at Trafikdage, and the full article, results for all case study cities will be provided. But more importantly, the results will consider supply in greater detail to better understand whether the changes to ridership are due to changes in the supply, hence making the public transport more attractive, rather than being an effect of the vehicles used. This will be done through the estimation of a statistical ridership model considering explicitly public transport supply.

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