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Electric buses in England and Sweden – Overcoming barriers to introduction

Malin Aldenius [a,d,*], Caroline Mullen [b], Fredrik Pettersson-Löfstedt [c,d]

[a] Environmental and Energy Systems Studies, Lund University, Lund, Sweden
[b] Institute for Transport Studies, University of Leeds, Leeds, UK
[c] Transport and Roads, Lund University, Lund, Sweden
[d] K2 - The Swedish Knowledge Center for Public Transport, Lund, Sweden

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ABSTRACT

Electric buses can improve the environmental performance of public transport. Yet, introducing electric buses brings novel challenges, such as requirements for operational changes, new forms of institutional collaboration, increased investment costs and technological concerns. This paper investigates these challenges and strategies for managing them by comparing experiences of electric bus implementation in English and Swedish cities. The comparative approach enabled us to understand the influence of governance context, organisational practices and relations between stakeholders. The comparison shows that experiences by involved stakeholders are highly context dependant. Financial and regulatory support from the national government, along with passenger demand and route characteristics had significant influence on the implementation. However, the relationship between stakeholders involved and the division of responsibility emerged as central factors to overcome challenges – the most important being the development of functioning collaboration between the stakeholders.

1. Introduction

The transport sector is responsible for around a fifth of CO_2 emissions globally (Ritchie, 2020). Achieving the rate and scale of decarbonisation required by the Paris agreement calls for a rapid shift to more efficient travel modes, and more energy efficient technologies and fuel (IEA, 2017). Electrification of public transport is an example of how both these measures can be deployed (IEA, 2019). Besides contributing to decreased CO_2 emissions, electrification of public transport can also improve air quality and noise pollution.[1] Yet transitioning to electric buses involves challenges, including upfront investment costs, uncertainties around technology development, and operational questions e.g. regarding scheduling, charging and maintenance (Aldenius et al, 2016; Åslund et al, 2021; Bakker and Konings, 2018).

The market for battery electric buses has emerged quickly although currently 99% of electric buses are operated in China (IEA, 2019). Yet there is growing interest worldwide (IEA, 2019). Cities around the world have signed the Fossil Fuel Free Streets

* Corresponding author at: Environmental and Energy Systems Studies, Lund University, Lund, Sweden.
E-mail addresses: malin.aldenius@miljo.lth.se (M. Aldenius), C.A.Mullen@leeds.ac.uk (C. Mullen), fredrik.pettersson-lofstedt@tft.lth.se (F. Pettersson-Löfstedt).

[1] There is a broad agreement that electric buses are considerably more energy efficient, produce less CO_2 emissions, and reduce noise (e.g. Borén & Grauers, 2019). Electricity (2016) reported that electric buses are approximately 80 % more energy efficient than diesel buses.

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Declaration, promising to procure only zero-emission buses as of 2025 (C40 Cities, 2019). A revision of the Clean Vehicle Directive (EU 2019/1161) includes targets for share of zero emission buses in procurements in EU countries until 2025 and 2030. In the UK, where transport policy is devolved, each government is providing financial support for adoption of zero-emission buses (Department for Infrastructure, 2020; Department for Transport, 2021a, 2021b; Transport Scotland, 2021; Welsh Government, 2021). At the beginning of 2020, there were 2,736 battery-powered buses in operation in the EU27, Iceland, Norway and Switzerland (Crow, 2020). This is still a fraction of the European bus fleet which comprises over 892,000 buses and coaches (ACEA, 2021). Nevertheless, just a few years ago battery-powered electric buses were most common in test and demonstration projects (Aldenius et al, 2016), now electric buses from many manufacturers, with different charging technologies, operate in regular traffic (Crow, 2020; Lundström et al., 2019).

While the commitment to push for alternative fuelled buses is growing within countries and cities in the EU and UK, many challenges to implementation still remain. Most of the research focuses on technological development and cost. For example, comparisons of potential of different power train technologies (Borén et al, 2016; Mahmoud et al, 2016), energy and environmental lifecycle performance (Zhou et al, 2016), battery capacity (Gao et al, 2017), modelling optimum options for charging infrastructure (Göhlich et al, 2018; Lajunen, 2018; Wang et al, 2017; Xylia et al, 2017) and lifecycle costs (Lajunen, 2018; Lajunen and Lipman, 2016; Potkány et al., 2018). Modelling best options can however be challenging because of its dependence on route characteristics (Rogge et al, 2018). Less attention has been paid to planning and organisational challenges when introducing electric buses, and the roles and influence of local stakeholders (Krawiec et al, 2016, Åslund et al, 2021). Previous research on implementation focuses either on country-based case studies (Bakker and Konings, 2018; Borén and Grauers, 2019; Miles and Potter, 2014; The Swedish Energy Agency, 2019), or solely on one stakeholder's experiences (Mohamed et al, 2018). These studies reveal that implementation challenges depend on context, institutional settings, and what stakeholders are involved. Since such circumstances are case-specific, previous studies have highlighted the need to elaborate on similarities and differences between cities and countries (Bakker and Konings, 2018).

This paper addresses the need for comparative research on challenges when introducing electric buses. This is done by comparing experiences in England and Sweden, two countries with different institutional settings, using case studies in four cities (Nottingham, York, Gothenburg, and Eskilstuna). The comparative approach enables us to investigate the influence of governance context, organisational practices and relations between stakeholders in the implementation process. The focus, which is on the early stages of introduction of electric buses, may provide insights for other cities planning transitions to electric buses.

Using documents and semi-structured interviews with a wide range of stakeholders in the case study cities, the following research questions will be addressed in the paper: 1) What were the main challenges experienced in the cities; were they similar or different? 2) What approach was taken in each city to overcome the challenges? 3) Does national context matter and, if so, in what way?

We begin by reviewing previous research on introduction of electric buses. This is followed by a description of the method (Section 3). Section 4, presents results and analysis of the documents and interviews, both at a national and city level. The differences and similarities between the cases are then discussed in Section 5 and conclusions and further research recommendations form Section 6.

2. Previous research on introduction of electric buses

Previous research of challenges to bus electrification have typically been carried out in single countries, including the Netherlands (Bakker and Konings, 2018), Canada (Mohamed et al, 2018), Sweden (Borén and Grauers, 2019; Mutter, 2019) and England (Miles and Potter, 2014). In this section we present some of the challenges identified, which can be categorised into five groups: 1) operation and scheduling, 2) charging infrastructure (planning and ownership), 3) uncertainties of costs, 4) new stakeholders and 5) lack of knowledge. Since the categories of challenges result from research in different countries, we do not know whether all the challenges are relevant in all countries or whether, or why, issues are qualitatively different in different places. So, we do not know whether some places manage changes to operation better than others, or explanations for any differences. Since the studies are specific to single places or stakeholders, they cannot offer insights into how challenges vary according to context. This understanding of the influence of context is needed if electric buses are to be widely introduced, and this paper aims to address that research gap.

2.1. Operation and scheduling

Many public transport systems are locked into conventional ways of operating, with each vehicle running multiple routes with little slack in schedules (Bakker and Konings, 2018; Mohamed et al., 2018). With electric buses, operation and scheduling become more difficult since they have limited range and less route flexibility (Bloomberg New Energy Finance, 2018; Mohamed et al, 2018). Buses only charged in the depot overnight (which we refer to here as 'depot charging') most closely reflect the operation of conventional buses. Yet, the limited battery range might not make it suitable for high demand traffic and can create a need for extra buses, and hence increased costs. Adding top-up charging on the other hand locks buses into routes, and requires extra time for charging which might not fit in to the current schedule and can also create a need for more buses (Mohamed et al, 2018; Varga and Iclodean, 2015). To address operation and scheduling problems, it is important to consider local circumstances carefully when choosing charging infrastructure and routes (Bakker and Konings, 2018; Krawiec et al., 2016; The Swedish Energy Agency, 2019), for example by first running demonstration projects (Mohamed et al, 2018), or tailoring operations planning for electric buses (Häll et al, 2019).

2.2. Charging infrastructure

As noted above, a bus running on conventional fuels can operate all day without refuelling. Depot charging for electric vehicles requires heavy, expensive, space consuming batteries, and even then they do not always allow for the required range (Bakker and

Konings, 2018). While top-up charging along the route compensates for limited range, it comes with its own technical barriers, including grid capacity issues and a lack of standardisation (Bakker and Konings, 2018; Bloomberg New Energy Finance, 2018; Mohamed et al., 2018). Top-up charging also requires space for charging infrastructure and transformer substations in urban areas where space is often scarce. Therefore, it is necessary to adapt the choice of charging technology to the route and to local circumstances. Other ways to address charging challenges and grid capacity include for example placing depots strategically (which may be a difficult issue in urban areas) (Bloomberg New Energy Finance, 2018).

2.3. Uncertainties of costs

At least until recently, it has been clear that the investment costs for electric buses are higher than those of conventional diesel buses, and that a large share of the cost comes from the batteries (Bloomberg New Energy Finance, 2018; Varga and Iclodean, 2015). However, there are substantial uncertainties concerning the costs of owning and operating electric buses (Åslund et al., 2021; Bakker and Konings, 2018). These uncertainties include technology development and economies of scale, implementation of national subsidies and incentives, depreciation times for vehicles and infrastructure (Åslund et al, 2021), maintenance costs (Bakker and Konings, 2018), and the risk of needing more buses (Mohamed et al, 2018; Varga and Iclodean, 2015). The total cost is also influenced by local circumstances such as choice of route and timetable (Grauers et al, 2020) and previous investments in another renewable fuel, such as biogas, especially when the connection between the bus system and regional biogas infrastructure is strong (Mutter, 2019). Suggestions to overcome the cost barrier include funding from the government (Bloomberg New Energy Finance, 2018; Energimyndigheten, 2019; Li et al. 2018; Mohamed et al, 2018), extended manufacturer warranty, battery and vehicle lease, or extended loans for the vehicles (Bloomberg New Energy Finance, 2018). There is also research showing that lower running costs can compensate for the higher investment costs, under the right operating circumstances (Grauers et al, 2020; Lajunen, 2018).

2.4. New stakeholders

Collaboration between stakeholders is also an important part of a successful introduction (Bakker and Konings, 2018; Borén and Grauers, 2019; Miles and Potter, 2014; The Swedish Energy Agency, 2019). According to Miles and Potter (2014), the numbers of new stakeholders involved in electric bus introduction mean that partners need to find new ways to work together, which provides confidence to all involved. Bakker and Konings (2018) have a similar view and maintain that existing conventional business models and the division of tasks within those models limit opportunities for collaboration. A paper by Borén & Grauers (2019) addresses the need for new ways of collaborating in the Swedish context by suggesting new collaboration models for procuring electric buses. Depending on level of experience among the stakeholders involved and the preference of charging technology, they suggest leaving more or less responsibility with the public transport authority (PTA), in order to address issues concerning planning, building permits and cost efficiency (Borén and Grauers, 2019). It should be noted that the suggestions made by Borén and Grauers (2019) imply a different approach to the standard procurement processes for public transport in Sweden. The applicability of their collaborative model in other contexts, such as the de-regulated bus service model that exists in many parts of England (outside London and Manchester), is probably limited.

2.5. Lack of knowledge

Conventional business models often assume a high level of knowledge of risks. Therefore, rapid technology advancement can be viewed as a key challenge (Mohamed et al, 2018). According to Miles and Potter (2014) the lack of experience and limited knowledge of risks among early adopters means that providing subsidies to introduce electric buses might not be enough. Previous studies highlight the importance of educating the staff to address the challenges of a new technology (Borén and Grauers, 2019; The Swedish Energy Agency, 2019), and the importance of involving the national and local governments (Bloomberg New Energy Finance, 2018). Another way to address the lack of knowledge is for the cities and PTAs involved to work closer with manufacturers to show demand (Bloomberg New Energy Finance, 2018).

2.6. Collaboration

The challenges identified for the introduction of electric buses recognise how implementation is influenced by relations between organisations, technological innovation, compatibility of systems standards, division of responsibilities, limited knowledge and uncertainty.

One study has considered potential effectiveness of different models of collaboration between actors involved in implementation (Borén and Grauers, 2019). Yet, there is far larger literature on collaborative governance which includes and extends beyond development of models of collaboration and which investigates the nature of inter-organisational relations which may be required for effective collaboration. This research on collaborative governance is based in work on public administration, governance, and socio-legal studies (e.g. Vincent-Jones and Mullen, 2010; Gilson et al., 2011; Sabel, 1994; van Slyke, 2009), and has been applied to a range of sectors including transport and specifically the organisation of conventional bus services (Hensher, 2010; Hrelja et al., 2018). To date, this literature has not been considered in relation to electric buses. This may be a research gap since collaborative governance is concerned with understanding how to manage the sorts of challenges faced in implementation of electric buses, especially challenges of uncertainty, limited knowledge and potential tensions in settling roles and responsibilities of different actors.

Collaborative governance has developed in response to the limitations of conventional contractual forms of organisation which rely on parties initially understanding fully what their responsibilities will require of them, and how they will respond in different situations. Those conventional contracts assume that actors are self-interested and so only act in pursuit of their own interests rather than a common project, and therefore divisions of responsibilities, and expected actions must be fully specified. The problem with these assumptions is that knowledge is incomplete and the future undetermined and so it is not possible to provide, ex-ante, a full specification of what is expected from each actor (Gilson et al., 2011; Sabel, 1994; van Slyke, 2009). Collaborative governance seeks to address this problem of asking actors to agree to a high-level common project, under that the full specification of what is required to meet this common project can be revised and determined as the project unfolds. This enables actors to respond to uncertainty. The intention is not to ask actors to give up their own interests, but it does ask actors to consider their interests in the context of achieving the common project (Vincent-Jones, 2013; Vincent-Jones and Mullen, 2010). Of course, there are multiple complexities involved in collaborative governance. In particular, it requires trust from all actors to respond to emerging challenges in ways which will facilitate the part the project and will not leave the other actors with unfair levels of burden or responsibility. While this does require a conception which differs from the idea of actors is solely self-interested, it also tends to involve practical characteristics such as trust built up between actors who have collaborated over a period of time (Brown et al., 2007; Grafton and Mundy, 2017; van Slyke, 2009; see also Heath, 2006). It also involves measures, particularly monitoring and benchmarking, which help enable assessment of whether or how each actor is contributing to realising the common project (see e.g. Gilson et al., 2011; Grafton and Mundy, 2017; van Slyke, 2009).

3. Method

To investigate how challenges, and the problem solving approach, vary according to governance context, we analyse and compare experiences in four different cities in two different countries. The countries and cities were chosen on the basis that they were early adopters of electric buses and at the same time represented large differences in regulation and national policy instruments and in institutional contexts.

At the time of this research, England and Sweden represented different ways of organising public transport. The bus market in England, outside London, was deregulated in 1986. The Transport Act 2000 included provision for franchising (in which transport authorities commission services) or partnerships between local transport authorities and private providers; however, these provisions did not lead to any cases of franchising and produced only a limited number of working partnerships. In practice, private operators retain a high degree of freedom to determine routes, fares and frequency, and they typically own the buses (van de Velde, 2014). Local transport authorities' provision of bus services has been largely confined to 'socially necessary' services which private operators do not consider sufficiently profitable (House of Commons Transport Committee, 2019). Local transport authorities tender only around 20% of bus services outside London. In Nottingham and York, electric buses are found on these regulated bus service routes and in Nottingham the local authorities also own the buses (Urban Transport Group, 2018). It should be noted that the regulation of buses in England may now be in a process of change. The Bus Services Act 2017 is intended to provide stronger powers to enable transport authorities to move away from deregulation towards a system of franchising (Butcher and Dempsey, 2018). In March 2021, Transport for Greater Manchester (in north-west England) announced that it will adopt franchising, and other local transport authorities might follow (Butcher and Dempsey, 2018; Transport for Greater Manchester, 2021). However, these are changes (and potential changes) which have come after the empirical research conducted for this paper.

The Swedish Public Transport Act (2010:1065) came into force in 2012 and opened up for deregulation. Nevertheless, a main difference from England is that planning of local and regional public transport has stayed almost exclusively with the regional public authorities and 90% is organised on the basis of comprehensive competitive tendering – where regional authorities contract out the operation to private actors who own and operate the buses (The Swedish Bus and Coach Federation, 2019). Local municipalities in Sweden historically have strong control over land use planning and it is they who have to grant planning permissions. In the case of public transport, this can affect the building of depots and charging infrastructure in town, for example.

In England, the cases in this paper were Nottingham, which at the time of the study had 58 electric buses, the greatest number of electric buses in Europe, and York with 14 electric single decker buses. In Sweden, the cases were Eskilstuna, operating 12 electric buses (at the time of the study the city with the most electric buses in Sweden), and Gothenburg that had a very ambitious test project

Table 1
Overview of electric buses, charging technology and organisation in the cities studied.

	England		**Sweden**	
Towns	*Nottingham*	*York*	*Gothenburg*	*Eskilstuna*
No. of buses (2017)	58	14 and 1 double-decker	3	12
Charging technology	- Depot charging - Top-up charging	- Depot charging - Top-up charging at P&R site	- Depot charging - Pantograph, ultra-fast charging at end stations	- Depot charging
Organisational setup	Contracted out	Contracted out	Test project	Under current contract
Ownership of buses	City council	Operator	Operator renting from bus manufacturer	Operator (with guarantee by PTA to acquire buses at end of contract)

involving many stakeholders, as well as plans to include electric buses in the upcoming tendering process. An overview of the electric buses, chosen charging solutions and organisational setup in these cities is presented in Table 1.

To identify crucial challenges and to understand how these were addressed by the stakeholders involved, we used documents and semi-structured interviews. Thematic analysis was adopted as the analysis was both deductive (informed by previous research) and inductive, and so grounded theory would not be suitable (Cho and Lee 2014). Further, since the analysis considered both themes and categories, it went beyond a content analysis (e.g. Vaismoradi and Snelgrove 2019). The documents were public records and included local transport plans and relevant strategies for each of the case study cities, EU Regulation, National level policy, guidance and government funding affecting low emission public transport, along with explanatory briefings produced for policymakers, planners and politicians (see Appendix 1). The documents foremost served to provide supplementary data to the interviews by providing background information and contextualising the research, but also to verify findings from the interviews (Bowen, 2009). These documents provided an understanding of the relevant regulatory and policy context in each city, and provided an insight into the ambitions and priorities of politicians and policymakers at different levels of government. We recognised that the intentions of the people and organisations writing each document might differ from how the documents' audiences (including transport planners and bus operators) interpreted the documents (Jupp and Norris, 1993, p.38), so attention was given to understanding any variations in interpretation when analysing the interviews.

Purposive sampling was used to ensure interviews were conducted with a wide range of stakeholders. Interviews were used in two ways in the study, both to identify evidential information and to find out how the interviewees experienced the process of introducing electric buses. At the city level, focus was on identifying challenges and showing how they were viewed from different stakeholders' perspectives. Factual information presented by interviewees was also triangulated with information from documents to help test validity (note that this translation differs from the analysis of interviews to understand variations in interpretation of document content noted above). The data were collected in 2017 and 2018 and represent the situations and processes leading up to the status quo in the cities at that time. This study does not cover the development that has happened since.

The semi-structured interviews were topic-based, providing a level of openness that allowed interviewees to give their own accounts and understandings of the challenges. (See appendix 2 for example of interview questions). However, the same topics were covered in all interviews, including:

- The choice of electricity over other fuel.
- The choice of vehicle and charging technology.
- The process of introducing electric buses and its challenges and opportunities.
- The opinion on incentives and policy instruments from the national level.

With the exception of three phone interviews, the interviews were held in person and were between 40 min and 2 h long. In England, eight interviews were conducted during autumn 2017 and in Sweden, seven interviews were carried out during spring 2018 (see Table 2). The sample of interviewees reflects the different stakeholders who were driving the introduction in different cities; this caused a small variation in the work position of the interviewees. Nevertheless, all the case studies included interviews with stakeholders from local governments, regional PTAs, operators, manufacturers, the national government and a partnership organisation. By interviewing several stakeholders at different positions, the aim was to gain a broader understanding of the challenges facing the introduction of electric buses.

All interviews were recorded, transcribed and coded in NVivo. Identifying and categorising critical challenges was done using an

Table 2
Interviewees in England and Sweden.

	Position	Interview carried out
England		
Interview A	Nottingham, Nottingham City Council, PTA	September 2017
Interview B	Nottingham, Nottinghamshire County Council (2 interviewees)	October 2017
Interview C	York, City of York Council, PTA	October 2017
Interview D	York, West Yorkshire Combined Authority, PTA	October 2017
Interview E	York, Private sector bus operator	October 2017
Interview F	Department for Transport (2 interviewees)	October 2017
Interview G	Low Carbon Vehicle Partnership , Public-private partnership organisation to facilitate adoption of low carbon vehicles (now called 'Zemo')	October 2017
Interview H	Bus manufacturer	November 2017
Sweden		
Interview I	Gothenburg, Västtrafik, Administration responsible for public transport under the regional PTA (2 interviewees)	January 2018
Interview J	Gothenburg, Private sector bus operator	December 2018
Interview K	Eskilstuna, Eskilstuna municipality	February 2018
Interview L	Eskilstuna, Private sector bus operator	January 2018
Interview M	Swedish Energy Agency (2 interviewees)	February 2018
Interview N	Svensk kollektivtrafik, Partnership organisation for Swedish regional authorities	March 2018
Interview O	Bus manufacturer	February 2018

iterative analysing process (Srivastava and Hopwood, 2009). A first round of coding sprang from findings from previous research and then developed inductively and complemented during the analysing process with codes and themes observed in the material. The final codes can be seen in Appendix 3. The codes were compared between countries, cities and stakeholders to identify the most important themes (Fereday and Muir-Cochrane, 2006). This served as basis in the discussion to be able to compare the experiences between countries and cities and show what role these challenges have played in the cases studied and for different stakeholders.

4. Results and analysis – Experiences from the studied cases

The analysis of experienced challenges and how they are addressed is presented per country. Within each country, the results are also divided based on experiences at the national level as well as in each separate city.

4.1. England – National level, funding schemes and partnership organisations

'*Let a thousand flowers bloom*' (Interview F) is how the interviewees at the Department for Transport expressed England's view on technology neutrality for funding of new technologies (Department for Transport, 2018). This refers to a strategy of seeking to allow the market to determine how new technologies come to the fore. It is an approach supported by the Partnership organisation (Interview G). This strategy, coupled with the regulatory context for buses in England, has influenced the role the national government has taken in the introduction of electric buses.

The main influence of national government was through funding schemes to support the introduction of low carbon buses. It is the private operators, the local transport authorities and local governments that have been responsible for procuring and introducing the buses (Interview F). One support programme, the Green Bus Fund, ran between 2009 and 2013, and resulted in around 1200 buses being funded, of which around 100 were fully electric (Department for Transport, 2013). The Green Bus Fund was subsequently replaced by the Low Emission Bus Scheme, which commenced in 2015 and was planned to continue until 2020. This scheme emphasised both air pollution and greenhouse gas emission reduction from buses and was also designed to encourage zero emission buses in city centres (Department for Transport, 2017). This framing, with performance in air quality leading to a higher score in the selection process for funding, benefited electric buses over biofuels, for example (Interview F). Other changes included the funding of infrastructure beyond the investments in buses and a stricter definition of a low emission bus (Low Carbon Vehicle Partnership, 2016a). By also funding infrastructure, the government hoped to see more battery electric buses being introduced in relation to hybrids (Interview F), but the introduction of biogas can also benefit from infrastructure funding (Interview G).

The UK had the largest fleet of electric buses in Europe in 2017 (191 fully electric, 153 plug-in hybrids) (Bloomberg New Energy Finance, 2018). The extensive funding helped to overcome the first investment cost barrier; nevertheless, many challenges remained. From a national level perspective, uncertainty is responsible for many of these challenges. Infrastructure investments and battery lifetime make the total cost uncertain. Other uncertainties are caused by a lack of standards both from the EU and within the UK and unknown future policies. This could be a downside of the strategy of handing out money and letting regions and cities choose the technology best suited to their context (Interview G). Sharing best practice experience and encouraging communication between stakeholders were therefore seen as an important role for the national partnership organisation in England. According to the Partnership organisation, the way of organising the division of responsibility between operators and local authorities was thought to be challenging since it affected possibilities for charging infrastructure and caused issues of responsibility (Interview G). Similarly, the representative from the national Government argued that the introduction of electric buses is easier if there is a public operator operating on behalf of the local authority (Interview F).

4.1.1. Nottingham

At the time of the study, Nottingham was English city, outside London, with most electric buses. All the electric buses were owned by Nottingham City Council (an ownership model uncommon in England). Since the electric buses were owned by the city council, they were mainly operated on non-profitable routes considered 'socially important', such as Park & Ride[2] routes (Low Carbon Vehicle Partnership, 2016b; Nottingham City Council, 2017). Prioritising electric vehicles on the city council's public transport routes accords with Nottingham's local transport plan (Nottingham City Council, 2011). The electric bus fleet consisted of buses from two manufacturers, with one type relying on 11 rapid chargers (around 2 h to top-up) and another type using only depot charging. The top-up chargers were also (Low Carbon Vehicle Partnership, 2016b) with funding from the Green Bus Fund and further funding from the Low Emission Bus Scheme for infrastructure (Department for Transport, 2013).

4.1.1.1. Charging, a technical, operational and collaboration challenge. Increased investment costs for vehicles and infrastructure were not the dominating challenge due to funding from national government and from a local work-parking levy. Instead, charging solutions became a main challenge. Challenges concerned technical issues, scheduling and operation, and the division of responsibilities between different stakeholders. Below, a few examples of conflicts following from such challenges are presented.

Early on, problems occurred with technical compatibility between chargers and buses. This led to conflicts between manufacturers,

[2] A place in or near a town or city where you can park your car cheaply and take a bus or other form of public transport into the centre (Cambridge Dictionary, 2021)

the company supplying the chargers, the bus operator and local government over fault and responsibility for the chargers not working properly (Interview A, H). Challenges concerning charging also went beyond technical issues. Fitting electric buses into the existing operational system was difficult due to the limited range of the buses, particularly for an operator that attempted to operate the buses like diesel buses. Top-up charging was introduced by the local government as a solution to the limited range. However, top-up charging had its own challenges, including convincing the stakeholders involved of the need to invest in top-up chargers, and finding suitable locations for the chargers. The choice fell on chargers that require two hours top-up during the day, since they are cheaper and easier to move than pantographs. Yet, this type of top-up charging requires breaks during the day. Therefore, timetables had to be made compatible with drivers' schedules, which required a thorough involvement of the operators (Interview A).

4.1.1.2. Working collaboration with the operator was the key to success. Besides technical improvements, most of the challenges were overcome thanks to a change of operator to a local community transport operator (a charitable trust aiming to prevent social isolation). A closer collaboration with the new operator made it possible to solve common problems, thus facilitating the introduction of electric buses (Interview A). The bus manufacturers emphasised the importance of working together towards a common goal as a key to the introduction of electric buses (Interview H). Nevertheless, it was pointed out that achieving a functioning collaboration has a long learning curve (Interview A).

Compatibility issues between the chargers and buses were solved by close monitoring of operation and improved communication (Interview A, H). The closer collaboration with the new operator made both installing top-up charging and fitting the buses into current operation easier. The community transport operator was also successful in educating drivers, which led to drivers preferring electric buses (Interview A). Lastly, charging infrastructure affected the role of the manufacturer and instead of just selling a bus, they had to adjust to sell a turnkey solution adjusted to the customer's needs (Interview H).

4.1.2. York

A long-term goals in City of York Council's (2012) Low Emission Strategy is to introduce electric buses. In 2012, the local government in York also started envisioning the possibility of electric buses using top-up charging (Interview C). Two years later, the first six electric buses were operating on one of the City council's Park & Ride routes (Interview C). In 2017, there were electric buses operating on all of the city council's Park & Ride routes and the world's first electric double-decker was retrofitted for sightseeing routes (City of York Council, 2017). As in Nottingham, electric buses were operated on routes regulated and planned by the local authorities. However, unlike Nottingham, the electric buses were owned by the private operator who won the tender process.

The local government, the winning operator, and the bus manufacturer were the main stakeholders involved (Interview C). The local government was responsible for top-up charging infrastructure, the operator put the operational process in place, owned the buses and charging infrastructure in the depot and paid for the electricity, while the bus manufacturer provided warranty support for the vehicles and engineers (Interview C, E). The additional investment cost for electric buses was to a large extent funded by the national support programmes (Interview C), especially the LEBS programme. Both the local government and operators obtained funding for electric buses (Department for Transport, 2013).

4.1.2.1. Conflicts related to charging, scheduling and responsibility. Key challenges concerned charging and included technical challenges with the compatibility between buses and chargers, challenges with scheduling, and unclear division of responsibility between the stakeholders. Despite funding from the national programmes, lack of knowledge and uncertainty about costs were also challenging.

As in Nottingham, the lack of compatibility between charging infrastructure and vehicles was a problem. This technical issue escalated into a disagreement over responsibility between the charger manufacturer and the bus manufacturer, both of whom claimed the lack of compatibility was the other's fault. One interviewee from the local government said that they had to mediate between the two (Interview C).

> "…we've had to make sure the buses are compatible with the infrastructure, and quite a lot of conflict resolution as well between the charge point manufacturers and the bus manufacturers because there was an incompatibility at first. They all told us it was compatible when the buses were ordered by the operator and when the charge points were ordered … but it turns out it wasn't quite compatible or wasn't quite able to do what they expect it to do." (Interview C)

However, the interviews showed that the stakeholders involved viewed the problem differently. The manufacturer said the operator used the chargers wrongly at first because the staff lacked competence (Interview H). On the other hand, the operator said they solved the technical issues in cooperation with the manufacturers and then had to facilitate a meeting with experts to convince the local government that the chargers could be used and the issue had been solved (Interview E). As such the problem was a communication and collaboration issue between stakeholders rather than a technical issue.

According to the local government, they had to take much more responsibility than they expected, even when the buses were in operation, because the operator did not adjust to running electric buses instead of diesel buses. Therefore, the local government felt they had to assist the operator in putting a monitoring plan in place, up-skill the engineers, adjust scheduling, and resolve problems with infrastructure (Interview C).

> "So I was quite surprised that there wasn't any of this; there wasn't any monitoring, there wasn't any training, there wasn't any implementation plan. They were actually treating the buses like diesel buses and didn't adjust in terms of their training … And of course they then ran into problems because if there isn't a plan and there isn't a properly engineered project-managed approach then people run into problems. And so in some ways the council had to fill that void so we've had to put a

monitoring plan in place for them, we've had to up-skill their engineers, we've had to help them adjust scheduling, we've had to deal with resolving problems with infrastructure…"(Interview C)

However, the operator had a different view, arguing that local government did not have full visibility over operational challenges and what scheduling extra breaks means for operational efficiency (Interview E).

Lastly, the lack of knowledge about the new technology was also a challenge. A main issue was uncertainties of total cost of ownership, and whether lower operating costs would compensate for the high fixed costs. Uncertainties about battery lifetime made the operator doubt that the electric buses could be cost efficient (Interview E). Since the operators in York are private, the local government felt it took a lot of convincing from their part to get the operators on board (Interview C).

4.1.2.2. Improved communication the key to address challenges. Since the challenges with charging infrastructure resulted in conflicts between the stakeholders involved, improved communication was a key to overcoming challenges. This included face-to-face communication, consulting each other on views, providing data through monitoring and bringing in external experts (Interview E). It was also crucial to get all stakeholders on board. A lesson learned was to deal with staff engagement from the start. Nevertheless, since new technology always has challenges, it is important to "*expect the unexpected…there are going to be unknown unknowns*" (Interview C). Since knowledge is often limited, education was also viewed as an important part of the introduction, and interviewees E and H argued that education should be put into contracts.

4.2. Sweden

The Swedish government had the same basic idea of technology neutrality as its UK counterpart when supporting renewable fuels (Interview M). However, the situation in Sweden differed from that in the UK since a majority of the Swedish public transport sector already used renewable fuel (Sveriges Bussföretag, 2019). Key arguments for supporting a transition to electric buses concerned improved energy efficiency, the promotion of sustainable city environments, achieving attractive public transport, and decreasing air and noise pollution (Interview M, N).

Despite the neutral technology approach, the Swedish Government specifically supports electric buses. In 2016, the Swedish government introduced "Elbusspremien", allowing PTAs or local governments to apply for subsidies for full electric buses or plug-in hybrids (SFS 2016:836). However, flaws in the design of the subsidy meant that it was not used to a great extent (Interview N). Several changes were made to the subsidy in 2018, e.g. allowing operators to apply, and allowing for application before buses were ordered. However, it was still not possible to seek funding for charging infrastructure (SFS 2017:1341). Before Elbusspremien, the Swedish Energy Agency mostly supported electric buses through demonstration programmes (Interview M). There was also broader national economical policy instrument for decreasing greenhouse gases available, not targeting electric buses specifically. According to the interviewee from the partnership organisation the government ought to improve support for investments in charging infrastructure, since it is likely to be the largest cost barrier in the future. The partnership organisation also highlights the importance of supporting collaboration as electric buses are introduced because of the many stakeholders involved (Interview N).

In 2017, Sweden had 43 full electric buses and 93 plug-in hybrids (Bloomberg New Energy Finance, 2018). At this time, the electric buses were mainly introduced through demonstration and test projects in cities, and there were few examples of electric buses in regular operation (Aldenius et al., 2016).

"Then I experience that we are in a kind of try out, both when it comes to technology and other things, but do not really dare to take the step…" (Interview M)

The interviewees at the national level agreed that main challenges included charging infrastructure, e.g. lack of standards, ownership of infrastructure and vehicles, high investment costs, building permits for charging stations, and connections to, and the capacity of, the electricity grid. (Interview M, N). The representative from the Partnership organisation highlighted challenges with winning procurement bids due to higher costs, as well as uncertainties about technology, for example the rapid development of batteries (both in capacity and price). The stance of the Partnership organisation was therefore that waiting with large scale introduction might have been a good thing and that the exchange of experience between cities could still improve (Interview N).

4.2.1. Gothenburg

The approach in Gothenburg differed from the other case study cities. Here the starting point was a test project outside the normal timetable, involving collaboration with 15 different stakeholders[3], with the aim of learning for future tenders. The bus manufacturer was the initiator of the project. The vehicles were concept buses designed by the local bus manufacturer to test and evaluate new environmental solutions, and they were charged at the end stations with ultra-fast pantographs (3–4 min) (Electricity, 2016). The bus manufacturer and the local authority had an important leading role (Interview I). The operator rented the buses from the manufacturers and paid for the grid and the electricity, while the energy company owned the charging infrastructure (Interview J). Following the test project, the ambition was to get buses into current contracts and then include the buses in upcoming procurements with the goal that all city traffic will be electric by 2025 (Interview I).

[3] Bus manufacturer, operator, university, real estate companies, Swedish Energy Agency, research and collaboration and development organisations, regional authority, PTA, city authority, energy company, technology company (Electricity, 2016)

4.2.1.1. The challenges of many stakeholders and time consuming collaboration. In Gothenburg, the number of stakeholders, issues concerning ownership, the lack of standards and choosing charging solution were all viewed as challenging.

New responsibilities for stakeholders (such as local government being involved in charging), as well as the involvement of stakeholders that are not traditionally involved in public transport (such as electricity companies and charger manufacturers), required a lot of collaboration. The test project consortium, bringing together many new partners, meant that collaboration was not problem free. Interviewee J argued that the lack of a common goal was challenging when many stakeholders were to collaborate. In addition, interviewee J said that meetings and discussions with the large stakeholder group was also very time consuming.

> ”this collaboration part has been…is of course a good thing, but it is also a challenge in itself.” (Interview I)
>
> ”…there is no common problem area that we are gathered around and there are always discussions because everyone is there for their own gain. There is no one that is there to solve a problem and I think you need to be clear when running a project like this. Why are we doing it, is there a common problem that we should solve…” (Interview J)

Like in the other cities, charging infrastructure caused many challenges. This included how to organise ownership and responsibility for the infrastructure, for example. Another main issue was lack of standards; no city or operator will make large-scale investments in electric buses before there are standards (Interview J).

> “… [A key challenge] treacherouswith electric operation right now, is the lack of standards… It creates very large lock-in effects, both mechanical but also when it comes to communication protocols and such… nothing will happen until there is a standard, because they [cities, and operators] will not invest billions and then realise it does not work. The infrastructure must work, depots, terminals, buses, and all that.” (Interview J)

Another key challenge was choosing the type of charging infrastructure. Initially, end-station ultra-fast top-up charging was viewed as the only solution. As the market evolved and batteries improved, the discussion opened up for possibilities of depot charging and operating the electric buses more like conventional buses, which according to the manufacturers is a general wish among operators (Interview I, O). However, many factors were decisive for which technology to consider the best choice in a city. For example, possibilities for opportunity charging in the timetable, availability of land and electricity, the cost of bigger batteries and depot charging (Interview J), and the accessibility of the depot location (Interview I). In Gothenburg, a central location of a depot was deemed necessary, and therefore depot charging was viewed as a complicated solution (Interview I). Both top-up charging and new depots also require building permits, which created more collaborative challenges (Interview I, O).

There was also uncertainty about how expensive electric buses actually are. Even though one aim of the test project was to learn about costs, lack of transparency between the stakeholders meant that it was difficult to evaluate the total cost. Several potential cost-drivers were however identified, e.g. extra costs for the possible risks that come with a new technology, operational costs, adjusting depots, educating staff, changing routes and timetables (Interview I), land for charging infrastructure (Interview J) and salaries for extra drivers (Interview I, J).

4.2.1.2. The importance of defining a common problem to make collaboration work. An important strategy to improve collaboration in the large stakeholder group was to find a common problem area with common goals, and a shared view that there is a need for change (Interview J, O). Also the manufacturer found that they had to take on a new role when it came to electric buses. They started giving courses, both internally and externally, to educate staff and drivers. Similar to manufacturers in the UK, they started to see themselves as transport providers instead of just bus manufacturers, selling a turnkey solution adjusted to the customer’s needs and offering support also after the bus was sold (Interview O).

The PTAs also found themselves taking on more responsibility for electric buses. For example, as an extra support, the PTA promised to take care of the buses after the contract is finished. The PTA was also prepared to take extra cost for electric buses (Interview I). Increased costs were therefore less of a problem for the operators. However, the operator still questioned whether electric buses are the most efficient way to solve environmental issues (Interview J). Nevertheless, the PTA believed the increased investment costs would in the long run be off-set by electric buses being cheaper to operate (Interview I).

4.2.2. Eskilstuna

In Eskilstuna, the introduction of electric buses was viewed as rather uncomplicated (Interview K). In contrast to the large group of stakeholders in Gothenburg, the introduction in Eskilstuna was a joint project between the PTA and operator through an additional agreement to operate electric buses in city traffic under the current transport contract (Kommunalförbundet Sörmlands Kollektivtrafikmyndighet, 2014) and in collaboration with the local government (Interview K). The aim was to decrease noise and emissions, but also to test technical operation of electric buses (Kommunalförbundet Sörmlands Kollektivtrafikmyndighet, 2014). According to this interviewee (Interview K), the latter aim was important and made the operator the driving force behind the introduction. Two buses were introduced as a test in late 2015; following a successful evaluation, a further ten buses were taken into operation in 2016 (Interview K, L; Kommunalförbundet Sörmlands Kollektivtrafikmyndighet (2014). The electric buses operated on all routes under the same conditions as biogas buses. All buses relied on depot charging only (Interview K, L).

The introduction of electric buses was carried out without subsidies from the government. However, the PTA had applied for the new version of “Elbusspremien” for the buses they already had, but since the buses were already there, it had no effect over choice of technology (Interview K).

4.2.2.1. Introduction in competition with other renewable fuel. Both the local government and the operator were positive as to how the

introduction of electric buses developed. The buses were easy to maintain and the manufacturer was supportive and involved, even providing engineers on site (Interview L). However, like in the other cities, they had to agree on decisions concerning the charging infrastructure and costs. Beyond that, they also had to address the conflict with other renewable fuels.

Unique in Eskilstuna was that the introduction of electric buses was not a change from fossil fuels to a fossil free fuel since the whole bus fleet was already running on biogas. In 2017, 94% of vehicle kilometre in the region was run with renewable fuel (Kommunalförbundet Sörmlands Kollektivtrafikmyndighet, 2017). Initially, this sparked fear among politicians that the local biogas production would be affected (Interview K). However, the operator did not view biogas and electricity as competing, but rather as complementary energy carriers.

> "…it was very interesting to have a dialogue with the local government and the energy company, since they have their own biogas production… they became a bit worried when we first introduced two electric buses and then they heard that we would have ten more. They saw a risk that the whole biogas plant would have to close down. We had to discuss with them and explain that it is no risk, that biogas production is not in contradiction with the electric buses, they complement each other." (Interview L).

Discussions also focused on charging infrastructure and increased costs. The choice of depot charging, and the limited range compared to previous buses was debated (Interview K, L). The investments in charging infrastructure resulted in higher initial costs (Interview L). In addition, costs were adding up due to higher investment costs for the buses which were bought without any grants from the government. The first two buses in the project were expensive since they had a shorter depreciation time because of uncertainty about the new technology (Interview K).

4.2.2.2. Political acceptance and adjustment to local circumstances for an easy introduction

> "I think it has been rather simple for us in a way since our politicians have invested so much in the environment before and we have our ambitious environmental targets… They have not had any doubts in testing electric buses. I do not think it has been very challenging actually." (Interview K)

Supportive politicians with high environmental ambitions were one of the keys to a relatively pain free introduction of electric buses in Eskilstuna (Interview K). Nevertheless, investment costs still influenced the choice of charging infrastructure, for example. Reducing challenges relating to administration and costs were maintained as reasons to choose depot charging in Eskilstuna (Interview K). However, the geography and the nature of the test project also influenced the choice. Eskilstuna is relatively flat and the routes are not very long, which makes the city suitable for depot charging (Interview L). The local government also found depot charging beneficial since top-up charging is a big investment if you do not want to continue or do not know which route the buses will operate on in the future (Interview K). However, the shorter range of the buses required well planned routes. The first two buses were driven on a service route because the route had a suitable length, was less busy than normal routes, and had a limited number of drivers to educate. The route also traverses the city centre and areas where electric buses have most potential to reduce noise and air pollution. Later the electric buses started to operate on most routes and, in principle, had the same role as gas buses (Interview L).

Political acceptance for increasing investment costs was also important. Here the argument that higher initial investment costs would be offset by cheaper operating costs was central (Interview K). However, it is still hard to know how the costs will develop compared to other fuels, since the technology for both batteries and biogas engines are constantly improving. For electric buses the variable costs could potentially decrease even more if the grid fee was removed, similar to how it is for trains (Interview L).

Lastly, for the operators to be able to invest in electric buses under an ongoing contract it was necessary with a guarantee from the PTA to buy back the buses at the end of the contract. The same deal was made for the depot charging infrastructure since the operators only rent the depot. (Interview L). That the PTA was responsible for acquiring the buses at the end of the contract was included as a criterion in the contract (Kommunalförbundet Sörmlands Kollektivtrafikmyndighet, 2014).

Table 3
Summary of key findings from the four cases.

	Nottingham	York	Gothenburg	Eskilstuna
Challenges	- Technical issues charging - Scheduling and operation - Division of responsibility	- Technical issues charging - Scheduling and operation - Division of responsibility - Lack of communication - Uncertainty and lack of knowledge of TCO	- Ownership/responsibility and choice of charging - Lack of standards - Uncertainty TCO - Collaboration time consuming - Many stakeholders with new responsibilities	- Choice of charging - High investment costs - Competition with other renewable fuels
Solutions	- Closer collaboration - Monitoring - Education - New roles	- Improved communication - Monitoring - Education - External experts	- Find common problem area and goal - New roles - Test project	- Local politicians supporting increased costs - Smaller city suitable for depot charging - New roles

5. Discussion of differences and similarities between the cases

5.1. Were the experienced challenges similar or different in the cities?

Comparisons between the four cities in this study show that challenges differ between the cases depending on context specific factors such as geography, passenger demand, current organisation of bus schedules, current regional organisation/approach and national governance. However, similar in all cases was the importance of functioning collaboration and communication. The challenges found in the case studies corroborate findings from previous research (e.g. Miles and Potter, 2014; Bakker and Konings, 2018; Mohamed et al., 2018; Borén and Grauers, 2019), including charging infrastructure, operation and scheduling, higher and unknown costs, involvement of many (new) stakeholders, lack of knowledge, and competitive tendering. See Table 3 for a comparative overview of the challenges and solutions in each city.

The importance of context was specifically clear in connection to charging infrastructure choices and challenges. All the larger cities (Nottingham, York and Gothenburg) with higher passenger demand had chosen top-up charging. The choice of top-up charging in turn entailed different challenges. In Gothenburg, ultra-fast charging at the end stations was used which created a lock-in to specific routes, putting demand on the local electric grid. In the UK, a slower top-up charging solution was used, which created a need for large adjustments in the operational schedule, seen as challenging by the operators. The choice of top-up charging was also connected to who owns the land and who was involved in the introduction process. In the smaller city, Eskilstuna, the low passenger demand, short routes, and flat geography allowed for depot charging and operation in the current system without the need for large adjustments. That all current charging solutions have their challenges, corroborates the findings from previous research (e.g. Bakker and Konings, 2018; Bloomberg New Energy Finance, 2018; Mohamed et al., 2018). This study further shows that the optimum charging solution is dependent on the contextual circumstances.

Including electric buses in the procurement process was also seen to be challenging because of the high initial investment cost and difficulties in accounting for risks and uncertainties in contracts. Different strategies were used in the cities to overcome this challenge. In Gothenburg, electric buses were first introduced as a test projects outside normal operation and in Eskilstuna the buses were introduced under current contracts. It was also important in both the Swedish cases that the PTA took on extra responsibility for the buses at the end of the contracts. In Nottingham, the electric buses were owned by the city council and only the operation was contracted out to the operator. In York, the challenges with procuring traffic from private operators were exemplified through conflicts concerning writing the contracts and responsibility. However, what is interesting about the English cases is that all electric buses were found in public authority regulated traffic and not in deregulated traffic. There is limited research on procuring electric buses, but the findings in this study together with Borén and Grauers (2019) highlight the need for further research on how to develop traditional procurement processes.

In many cases, the challenges were related to lack of functioning collaboration and communication between the stakeholders since they have different interests and work under conditions of partial knowledge and uncertainty. In the cities in the UK, the lack of communication and collaboration between the stakeholders involved, for example, was viewed as a key challenge when problems with the compatibility between buses and chargers occurred. This also highlights the temporal dimension of building trust between stakeholders in new actor constellations, which has been identified as a challenge in previous research on collaboration in other types of processes (e.g. Brown et al. 2007; Grafton & Mundy 2017; Van Slyke 2009). Also, when it came to who was responsible for different costs, communication was a challenge. These challenges seemed to be less central in the Swedish cities, where collaborative projects constituted the foundation for the introduction of electric buses. However, in Gothenburg, the introduction was based on a very large collaboration test project. As found in wider studies on collaboration in public transport delivery (e.g. Hrelja et al., 2018) this led to other collaborative challenges such as a lack of a common problem area and time consuming processes.

5.2. What approach was taken in each city to overcome challenges?

While we found similarities in challenges the interviewees emphasised in the case studies, we have also identified differences in the difficultly these challenges presented. These differences highlight the importance of governance context, organisational practices and relations.

Developing good collaboration with good communication was found to be key in overcoming challenges. In Nottingham, addressing challenges became easier following the replacement of the private operator by a local charity trust operator, with whom they had closer collaboration with improved communication working towards a common goal. The responsibility for unknown challenges was very difficult to write into a contract with a private operator. Again this echoes wider research on collaboration which identifies how trust builds up over time (Hrelja et al., 2018), and how the need for having specific obligations defined in contracts decrease as trust between the stakeholders' increase (Van Slyke, 2009).

Also in York, improving communication and engaging all stakeholders from the start was crucial. It was important to include those is responsible for educating engineers and bus drivers in the contract. In Gothenburg, where the introduction built on a large collaborative test project, the key was to find ways to make such a large collaboration function more effectively. It was deemed important to find a common problem area with common goals and a shared view of the need for change. This reflects a general conclusion about collaboration drawn e.g. by Hrelja et al., (2018) that a key condition for any type of collaboration is the willingness of organisations to explore mutual, or at least compatible, goals in order to reap the benefits of working together.

In Eskilstuna, the interviewees thought that the collaboration between the stakeholders had run smoothly and the operator as initiator of having electric buses had functioned well.

Another solution was for stakeholders to adjust and take on new roles. For example, the manufacturers interviewed in both Sweden and the UK saw that they had to take on a new role and sell a turnkey solution adjusted to customers' needs, since the best solution for electric buses is very context dependant compared to combustion engine buses. Also the PTAs in both York and Gothenburg brought up the need to take on a greater responsibility when initiating introduction of electric buses. In York, it included supporting the private operators in overcoming challenges with operating electric buses in a conventional system, while in Gothenburg the PTAs were prepared to take on increased costs.

5.3. Does national context matter and if so in what way?

Many of the challenges, and the approaches to overcome them, came down to local and regional context. However, some things also differ between the Swedish and the UK national systems. Two main differences are the funding system and deregulation vs a competitive market. The exact connection between these and the introduction of electric buses is not entirely clear since so many things influence it.

As for all technologies not yet being fully commercialised, increased costs are almost inevitable and seen in almost all previous studies as a key barrier to introducing electric buses (e.g. Åslund et al., 2021; Bakker and Konings, 2018; Mohamed et al., 2018). However, this study shows that depending on the national funding system and the organisation of public transport, the influence of increased costs varies. In the UK, funding from the national government was generous and therefore the public authorities did not see investments costs as a key barrier to electric buses. In Sweden, the national funding system, specifically for electric buses, was less developed and the introduction relied more on local and/or regional political acceptance of increased costs, including arrangements where the PTAs took more responsibility and bought back buses and charging infrastructure at the end of the contract. These differences indicate that subsidies can influence the introduction, even though previous research on early adoption of electric buses has shown that due to lack of experience and lack of risk knowledge subsidies are not enough on its own to promote introduction (Miles and Potter, 2014).

In all cases the total cost of ownership was an uncertainty, depending on for example charging infrastructure, payoff time and running costs. Some stakeholders held that total cost could be lower than for other fuel options, an argument perhaps most prominent in Eskilstuna where the electric buses replaced biogas buses. This view on cost can be expected in many Swedish cases, compared to other countries, since the Swedish public transport sector already runs on biofuels to a large extent. One of the goals of the test project in Gothenburg was to understand the total cost of ownership, but with so many stakeholders, and some lack of transparent collaboration, it was difficult l to get a picture of the actual costs.

The other main difference between Sweden and the England is how public transport is organised. In England, buses outside London remain mostly deregulated. However, in the cities studied, electric buses were only operated on routes belonging to the public authorities. This means that upscaling may be limited to their buses. Three years after the interviews, Nottingham had not put any new electric buses into operation (Interviewee A, personal communication 2021), while York had expanded their park & ride routes with 21 new all-electric double-deckers (Lewis, 2020). It also means a limitation of route choices and the electric buses might not be operated where they have the highest benefits for reducing air and noise pollution. In Gothenburg and Eskilstuna, as in much or Sweden, public transport is contracted out, and electric buses can be introduced by the PTA through requirements in the procurement documents. Yet specifying those requirements in a way that accounts for uncertainties was seen as a challenge early in the introduction of electric buses. This was addressed by running the first buses as test projects and exchanging some buses under the existing contract. The test project in Gothenburg first led to electric buses being introduced under the existing contract and 150 new electric buses started running in 2020 (Electricity, 2020). Today a further 137 electric buses have been procured and are to be put into operation in 2022 and 2023 (Trafik Göteborg, 2021). In Eskilstuna, the 12 electric buses have been procured in a new contract, while the rest of the fleet are biogas buses (Sörmlands Trafiken, 2020).

The different collaborative approaches in the two countries are found to have implications for the challenges faced in implementation of electric buses, and the ways in which actors are able to address those challenges. This is something which could be expected given the wider literature on collaboration (outlined in Section 2.6). In the UK, the introduction commenced with the stakeholders taking on their traditional roles. This, together with a lack of communication between the stakeholders involved turned out to be the main cause of many difficulties that occurred during the introduction. Improving collaboration and communication, and stakeholders taking on new roles, were some of the main ways to address the challenges that arose when introducing electric buses in the UK cases. In the Swedish cases, there was more emphasis on collaboration from the start. Nevertheless, large collaborations, such as the Gothenburg case, still had challenges and needed to be improved for a successful introduction of electric buses. Here the numerous stakeholders involved was itself a challenge.

The data underpinning this study do not provide us with a clear explanation for the differences in collaborative approaches between cases in the two countries. A possible interpretation of this finding is that the national context in terms of governance structures, as well as funding options for electric buses, influences the dynamics between the stakeholders, and thereby also the conditions for collaboration.

6. Conclusion

The aim of this paper was to compare experiences of introducing electric buses in the UK and Sweden, two countries with different institutional settings, by way of case studies of four cities. The comparative approach enabled us to investigate the influence of governance context, organisational practices and relations between stakeholders in the implementation process. We found both

similarities and differences between the challenges of introducing electric buses in the cities studied.

In all the cities, challenges included charging infrastructure, operation and scheduling, higher and unknown costs, involvement of many (new) stakeholders or stakeholders taking on new roles, lack of knowledge, and competitive tendering. However, we also found some differences concerning how difficult challenges were experienced by the interviewees between the cases depending on context specific factors such as geography, passenger demand, current organisation of bus schedule, governance of public transport and national level approaches to introducing electric buses.

We conclude that achieving functioning collaboration between the stakeholders was both an important challenge and a key to overcoming challenges in all the cases. We found some differences in the collaborative approaches between the cases, where there seemed to be a distinct difference between the Swedish and the UK cases. In the UK, collaboration was difficult because the electric buses where introduced at a relatively large scale in everyday operations where they were expected to replicate the roles of conventional buses. When stakeholders assumed their traditional roles, conflicts arose over issues of responsibility for unknown risks. In the Swedish context, introduction took place on a more limited scale and in a context of test projects. In Gothenburg, where the test project involved many stakeholders, a key challenge was to manage the collaborative process in itself. In Eskilstuna, where the test project involved a limited group of stakeholders, with bus operators as the main driving stakeholder, the technical and operational challenges were managed well. However, Eskilstuna also represents a smaller city with less passenger demand and shorter routes where depot charging was enough.

Increased investment costs were a challenge to deal with in all the cases studied. Differences in the national support systems for electric buses in the two countries seemed to have produced differences in terms of the speed of the roll out. In the UK, the approach resulted in a relatively high number of electric buses being introduced in regular services in a short time. In Sweden, the test project approach resulted in fewer electric buses within the same timeframe. However, more research is needed in order to follow up on the development in the two countries to see how the approaches encourage or limit upscaling and further introduction of electric buses.

To sum up, how the introduction of electric buses is experienced by the stakeholders involved is very dependent on both the physical and organisational contexts. Best method to introduce electric buses is therefore very independent from case to case and the current circumstances in a city must be considered. This includes for example national support, the stakeholders involved and the division of responsibility, passenger demand and route characteristics. A question that can also be raised is whether electric buses should adjust to the current system and organisation or there is a need for a system change to enable large scale introduction. It is also important to note that the data were collected in 2017 and 2018 and development has come a long way since. Hence, we have studied an example of early introduction of a new technology and do not seek to represent the status quo in the cities today.

CRediT authorship contribution statement

Malin Aldenius: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Caroline Mullen:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Fredrik Pettersson-Löfstedt:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1

Table A Documents included in the documentary analysis.

Government level	Type of documents
Local plans and strategies	Nottingham - Local Plan to Improve Air Quality in Nottingham (2017) - Nottingham Local Transport Plan Strategy 2011–2026 York - 2017 Air Quality Annual Status Report (ASR) - Low Emission Strategy (2012) Gothenburg

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Government level	Type of documents
	- Miljö- och Klimatstrategi för kollektivtrafiken i Västra Götaland (2013) (*Environmental- and Climate Strategy for Public Transport in Västra Götaland*) - Regionalt trafikförsörjningsprogram Västra Götaland. Programperiod 2017–2020 med långsiktig utblick till 2035 (*Regional Transport Supply Program Västra Götaland*) - Samarbete för en hållbar och attraktiv kollektivtrafik. Statusrapport juni 2016 (*Collaboration for a Sustainable and Attractive Public Transport*) Eskilstuna - Sörmlands regionala Trafikförsörjningsprogram (2017) (*Sörmland's Regional Transport Supply Program*) - Tilläggsavtal till trafikavtal avseende stads- och landsbygdstrafik i trafikområde Eskilstuna 2011–2017 (-2020) (*Additional contract to city- and regional traffic in Eskilstuna*)
National level policy, guidance, government funding and explanatory briefings	Sweden - Förordning (2016:836) om elbusspremie (*Regulation on Electric Bus Premium*) - Förordning om ändring i förordningen (2016:836) om elbusspremie (SFS 2017:1341) (*Regulation on changes on Regulation on Electric Bus Premium*) - Informationsstöd om elbussupplägg till kollektivtrafikhuvudmän (2019) (*Information support on electric bus arrangement to PTAs*) - The Public Transport Act (2010:1065) England - A Green Bus For Every Journey (2016) - Bus Back Better – National Bus Strategy for England (2021) - Bus Services Act 2017 - Decarbonising Transport – A Better, Greener Britain (2021) - Explanatory memorandum to the cleaner road transport vehicles (amendment) (EU exit) Regulations 2020 - The Low Emission Bus Guide (2017) - The Road to Zero – Next steps towards cleaner road transport and delivering our Industrial Strategy (2018)
EU regulation	Clean Vehicle Directive (EU 2019/1161)

Appendix 2

Interview guide local authorities
Role of interviewee
1 Can you start by describing your work position at X?
The process of introducing EBs, step by step
2. What motivated the introduction?
3. Can you explain how the process of introducing EBs started and carried out?
4. How did you continue after the first introduction until today?
5. What are your plans for the future?
The challenges and opportunities
6. Other challenges? During which of above steps did you face the greatest challenges?
7. What do you see as the greatest benefits of introducing electric buses?
Infrastructure
8 Who owns and funds the charging infrastructure?
Affordability
9 In what way has the introduction of EBs affected the cost for public transport?
Fiscal incentives and policy instruments (Grants, Preferential access, tax incentives, local schemes, Clean Air Zones)
10. What support did you get from the national level and what was it for?
11. What local and regional initiatives, restrictions, support or goals influenced the choice of electric buses?
12. What has the largest influence over the choice to introduce electricity, the national or local level?
Far future (*more of interest and for future studies)*
13 What bus technology/fuel do you think will dominate in 2030?
Ending
14. Is there something you want to add that I have not asked about?
15. Is there someone else in X that you think I should talk to that has been involved in the introduction of electric buses?

Appendix 3

Table B Themes and categories used to code the interviews.

Themes	Categories	Sub-categories
Description of project	Vehicles and charging	

(*continued on next page*)

(*continued*)

Themes	Categories	Sub-categories
	Organisation of public transport in country/city	
Roles and responsibility of actors		
Motivation	Choice of fuel/technology	
	Political goals	
Local government resp. national government	Policy instrument	
	Funding	
	Strategies	
	Targets	
	Regulations	
Challenges & Solutions	Economic	Charging infrastructure; Fuel cost; Future cost; Payback time; Vehicle
	Technical	Battery; Charging infrastructure; Green electricity; New technology; Noise; Previous investment in other fuels; Range; Technology development; Education; Vehicle
	Organisational	Contracts & warranty; Delivery time; Lifetime expectancy; Ownership; Procurement; Responsibilities; Sell as solution; Traffic planning
	Personal	Knowledge; Staff engagement; Understanding; Collaboration
Future plans and thoughts		

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