**Exploring the Challenges of Electric Vehicle Adoption in Final Mile Parcel Delivery**

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**Abstract**

The rise in e-commerce has increased last mile parcel deliveries, in turn affecting the sustainability of transport. With the worldwide efforts to minimise fossil fuel use including the UK Government's plans to end the sales of new petrol and diesel vehicles by 2035, alternative fuels need to be explored. Currently one of the most promising solutions is the electric vehicle which produces zero tailpipe emissions. This paper aims to explore the challenges of adopting Electric Vehicles (EVs) in final mile parcel deliveries, and thus identify potential directions for future research. To achieve this, we developed a systematic literature review to better understand the nature of these challenges and to provide a background from which to acquire more information from leading logistics companies in the form of in-depth interviews. We found that the companies encountered different challenges based on their fleet sizes, schedule and capacity to implement the required structural and infrastructural changes to support the efficient running of their last mile delivery operations on EVs.

**Keywords:** Systematic Literature Review, Last Mile Logistics, Electric Vehicles, Concept Map, Thematic Analysis, Concept Map.

## 1 Introduction

The UK transport sector accounts for over a quarter of national CO2 emissions, and around 92% of this is due to road transport (Nicolaides et al. 2018). This can be broken down further to show that 17% of road transport emissions result from commercial light goods vehicles (LGV) (Nicolaides et al. 2018). The use of commercial vehicles for last mile parcel deliveries has seen a significant increase in recent times due to increasing ecommerce activities and urbanization (Oliveira et al., 2017; de Mello Bandeira et al., 2019) thus affecting the sustainability of transport. Consequently, social and political pressures to limit the sustainability impacts of transport have been growing (Feng et al. 2012) with organisations such the European Commission aiming to decrease the negative effects of commercial transport on the environment and quality of lives (Klauenberg et al. 2016). Coupled with the UK Government's plans to end the sales of new petrol and diesel vehicles by 2035 and ecommerce demands continuing to rise, alternative fuels need to be explored for parcel deliveries.

The use of new technologies such as zero emission vehicles could be a key element in reducing the negative impacts of LGV transportation as well as being a convenient transition to a new transportation infrastructure, all while maintaining an efficient freight transport system (Oliveira et al., 2017; Quak et al. 2016,). Currently one of the most promising technologies is battery powered electric vehicle (EV) which produces zero tailpipe emissions (Saldaña et al., 2019), and dependent on the way in which the electricity is produced, has significant potential in reducing overall CO2 emissions (Quak et al. 2016). The use of EVs, whilst offering substantial long term benefits, also provide short term solutions in the form of zero tailpipe emissions, low operating noise and regenerative braking (Nicolaides et al. (2018). EVs are either fully or partially electric powered, therefore, reducing the dependency on fossil fuels and CO2 emissions (Biresselioglu et al. 2018).

For last mile parcel carriers, the prospect of a switch to alternative fuel sources such as EVs presents some operational and performance based challenges. As acknowledged by Berkeley et al. (2017), EVs do not establish a new market; rather they are a niche product seeking to disrupt conventional vehicles. On both the supply and demand side, the society has been locked into conventional vehicles. The ways in which conventional vehicles are produced, driven and refuelled coupled with the flexible independence that they provide has created deeply rooted patterns of behaviour that have existed for over a century. Berkeley et al. (2017) conclude that introducing niche technologies to disrupt an already established market is not straightforward, and this has been well illustrated within the current automotive market with the required improvements in battery performance proving difficult to achieve. Also, batteries are competing with other technologies such as fuel cells and the significant improvements of efficiency in conventional vehicles. These factors have created some challenges throughout the market that affect both manufacturers and consumers with regards to the adoption of EV technology.

The widespread penetration of EVs is dependent on overcoming the barriers and challenges to their adoption. Whilst the barriers to the adoption of EVs have been widely discussed in literature such as in the works of (Teho et al. 2016) and Morganti & Browne (2018), Jiea et al (2019), Quak et al (2016), Biresselioglu et al. (2018), Schucking et al. (2017), Lebeau et al. (2016), Berkeley et al. (2017), Haddadian et al. (2015), Kuppusamy et al. (2017) etc., research into specific fleet environments is sparse with some of these centering around generic last mile operators. This research aims to provide a more comprehensive view of the challenges from two main perspectives: firstly, from the perspectives of the academic community in terms of published literature; and secondly, from the perspective of last mile parcel carriers. Within this second perspective, two further perspectives are sought: from the perspective of parcel carriers that that have not yet adopted EVs in their operations; and, from the perspective of parcel carriers that have adopted EVs. In this way, a richer understanding of the barriers and challenges within this sector is captured. Based on these, the following research questions have been developed:

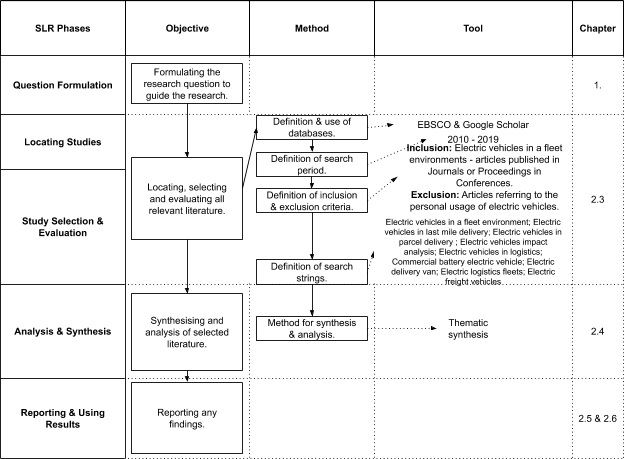
* RQ1: What are the challenges and barriers of introducing EVs in final mile operations from the literature?
* RQ2: How are these challenges dealt with or overcome by parcel carriers who have introduced EVs in their final mile operations?
* RQ3: How are these challenges perceived by parcel carriers who are exploring the introduction of EVs in their final mile operations?

To address these research questions, this study adopts a multi-method research approach involving Systematic Literature Review and Semi-Structured interviews. The SLR is used to address RQ1 and the detail of this are presented in the next section, section 2. RQ2 and RQ3 are addressed using semi-structured interviews with two major parcel carriers involved in final mile logistics in the UK and who also have strong presence worldwide. In this paper, these two carriers are denoted as Company 1 and Company 2 and the semi-structured interviews with them address RQ2 and RQ3 respectively. We argue that these two companies are representative of the companies within the sector particularly as they are two of the top five carriers, and altogether, the top five carriers account for 80% of the overall UK market (Pitney Bowes 2018). The details of this part of the research are presented in section 3. Section 4 provides directions for future research, and section 5 concludes this paper.

## 2 Systematic Literature Review (SLR)

For the literature review, an SLR approach was adopted as it provides explicit procedures for carrying out literature review ensuring that the review is both thorough and does not reflect any biases the author may have (Bryman & Bell 2015). The process has been used to locate the literature, evaluate its contribution, analyse and synthesise the findings and to report the evidence allowing for conclusions to be developed about what we currently know (Saunders et al. 2016). This research has adopted the SLR protocol from Garza-Reyes, (2015) which has some similarities to the method adopted by Cassia et al., (2020). The diagram below shows the 5 specific SLR phases from the same author. They are: (1) question formulation, (2) locating studies, (3) study selection and evaluations, (4) analysis and synthesis, and (5) reporting and using the results. While the first phase has been reported in section 1, the remaining phases, 2 to 5, are reported in this section (sub-sections 2.1 to 2.3).

2010 - 2020



**Section**

**1**

**2.1**

**2.2**

**2.3**

**Figure 1.** SLR phases, methods, tools and the location within the article.

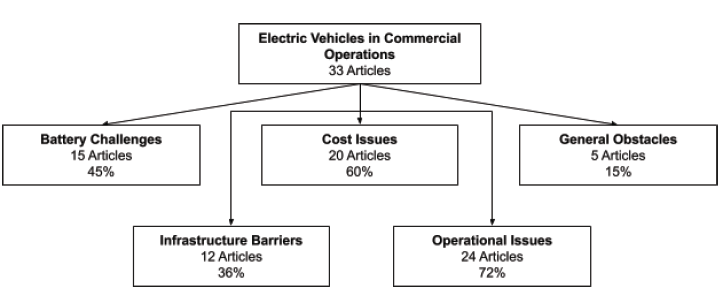
***2.1 Locating Studies and Selection of Studies***

Articles were located by searching EBSCO, Science Direct, Elsevier and Google Scholar and due to the need for reliable information, the review focused on journal and conference publications (Collis & Hussey 2003). Also due to the recent and emerging nature of the topic as demonstrated by the current focus on EVs coupled with the constant development of battery technology and government policies, a search period for this research was set to include articles from 2010 to 2020.

Using the search strings identified in figure 1, a range of articles were identified, and in some cases, articles were found to reoccur throughout different search strings. Despite creating an overlap, this served as validation that all relevant literature falling under the search strings were included. A manual check based on the articles abstract was conducted for all articles that fell within the identified search strings, and articles that did not address the topic were then removed. Based on these, 33 articles were selected.

***2.2 Analysis and Synthesis***

There are a number of methods to consider for the synthesis of qualitative research. The thematic synthesis model combines approaches from both meta-ethnography and grounded theory to effectively identify reoccurring themes from the structured use of data (Barnett-Page & Thomas 2009). Findings are organised into descriptive themes with an inductive approach, developing a constant comparison method (Barnett-Page & Thomas 2009). Therefore, thematic synthesis has been considered the most appropriate method for the evaluation of results of the systematic review. Due to the vast nature of EVs, classifications were used to identify common themes between the articles, separating the articles into 5 groups of categories.



**Figure 2.** Preliminary thematic categorisation of articles included in the literature review.

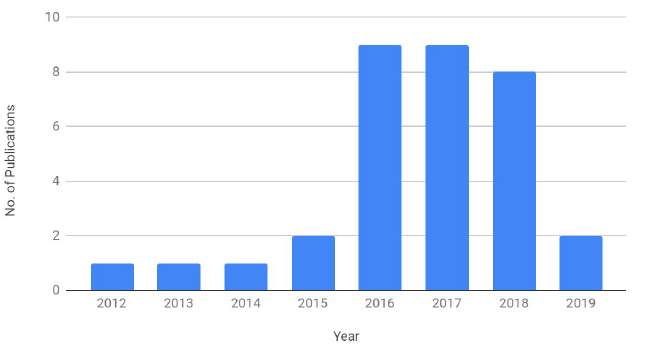
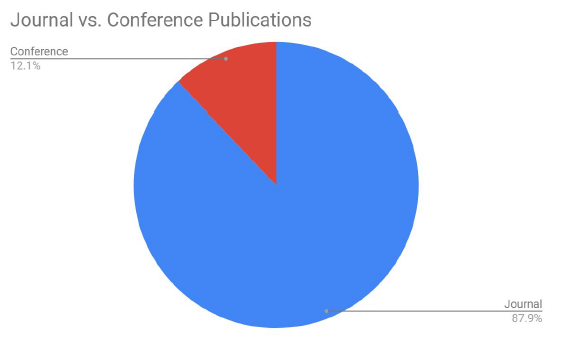
The preliminary categorisation allowed the evaluation and analysis of all 33 articles as well as their assignment to the relevant category, followed by a comparison against papers in differing categories. The number of articles assigned to each category is shown in the above figure 2. The figure demonstrates that the topic of electric vehicles in fleet environments has been studied well in literature.

Overall, 72% (24 articles) discussed the operational impacts that EVs could potentially have on fleet environments. A further 60% (20 articles) referred to the cost impacts. Within the articles in both of these categories were also the additional elements of other categories previously highlighted in figure 2. Due to the overlap of categories and research streams, further clarification is required. Therefore, a concept map highlighting any potential research paths and interactions between topics has been developed and presented in sub-section 2.4 (figure 4). A clearer presentation of figure 4 is found in the appendix

***2.3 Reporting and Using the Results***

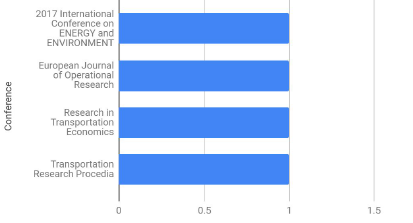
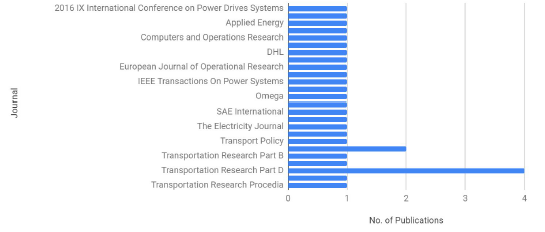
Table 1 (in the appendix) presents the details of the selected 37 articles with descriptive data presented in figure 3.

The below figures present the descriptive data of the SLR in terms of sources and number of publications, proportions of journal and conference papers and yearly number of publications.

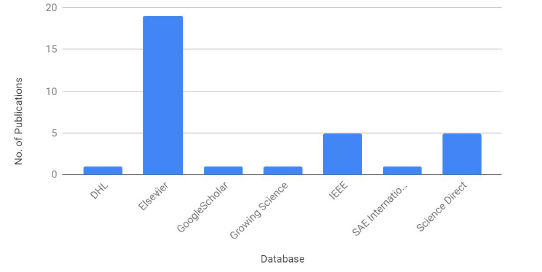


1. (b)

(a)



(c) (d)



(e)

**Figure 3.** Descriptive data – (a) Proportion of journal vs. conference publications, (b) Number of publications per year, (c) Number of publications per journal, (d) Number of publications per conference, (e) Number of publications per database.

Figure 3(a) shows that there was a significant jump in published articles from 2015 to 2016 with a 450% increase, indicating a huge gain in interest for EVs in fleet environments. Figures 3(b, c & d) indicate that whilst conferences have been used by academics to share results from previous investigations, journal publications remain the leading choice for researchers. Figure 3(e) shows that Elsevier has the highest number of articles found in a specific database with 19 articles with the next being IEEE and Science Direct with 5 articles each.

***2.4 Concept Map for Challenges of Replacing a LGV Fleet with Electric Vehicles***

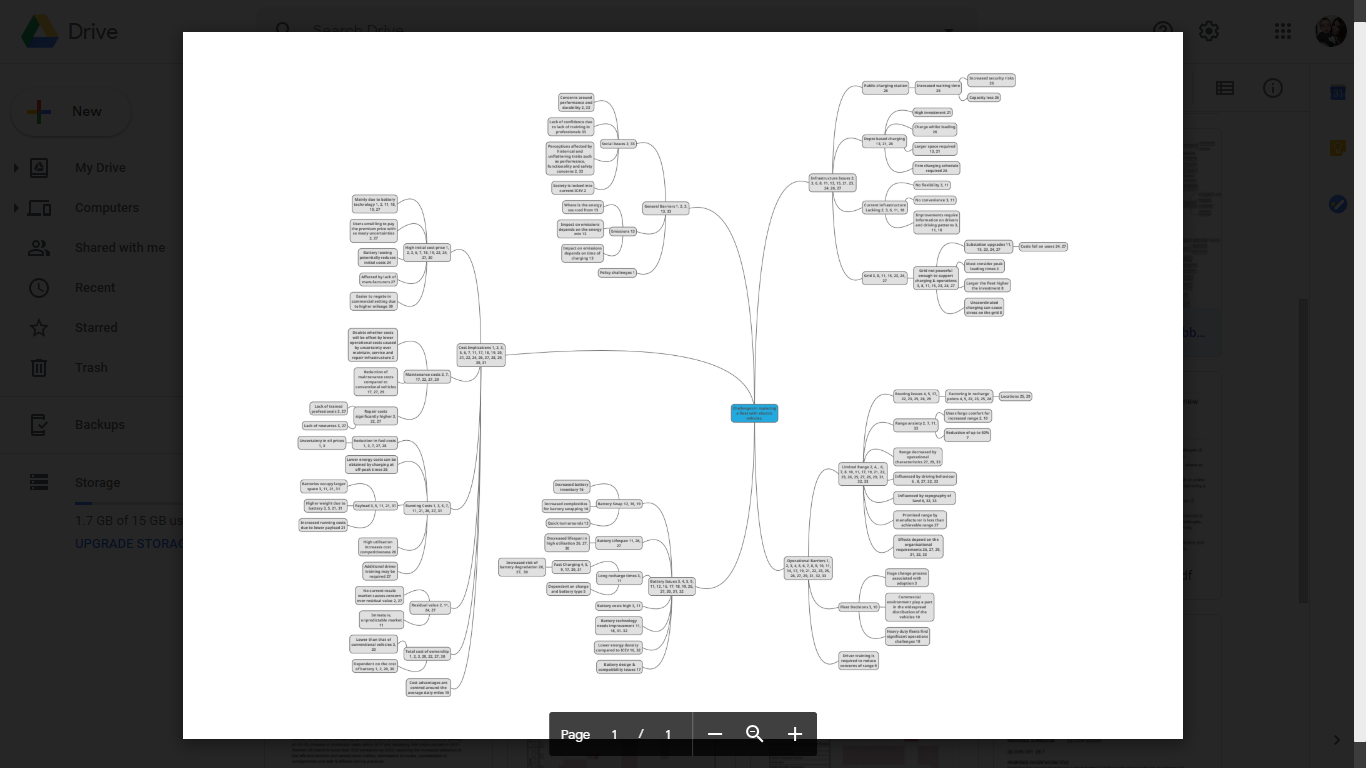
In the preliminary thematic analysis presented in section 2.2 (figure 2), five main categories were identified i.e. operational, infrastructure, battery technology, cost and general barriers. However, further thematic analysis indicates that a number of these categories overlap and interact. Therefore, a concept map has been developed to structure and map these overlaps and interactions through sub-categorisation to facilitate clearer visualisation and discussions of the findings of the SLR. The concept map is presented in figure 4 below with the article numbers in the concept map corresponding with the article numbers in Table 1 (in the appendix). The sub-sections that follow discusses the main categories including the sub-categories whilst pointing out the overlaps across categories.

*2.2.1 Operational Barriers*

Operational barriers are sub-divided into limited range, fleet decisions and driver training with most articles focused on limited range. Teho et al. (2016) acknowledge that in comparison to conventional vehicles, EVs have significantly less driving range due to both technical and financial limitations of energy storage. Attitudes towards EVs range have been further hampered by the differences between manufacturers promised range and the significantly lower actual range (Quak et al. 2016). The research shows that range can be influenced by a number of externalities such as driving behaviour, outdoor temperature, topography of the land and the weight being transported (Christensen et al. 2017). In particular weather conditions provide a negative impact on battery range for EVs and Wikstrom et al. (2016) conclude that this is due to the increased usage of auxiliary loads (for example the heating/cooling systems in the vehicle), with many users stating that they would sacrifice comfort to ensure they had sufficient range, further negatively influencing attitudes towards electric vehicles. Furthermore, aggressive driving styles also cause a reduction in range, requiring additional costs to train and educate drivers properly (Foiadelli et al. 2017).

The range of EVs can be further impacted by “range anxiety” where drivers’ concerns about the limited range lead to a reduction of utilised range by up to 50% (Feng et al. 2012). Berkeley et al. (2017) have also acknowledged range anxiety and concluded that it has a detrimental effect on the experience of users resulting in them choosing conventional vehicles for longer distances. However, Gebauer et al. (2017) argue that experience is vital in order to reduce the psychological barriers concerning EV’s driving range. Whilst range limitations still exist, attitudes towards them are changing. Quak et al. (2016) note that as more companies are conducting trials of the technology, organisations are finding two options, either they do not require high range in their operations or they adapt their routines to the available range. This is also demonstrated in research by Wikstrom et al. (2016) who found that for a large share of commercial fleet vehicles the range still allows for a significant proportion of journeys to be undertaken by an EV. Schiffer & Walther (2018) mention that for short-haul logistics, a limited driving range is not such an issue as it would be sufficient to recharge once a day. Whilst this is suitable for urbanised areas, operators in less urban areas need to determine which infrastructure they would require such as battery swapping or recharging.

Munoz-Villamizar et al. (2017) considers that the routing characteristics for EVs have specific requirements that must be considered within routing models. This is supported by Schiffer & Walther (2018) who note that future routing decisions depend upon the location of charging infrastructure and infrastructure depends on the expected routes. Furthermore, Paz et al. (2018) argue that not only is the location of charging stations important, but also vehicle downtime whilst charging and travelling to the charging station both impact the vehicle operating time. The importance of routing and charging location decisions not only affect costs but also is essential to foster competitiveness within the industry (Schiffer & Walther 2018).



**Figure 4**. The concept map, illustrating the five main search streams, battery issues, cost

barriers, general impacts, infrastructure issues and operational barriers.

*2.2.2 Infrastructure*

Berkeley et al. (2017) and Guo et al., (2018) suggest that the lack or perceived lack of charging infrastructure is a major deterrent for adoption, a point that Haddadian et al. (2015) have agreed upon and expanded on, stating that the fundamental challenge in ensuring the development of EVs is the adequacy and flexibility of the charging infrastructure. However, Biresselioglu et al. (2018) state that the charging infrastructure can only be realised and developed with extensive information of drivers and driving patterns. Charging options include depot based charging and public charging stations but Pelletier et al. (2017) note that whilst the main barrier is the limited charging infrastructure, there are further hurdles to overcome such as the cargo security risks that long charging times require and also the ineffective use of the drivers time whilst charging during delivery.

Depot based charging would require investment in charging stations, potentially, fast charge stations to ensure that sufficient time is provided to charge vehicles between routes (Vosooghi et al., 2020). This would combat potential waiting times at charging stations, and the security risks and driver inefficiencies (Morganti & Browne 2018). Whilst this provides autonomy on the management of recharging, previous projects show that existing power grid is simply not sufficient to charge a fleet and upgrades to the grid are required (Quak et al. 2016). This results in cost increases, both from consumed electricity and any upgrades required. This view is supported by Haddadian et al. (2015), who argue that as charging requirement for EVs increases, the demand placed upon the distribution network increases resulting in a need for upgrade to the aggregated distribution network.

Breunig et al. (2019) argue that recharge points at customer locations could help alleviate the shortage of charging infrastructure, however, in the case of last mile delivery this is not a viable option due to the nature of the operation coupled with the additional cost for charging that this would entail. Pelletier et al. (2017) acknowledge that as urban delivery routes are typically shorter than the range achievable by EVs, there would often be no requirements to charge on route.

*2.2.3 Battery Technology*

EV batteries have a much lower energy density compared to the fuel of combustion engine vehicles (Keskin & Catay 2016 and [Vahidi & Sciarretta 2018](https://www.sciencedirect.com/science/article/pii/S1361920919307114?casa_token=fZ-94nmfLxYAAAAA:U4D3zi7pZRJ0ELQ_74hweYZTyZA_o9TqA-uvVTbpvWnRVnbVVJvPWTUb1IexzWJWGwo2Q8HK" \l "b0190) in Vosooghi et al., 2020). This point has been corroborated by Haddadian et al. (2015) who argue that battery technology is not close to the hypothetical boundary for energy density, and that further research is vital for producing lower cost, higher performance batteries. Wikstrom et al. (2014) acknowledge that battery performance is inhibited by both the technical specification of the battery and the operational conditions in which the vehicle is used. The high price of batteries has also been noted by Biresselioglu et al. (2018) as an issue arguing that not only are battery costs excessive but also their expected lifespan is uncertain.

Battery lifespan has been subjected to much criticism, Quak et al. (2016) state that with typical use, EV batteries should last roughly six years. However, they proceed to note that battery health can be influenced by the type of charging utilised, frequent overcharging or frequent discharging can affect the lifespan extensively (Gao et al., 2019). Last mile delivery operations normally requires high utilisation of vehicles and Pelletier et al. (2017) and Schucking et al. (2017) agree that with high vehicle utilisation rates, battery aging can be accelerated.

Whilst long wait times for recharging were once a key barrier in EVs, technological advancements have provided fast charging, allowing for charging a battery from empty to 80% in less than 30 minutes (Gebauer et al. 2017). Teho et al. (2016) comment that the increased speed of charging will have positive effects on the driving range and therefore increased service capacity. Keskin & Catay (2018) agree noting that by using fast charging the duration of recharge is decreased, thus, allowing service to more customers along the route. However, whilst fast charge has major advantages, Schucking et al. (2017) have acknowledged that a significant investment for the charging stations is required, and stronger impact and stress is placed upon the battery, potentially reducing the lifespan.

Battery swapping is a strategy that has potential to reduce the risks of limited range. Jiea et al (2019) explain that in battery swapping, an existing battery that is close to empty is replaced with a fully charged one, and the whole operation takes about 10 minutes which significantly shorter than fast charging. However, Keskin & Catay (2016) have illustrated that battery design and compatibility, battery lifespan, ownership and swap station infrastructure all provide additional complexities, further adding to the challenges of routing. Kuppusamy et al. (2017) further explain that a sufficient number of charged batteries would need to be stocked to enable quick changeover, thus it is important to evaluate the need for increased battery inventory therefore increased costs.

*2.2.4 Cost Implications*

Kuppusamy et al. (2017) report that adopting EVs on a purely fuel cost saving basis over conventional vehicles can be short sighted, noting that fuel cost savings are substantial, however, costs increase with battery inventories required for battery swapping. This is corroborated by Noon (2015) who state lower running costs occur but there is potential for significant costs in infrastructure upgrades. Kuppusamy et al. 2017 argue that the variations in typical miles driven for last mile delivery coupled with the high purchase price of EVs results in operators needing to be cautious in EV adoption decision making. The potential increase in costs is subject to debate with regards to the passing the increase to end customers. Quak et al. (2016) note that EV’s do not result in extra revenue and most customers do not wish to pay a premium for zero emission deliveries, however, Noon (2015) argues that if a company wishes to convert its fleet to electric vehicles the company can pass on any additional costs to the end customer.

2.2.4.1 Initial Costs

Biresselioglu et al. (2018) argue that EVs purchase price when compared with conventional vehicles is one of the main barriers of EV adoption for fleet operations. This is supported by Quak et al. (2016) noting that the purchase price and total cost of ownership (TCO) for EVs is significantly higher than that of a conveniently fuelled vehicle, this is partially down to high battery prices and limited production of current EVs. However, Feng et al. (2012) point out that whilst the initial purchase price is high, EVs have lower per mile operating and maintenance costs. Feng et al. (2012) also conclude that this means that fleet operations must account for trade-offs between the initial purchase costs against life-long operating costs, emissions costs, and minimal service requirements.

Schucking et al. (2017) maintains that the higher purchases costs of EVs are easier for fleet operations to overcome, stating that the higher annual mileage negates the higher purchase cost due to the lower operating and maintenance costs when compared against conventional vehicles. However, as Knupfer et al. (2016) have acknowledged ,the EV is still a niche product, with only expensive and premium manufacturers offering batteries with an acceptable range. On the positive side, Quak et al. (2016) acknowledge that battery leasing or swapping options could be regarded as potential routes to reduce EV purchase price. Berkeley et al. (2017) also note that the high purchase price of EVs due to battery prices is set to decline, stating that battery prices are falling rapidly so the pricing barrier will become much less of an issue over the following decades. Quak et al. (2016) supports this, arguing that in time, the initial costs of EVs will reduce with wider uptake and consequent mass production.

2.2.4.2 Maintenance Costs

Keskin & Catay (2018) note that EVs have fewer moving parts than a conventional vehicle leading to significant reduction in maintenance costs. A point that Quak et al. (2016) agree with but also acknowledge that if the EV does break, the repair costs can become extremely high. Berkeley et al. (2017) corroborate this statement, claiming the there is uncertainty over the availability of maintenance, service and repair infrastructure, creating doubts over whether the high purchase price will indeed be offset by lower operational costs. Quak et al. (2016) note that uncertainty over maintenance is mainly due to EVs not being as common as conventional vehicles, with only a few skilled servicemen available to repair any issues that an EV may have.

2.2.4.3 Fuel & Running Costs

Conventional vehicles may have lower purchase prices but fuel costs constitute the largest cost components during their lifetime and are highly uncertain (Ahani et al. 2016). Briesseliogul et al. (2018) examined this further, stating that a major economic factor affecting the adoption of EVs is the general uncertainty around oil and energy prices, if oil prices fall and energy prices increase, an investment in EVs may not be financially beneficial. However, research conducted by Ramroth et al. (2013) showed that an EV freight could obtain significant fuel savings, but overall may not be as economically viable, dependent on battery costs and daily driving distance. High utilisation has been found to be critical to increase the cost benefits of EV adoption (Pelletier et al. (2017). However, as previously explored, high utilisation can also increase the risks of battery degradation. Quak et al. (2016) have acknowledged that potential increases in costs could arise from the hiring and/or training drivers, due to the drivers requiring a different skill set than that needed for a conventional vehicle. However, Pelletier et al. (2017) have stated that lower energy costs could be obtained through commercial off-peak electricity rates when depot based charging is utilised.

2.2.4.4 Total Cost of Ownership

As previously explored, the purchase price of EVs is much higher than that of a conventional vehicle (Darlington, 2020), however, Lebeau et al. (2016) comment that when analysing financial viability, a total cost of ownership (TCO) analysis would be more relevant for EVs. Schucking et al. (2017) acknowledge that TCO is influenced by two categories, technological factors and regional factors. Technological factors include durability of EVs and their batteries which is a basis of comparison to a conventional vehicle. The regional factors include energy prices, taxes, incentives and market circumstances which are dependent on that region. Ahani et al. (2016) agree, stating that energy cost fluctuations and EV purchase prices constitute the largest components of TCO. Lebeau et al. (2016) advises that the TCO primarily depends on the battery due to the cost of the batteries as they require replacements as a result of degradation, and due to the uncertainty regarding its life span. Lebeau et al. (2016) go on to conclude that to reduce these uncertainties, manufacturers have developed warranties for the batteries or offered battery leasing solutions. Quak et al (2016) note TCO is higher than conventional vehicles due to high battery costs and limited EV production. Lebeau et al. (2016) however, disagree with this statement, claiming that TCO could be lower as long as the EV is used optimally. Overall, Biresselioglu et al. (2018) argue that TCO for EVs is much lower than that of conventional vehicles, due to their fuel savings and the lower maintenance costs.

2.2.4.5 Residual Value

Berkeley et al. (2017) identify that an additional concern in the adoption of EVs is the current absence of any second-hand resale market, creating uncertainty over residual value, and this uncertainty does not help to alleviate concerns with the high purchase prices of EVs. Haddadian et al. (2015) agree with the statement, adding that as the resale values are unknown due to the immaturity of the EV market, TCO is highly unpredictable. This causes fleet operators to hold back in their decision to adopt EVs, as the unknown residual value makes them reluctant to invest with such a high level of uncertainty (Quak et al. 2016).

2.2.4.6 Payload Restrictions

A further issue identified in literature is the size and weight of EVs resulting in a reduced payload than that given for traditional vehicles (Morganti & Browne 2018). Christensen et al. (2017) acknowledge that this is due to the higher weight of the vehicle due to the battery, potentially reducing the payload by up to 200-400kgs.

2.2.5 General Barriers

Wikstrom et al. (2016) acknowledge that a crucial factor in the successful adoption of EVs is user acceptance. Berkeley et al. (2017) agree with the statement, concluding that the socio-technical barriers to EVs are a major barrier. These issues surround the concerns and perceptions of consumers around the technology. Berkeley et al. (2017) found that consumer concerns over the battery range ranked highly in their study, whilst they also discovered operational barriers relating to the users lack of confidence in the technology and ineffective training on issues such as range and repairs capabilities.

## 3 Semi-Structured Interviews

Having provided a thorough SLR based discussion of the challenges of EV adoption in the preceeding section thus addressing research question1 (RQ1), this section presents the research that addresses research questions 2 and 3:

* RQ2: How are these challenges dealt with or overcome by carriers who have introduced EVs in their final mile operations?
* RQ3: How are these challenges perceived by carriers who are exploring the introduction of EVs in the final mile operations?

***3.1 Data Collection***

Semi-structured interviews were chosen as a means of data collection for addressing both research questions. This is due to the research being concerned with the respondents’ point of view, meaning that the interviewer will encourage the respondent to give insight into what they think is important or relevant in addressing the research questions (Bryman & Bell 2015). Furthermore, the use of semi-structured interviews will allow for an in-depth exploration of the general area of introducing EVs into operations, encouraging the respondent to talk freely about any areas they feel are relevant to the topic (Saunders et al. 2016).

Non-probability sampling will be undertaken as the study aims to make no statistical inferences about the population, rather generalisations are being applied to theory (Quinlan 2011). As the research questions require in depth information about last mile carrier operations, homogenous sampling is the most applicable for the study. This uses similar characteristics of selected participants to allow for a greater depth of exploration and for any small differences to become apparent (Saunders et al. 2016). However, as the research will utilise a small sample size the need for purposive sampling is required, ensuring that cases are highly informative (Bryman & Bell 2015).

Companies 1 and Company 2 is used to denote the companies that have been selected to address RQ2 and RQ3 respectively. Both companies have seen a growth rate of over 5% over the past 4 years (Apex Insight 2018). Additionally, both companies appear in the top 5 carriers for parcel shipments in the UK where all five companies account for 80% of the overall UK market (Pitney Bowes 2018). However, whilst Company 1 has already adopted EVs in their operations, Company 2 has not done so yet, thus, it is argued that the foregoing makes both companies representative samples and suitable to address RQ2 and RQ3 respectively.

The respondents are senior individuals with minimum of 3 years’ experience in director level roles in either transport or transport operations at each of these organisations. These individuals have current knowledge of the technology and operations that is required for the in-depth analysis required.

***3.2 Semi-Structured Interview Topics***

Interview topics were identified from the information and the concept map resulting from the systematic literature review with focus on the most relevant topics. These topics and sub-topics are structured as follows:

* **Limited Range**
  + Range Anxiety
* **Infrastructure**
  + Depot Based Charging
  + Grid Improvements
* **Routing Complications**
* **Battery Technology**
  + Battery Life Span
  + Fast Charging
  + Battery Swapping
* **Potential Costs**
  + Initial Costs
  + Maintenance Costs
  + Fuel and Running Costs
  + Total Cost of Ownership
  + Residual Value
  + Payload Restrictions
* **General Barriers**

Once the qualitative data has been collected and transcribed, an analysis was carried out as presented in the next sub-section.

***3.3 Data Analysis and Discussion***

Dealing with qualitative data can be challenging as there is no clear and accepted set of rules for its analysis (Collis & Hussey 2003). However, it has been suggested that due to the nature of qualitative data and its non-standardised format, the analysis method needs to ensure that the analysis of the data collected explores and extracts meaning relative to the research questions (Saunders et al. 2016). After reviewing a range of data analysis methods such as Deductive Explanation Building, Analytic Induction, Pattern Matching, Thematic Analysis, Narrative Analysis, Discourse Analysis and Content Analysis (Saunders et al. 2016; Collis & Hussey 2003; Bryman & Bell 2015), Thematic Analysis was chosen. This is because, thematic analysis helps to ensure that patterns and relationships are identified throughout the data assisting in the extraction of the key themes found (Bryman & Bell 2015).

In this research, a framework approach to thematic analysis presented in Saunders et al., (2016) has been chosen due to its clear and structured approach. Following the transcription of both interviews, notes in the form of short phrases were made against pieces of data that required further analysis. The short phrases were then used to search for patterns and relationships that relates to the research question by categorising them against priori headers (Saunders et al. 2016). The priori headers used are the main initial headers of challenges identified from the systematic literature review. Following this, all categories were allocated their own colour code and both transcripts were worked through and data that fit under each category header was marked with its corresponding colour. This process has allowed the identification of links and aspects that need to be compared and contrasted between the two operations (Saunders et al. 2016).

Anchored on the need to make e-commerce and parcel delivery a cleaner endeavour through a clearer understanding of the challenges that delivery companies encounter in their daily operations concerning the adoption of EVs, especially with the looming deadline of 2035 fast approaching (the year in which the use of the traditional combustion engine will come to an end as mandated by the government of the UK), this study offers a fresh contribution to the transport and logistics management literature by conducting an interview with two of the most commonly used carriers in the UK. Through literature review and the interview, a better practical understanding of the challenges facing last mile parcel delivery companies in their efforts to adopt and implement EVs has been gained. This provides a platform for carriers in their efforts to adopt EVs.

Table 2 below shows the thematic analysis framework, their placements within the priori code framework and the sub-sections in which the results are discussed.

**Table 2.** The initial coding notes feeding into the priori code headers.

|  |  |  |
| --- | --- | --- |
| **Priori Code** | **Initial Framework** | **Sub-Section** |
| **Operational Fit** | * Operations * Continuous Improvements * Research & Development | 3.3.1 |
| **Routing Complications** | * Fixed geography * Predictable range * Predictable route | 3.3.2 |
| **Depot Based Charging** | * Long charging windows * Short charging windows * Multi-shift operations * Single shift operations | 3.3.3 |
| **Infrastructure** | * Depot based charging * Grid overloads * Grid upgrades * High demand on grid * Smart grids | 3.3.4 |
| **Battery Technology** | * Battery prices * Battery size * Fast charging * Emerging battery technology | 3.3.5 |
| **External Impacts on Range** | * Driving conditions and range * Driving styles * Power regeneration * Operation characteristics on range implications | 3.3.6 |
| **Initial Costs** | * Grid costs * Lack of manufacturers \*\* * Vehicle retrofitting * Potential costs for green energy implementation | 3.3.7 |
| **Maintenance Costs** | * Maintenance * Retraining | 3.3.8 |
| **Payload** | * Size and weight of batteries * reducing payload | 3.3.9 |

*3.3.1 Operational Fit*

Quak et al. (2016) argue that companies must undergo a trial and demonstration process to ensure that their organisation and operations best fit the use of EVs. Company 1 has operated EVs within London for over 10 years with focus on adapting EVs to fit their operations rather than adapting operations to meet vehicle characteristics. The company has made significant investment in this area including in experimental facilities they have named rolling laboratories which enables them to continuously evaluate and add new EVs to their fleet, and also retrofit existing traditional vehicles.

Company 2’s operational model is interesting as they also use self-employed couriers who pick their workloads up from designated “mini depots” in addition to the company’s own fleet. This allows them to have a smaller owned fleet than most parcel delivery operators, and also provides them with scalability opportunities through the self-employed courier scheme. However, this limits their scope of potential adoption of EVs to owned vehicles which they use to deliver to ‘mini-depots’ where the self-employed couriers collect parcels from. According to Globischa et al. 2018, commercial vehicle fleets are considered better candidates for the adoption of EVs due to business’ need to demonstrate their environmental credentials whilst reducing running costs which is not always the case with personal vehicles that are used by self-employed couriers due to varying personal circumstances. This potentially opens up an area for future research because research and development need to be conducted on the readiness of fleets to adopt EVs with the capacity to complete the required journeys. Readiness frameworks could be developed to help assess the readiness of organisations for EV adoption.

*3.3.2 Routing Complications*

Current operations heavily impact route planning, typically urban delivery routes are shorter than the current range available from electric vehicles, therefore there are no concerns relating to charging the vehicles outside of the depot (Pelletier et al. 2017). Companies 1 and 2 currently operate within fixed geographies, resulting in routes and range that are both fixed and predictable. The predictability of routes and daily range is beneficial to the introduction of electric vehicles, providing the organisations with knowledge and insight into any constraints that may affect operations. Wilkstom et al. (2016) agree stating that for a large share of commercial fleets, a significant proportion of the journeys undertaken can be completed with electric vehicles due to the predictability in fleet driving operations. Considering both company 1 and 2’s routing complications, it would be of great interest to research whether or not route planning would result in additional complications being suffered, especially given that both companies operate within fixed geographical locations, and have predictable routes resulting in little or no concerns regarding depot charging activities.

*3.3.3 Depot Based Charging*

The charging of vehicles from the depot requires significant planning to ensure demand is always met (Pelletier et al. 2017). However, as noted by Quak et al. (2016) there is relatively long charging time for EVs on standard charge. For operators of single shifts, this allows for charging at the optimal hours of off-peak, known to be the cheapest solution (Kabatepe & Turkay 2017). As Company 1 runs a single shift operation with vehicles stored at the depot overnight, they have a long charge window available. This allows them to take advantage of off-peak energy demands, resulting in lower cost charging.

On the other hand, Company 2 runs multiple shifts, resulting in a small 3-hour window between shifts for reloading and charging activities which presents a challenge as the standard charging of EVs requires several hours. Although there have been recent developments in fast charge which allows EVs to be charged in under half an hour (Breunig et al. 2019), fast charging would place significant demands upon the grid infrastructure.

*3.3.4 Infrastructure*

Schiffer & Walther (2018) state that within parcel carrier operations the lack of external charging infrastructure plays a minor role, as the daily range is sufficient to charge the vehicles once a day within the depot. However, with regards to power grid infrastructure, both Biresselioglu et al. (2018) and Foiadelli et al. (2017) stress the importance of large fleet charging and the significant demands placed upon the grid. As demands increase at a rapid pace, frequent power failures and load shedding issues will occur, thus, requiring the upgrades to local substations near each organisation’s operations to restore stability to the grid (Kaur et al. 2016). These upgrades are charged to the organisations directly, so whilst running costs are lower, and the environmental and marketing benefits associated with the use of EVs are realised, these could be stripped away with the potential costs associated with infrastructure upgrades (Noon 2015). Company 1 found that their increasing demands on power required them to upgrade the local grid at their own expense.

Subsequently, Company 1 identified an alternative approach to dealing with grid difficulties through Smart Grids. Smart Grids use algorithms to rebalance frequency deviations by spreading the supply of energy evenly across the demand (Kaur et al. 2016), thereby increasing the efficiency, reliability and security of the conventional grid. Company 1 worked with a third party to implement Smart Grid technology, allowing them to even out power distribution between charging and overnight sorting operations. This worked for the company as they only run a single shift, so whilst vehicles were parked in the depot overnight there was a 12-hour window to distribute charging amongst the fleet.

However, Company 2 runs multi-shift operations which result in a reduction of the charging window to just 3 hours. This has not only made it more challenging for Smart Grid technology to work within such a limited charge window but also, the alternative of fast charging would require costly grid upgrades. Company 2’s use of multi-shifting requires them to search for a solution to their high power demands and limited charging windows. This inevitably opens up the possibility to explore fast charging and the upgrade costs to its local substations and possibly for companies operating similar shift conditions as and possessing characteristics as Company 2. Also, the UK Government's plans to end the sales of new petrol and diesel vehicles by 2035 means that carriers need to identify ways to deal with the challenges associated with making the transition to EVs. This could be addressed by researching and developing frameworks or models that would enable carriers to carry out detailed evaluation of their operations for the adoption of EVs.

*3.3.5 Battery Technology*

Biresselioglu et al. (2018) state that battery prices are high, their lifespan is uncertain, and they have long charge times. Currently, one of the strategies for mitigating these is battery swapping which involves the replacement of an existing depleted battery of an EV with a fully charged one, with an replacement time of less than 10 minutes (Jiea et al. 2019). However, it does raise issues of increased costs from additional battery inventories and the chances of battery degradation (Keskin & Catay 2016). However, Haddadian et al. (2015) who argue that a more lasting solution would require further R&D to increase battery energy density, operating range and lifespan.

Company 1’s predictable operations enabled them to work with a third party to develop a commercial electric vehicle that suited their operations. The predictability of their operations allowed them to accurately specify battery sizes and develop detailed charging schedules. However, as they were one of the first, beginning the introduction in 2008, to adopt the technology they also incurred high costs.

Company 2’s multi-shift operations see them potentially struggling to fit charging times into their schedules between shifts. Fast charge seems to be the solution to increase the availability of electric vehicles within fleet operations however, fast charging comes with disadvantages of increased investments in charging equipment, and increased stress placed upon the battery cells (Schucking et al. 2017). Additionally, battery health can be influenced by the way in which it is charged and discharged, frequent charging or discharging to deep levels can affect the lifespan (Quak et al. 2016) highlighting the importance of charge scheduling (Pelletier et al. 2017).

*3.3.6 External Impacts on Range*

As literature suggests, not only is the range of electric vehicles heavily dependent on user operations, relating to speed, acceleration and braking, but also the outdoor temperature, topography and transported weight (Christensen et al. 2017). The outdoor temperature impacts the range due to the use of the internal heating and cooling systems (Globischa et al. 2018).

Company 1 stated that the ability to regenerate energy lost from aggressive driving styles would negate the impacts upon the range. Furthermore, as explored above, their predictable operations have enabled them to estimate the energy efficiencies of the driver and operating conditions and have built considerations into their operations and battery sizes. Whilst this enables them to just barely manage to meet the harder and higher demands placed upon the vehicles in the winter months to an extent, they are then left with having oversized batteries for the summer months.

Company 2 stated that they heavily measure driving styles on their current conventional vehicles and ensure that they score high within the industry. If they were to introduce electric vehicles they would need to ensure, much like Company 1 had done, that they factor in contingencies for the harder and colder winter months. Whilst this means that they will be operating under capacity within summer, the risks associated with operational impacts on range will be mitigated.

*3.3.7 Initial Costs*

Ahani et al. (2016) have noted that the relatively high purchase price of electric vehicles makes them less attractive to stakeholders within the commercial sector. This is supported by Feng. Et al., (2012) who argue that whilst for the use of EVs for the commercial sector has benefits of lower per-mile operating and maintenance costs, there are trade-offs due to the high initial capital costs.

Company 1 is aiming to mitigate these by retrofitting their current delivery trucks with electric drive trains, working with their own maintenance departments and a third party to offer solutions. Whilst retrofitting vehicles is a viable solution for them particularly as they use purpose-built vans already, Company 2 may struggle to find this a viable option as they use generic transit vans for their operations. There is therefore an opportunity in this circumstance for research into mutually beneficial partnership models between carriers and power grid companies to help minimise the cost of grid upgrades.

*3.3.8 Maintenance Costs*

The uncertainty over maintenance and repair infrastructure adds doubts to whether true cost savings would be realised from the introduction of electric vehicles within the fleet (Berkeley et al. 2017). Quak et al. (2016) argue that whilst maintenance costs are reduced due to a reduced number of moving parts in EVs, repair costs could still be high as the expertise for the repair of EVs is still minimal.

Due to the sheer size and nature of Company 1’s fleet and operations, they run not only their own laboratories for the testing and introduction of new technologies, but also their own maintenance workshops. This has allowed them to avoid the increased risks associated with a lack of professionals able to maintain electric vehicles. This is an area where Company 2 would struggle with, at least, initially.

*3.3.9 Payload*

The batteries for electric vehicles occupy more space than a conventional fuel tank (Biresselioglu et al. 2018). The reduction of useable space coupled with increased weight of the batteries reduces payload by 200 - 400kg (Christensen et al. 2017). Therefore, the reduction in payload directly affects the number of parcels delivery per journey, thus resulting in an increase of unit costs (Morganti & Browne 2018).

This is not a major issue for Company 1 who has a history of using purpose built vehicles as these are considered during retrofitting or taking on new EVs. However, this is an area of concern for Company 2 who suggest that further works needs to be undertaken to ensure the size and weight of the batteries to minimise their impact on daily operations and unit costs.

## 4 Conclusions

The overall aim of this paper is the explore the challenges of EV adoption in the final mile logistics, and thus identify potential directions for future work. To achieve this, four research questions, RQ1 to RQ4 were developed.

* RQ1: What are the challenges and barriers of introducing EVs in final mile operations in academic literature?
* RQ2: How are these challenges dealt with or overcome by carriers who introduced EVs in their final mile operations?
* RQ3: How are these challenges perceived by carriers who are exploring the introduction of EVs in the final mile operations?
* RQ4: What are the potential research directions that could facilitate further EV adoption in the industry.

To address RQ1, a thorough analysis of literature in this areas was carried out using a Systematic Literature Review which resulted in comprehensive thematic concept map of the challenges. Primary research, in the form of semi-structured interviews were carried with two of the 5 biggest players within the industry to address RQ2 and RQ3. The findings from these show that the operational characteristics, particularly the shifts pattern, are the key driver in determining the severity of the challenges to potential adoptees of EVs in final mile logistics. Based on this, a number of research directions were identified including the need for frameworks and models for understanding and evaluation the challenges of EV adoptions within given operational characteristics as well as readiness and partnership frameworks.

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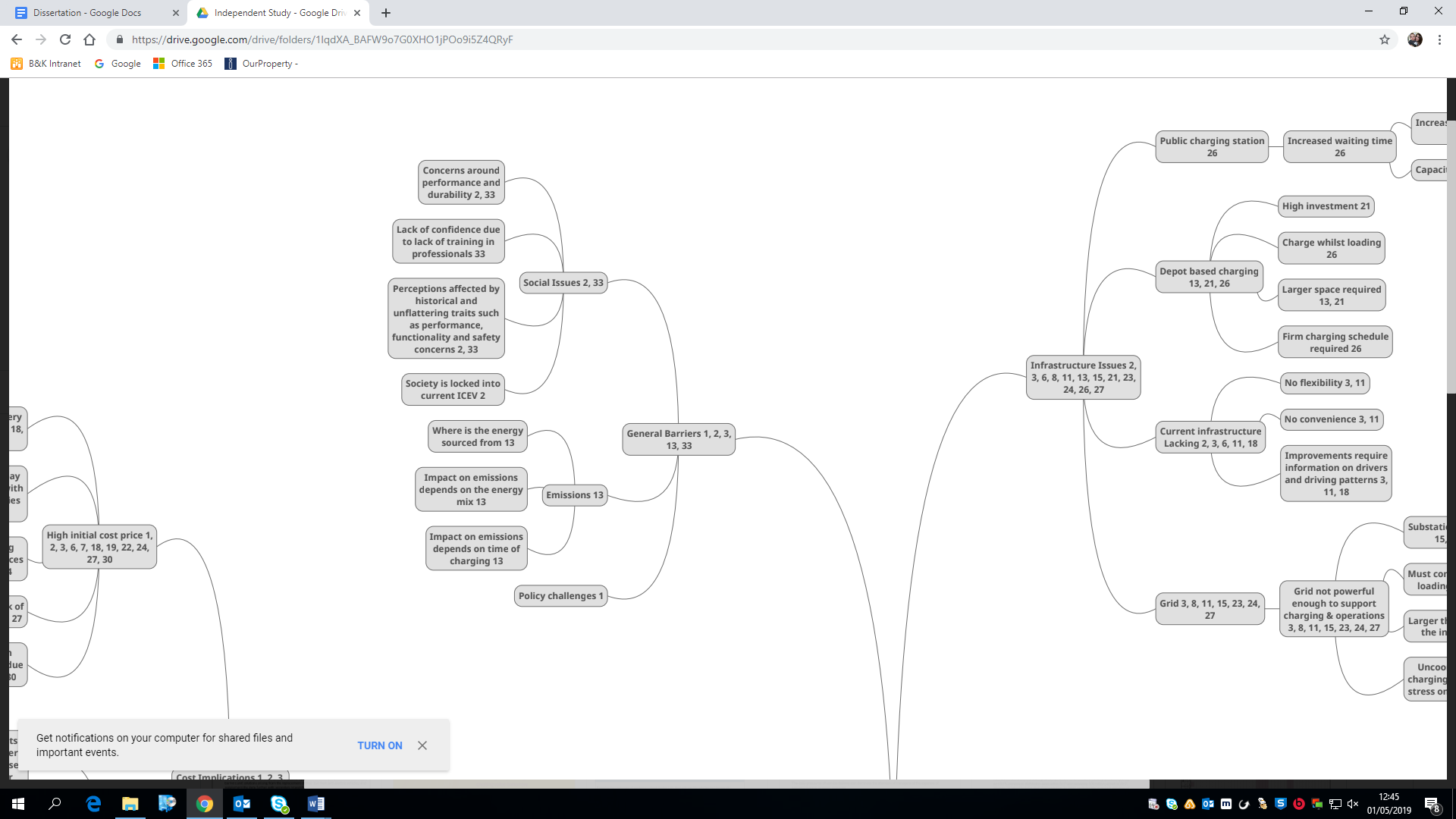
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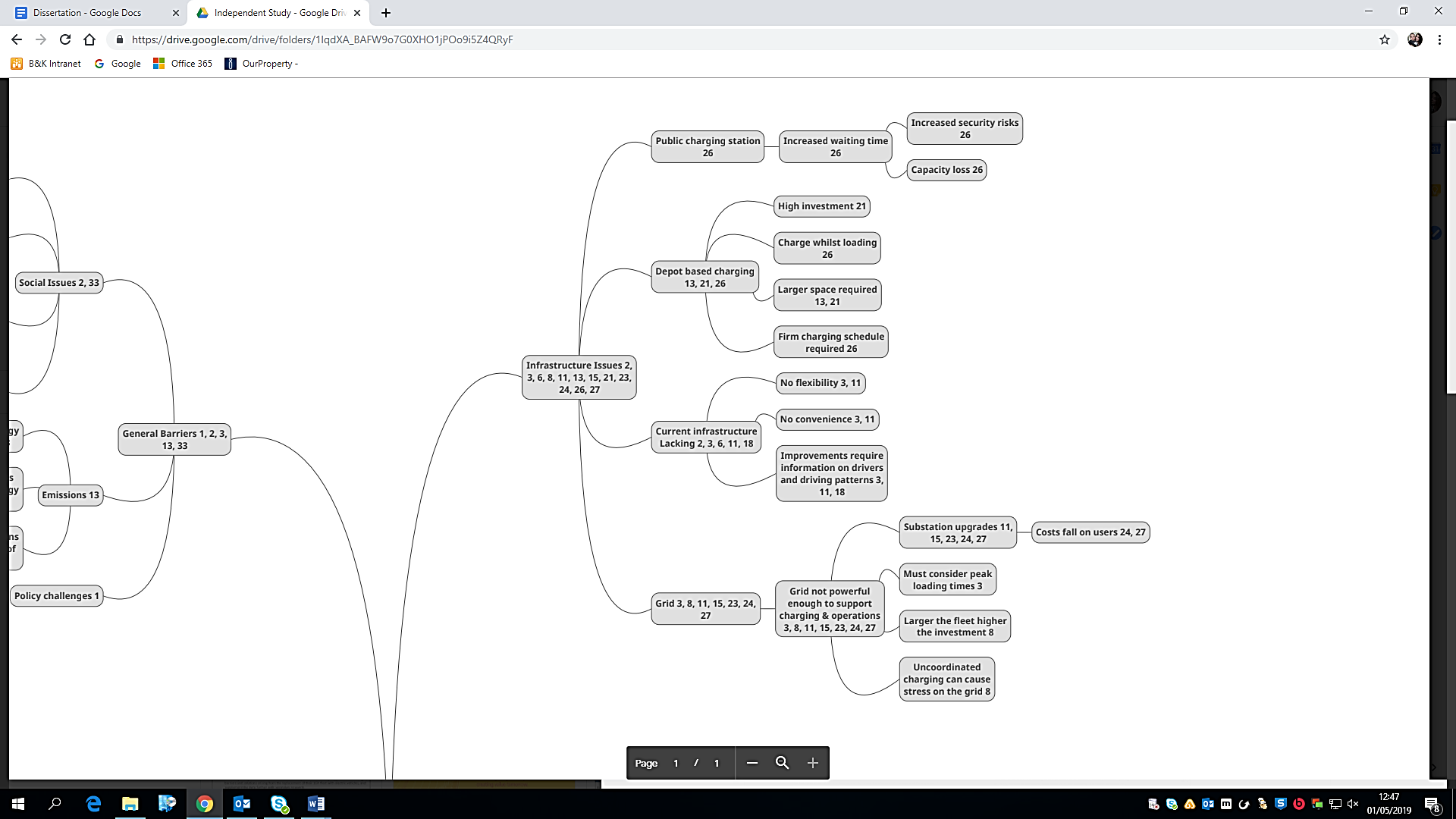
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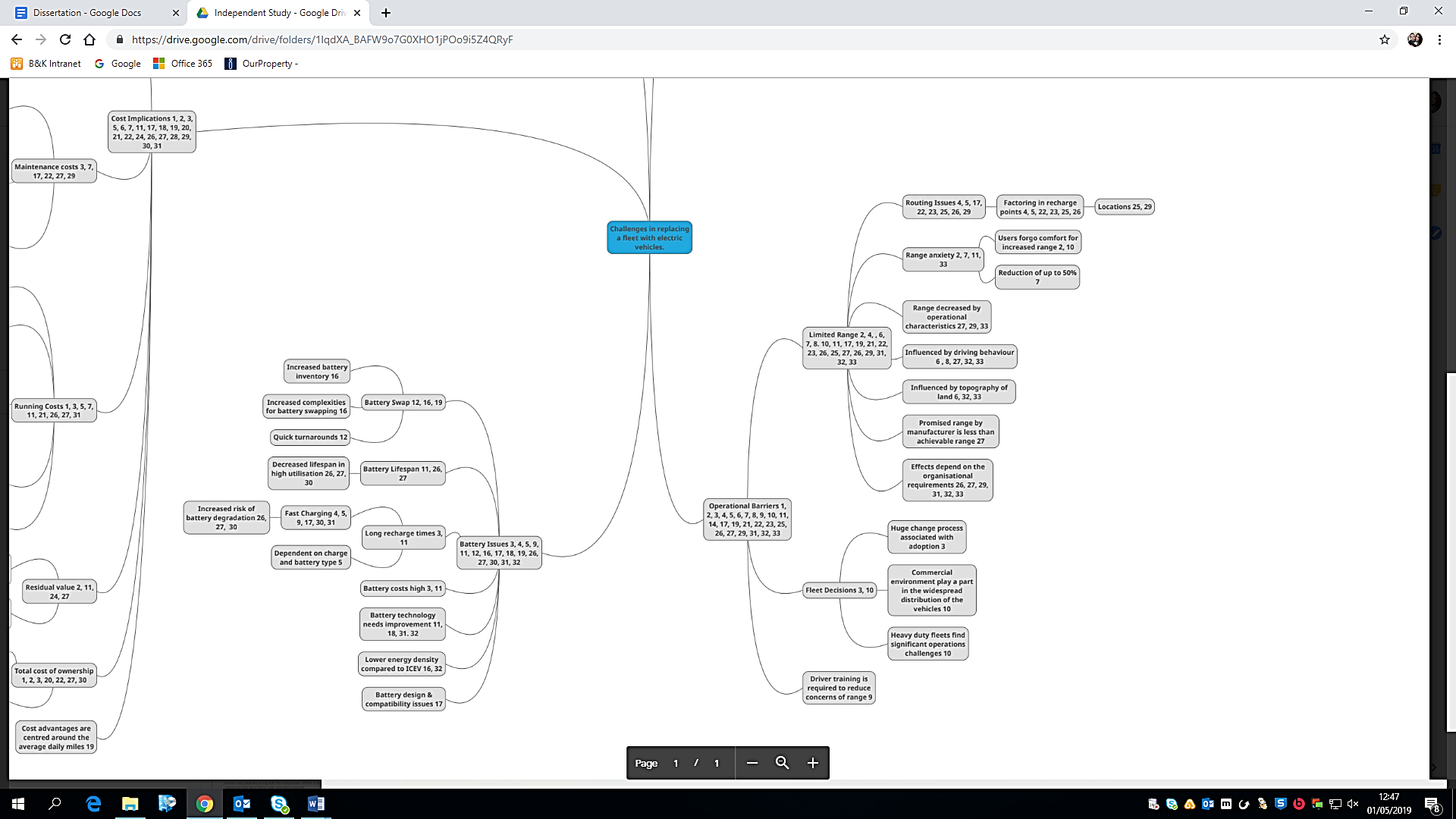
## Appendix 1



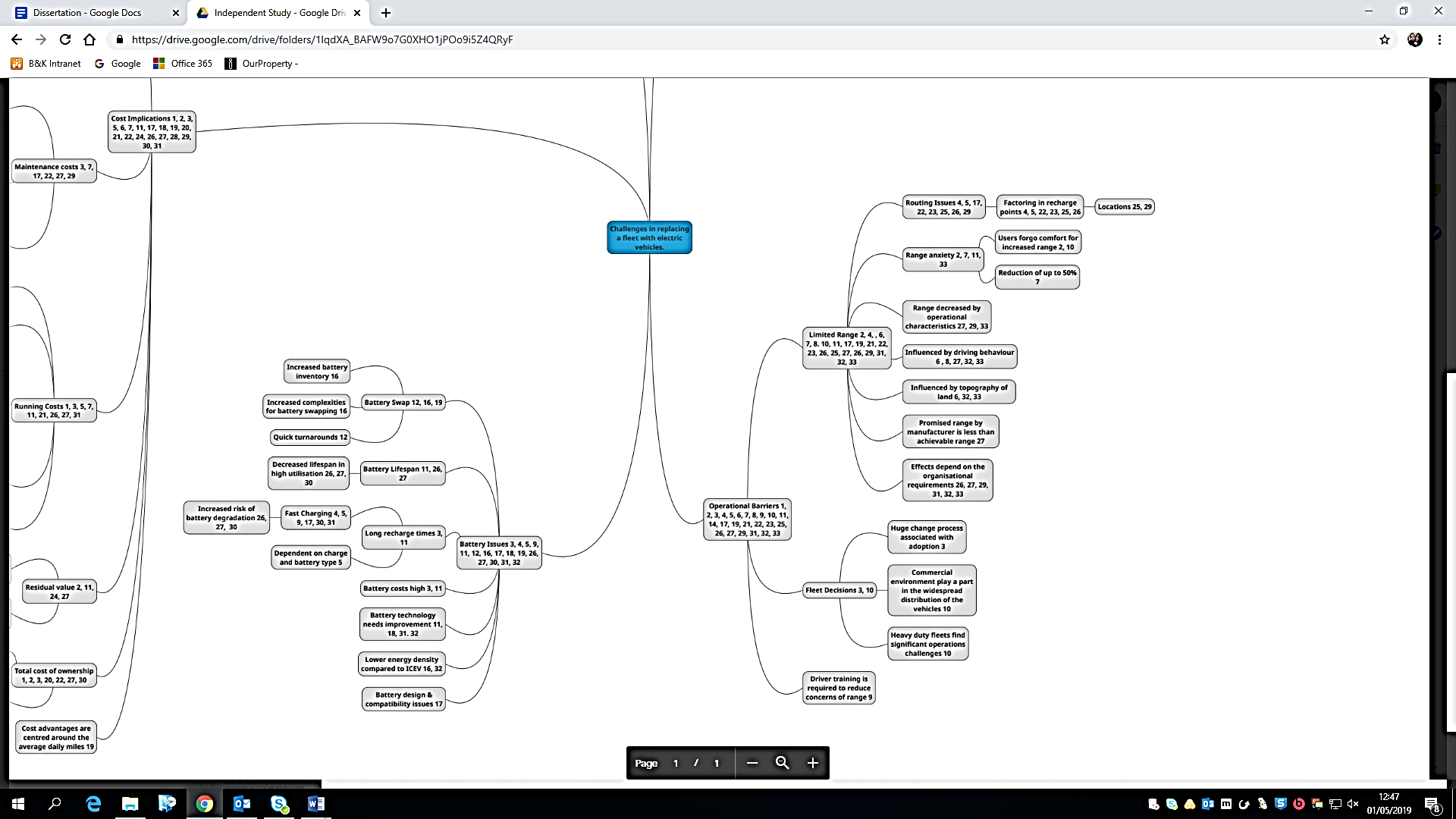
Challenges in replacing a fleet with electric vehicles



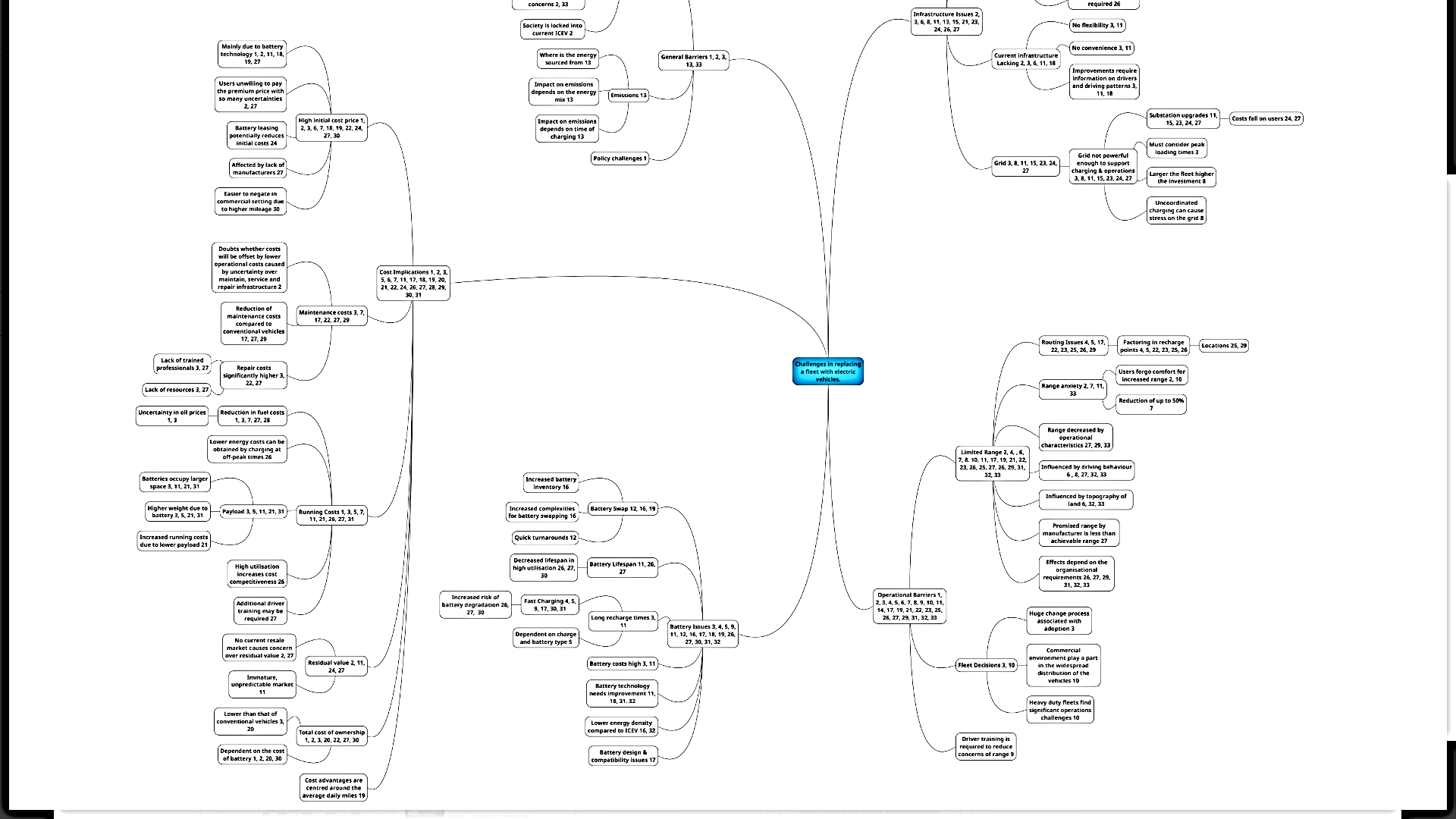
Challenges in replacing a fleet with electric vehicles



Challenges in replacing a fleet with electric vehicles



Challenges in replacing a fleet with electric vehicles



Challenges in replacing a fleet with electric vehicles

## Appendix 2

**Table 1.** Articles included in the literature review

| Article No. | Author | Year | Title | Found on: |
| --- | --- | --- | --- | --- |
| 1 | Ahani et al. | 2016 | A portfolio approach for optimal fleet replacement toward sustainable urban freight transportation | Elsevier |
| 2 | Berkeley et al. | 2017 | Assessing the transition towards Battery Electric Vehicles: A multi-Level Perspective on Drivers of, and barriers to, take up. | Elsevier |
| 3 | Biresselioglu et al. | 2018 | Electric mobility in Europe: A comprehensive review of motivators and barriers in decision making processes | Elsevier |
| 4 | Breunig et al. | 2019 | The electric two-echelon routing problem | Elsevier |
| 5 | Catay & Keskin | 2017 | The Impact of Quick Charging Stations on the Route Planning of Electric Vehicles | IEEE |
| 6 | DHL | 2018 | DHL Trend Radar 2018-2019 | DHL |
| 7 | Feng et al. | 2012 | Conventional vs electric commercial vehicle fleets: A case study of economic and technological factors affecting the competitiveness of electric commercial vehicles in the USA | Science Direct |
| 8 | Foiadelli et al. | 2017 | Electric vehicle use in public fleets: The use of the Genoa University | IEEE |
| 9 | Gebauer et al. | 2017 | Changing attitudes towards e-mobility by actively elaborating fast charging technology | Elsevier |
| 10 | Globischa et al. | 2018 | Adoption of electric vehicles in commercial fleets: Why do car pool managers campaign for BEV procurement | Elsevier |
| 11 | Haddadia et al. | 2015 | Accelerating the Global Adoption of Electric Vehicles: Barriers and Drivers | Science Direct |
| 12 | Jiea et al. | 2019 | The two-echelon capacitated electric vehicle routing problem with batter swapping stations: Formulation and efficient methodology | Elsevier |
| 13 | Kabatepe & Turkay | 2017 | A bi-criteria optimization model to analyse the impacts of electric vehicles on costs emissions | Elsevier |
| 14 | Kaplan et al. | 2016 | Intentions to introduce electric vehicles in the commercial sector: A model based on the theory of planned behaviour | Elsevier |
| 15 | Keskin & Catay | 2016 | Partial recharge strategies for the electric vehicle routing problem with time windows | Elsevier |
| 16 | Kaur et al. | 2016 | A coloured petri Net Based Frequency Support Scheme Using of Fleet of Electric vehicles in Smart Grid Environment | IEEE |
| 17 | Keskin & Catay | 2018 | A metaheuristic method for the electric vehicle routing problem with windows and fast chargers | Elsevier |
| 18 | Knupfer et al. | 2016 | Cross Impact Analysis of Vehicle-to-Grid Technologies in the Context of 2030 | IEEE |
| 19 | Kuppusamy et al. | 2017 | Electric vehicle adoption decisions in a fleet environment | Elsevier |
| 20 | Lebeau et al. | 2016 | Exploring the choice of batter electric vehicles in city logistics: A conjoint-based choice analysis | Elsevier |
| 21 | Morganti & Browne | 2018 | Technical and operational obstacles to the adoption of electric vans in France and the UK: An operator perspective | Elsevier |
| 22 | Munoz-Villamizar et al. | 2017 | Impact of the use of electric vehicles in collaborative urban transport networks: A case study | Elsevier |
| 23 | Nicolaides et al. | 2018 | Prospects for Electrification of Road Freight | IEEE |
| 24 | Noon | 2015 | Electric Dreams: Thinking Cities | Google Scholar |
| 25 | Paz et al. | 2018 | The multi-depot electric vehicle location routing problem with time windows | Growing Science |
| 26 | Pelletier et al. | 2017 | Charge Scheduling for Electric Freight Vehicles | Elsevier |
| 27 | Quack et al. | 2016 | Possibilities barriers for using electric-powered vehicles in city logistics practice | Science Direct |
| 28 | Ramroth et al. | 2013 | Assessing the Battery Cost at Which Plug-in Hybrid Medium-Duty Parcel Delivery Vehicles Become Cost-Effective | SAE International |
| 29 | Schiffer & Walther | 2018 | Strategic planning of electric logistics fleet networks: A robust location-routing approach | Elsevier |
| 30 | Schucking et al. | 2017 | Charging Strategies for economic operations of electric vehicles in commercial applications | Elsevier |
| 31 | Teoh et al. | 2016 | Methodology to evaluate the operational suitability of electromobility systems for urban logistics operations | Science Direct |
| 32 | Wikstrom et al. | 2014 | Socio-technical experiences from electric vehicle utilisation in commercial fleets | Elsevier |
| 33 | Wikstrom et al. | 2016 | An end has a start – Investigating the usage of electric vehicles in commercial fleets | Science Direct |
| 34 | Vosooghi et al. | 2020 | Shared autonomous electric vehicle service performance: Assessing the impact of charging infrastructure. | Science Direct |
| 35 | Darlington et al. | 2020 | Barriers to Electric Vehicle Adoption in Finland and How to Overcome them: An Analysis of Consumer Opinions and Perceptions. | Science Direct |
| 36 | de Mello et al. 2020 | 2017 | Electric vehicles in the last mile of urban freight transportation: A sustainability assessment of postal deliveries in Rio de Janeiro-Brazil. | Science Direct |
| 37 | Oliveira et al. | 2017 | Sustainable vehicles-based alternatives in last mile distribution of urban freight transport: A systematic literature review | Multidisciplinary Digital Publishing Institute |