Cabot Institute for the Environment

University of Bristol

Many minds, one mission

Electric vehicle policy and infrastructure approaches in Bristol

The viability of applying Oslo's adoption methods

Daniel Jones

September 2020

MSc Environmental Policy and Management

ELECTRIC VEHICLE POLICY AND INFRASTRUCTURE APPROACHES IN BRISTOL: THE VIABILITY OF APPLYING OSLO'S ADOPTION METHODS

DANIEL JONES

SEPTEMBER 2020

Word Count: 14,988

Project Supervisor: Dr Sue Rodway-Dyer

Presented as part of, and in accordance with, the requirements for the Final Degree of MSc in Environmental Policy and Management at the University of Bristol, School of Geographical Sciences, September 2020.

Author's declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Taught Postgraduate Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, this work is my own work. Work done in collaboration with, or with the assistance of others, is indicated as such. I have identified all material in this dissertation which is not my own work through appropriate referencing and acknowledgement. Where I have quoted from the work of others, I have included the source in the references/bibliography. Any views expressed in the dissertation are those of the author.

Signed: D. Jones Date: 18/09/2020

Acknowledgements

I would like to thank my supervisor, Dr Sue Rodway-Dyer, for providing fantastic advice and support. She frequently checked to see how I was doing and offered calls whenever needed. I also appreciate the GIS guidance from Dr Gemma Coxon and Edward Thomas. Finally, the negotiation of these 'unprecedented' times would not have been possible without my friends and family, offering constant kindness and encouragement.

Abstract

In this work, Oslo' electric vehicle (EV) policies and infrastructure approach are considered for replication in Bristol and compared against alternative policy and investment (P&I) Pathways.

EVs are increasingly considered an effective method for reducing emissions from urban transport. Oslo currently has by far the most advanced EV market, with 50,000 EVs in the city, owing to strong incentivisation policy and infrastructure investment. Announcing a 'Climate Emergency' in 2018, Bristol is aiming for carbon neutrality by 2030; requiring substantial decarbonisation of its transport sector. However, Bristol also envisions a "sustainable, healthy and fair" city by 2050 as part of BCC's (Bristol City Council) latest local plan.

Following a review of existing literature to highlight relevant concepts and set out this work's significance, a holistic policy analysis is conducted. Four EV P&I Pathways are compared, including Oslo's approach and Bristol's current plans, producing an outcomes matrix and 2030 projections. Next, Bristol's and Oslo's present-day EV-infrastructure characteristics are compared, identifying best practices. Using these findings, an EV-infrastructure development approach is designed for optimising scale, distribution and charger location.

It is proposed that a 'Hybrid Approach' would be most viable for Bristol. Although the complete inclusion of Oslo-style EV policy is expected to have the greatest carbon reduction potential, this is outweighed by its negative implications on Bristol's other development priorities, such as congestion and connectivity. An additional 776 charging stations would be required to support 50,000 EVs with a greater number of outlets per station and a less centralised distribution. A manual charging site selection method would best address Range Anxiety and consequently maximise EV uptake potential. The method prioritises areas of prolonged parking times, high traffic, office clusters and on-street residential parking. Owing to the novelty of EV, policy and infrastructure development must be adaptable to future uptake and technological developments.

Table of contents

List of tables

List of figures

Abbreviations

BCC:	Bristol City Council
BEV:	Battery electric vehicle
DfT:	Department for Transport
EV:	Electric vehicle
ICEV:	Internal combustion engine vehicle
P&I:	Policy and investment
PAT:	Public and active transport
V2G:	Vehicle-to-grid

1. Introduction

1.1. Environmental sustainability of urban transport systems

This work sets out to assess the potential for applying Oslo's world leading EV strategies to Bristol, consequently recommending a holistic best policy and infrastructure approach.

Locally, pollution from internal combustion engine vehicles (ICEVs) has adverse effects on human health (Buekers *et al.*, 2014; Hoek *et al.*, 2013), while contributing to climate change at a global level (Lorenzoni & Pidgeon, 2006; Woodcock *et al.*, 2009). In 2018, Bristol became the UK's first city to declare a 'climate emergency', setting itself a 2030 net carbon neutrality target (BCC, 2019a). Achieving this will require a significant reduction in GHG emissions, 25% of which come from Bristol's transport sector (BCC, 2019b). With over half of these produced from car commutes (BCC, 2019c), private vehicle emissions are the focus of this work. Outlined in Bristol's most recent local plan (BCC, 2020), Bristol's goal is 50,000 BEVs by 2030, from a nascent market of less than 1,000 today (DfT, 2018a).

As opposed to plug-in hybrids that combine an electric motor with a combustion engine, 'battery electric vehicles' (BEVs) are exclusively electric. These vehicles produce zero-emissions locally, with their greenhouse gas (GHG) emissions depending on local electricity mix (Faria *et al.*, 2012). As the technology's costs and limitations continue to reduce (Cecere *et al.*, 2018), and global investment in renewables advances (Bellocchi *et al.*, 2019), the potential for EV adoption to reduce urban transport emissions is becoming increasingly recognised. Over the last decade, EV has progressed from a fringe technology to a fast-growing component of the private vehicle market; a trend that is projected to continue over the next ten years (Cecere *et al.*, 2018; Klein *et al.*, 2018). Increasingly, governments are sending clear market signals towards vehicle electrification, through enhanced funding and the intent to ban ICEV sales (Burch & Gilchrist, 2018). Meanwhile, city leaders have been even more progressive, revealing advanced phase-out targets of their own (Lutsey *et al.*, 2018).

Referred to as the 'EV capital of the world' (Aasness & Odeck, 2015), Oslo has the world's highest number of EVs per capita (Hall & Lutsey, 2020). Of the many governments that have introduced EV-uptake policies, Norway's have been the most comprehensive, dating back to the early 1990s (Figenbaum, 2017). National tax reliefs make EVs cheap to buy at a national level, while Oslo has made ownership affordable, practical and convenient through local initiatives. Currently, there are 50,000 BEVs in the city (KlimaOslo, 2019), equivalent to Bristol's 2030 target. It was also not until the last decade that EV technology was sufficiently advanced for Oslo's mainstream adoption (Figenbaum, 2017), aligning with Bristol's proposed timescale.

In addition to incentivisation policy, the development of charging infrastructure has been identified as one of the main predictors of EV uptake (Harrison & Thiel, 2017; Sierzchula *et al.*, 2014; Slowik & Lutsey, 2017). As well as supporting existing EV user, the presence of chargers addresses what's known as 'Range Anxiety', acting to restrict uptake potential (Bonges & Lusk, 2016). This refers to the fear that charging stations are too infrequent, thus disincentivising frequent and long journeys (Bonges & Lusk, 2016). Therefore, to sufficiently instil confidence in prospective EV consumers, more charging infrastructure needs to be installed than is practically required (Melliger *et al.*, 2018).

If large-scale EV uptake is to occur in Bristol, both effective incentivisation policy and infrastructure development will be needed. But neglecting the progression of public and active transport (PAT) can have repercussions for a city's connectivity and inclusion, creating an investment trade-off. Consequently, this work considers EV for achieving 2030 carbon neutrality, while considering Bristol's specific challenges and ambitions.

1.2. Research questions and approach

Mindful of the background motivations, the following research questions form the basis of this work:

1. Could and should Oslo's EV policy approach be replicated in Bristol?
2. How do Oslo's and Bristol's EV-infrastructure characteristics currently vary?
3. Considering these outcomes, what would be the optimal infrastructure development approach for Bristol up to 2030?

This work begins by critically analysing existing literature on the status of EV technology and infrastructure, the outcomes of Oslo's approach, and Bristol's transport challenges. Next, an analysis of policy is conducted to holistically compare the viability of Oslo's approach for Bristol, against their current plans. Following that, spatial analysis contrasts Bristol's and Oslo's current EV-infrastructure to identify best-practices, before proposing a method for optimising charging locations. Finally, recommendations for a best policy and infrastructure approach are provided for Bristol up to 2030.

2. Literature Review

2.1. EV-Infrastructure context

Although home charging accommodates most EV drivers' needs, public charging infrastructure improves the proposition of EV for perspective buyers, increases travel distance potential and provides for those without home charging (Nicholas, 2019). Unlike ICEVs, the 'refuelling' time for EVs is a considerable factor, but the more compact design of charging infrastructure means it can be deployed in less conventional locations (Bonges & Lusk, 2016). Consequently, a number of factors have been proposed to optimise charger locations, addressing Range Anxiety and maximising uptake. Firstly, identifying areas of prolonged parking times can minimise additional waiting time. This has been approached directly, through the application of parking duration data (Chen *et al.*, 2013), and indirectly, via points of interest such as restaurants, shops and parks (Wagner *et al.*, 2013).

Secondly, the consideration of user convenience and existing demand have been proposed, with Andrews *et al.* (2013) determining locations through minimising travel; rapidly improving reported user convenience. Clearly, charger distribution is important, but generally increasing their abundance will also reduce average travel distances (Nicholas, 2019). Additionally, addressing demand, urban traffic data can be included to represent charging demand (Choi *et al.*, 2020). Further to location efficiency, social welfare has been integrated into site selection (He *et al.*,2013). This study addresses the potential for social exclusion, owing to premium EV prices (Davis, 2019a; Vassileva & Campillo, 2017). Eisel *et al.* (2015) have produced a model combining a number of these factors, but not accounting for a city's individual challenges and requirements.

Charging time depends on the station's power output, of which there is a trade-off with installation cost (*Table 1*). This results in context-dependent decision-making, with more powerful chargers selected where fast charging times are required (Hall & Lutsey, 2017). In the UK, Level 1 chargers are typically only used for home and workplace charging (Zapmap, 2020), taking advantage of all night and day parking (Lee *et al.*, 2020). Level 2 chargers are the more typically public chargers, producing moderate speeds (Zapmap, 2020), while DC rapid chargers tend to have only commercial function due to their high expense and grid power outlay (Wolbertus & Van den Hoed, 2019). Although investment in less advanced technology increases the risk of technological 'lock-in' (Figenbaum, 2017), DC technology is projected to remain unprofitable until EV adoption rates become much higher (Schroeder & Traber, 2012; Burnham *et al.*, 2017).

Table 1: Charger types and characteristics (Hall & Lutsey, 2017; Zapmap, 2020).

Charging type	Typical power (kW)	Typical Price (£)	Charging speed (to 90%)
Level 1 (slow)	1.2 - 1.8	250 - 750	6 - 12 hours
Level 2 (fast)	3.6 - 22	1,500 - 2,000	2 - 4 hours
DC (rapid)	50 - 350	50,000 +	15 - 40 minutes

Public installation has become considerably cheaper in Europe over the past decade, with Amsterdam's Level 2 chargers reducing from €12,000 to €2,000 between 2009 and 2017 (Hall & Lutsey, 2017), a trend that is expected to continue across Europe and the UK over the next decade (Rogers & Nelder, 2019). Additionally, there are a number of methods for reducing costs further, such as more outlets per station; multiple stations in close proximity; and pre-install identification of local electrical capacity (*ibid*). In this work, 'station' refers to a single charging location, often comprising of multiple 'outlets'.

To date, EV-infrastructure has been largely government-funded, without the expectation of profits (Lutsey *et al.*, 2018). However, as EV shifts towards the mainstream, governments are increasingly interested in commercial sustainability (Lutsey *et al.*, 2018). There have been a number of methods proposed to achieve this, such as selling electricity at a mark-up to users, basing the business case on increased retail sales at charge points and introducing advertising revenue (Hall & Lutsey, 2017; Nicholas & Tal, 2017). The progression from low penetration rates to commercial sustainability is referred to as the 'chicken-and-egg' problem, considered one of the most intractable barriers to success during EV's infancy (Romm, 2006; Van Bree, 2010). This is the paradox whereby the building of charging stations depends on the number of EVs, but potential users are reluctant to purchase an EV due to insufficient charging infrastructure.

However, Delacrétaz *et al.* (2020)'s more recent analysis of Norwegian empirical evidence concluded that an early investment in infrastructure is needed as a first mover, in turn creating private sector business opportunities and revenues over time. This supports findings that charging infrastructure is often the best predictor of national EV market share (Harrison & Thiel, 2017; Sierzchula *et al.*, 2014; Slowik & Lutsey, 2017). The omission of unobserved factors such as environmental attitude and governmental policy (Li *et al.*, 2017) in this study produces some uncertainty. The additional exclusion of feedback effects means resultant uptake from early investment could be even greater than predicted.

The optimum number of chargers required for EV success is not universally accepted, with EV-to-charger ratio suggestions ranging from seven (Cooper & Schefter, 2017) to over twenty (CEC & NREL, 2017; Wood *et al.*, 2017). Oslo maintained a ratio of ten during their early adoption, aligning with the European Parliament's (2014) recommendations. However, during the city's rapid EV expansion in the last few years, this ratio has increased to twenty-four- resulting in considerable supply-demand problems (Hall & Lutsey, 2020). Despite the importance of infrastructure, the Netherlands have installed an equivalent number of chargers per capita as Norway, but uptake has been much lower (Hall & Lutsey, 2017). Consequently, the next section discusses the influence of policy in Norway's and Oslo's EV penetration success.

2.2. Oslo's EV approach

Consumer incentives play a fundamental role in making the near-term purchase of EVs more affordable, as technology develops and production transitions to higher volumes (Lutsey *et al.*, 2018). As outlined in *Table 2*, Norway makes EVs cheap to buy while Oslo makes them affordable, practical and convenient to own. Direct incentives in the form tax exemption are implemented at a national scale, of which Norway has the highest level in Europe (Tietge *et al.*, 2016). Locally, Oslo provides additional charging infrastructure, access to transit lanes, reduced parking costs for EV users and the introduction of an EV-only congestion zone. Although this work investigates Oslo's approach, Norway's national support must also be considered for a comprehensive understanding of the city's success.

Norway's especially high vehicle purchase tax, adding 50-150% of the car's price, makes BEVs cheaper to buy than the average medium-sized ICEV (Fridstrøm & Østli, 2017). The consequent policies, incrementally introduced since 1990, are rooted in laws and regulations set by the Norwegian Ministry of Finance and Ministry of Transportation (Holtsmark & Skonhoft, 2014). Although these policies didn't largely yield results until the development of lithium ion battery EVs in 2010, their longevity and security instilled confidence in the market (Figenbaum, 2017). This long-term support signalling has been identified as one of the key components of Norway's successful policy design (Tietge *et al.*, 2016).

Disproportionally benefitting from national policy, Oslo has a high traffic €4 'toll ring' (Grundt, 2016), along with the highest number of cars in Norway to take advantage of parking subsidies (Hall & Lutsey, 2017). This BEV ownership convenience is furthered by local-level access to bus lanes and the new congestion zone. Additionally, ongoing municipal funding for EV-infrastructure has doubled the national density average (Tietge *et al.*, 2016). This includes private charger funding, expanding coverage into apartment complexes and shopping malls (*ibid*). Beyond the consumer-facing incentives, Oslo has also introduced ways to raise EV awareness. This includes the electrification of the municipal's 1,000-car fleet in 2015 and European collaboration via the Electric Vehicles in Urban Europe (EVUE) project to support knowledge exchange (Oslo Kommune, 2013).

Table 2: Norway and Oslo EV-uptake policies, currencies are converted and rounded (Oslo Kommune, 2013; 2016; 2019; Tietge *et al.*, 2016).

Support type	Norway: national level	Oslo: local level
Regulatory incentives	By 2020: 85 g/kmCO2 emissions for new cars.	–
Direct incentives	Purchase tax exemption. VAT exemption. Reduced company car tax.	–
Indirect incentives	Toll charge exemption. Reduced ferry rates. Free municipal parking (terminated for 34 major municipalities since 2017).	Bus lane access. ICEV Congestion zone (2018). Continuation of subsidised municipal parking from 2017.
Charger funding	Slow charger funding 2009-2010: ~£11 million. Fast charger funding 2013: ~£650,000. Ongoing fast charger funding.	EV charger funding 2008-2011: ~£350,000 p/y. Increasing municipal EV charger funding since. 60% private charger subsidy.
Other	120-140 g/kmCO2 emission cap for government vehicles. Transnova utility company research support.	Completely electric municipal fleet by end of 2015. EV awareness schemes.

Oslo's BEV sales share of 43% is considerably higher than other EV leaders, such as 14% in Beijing and 7% in Amsterdam (Hall & Lutsey, 2020). The previously described policies have been identified as the drivers of this success (Rietmann & Lieven, 2019), particularly with adjacent Sweden and Denmark experiencing substantially lower uptake (Holtsmark & Skonhoft, 2014). Through analysing Europe's largest EV markets, Hannisdahl *et al.* (2013) and Tietge *et al.* (2016) both concluded that strong levels of national direct incentives are likely the most important driver of EV uptake, but are insufficient without the additional implementation of local indirect incentives. Within Norway, Mersky *et al.* (2016) found access to charging infrastructure, proximity to major cities and regional income to have the highest predictive power.

Oslo's policy approach has drawn praise and criticism, both in relation to the policies and the resultant EV market. The literature's contested perspectives on the approach are therefore discussed next.

2.3. Perspectives on Oslo's approach

First are the economic benefits for EV consumers. Savings from fuel, parking and toll costs in Oslo are estimated at £2,900 per year for EV users in Oslo (Aasness & Odeck, 2015). Including the initial tax savings on the purchase of the vehicle, subsidies and exemptions are estimated to save the average Nissan Leaf owner £6,200 annually over ten years (Holtsmark & Skonhoft, 2014). Consequently, the cost barrier to EV uptake is addressed at the lower end, while the average consumer has access to more premium vehicles (Figenbaum *et al.*, 2014).

Despite this, its rapidly growing EV market means these incentives are becoming increasingly costly for both government and municipality. Norway's road toll exemptions alone were calculated at £2.4 million in 2012, projected at £86 million for 2020 (Aasness & Odeck, 2015). The cost of tax exemptions has also been criticised, with alternative investment into PAT proposed to address social welfare and congestion issues (Holtsmark & Skonhoft, 2014; Wangsness *et al.*, 2020). But previously identified as the primary driver of EV uptake, removal of this policy could significantly impact EV uptake. This presents a trade-off between EV investment and alternative forms of sustainable urban transport. Although this trade-off is lessened in Norway due to the extortionate purchase tax that ICEV users continue to pay (Figenbaum *et al.*, 2014), other countries would likely need to redirect existing funding.

EV policies are also criticised for encouraging increasing car use (Holtsmark & Skonhoft, 2014). This undermines the role of PAT, centred around the shift away from private transport; referred to as 'Mobility as a Service' (Jittrapirom, 2017). Additionally, EV access to Oslo's bus lanes, congestion zone and cheaper city parking has further increased congestion as the market has developed (Aasness & Odeck, 2015). Known as the 'second-car-problem', ICEVs are often kept alongside an ICEV to ease Range Anxiety (Holtsmark & Skonhoft, 2014; Klöckner *et al.*, 2013). Behaviour analysis has found that EVs are typically used for daily commuting, but ICEVs are used for long trips and vacations (Klöckner *et al.*, 2013).

But since establishing a mature EV market, Oslo's transport focus has been directed towards Mobility as a Service. In 2019, Oslo released the 'The Car-free Livability Programme' (Oslo Kommune, 2019), outlining ambitions to decrease private vehicle use and better accommodate cyclists and public transport. This is alongside planning to make all public transport electric by 2028, taking advantage of the EV market and infrastructure. Oslo has demonstrated the adaptability of its policies, altering EV bus lane access to require two passengers (Oslo Kommune, 2019). The second-car-problem has not been completely overcome, but EV range and infrastructure improvements have diluted it in Oslo more recently (Davis, 2019b; Oslo Kommune, 2019).

This work proposes EV uptake as a method for transport decarbonisation. But an EV's per-mile GHG emissions are dependent on electricity mix (Casals *et al.*, 2016; Fernández, 2018), a factor that varies significantly from country to country (IEA, 2018a). Norway's electricity mix consists of 96% hydropower (IEA, 2018b), resulting in only 8 gCO2/kWh emissions compared with the OECD (2019) average of 432 g/kWh. Consequently, driving a BEV in Oslo emits almost no GHGs (Viola & Longo, 2017). Conversely, in areas where coal dominates electricity consumption, such as China at 60-70% (IEA, 2020b), BEVs perform worse than ICEVs. By 2040, BEVs are projected to have a 45-78% lower impact on climate change than today (Cox *et al.*, 2018). Electricity mix is the largest source of variability, requiring careful local consideration when investigating its potential (*ibid*).

Owing to the energy intensity of battery manufacturing, EV production is considerably more GHG-intensive, having implications on a city's indirect (Scope 3) emissions (Sharma *et al.*, 2013; Tagliaferria *et al.*, 2016). However, this contributes to a relatively small proportion of the total lifecycle (Hawkins *et al.*, 2013; Tagliaferria *et al.*, 2016) and material recycling has the capacity to offset these emissions by 34% (Hao *et al.*, 2017). With most European countries- including the UK- currently substantially decarbonising their energy mix, investment into EV uptake today will benefit from cleaner electricity production in the future (Jochem *et al.*, 2015).

2.3. EVs in Bristol

Table 3 summarises this work's position in the literature. As presented so far, EV technology and infrastructure development, along with Oslo's world-leading market, are well-researched. Overall, the potential to reduce carbon emissions and pollution versus future uncertainties and societal compromises has caused a split between the advocation of Oslo's approach. Less researched is the application of this approach to specific cities, along with consequent implications on charging infrastructure development. Also, with most previous urban case studies limited to the world's most globally influential cities, Bristol-centric research is particularly sparse.

Table 3: This work's position in existing literature.

Theme	Existing research	Research gap	References
Replication of Norway's and Oslo's approach elsewhere	General replication of approach elsewhere. Projected impact of EV development in a particular city.	Replication in context of Bristol's resources, challenges and ambitions. Direct comparison between projections for differing levels of EV P&I in Bristol.	Aasness & Odeck, 2015; Ajanovic & Haas, 2016; Bellocchi *et al.*, 2019; Casals *et al.* 2016; Figenbaum, 2017; Figenbaum *et al.*, 2014; Fridstrøm & Østli, 2017; Holtsmark & Skonhoft, 2014; Mersky *et al.*, 2016; Sierzchula *et al.*, 2014; Tietge *et al.*, 2016.
Urban EV-infrastructure design	Theoretical guides for optimal urban infrastructure development. Proposition of criteria for selecting charger locations, both generally and in specific cities.	Proposition of practical infrastructure development plan for Bristol. Selection and application of charger location criteria, specific to Bristol's challenges and requirements.	Bonges & Lusk, 2016; Chen *et al.*, 2013; Choi *et al.*, 2020; Csonka & Csiszá, 2017; Delacrétaz *et al.*, 2020; Hall & Lutsey, 2017; 2020, He *et al.*, 2013; Helmus & van den Hoed, 2016; Morrissey *et al.*, 2016; Nelder & Rogers, 2019; Straka *et al.*, 2019; Wolbertus & van den Hoed, 2019; Xi *et al.*, 2013.

Bristol and Oslo are comparable in terms of population, area and the number of vehicles within the city (*Table 4*). Consequently, both cities face congestion issues, with Bristol identified as the UK's most congested city (Paddeu, 2017) and Oslo recently developing a plan to reduce car use (Oslo Kommune, 2019). This comparability enables the scale of Oslo's EV strategies to be realistically considered for Bristol. The key difference, and the premise to this work, is the fifty-times more BEVs in Oslo. The 70% contrast between average income should also be considered, due to the recognised barrier of vehicle affordability to EV adoption (Davis 2019a; Vassileva & Campillo, 2017). This barrier is reducing as EVs become cheaper though, with uptake expected to become decreasingly exclusive to typically wealthy, well-educated, environmentally conscious 'pioneering' EV consumers over the next decade (Axsen *et al.*, 2016).

Table 4: Characteristic comparisons between the cities of Oslo and Bristol (DfT, 2017; 2018a; Eurostat, 2020; Grønn Bil, 2015; PayScale, 2020a; 2020b).

	Population	Area (km^2)	Average income (£)	Number of vehicles	Number of BEVs
City of Oslo	680,000	145	51,000	275,000	50,000
City of Bristol	540,000	112	30,000	226,000	<1,000

Unlike Norway, the UK has not implemented severe policies to make EVs more affordable. Currently the Office for Low Emission Vehicles (OLEV) offers a £3,000 grant for EVs under £50,000, alongside £350 (~75%) towards Level 1 home chargers (GOV.UK, n.d.). In 2016, the government announced the Go Ultra Low Cities scheme, awarding £40 million across Bristol and the UK's other most sustainable cities, in an attempt to create international ultralow-emission pioneers (Go Ultra Low, 2016). EV sales in the UK are growing, but from a low base (IEA, 2020a). Of the 150,000 cars sold in January 2020, 2.7% were BEVs; compared with 44% in Norway (*ibid*).

The UK's decision to bring its non-BEV vehicle sale ban from 2040 to 2035 (GOV.UK, 2020) remains ten years behind Norway, but will undoubtedly require a significant increase in supporting infrastructure. The Department for Transport (2018) has proposed an additional 83% public chargers on the current 14,000 over the next two decades to keep up with expected UK demand. Other research has suggested existing EV-infrastructure is sufficient for current demand and market response will adjust appropriately into the future (Morrissey *et al.*, 2016; Wolbertus & Van den Hoed, 2019).

The One City Plan is Bristol's latest local plan, setting out how the city will become "*fair, healthy and sustainable*" by 2050 (BCC, 2020, p12). The 2030 carbon neutrality target is incorporated into the plan's transport goals, including the progression of their EV market. This includes a comprehensive charging network by 2024, with 120 new outlets currently being rolled out, and for BEVs to make up 50% of cars 2026 (BCC, 2020). Furthermore, as part of Bristol's Climate Emergency declaration, the mayor announced a goal of 50,000 EVs by 2030 (BCC, 2019a), matching what Oslo achieved over the previous decade. Despite this ambitious target, Bristol's One City plan (BCC, 2020) and Transport Strategy (BCC, 2019c) put a much greater emphasis on the progression of PAT. Moreover, the EV plans are not developed and presented as holistically as in other literature, such as case studies or policy reports (Ajanovic & Haas, 2016; Hall & Lutsey, 2020).

2.5. Summary

From a review of the wider literature, this work incorporates a broad range of contributing information across multiple sectors and scales. This review establishes areas of literature that need to be developed, while also providing the key themes integrated into the following methodology and consequent discussion. This ensures the proposed Bristol approach is both holistic and considerate of Bristol's localised concerns.

3. Methodology

To best address the research questions, two methods are employed. Firstly, an analysis of policy is conducted, to investigate a range of EV P&I Pathways for Bristol, including Oslo's approach. Secondly, spatial analysis compares Bristol and Oslo's current EV network, before proposing a best approach for Bristol to develop their charging infrastructure towards 2030. These two methods function together, applying the actions identified in the policy analysis to practical implementation on a spatial level. This combines qualitative and quantitative perspectives, providing a more comprehensive and holistic approach to the research questions (Sui & DeLyser, 2012).

3.1. Policy analysis

Policy analysis describes present and future policy impacts, combining relevant existing information with facts and assumptions (Manski, 2019). Its purpose is to overcome complex alternatives based on predetermined criteria, to assist policymakers in making more effective policy decisions to overcome problems and accomplish goals (Walker, 2000). This work's approach to analysing policy takes a more scientific stance, based on Bardach's (2012) Eightfold Path method. Due to this work's objectives and resource limitations, Bardach's 'Policy Analysis' methodology is not definitively followed. Instead, the process is adapted to best fit the requirements of this study, maintaining the core concepts and structure (*Figure 1*). The overarching purpose of this policy analysis is to establish the optimal course for EV in Bristol, compared to Oslo's approach over the last ten years and Bristol's current plan.

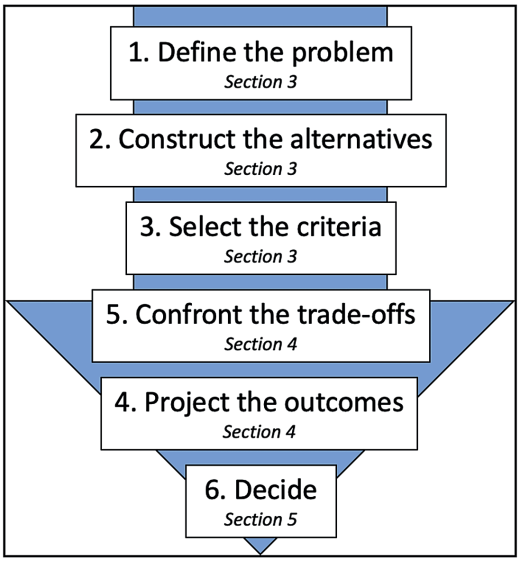

Figure 1: This work's policy analysis stages, adapted from Bardach (2012).

Currently, transport contributes to 25% of Bristol's total GHG emissions (BCC, 2019b). Achieving 2030 carbon neutrality will therefore require a significant decarbonisation of this sector (BCC, 2019c), consequently defining the problem as:

Bristol's current transport sector is not in line with its 2030 carbon neutrality target.

Next, four alternative Pathways are constructed, presenting different levels of EV P&I for Bristol between now and 2030 (*Figure 2*). Pathway 1 introduces all of Oslo's local EV incentivisation policies (*Table 2*), and a high increase in investment. Due to price reductions since Oslo's uptake (Hall & Lutsey, 2020) and unpredictable market feedback effects (Sakamoto *et al.*, 2016), the precise calculation of required funding is beyond the scope of this study. As a broad interpretation, Oslo spends 12 million NK (~£1 million) on chargers every year (Oslo Kommune, 2019), whereas Bristol has committed only £2 million up to 2030 so far (BCC, 2019a). At £200,000 per year, this suggests a substantial increase in EV investment would be required to match Oslo's approach.

Pathway 2 introduces EV bus lanes access, an ICEV congestion zone and a moderate funding increase, but not subsidised parking. This particular omission is made for two reasons. Firstly, access to bus lanes has been identified as a significantly more influencing factor for EV uptake in Oslo than free parking (Bjerkan *et al.*, 2016). Secondly, free parking costed Oslo 12 million NK (£~1 million) per year, hence why other Norwegian cities ceased this incentive in 2017 and Oslo eventually introduced a reduced fee in 2019 (Deuten *et al.*, 2020). Next, Pathway 3 represents Bristol's current EV plans, with no additional EV policies currently being introduced. Finally, Pathway 4 ceases all EV plans, relying on the natural market.

Despite numerous streams of funding, including new sources through devolution and the establishment of the West of England Combined Authority (BCC, 2019c), Bristol's transport strategy declares that "additional sources of funding will be needed to deliver and maintain the proposals in this strategy" (BCC, 2019c, p36). So, with no

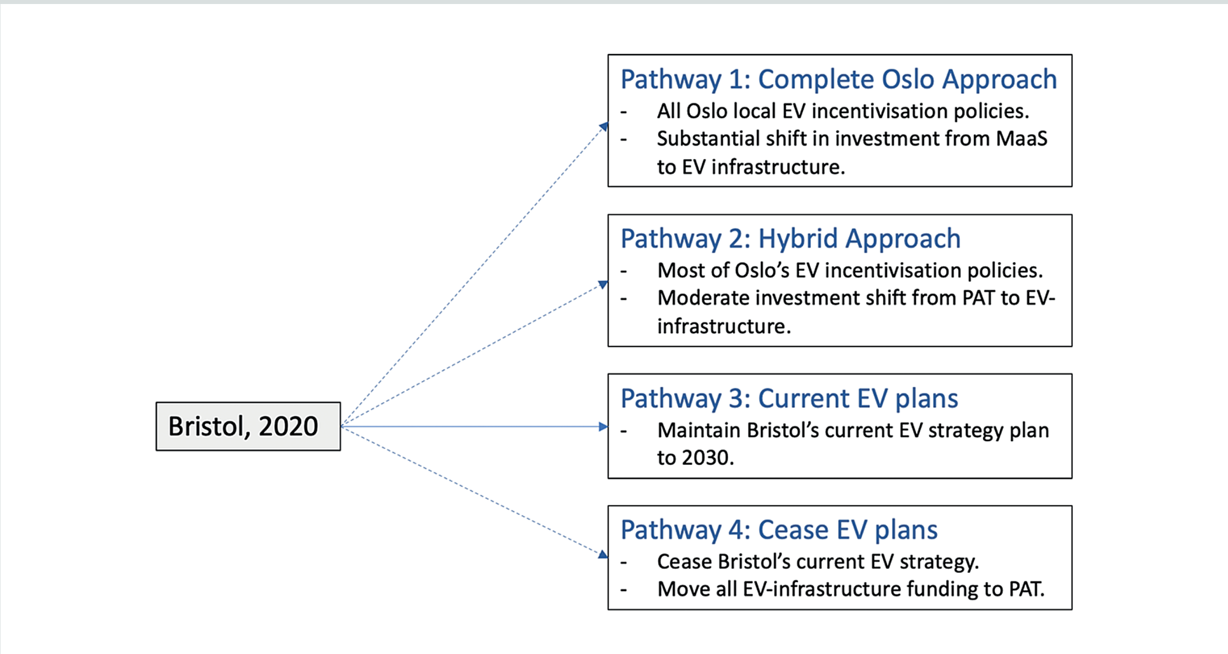

Figure 2: The four EV P&I Pathways compared for Bristol up to 2030.

spare funding currently available, this analysis will assume additional EV investment under Pathways 1 and 2 would be redirected from PAT development, outlined as Bristol's transport priorities (BCC, 2019c, 2020b).

Next, an outcomes matrix breaks the Pathways down into expected performance for eight relevant criteria, acting to simplify uncertainties and complexities (Bardach & Patashnik, 2019; Dunn, 2015). A performance score of 1-4 (low-high) is given to each criterion under each Pathway, while a weighting scale of 1-3 (least-most important) prevents less important factors from having as much impact on the outcome (Bardach & Patashnik, 2019; Emrouznejad *et al.*, 2010). Due to their subjective nature, justifications are provided for each criteria and weighting in *Table 5*. Each matrix score is then multiplied by the criterion weighting and summed across all criteria, providing a final performance score for each Pathway. The weighting values are specific to Bristol, meaning the scores are tailored to the city's specific requirements.

BCC's relevant documents and plans inform the process, directed by the literature review and the Oslo case study. The performance of each criteria is analysed, before the 2030 Pathway outcomes are projected.

Table 5: Policy analysis assessment criteria, with justified weightings.

Criteria	Weighting	Criteria selection and weighting justification
Carbon reduction potential	3	Addressing the problem defined, this is the single most important factor.
Local emission reduction potential	2	Reducing local pollution has been highlighted by BCC as a priority. Health concerns have been raised and Clean Air Zones have been considered to address the problem (BCC, 2019c).
Congestion reduction potential	2	Bristol is one of the UK's most congested cities (Paddeu, 2017) and addressing this problem is one of the key objectives in BCC's (2019a) transport plan.
Minimal barriers to implementation	2	More serious technology- and city-specific barriers can make an option significantly less viable. However, adaptive and considerate policy can often overcome smaller barriers (Rietveld & Stough, 2005).
Inclusiveness to entire city	2	The Mayor of Bristol outlines the importance of the city's transport system developing for everyone, ensuring "no one is left behind" (BCC, 2019c, p2).
Political acceptance and public image	2	Appealing to local council, national government and the public increases the ease and feasibility of policy implementation (Rietveld & Stough, 2005). But political and public palatability is irrelevant if the policy does not effectively reduce carbon emissions.
Potential for co-benefits	1	Secondary benefits can enhance effectiveness, while joined-up policies tend to be more successful (Cook *et al.*, 2012).
Affordability of implementation and maintenance	1	Although cost benefit should be discussed with BCC's limited budget, Bristol's commitment to 2030 carbon neutrality was made despite its inevitable costliness (BCC, 2020). Additionally, this analysis only considers existing funding availability.

3.2. Spatial analysis

The Bristol study site is established by the local authority boundary (*Figure 3a*). As Oslo's area of local authority extends beyond the city to rural regions of the municipality, Google Maps' urban land area classification is used to select the Oslo study site (*Figure 3b*). The small islands beyond Oslo's coastline are also omitted due to a lack of car access.

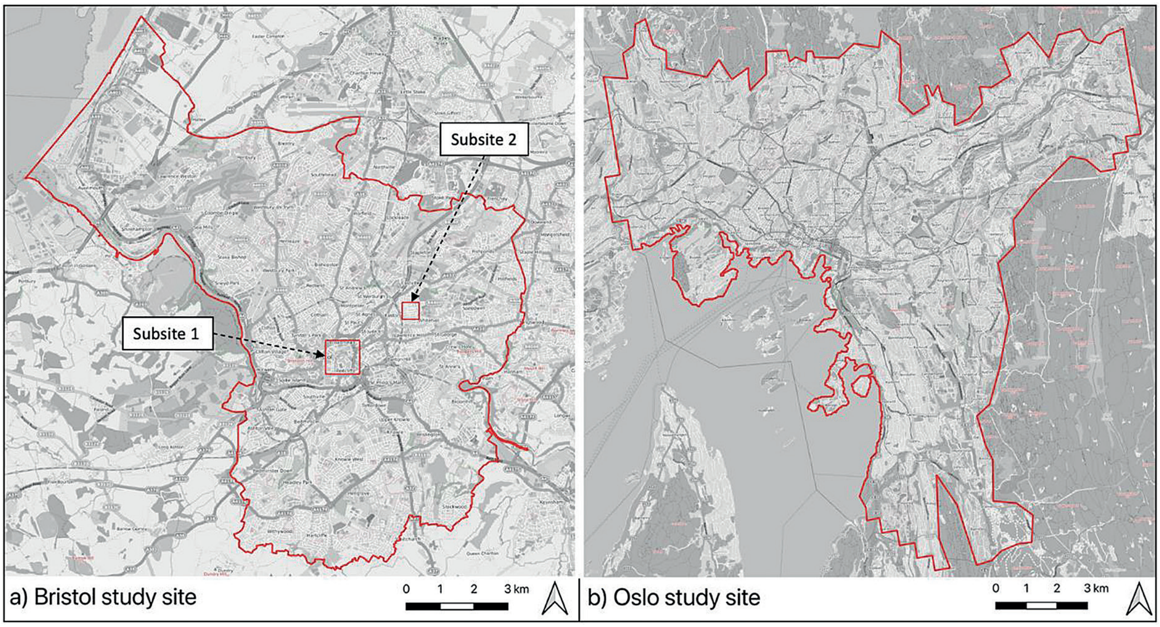

Figure 3: Oslo and Bristol study sites, including Bristol Subsites.

Firstly, side-by-side maps of charging stations in Oslo and Bristol compare their current coverage and distribution. The data is downloaded from Open Charge Map's API (OCM, 2020a). Open Charge Map is a non-profit, non-commercial data service, hosted and supported by a collaboration of global businesses, charities and developers (OCM, 2020b), as used for other recent EV analyses (Morlock *et al.*, 2020; Zeng *et al.*, 2020). Data is updated continuously, meaning this analysis is up to date as of the 8th June 2020. 'Heatmaps' are overlayed, interpolating the charging station vector data to visualise the point density. A 500m radius is found most appropriate for the data scale and the application of consistent continuous class thresholds between both maps ensures accurate comparison. Created only for a visual comparison, a heatmap density scale of 'low-to-high' provides greater clarity than quantitative values (Eghteabs *et al.*, 2017).

Introducing quantitative comparisons, individual station 'characteristics' data from within the OCM vector files are analysed. Along with the spatial information, this data is used to calculate and compare the average and maximum number of outlets per station; the number of stations and outlets per km2; the average distance between stations; and the proportion of Level 1 and Level 2 stations. Due to missing data for Bristol's number of outlets (56% missing) and Oslo's charger type (70% missing), estimations are made based on the data available. These characteristic differences provide an insight into aspects of Oslo's successful EV-infrastructure that can consequently be applied to Bristol's 2030 best approach.

This best approach is based on what BCC have set out to achieve, Oslo's best practices, and techniques highlighted from the literature. Firstly, the required scale of infrastructure is calculated and mapped. This process is formed around BCC's goal of 50,000 EVs by 2030, using the European Parliament's (2014) EV to charger outlet ratio of ten. As a best practice guide, Oslo's previously calculated outlet per station ratio is then used to determine the number of stations.

For mapping this result, two distribution patterns are presented for comparison. Firstly, Bristol's current distribution is upscaled, implying where demand has previously been identified. Due to the positive relationship between city centre proximity and distribution density, at three observable step changes, the site is split into three concentric segments (*Figure 4a*). The resultant proportion of stations per segment is then measured and upscaled for the proposed of 2030 locations. This process is repeated for Oslo's mature infrastructure distribution pattern, adjusting the segment sizes proportionally to the larger site area (*Figure 4b*). Finally, the calculated points per segment are randomly plotted, presenting the scale of Bristol's EV-infrastructure required for 2030, along with how this distribution would vary between the upscaling of both cities' current charging layouts.

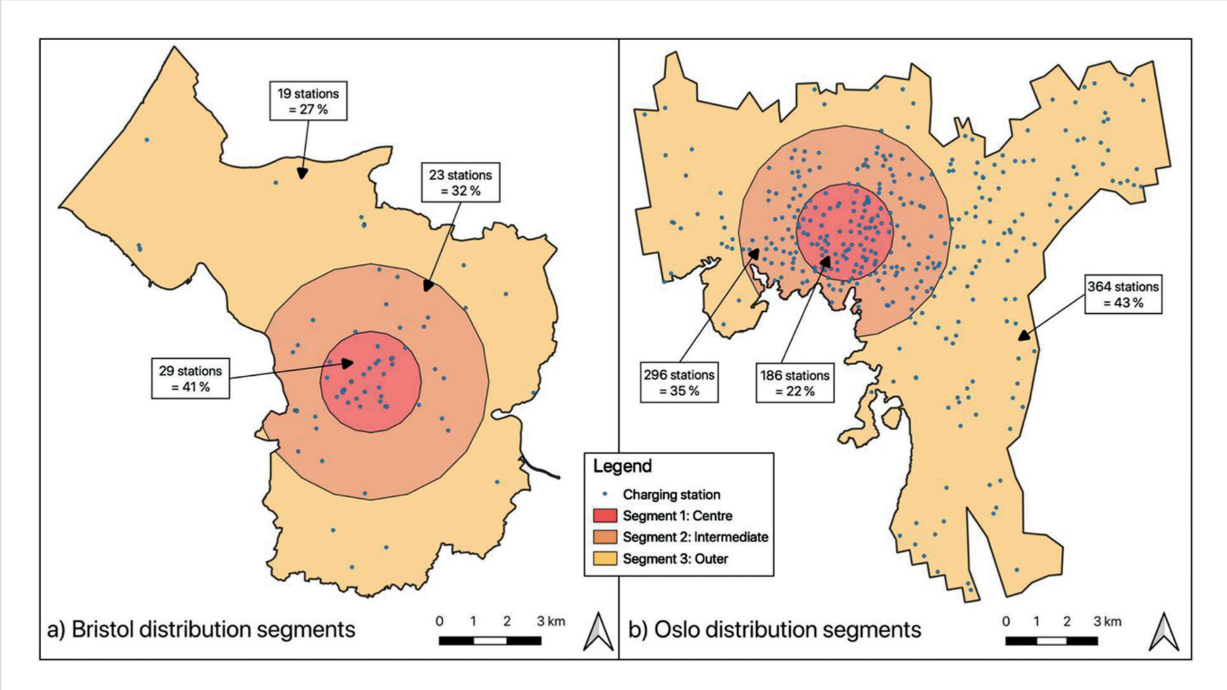

Figure 4: Distribution segments for Bristol and Oslo, with resultant charger proportions.

Following this, an approach for selecting individual station locations is proposed. Charging infrastructure has previously been identified as a primary predictor of EV uptake, the optimisation of which minimises consumer Range Anxiety (Section 2.1). Similar to Eisel *et al.* (2015), this method considers multiple factors for a best approach. Building on this, Bristol's individual challenges and requirements are also integrated into the choice of factors, while commercial and residential areas are separated to address their differing charging requirements. To demonstrate the process, six site selections are exampled across a 1000 m2 city centre subset and a 500m2 residential subset (*Figure 3a*). All associated data is downloaded from Open Data Bristol (ODB, 2020), with Google Maps providing satellite imagery.

3.3. Limitations

It is acknowledged that through this work's efforts to provide a holistic approach, it has not been possible to apply quantitative analysis to every contributing factor. Moreover, its intentional breadth means that some technical aspects of EV are not covered comprehensively. As referred to throughout, a number of estimations and generalisations are made to produce results within this work's scope. However, as opposed to estimating exact outcomes, this work instead aims to holistically consider Bristol's options. Due to the qualitative nature of the policy analysis, there is a level of author subjectivity present; enhanced by the inclusion of criteria weighting (Johnsen & Løkke, 2013). Nonetheless, the author attempts to minimise potential biases through a heavily evidence-based approach. Additionally, through addressing Bristol's specific challenges and ambitions, some of this work's recommendations and projections may not be applicable elsewhere; owing to the unique spatial and non-spatial nature of individual cities. It is finally acknowledged that, due to the rate of development of both EV technology and market functions, elements of this work will undoubtably become outdated and be superseded between now and 2030.

4. Results and analysis

4.1. Policy analysis

4.1.1. Matrix scores

As shown in *Table 6*, the Hybrid Approach achieves the highest outcomes matrix score by six points, scoring below '3' for only one criterion. Second is the Complete Oslo Approach, scoring a '4' in two of the criteria, but relatively poorly in the others. Bristol's current plan is a further point behind, leaving the cessation of these plans as the lowest scoring by nine points. The following sections justify the scoring process, combining the analysis of Bristol's policy documents with lessons learned from Oslo.

Table 6: Outcomes matrix for each criterion under the four EV P&I Pathways. Colours visually represent scoring and total is weighted using *Table 5*.

	Policy and Investment Pathway			
Criteria (weighting)	**1. Complete Oslo Approach**	**2. Hybrid Approach**	**3. Current EV plans**	**4. Cease EV plans**
Carbon reduction potential (3)	4	3	2	1
Local emission reduction potential (2)	4	3	2	2
Congestion reduction potential (2)	2	3	3	4
Minimal barriers to implementation (2)	2	4	3	3
City-wide inclusiveness (2)	1	2	3	2
Political/ public acceptance (2)	2	3	2	1
Potential for co-benefits (1)	2	3	3	1
Affordability of implementation (1)	3	3	2	1
Total weighted score	**39**	**45**	**38**	**29**

4.1.2. Carbon, local emission and congestion reduction potential

Future electricity mix and transport behaviour create uncertainty for each Pathway's carbon reduction potential. For Bristol, achieving 2030 carbon neutrality is heavily reliant on a shift to clean energy production, setting a goal of energy and transport carbon neutrality by 2025 (BCC, 2020). Due to projected population growth, the proportion of Bristol's commutes made by car would have to reduce 10% by 2036 to prevent an increase in congestion (BCC, 2019c). Achieving this, car journeys would still contribute to almost half of commutes, meaning decarbonisation of private transport would remain a priority. Consequently, the establishment of a developed EV market has a high decarbonisation potential, while the cessation of EV plans neglects these emissions.

Considering local pollution, EVs produce no exhaust emissions regardless of electricity mix. Additionally, the introduction of an Oslo-style ICEV congestion zone in Pathways 1 and 2 would reduce emissions in the city centre. Owing to the higher journey efficiency of public transport (Kwan & Hashim, 2016) and zero-emissions from active transport, a PAT modal shift also has potential. With the undermining of this shift highlighted as one of urban EV's main criticisms (Holtsmark & Skonhoft, 2014; Wangsness *et al.*, 2020), the Pathways perform oppositely for addressing congestion. This is one of Bristol's main transport challenges (BCC, 2019c; 2020) and encouraging additional car use would likely have significant repercussions on efficiency; hindering BCC's (2020, p12) 'connectivity' vision. This would be exacerbated by EV transit lane access under Pathways 1 and 2 and subsidised EV parking under Pathway 1, as both experienced in Oslo (Aasness & Odeck, 2015). Despite this, the introduction of an ICEV congestion zone has the potential to reduce central congestion in the short term, but this effect would decline with increasing EV adoption.

4.1.3. Barriers to implementation, inclusiveness and political/public acceptance

Norway's relief on an exorbitant purchase tax is considered the most influential incentive for Oslo's rate of adoption (Hannisdahl *et al.*, 2013; Tietge *et al.*, 2016). Consequently, the UK's comparatively insignificant EV purchase subsidies lead to a sizeable barrier to Bristol equivalently replicating Oslo's uptake. But due to their discrete nature, incrementally installing charging stations is easier than designing complex PAT networks (Hall & Lutsey, 2017). BCC acknowledge this, highlighting the challenging space restrictions in the dense and congested city centre (BCC, 2019c).

Due to premium vehicle prices, EV is criticised for excluding lower-income residents (Davis 2019a; Vassileva & Campillo, 2017). BCC recognise the EV uptake bias towards affluent, middle aged, well-educated males

(Go Ultra West, 2016). This group is categorised by the DfT (2015) as 'Educated suburban families', of which Bristol has a 10% higher proportion than the national average (Go Ultra West, 2016). However, a public consultation revealed existing dissatisfaction towards the 'reliability' and 'convenience' of Bristol's public transport (BCC, 2019d). Therefore, those that cannot afford an EV may be excluded without improvements to these networks.

This transport consultation (BCC, 2019d) also included fifty-five comments requesting the expansion of EV-infrastructure, implying public backing. Politically, as the leaders of the climate emergency, committing to an ambitious carbon neutrality target (BCC, 2020), it would be advantageous to select the most decarbonising Pathway. Likewise, ceasing all EV plans would appear negative towards sustainable development and innovation. Conversely, over-investment in EV investment risks public and political controversy, particularly in relation to criticisms of Oslo's approach (Section 2.3) and the uncertainties surrounding an emerging technology.

4.1.4. Potential for co-benefits and affordability

EV-infrastructure and vehicle uptake both have the potential to produce co-benefits for Bristol. Firstly, Oslo has demonstrated that establishing infrastructure can later accommodate the goal of electrifying public transport, through sharing of charging points and a sufficient grid capacity (Oslo Kommune, 2019). Secondly, Bristol's existing 'wealth of experience' with Smart Grid projects accommodates the development of vehicle-to-grid (V2G) systems (Go Ultra Low West, 2015, p17). This would support the development of renewables in the city (Noel *et al.* 2018), a fundamental component of Bristol's 2030 target (BCC, 2019a). The source diversity in Bristol's renewables plan- incorporating solar, wind and biomass (BCC, n.d.)- means EVs would also improve fuel diversification and stability (Sierzchula *et al.*, 2012). Public transport can also have co-benefits, such as less road accidents (Kwan & Hasham, 2016) and the aforementioned movement efficiency from decongestion. Active transport presents health benefits, while both create the opportunity to pedestrianize the city centre for a better living experience (BCC, 2019c).

Presently, UK installation of a Level 2 fast charger costs between £1,500 and £2,000 (Zapmap, 2020). Taking an average of these values, supporting 50,000 EVs (BCC, 2020) at ten charge points per vehicle (European Parliament, 2014), a total cost of £8,750,000 is calculated. Meanwhile, a 'mass transit system' in Bristol is estimated at up to £4bn (BCC, 2019c), making EV a much more affordable large-scale option. Despite this, BCC are also planning smaller, more affordable PAT schemes such as the MetroBus Rapid Transport network, the MetroWest suburban rail scheme and Cycle Ambition Fund programmes (BCC, 2019c). The only policy that would directly incur costs for BCC is Pathway 1's cheaper EV parking, consequently diminishing this revenue stream and decreasing affordability.

4.1.5. 2030 outcome projections

From these findings, *Figure 5* presents outcome summaries for the four Pathways.

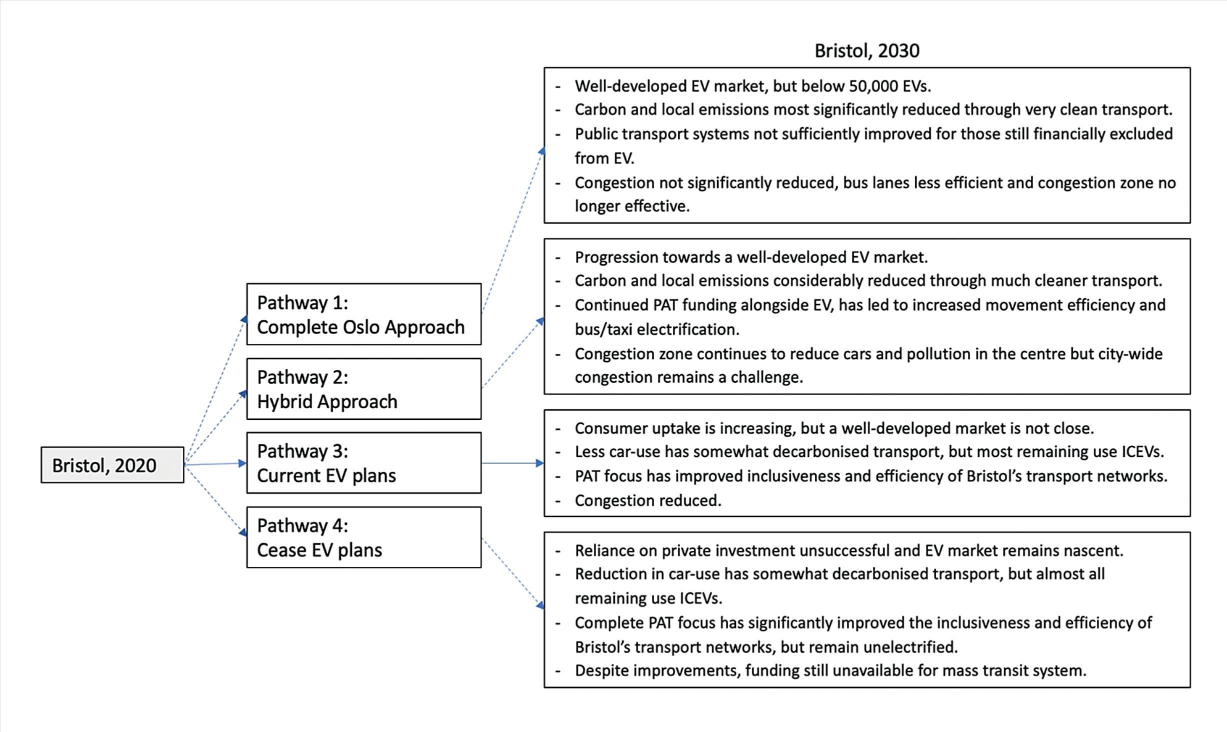

Figure 5: 2030 outcome projections for the four EV P&I Pathways.

4.2. Spatial analysis

4.2.1. Oslo-Bristol comparison

As shown in *Figure 6*, Oslo's charging network (6b) is far more developed than Bristol's (6a), at 358 stations compared with 71. Both have the highest density in the city centre, but this is much more pronounced for Bristol with the area of highest density contained within a 2km2 area. This is over three-times smaller than Oslo's central concentration, leaving the outskirts disproportionally much sparser.

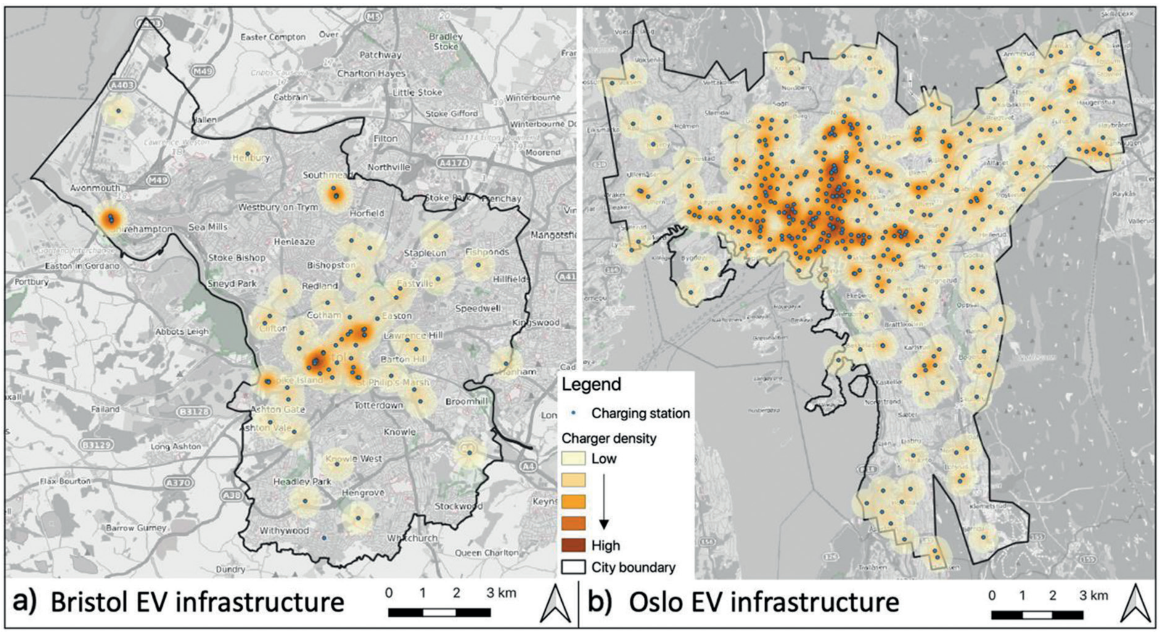

Figure 6: Present day EV charging stations mapped for Bristol and Oslo. Data from OCM (2020a).

Table 7 compares the cities' charging characteristics. With 287 more charging stations across a comparatively sized study site, Oslo's average station density is four-times larger than Bristol's, at 2.5 per km2. This means the average distance between chargers is 200m shorter. Oslo averages around double the number of outlets per station, resulting in ten-times the number of outlets in the city. Furthermore, Oslo's largest station has 86 outlets, compared with Bristol's 14. As a result, the difference between Oslo's and Bristol's charging capacity is greater than just the number of stations, with 14.5 outlets per km2 in Oslo compared with 2 per km2 in Bristol. Despite this, Bristol's proportion of Level 2 fast chargers is 30% greater than in Oslo, with only 10% of its stations providing slow Level 1 charging.

Table 7: Quantitative charging data comparison between Bristol and Oslo. Produced from the OCM (2020a) data. *value estimation due to missing data.

Variable	Oslo Site	Bristol Site
Size (km^2)	145	112
Number of charging stations	358	71
Station density (stations/km^2)	2.47	0.62
Av. (mean) distance between stations (m)	297	494
Number of outlets	2099	220*
Outlet density (outlets/km^2)	14.5	2.0*
Av. (mean) outlets per station	5.9	3.1
Max outlets per station	86	14
% Level 1 stations	38*	10
% Level 2 stations	59*	89

4.2.2. 2030 scale and distribution

Figure 7 presents the calculated scale of 847 charging stations required for 50,000 EVs in Bristol, using Bristol's (*7a*) and Oslo's (*7b*) upscaled distributions. This is twelve-times greater than Bristol's number of stations today (*Figure 6a*), as well as disproportionally more outlets, and more than double the scale of Oslo's current network (*Figure 6b*). Due to Bristol's more centralised distribution (*Figure 6*), *Figure 7a* allocates 347 of these stations to the city centre, leaving parts of the outskirts relatively sparse. In comparison, the upscaling of Oslo's less centralised distribution (*Figure 7b*) maintains high density in the city centre, while also producing clusters of higher density across the rest of the city. Next, the individual site selection examples for Subsites 1 and 2 are presented.

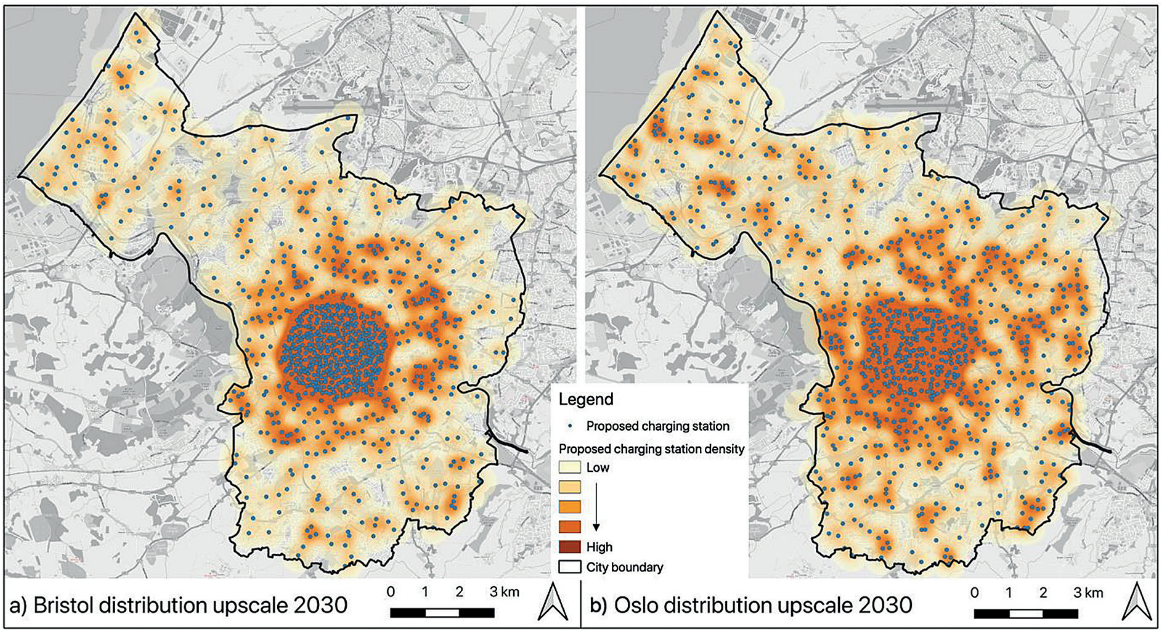

Figure 7: Proposed scale of charging stations required for supporting 50,000 EVs in Bristol, upscaling Bristol's (6a) and Oslo's (6b) current distribution patterns.

4.2.3. Charger site selection

Figure 8 examples the proposed charger site selection method for Bristol's city centre (8a) and residential areas (8b), to maximise EV uptake. To ensure sufficient space and improve building efficiency, particularly for the higher number of outlets per station, all three city centre locations take advantage of existing car parks. Firstly, the northern-most station is located between Castle Park and Broadmead shopping district, both expected to induce prolonged parking times. As this parking time is a couple of hours rather than all day or night, Level 1 slow charging would be inappropriate. Next, the south-eastern location is selected due to its proximity to A and B roads, presenting access and creating demand, while adjacent green space provides a pleasant waiting area. Similarly, Level 2 charging would be needed here to minimise this wait time. Thirdly, the south-western station is located in Queen Square, home to a number of large offices including KPMG and Stone King LLP. Therefore, this location is aimed at full-day workplace charging, requiring only Level 1 charging speeds.

For residential charging, points of interest and traffic density are less relevant. Instead, access to off-street parking is the primary consideration (Hall & Lutsey, 2017). Satellite imagery reveals that this subsite contains predominantly terrace housing without driveways, meaning installation of public chargers here would be beneficial. For parts of Bristol where the majority of houses are identified to have off-street parking or garages, installations can be less prioritised to best direct resources. As home charging is typically performed over-night (Morrissey *et al.*, 2016), Level 1 chargers would be appropriate in residential areas. Finally, to maximise coverage, the spacing between proposed chargers is considered for both Subsites.

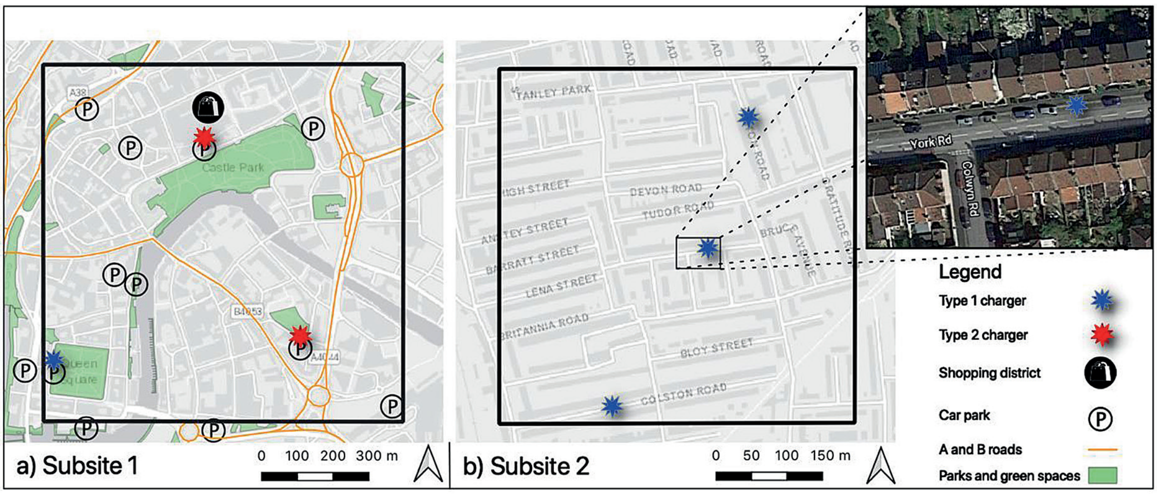

Figure 8: Example charger location selections in Bristol's city centre (7a) and the residential area of Easton (7b). Number of stations not representative.

5. Discussion

Following from analysis of the Pathway trade-offs, outcome projections and charging infrastructure development, this section seeks to discuss these findings in terms of a best approach for Bristol 2030. The discussion is formed around the research questions, informing recommendations for the future of EV in Bristol. These recommendations combine the policy and spatial analyses for a comprehensive approach.

With regard to Bristol's 2030 carbon neutrality target, the primary consideration in this work's analysis of policy, EV is expected to decarbonise the city's transport sector. Currently, local road transport accounts for a third of Bristol's direct emissions, having reduced only 7% since 2005 (BCC, 2019a). Clearly, more severe intervention is required. Private transport in Bristol, currently dominated by ICEVs, contributes to more than half of daily commuting emissions (BCC, 2019a). Despite BCC's (2019c; 2020) objective to reduce the number of cars on Bristol's roads, the UK's car traffic is forecast to grow between 11% and 43% between 2015 and 2050 (DfT, 2018b). It is therefore likely that Bristol's private transport emissions will remain a challenge if ICEVs are not removed. But a trade-off emerges, in the form of transport decarbonisation versus functionality in the city. As well as achieving carbon neutrality, Bristol's mayor envisions a transport system that is "empowering and caring", "fair and inclusive", "well-connected" and improves resident "wellbeing" (BCC, 2019c, p2). These visions are integrated into the following discussion and policy recommendations.

5.1. Applying Oslo's EV approach to Bristol

This section addresses the first research question, using results from the policy analysis. Firstly, the 'could' is discussed, considering whether Oslo's methods are capable of producing the same uptake in Bristol. Following this, is a discussion of the 'should', assessing whether this method would be the most appropriate transport approach for Bristol.

5.1.1. 'Could?'

Bristol is selected as a potential site for adopting these methods due to comparable area and population sizes. This means that the adopted scale of policy and infrastructure would be similar, with Bristol's goal of 50,000 EVs matching Oslo's current count. Like Oslo, Bristol has recently been named European Green Capital, proving its "commitment to further environmental and sustainable development" (Environmental Commission, 2020, p1). Less comparable is average income, at 70% higher in Oslo. Due to the high capital cost of EVs, consumer affordability is considered one of the primary barriers to large-scale uptake (Davis 2019a; Vassileva & Campillo, 2017). As a result, this barrier to adoption will be considerably higher in Bristol. This compounds what is perhaps Oslo's most significant advantage, Norway's national-level direct incentivisation policy. As concluded to be the most influential factor (Hannisdahl *et al.*, 2013; Tietge *et al.*, 2016), the subsidised cost of EVs in Norway makes their purchase much more economical. So, for Bristol to expect an Oslo-equivalent rate of uptake over the next ten years, a similar level of national subsidy would likely be required. Although predicting the feasibility of this is beyond this work's scope, the UK's much lower vehicle purchase tax- already excluded for BEVs- means that the subsidy would need to be funded from elsewhere.

Nevertheless, Bristol will have the advantage of an extra ten years of EV development. European nations have seen the cost of roadside Level 2 chargers reduce by 80% over the last decade (Hall & Lutsey, 2017), making large-scale infrastructure deployment more realistic within BCC's limited budget. Meanwhile, the greater establishment of this technology has reduced the investment uncertainty that was prevalent ten years ago (Fairley, 2010; Situ, 2009). Vehicle uptake access is also expected to increase, progressing from the wealthy, well-educated EV 'pioneers', towards less demographically focussed consumption (Axsen *et al.*, 2016). Consequently, development of an EV market in Bristol over the next decade will likely be more cost effective, politically palatable and publicly accessible.

On balance, the Complete Oslo Approach Pathway is projected to produce a well-developed EV market in Bristol by 2030 but achieving BCC's target of 50,000 vehicles by this date is unlikely.

5.1.2. 'Should?'

As outlined in the literature review (Section 2), existing research is divided on whether Oslo's and Norway's strong EV policy approach, and resultant mass-uptake, should be replicated elsewhere. For the first time, this work's analysis of policy applies this question to Bristol, considering the city's specific challenges and ambitions. Despite the potential barriers to applying the approach to Bristol, the higher outcomes matrix scoring of the two Oslo-inspired Pathways than the current EV plan implies net benefits from an enhanced EV focus. Meanwhile, the prospect of ceasing all EV investment scores by far the lowest, neglecting to address private vehicle emissions, and can therefore be dismissed.

The policy analysis highlights a selection of positive projections for a 2030 Bristol under Oslo-style P&I (Pathways 1 and 2). Most crucially the increased EV uptake is expected to have the largest carbon reduction potential, best addressing the initial problem. But this potential depends on how successfully Bristol can simultaneously decarbonise its electricity mix. Along with the goal for 50,000 EVs, BCC estimate that a 200% increase in local renewable energy production will be required to achieve 2030 carbon neutrality (BCC, 2019a). A Regen (2019) report, commissioned by BCC to assess the practicalities of this target, comments that the necessary solar photovoltaic growth required to achieve this would be 'extremely challenging' (p40) and that Bristol will continue to be a net importer of electricity across all scenarios (p39). BCC acknowledge that the city will need to rely on surrounding areas and the 'wider UK energy supply system' to generate its clean, renewable electricity (BCC, 2019a, paragraph 67).

This considered, under the UK's 2019 electricity carbon intensity of ~150 g CO2/kWh the lifetime emissions of a Nissan Leaf is already three-times lower than the average ICEV, 'paying back' its higher production emissions after two years (Carbon Brief, 2019). Through the continued national development of renewable sources, the Department for Business, Energy and Industrial Strategy (2019) project a UK carbon intensity of 80 g/kWh by 2030, further reducing to 41 g/kWh by 2035. Although this is still a way off Oslo's 8 g/kWh, it is far lower than today's OECD average of 432 g/kWh (OECD, 2019). Consequently, EV travel in Bristol will have a considerably greater decarbonisation effect by 2030, continuing to increase into the longer-term.

As well as carbon savings, the application of Oslo-style EV policy to Bristol is projected to have other benefits towards Bristol's transport vision. Due to zero exhaust emissions, local air quality would be significantly improved in 2030. In turn, the 300 premature deaths annually resulting from poor air quality in Bristol would be reduced, while improving quality of life for asthma sufferers (BCC, 2019c; Buekers *et al.*, 2014; Sustrans, 2016). Furthermore, cleaner air feeds back to encouraging increased active transport, supporting Bristol's vision of 'healthy, active, sustainable transport' (BCC, 2020, p12). Despite this, an EV-uptake focus mostly undermines Bristol's aim for a modal shift away from private vehicle use (BCC, 2019c, 2020).

Although lessening as the technology becomes cheaper, the high capital cost of EVs without Norwegian-style national subsidies means that affordability will remain a significant barrier to adoption in Bristol. In turn, the minimal investment into improving PAT networks under the Complete Oslo Approach will exclude those that do not have access to EV, neglecting Bristol's aim for a 'fair and inclusive' transport system (BCC, 2019c, p2). The undermining of a modal shift away from private journeys also fails to address congestion, highlighted as one of BCC's primary challenges. Moreover, as demonstrated in Oslo, EV transit lane access can result in their congestion; further hindering the improvement of public transport systems (Aasness & Odeck, 2015).

As well as incentivising EV uptake, the introduction of an ICEV congestion zone is expected to offset this congestion in the short term, compounding its local emissions co-benefit to make active transport in the city centre more appealing. In the longer-term however, its effectiveness will decrease as the number of EVs in the city rises. Congestion charging has been criticised for disproportionately affecting low income groups through pricing them off the road, further undermining BCC's fair transport vision (Eliasson, 2016; Kristoffersson *et al.*, 2017). Also, the exclusion of less wealthy groups from EV-uptake, and therefore free access to the zone, would likely accentuate this effect. To address this, the income generated by the congestion zone could be reinvested into improving alternative transport systems in more deprived areas of the city. In London, all of the congestion zone's £1.7bn revenue generated since its introduction in 2003 has been put towards improving other forms of transport infrastructure (TfL, 2017).

Named one of six European 'Cities of Innovation' last year and instigator of the UK's Climate Emergency movement (BCC, 2018b; 2019a), Bristol has proved itself as an ambitious and progressive city. EV development presents new opportunities for both public and private investment for such a city, capitalising on a new type of infrastructure and a market projected to grow significantly in the coming decades (Cecere *et al.*, 2018; Klein *et al.*, 2018). This investment can in turn create further opportunities. For example, Oslo's well-established EV-infrastructure has enabled the target to electrify their entire public transport network by 2028 (Oslo Kommune, 2019). Additionally, the previously discussed benefits of developing cleaner electricity for improving EV decarbonisation potential functions in both directions. With Bristol's Smart Grid network expected to further develop over the next decade (Go Ultra West, 2016), the integration of V2G as a form of storage and distribution will improve the reliability of renewable sources (Noel *et al.* 2018). This would then feed back into the ability of EV uptake to reduce Bristol's transport emissions, creating a 'positive feedback loop' (Ford, 2010). This loop is reinforced by the greater fuel security from electricity, owing to Bristol's diverse renewable investment plan (BCC, n.d.).

All considered, the application of a complete Oslo-style EV approach to Bristol is expected to significantly progress the city towards its 2030 carbon neutrality target, at the expense of other transport development priorities. Scoring higher in the policy analysis outcomes matrix, the Hybrid Approach offers a more considerate Pathway. Despite a lower decarbonisation potential, the more balanced policy approach has fewer barriers to implementation and fewer repercussions on the city's congestion, inclusivity and acceptance. This is firstly through a more compromising redirection of BCC's transport funds towards EV, also continuing to develop other forms of sustainable transport in the city. Furthermore, this Pathway's omission of Oslo's EV parking subsidy means this revenue stream is not lost and, therefore, less funding needs to be redirected from PAT development. This saving is particularly significant for Bristol, with the fourth highest parking earnings of any council outside of London (RAC, 2017). In 2016, this parking revenue was £16.5 million, the surplus of which (£7.7 million) (*ibid*) is reinvested back into community transport initiatives every year (BCC, 2016). This Hybrid Approach is consequently proposed as the most appropriate option for Bristol.

5.2. Bristol EV-Infrastructure development

This section addresses the second and third research questions, investigating the differences between Bristol's and Oslo's EV-infrastructure today, before discussing how Bristol should consider moving forwards. To achieve this, results from the spatial analysis are combined with themes from the policy discussion in the previous section. As presented in existing literature, charging infrastructure is integral for the uptake and support of EV in a city. Further to the role of chargers as a refuelling network, Range Anxiety means that prospective consumers require a greater level of infrastructure than is technically needed to feel confident enough to go electric (Bonges & Lusk, 2016; Mellinger *et al.*, 2018). Charging infrastructure has been identified as the first mover for uptake in Norwegian cities (Delacrétaz *et al.*, 2020) and is often the best predictor of EV market share (Harrison & Thiel, 2017; Sierzchula *et al.*, 2014; Slowik & Lutsey, 2017). Consequently, applying the funding made available from the Hybrid Pathway to effectively development Bristol's charging network will be fundamental for EV uptake success.

5.2.1. A comparison of Bristol's and Oslo's infrastructure today

Side-by-side mapping of the two cities' charging stations provides a visual comparison between Bristol, aiming to have 50,000 EVs by 2030, and Oslo, currently supporting this many. Beyond its 400% more stations, Oslo's charging network has a number of characteristics that should be considered for developing a best approach for Bristol. Firstly, Oslo has an average of 2.1 more outlets per charger, with its largest station made up of 86 outlets, versus Bristol's 14. Increasing the number of outlets per stations was highlighted in the literature as a cost-saving method (Nelder & Rogers, 2019), meaning less funding would be required to establish the same number of charge points. A potential downside of fewer stations per outlet is a reduced impact on addressing Range Anxiety. However, charger availability is identified as a contributor to prospective consumer confidence (Bonges & Lusk, 2016), a factor that would be improved by bigger stations.

The higher proportion of slow Level 1 chargers in Oslo than Bristol can likely be attributed to the age of the network. Oslo's success demonstrates that these cheaper slow chargers can still be effective for establishing a mature EV market. But faster Level 2 chargers have become significantly more cost effective over the last decade and investing too heavily in older technology increases the risk of technological lock-in (Figenbaum, 2017). A more centralised distribution of Bristol's EV-infrastructure is also revealed, likely targeting areas of current demand and existing business cases (Coffman *et al.*, 2017). Conversely, Oslo has expanded away from its city centre, creating EV-viability in a greater proportion of the city.

5.2.2. Optimal charging infrastructure approach for Bristol

The third research question is first approached by estimating how much charging infrastructure is needed to achieve Bristol's EV target. Although the policy analysis outcomes suggest this target is over-ambitious without increased national intervention, sufficient infrastructure will maximise Bristol's progression towards it. Using the European Parliament's recommended vehicle-to-charger ratio of ten and applying Oslo's more cost-effective outlet-per-station ratio of 5.9, it is calculated that Bristol will require 847 stations to support 50,000 EVs. Although this is more than double Oslo's current scale, supporting the same number of vehicles, Oslo's vehicle-to-charger ratio was also ten during their period of initial uptake (Hall & Lutsey, 2020). Only in the last few years has it increased considerably to twenty-four, resulting in notable issues with charger availability (*ibid*). Moreover, without Norway's direct incentives, Bristol is more reliant on infrastructure development to encourage EV adoption.

Applying the price calculation from the policy analysis, this infrastructure cost is estimated at £875,000 per year. This is comparable with Oslo today, allocating ~ £1 million annually in an attempt re-establish a strong vehicle-to-charger ratio (Oslo Kommune, 2019). This Bristol estimate is an upper bound, assuming all chargers will be isolated Level 2 outlets, compared with Oslo's 58% proportion, and price consistency.

So, with the increase in the number of outlets per station, the inclusion of some Level 1 stations and projected price reductions (Nelder & Rogers, 2019; Nicholas, 2019), this figure could be considerably lower. Furthermore, the increasing private investment potential as the market develops (Lutsey *et al.*, 2018; Delacrétaz *et al.*, 2020) means that BCC will not be responsible for the full cost. Measures to introduce commercial sustainability as soon as possible should therefore encouraged, such as through advertising revenue; electricity mark-ups; and retail opportunity (Hall & Lutsey, 2017; Nicholas & Tal, 2017). These techniques can also have negative short-term impacts on consumers (Nicholas & Tal, 2017), so should be balanced with maximising uptake in the early stages. The immediate consideration of Oslo-style awareness schemes could assist this, such as engagement with the EVUE project to enhance knowledge exchange (Oslo Kommune, 2013).

With regard to BCC's (2020) inclusiveness and connectivity priorities, the expansion of Bristol's currently more centralised distribution pattern risks leaving some communities spatially excluded. When instead upscaling Bristol's current infrastructure using Oslo's less centralised distribution pattern, there are considerably fewer areas greater than 500m from a charger outside the city centre. Therefore, despite Bristol's above-average proportion of 'Educated suburban families' (Go Ultra West, 2016), predicted to enhance uptake potential, a less spatially concentrated distribution would improve inclusiveness.

For selecting optimal charger site locations, a number of factors proposed in previous literature are selected and combined for a best practice in Bristol. In the city centre, existing car parks are proposed for installation cost and time efficiency, along with providing information on where cars already park for prolonged periods of time (Chen *et al.*, 2013). This is particularly important in Bristol due to aforementioned concerns over available transport development space (BCC, 2019c), Unlike for ICEVs, the considerable 'refuelling' time for EVs means that the time already spent at points of interest can minimise additional user waiting time (Wagner *et al.* 2013). Consequently, Bristol's parks and shopping district are targeted. The large parking turnover and capacity associated with these points of interests would create viable sites for introducing Oslo-style stations with upwards of fifty outlets. When applying the method across the entire city, and identifying other points of interest, both popularity and average parking time should be considered for the greatest effect. Secondly, with Bristol's corridors traversing 50,000 cars in and out of the city every day (DfT, 2017), the adjacency of stations to A and B roads addresses demand (Choi *et al.*, 2020), while instilling confidence in a large number of prospective users. Both of these situations require Level 2 charging, providing considerable charge in a short period of time.

Next, Bristol's economically active centre and high proportion of commuting made by car (BCC, 2019c) means workplace charging has a high potential. Queen Square's office hotspot is selected as an example, enabling Bristol's EV commuters to charge their vehicles during the day. With the average working day lasting ~8 hours, Level 1 charging would be appropriate and more cost effective to install. Considering all of these factors, avoiding close proximity to existing and other planned stations is also suggested, decreasing maximum user travel time (Andrews *et al.*, 2013) and minimise Range Anxiety (Bonges & Lusk, 2016). Bristol's congestion problem also means that significant gaps in infrastructures can disproportionally impact travel time to chargers, making the system less efficient and disincentivising uptake.

The function of public chargers in residential areas is almost exclusively to provide those without off-street parking with an option for home charging (Hall & Lutsey, 2017). Bristol's Residential Parking Scheme means residents cannot be guaranteed a space directly outside their house (BCC, 2019b); a key pre-requisite for home charging (Hall & Lutsey, 2017). Consequently, targeting installations in areas of Bristol without off-street parking, exampled by Easton's predominantly terraced housing, will increase access to home charging and therefore uptake potential. This approach will also expand Bristol's charging infrastructure into less wealthy communities and help replicate Oslo's less centralised infrastructure distribution. Due to the absence of a dataset, satellite imagery is proposed for manual identification of residential parking types. Although the high resolutions available enable a high level of accuracy, repeating this approach for every site would be time intensive. It is therefore suggested that a spatial dataset of Bristol's residential parking types is produced, adding to the other open datasets used in this work (ODB, 2020).

These site selection factors have been applied individually to different cities previously, but this work combines and applies them in light of Bristol's specific spatial and non-spatial requirements. While this creates a relatively time-consuming process, the optimisation of stations will maximise uptake potential. This is especially true for the early stages, where each station has a greater impact; enhanced by the proposed increase in outlets per station. Therefore, to limit resource intensity for BCC, the process could be adapted and reduced for smaller stations after initial adoption. But, with Bristol's reliance on the establishment of a charging network to encourage EV uptake, this should not be done prematurely. Remaining adaptable to developments in uptake and technology will be key for achieving EV success in the city.

6. Summary of key findings and policy recommendations

This section summarises the key findings and proposes policy recommendations for Bristol accordingly. As per the findings, all recommendations can currently be considered viable for Bristol.

- **Bristol's current EV plans are insufficient for 50,000 EVs by 2030, reducing the likelihood of achieving 2030 carbon neutrality.**
    - Increase BCC investment in EV-infrastructure above current OneCity plans.
    - Introduce Oslo-style EV incentives.
- **A Complete Oslo Approach would neglect Bristol's other transport objectives, such as inclusiveness and connectivity.**
    - Adopt a Hybrid Approach, redirecting less PAT funding and omitting Oslo's parking subsidies.
    - Re-invest the revenue from the new ICEV congestion zone into sustainable transport for less wealthy communities.
    - Establish new sources of funding to minimise this PAT-EV trade-off.
- **Optimising EV-infrastructure is integral to the future of EV in Bristol.**
    - Establish a charging network of over 800 stations by 2030 to encourage and support EV adoption.
    - Decentralise charger distribution beyond existing business cases to improve inclusiveness.
    - Select site locations using factors to maximise their uptake potential, differentiating between commercial and residential areas.
        - Produce an off-street parking dataset to improve process efficiency.
- **EV-infrastructure installation costs can be reduced, minimising the redirection of PAT funding.**
    - Hasten commercial sustainability.
        - Commit beyond current short-term infrastructure roll-out, sending longer-term market signals.
        - Encourage new charging revenue streams, such as through advertising, charging cost mark-up and retail business cases.
    - Install cheaper Level 1 stations for residential and workplace charging.

- **Integration of futureproofing and co-benefits will improve the long-term effectiveness of EV in Bristol.**
  - Maintain adaptability of policy.
    - Adjust EV transit lane usage if congestion occurs.
    - Adjust investment as funding changes and technology develops.
  - Consider trialling taxi and bus electrification after early adoption, capitalising on EV-infrastructure.
  - Simultaneously progress V2G and smart grid development to improve the reliability of Bristol's renewable energy.

7. Conclusions

In conclusion, this work has proposed a best EV Pathway for Bristol, considering both the 2030 carbon neutrality target and Bristol's other transport development priorities. The partnering of policy and spatial analyses effectively combined qualitative and quantitative perspectives, enabling the practical application of theoretical findings; resulting in realistic outcomes. With a substantial proportion of journeys in Bristol expected to continue using private transport, the establishment of a large-scale EV market will be fundamental for reducing transport emissions. With the world's most developed EV market, Oslo provides a best case-study for urban EV adoption. However, these local strategies need to be adapted in alignment with Bristol's local resources, challenges and ambitions for a holistically considerate approach.

7.1. Future work

Recommending the introduction of new EV policies and increased funding, this work creates a guide for BCC to underpin changes to future iterations of their local plan and transport strategy. This work incorporates a broad range of factors to establish the best of four EV Pathways. To enhance the precision of these updated targets future research should build upon these findings to produce an action timescale, aligning with the OneCity plan's annual progress structure. Finally, this methodology could be replicated for other EV-nascent cities striving to decarbonise their transport sector.

References

- Aasness, M.A. and Odeck, J., 2015. The increase of EV usage in Norway—incentives and adverse effects. *European Transport Research Review*, *7*(4), p.34.
- Ajanovic, A. and Haas, R., 2016. Dissemination of EVs in urban areas: Major factors for success. *Energy*, *115*, pp.1451-1458.
- Andrews, M., Dogru, M.K., Hobby, J.D., Jin, Y. and Tucci, G.H., 2013, February. Modelling and optimization for EV charging infrastructure. In *IEEE innovative smart grid technologies conference*.
- Axsen, J., Goldberg, S. and Bailey, J., 2016. How might potential future plug-in EV buyers differ from current "Pioneer" owners?. *Transportation Research Part D: Transport and Environment*, *47*, pp.357-370.
- Bardach, E., 2012. A Practical Guide for Policy Analysis. *University of California, Berkeley. CQ press.*
- Bardach, E. and Patashnik, E.M., 2019. A practical guide for policy analysis: The eightfold path to more effective problem solving. *CQ press.*
- Bellocchi, S., Klöckner, K., Manno, M., Noussan, M. and Vellini, M., 2019. On the role of EVs towards low-carbon energy systems: Italy and Germany in comparison. *Applied Energy*, *255*, p.113848.
- Bjerkan, K.Y., Nørbech, T.E. and Nordtømme, M.E., 2016. Incentives for promoting BEV adoption in Norway. *Transportation Research Part D: Transport and Environment*, *43*, pp.169-180.
- Bonges III, H.A. and Lusk, A.C., 2016. Addressing EV sales and range anxiety through parking layout, policy and regulation. *Transportation Research Part A: Policy and Practice*, *83*, pp.63- 73.
- Bristol City Council, 2016. Section 55 Statement. [Online],[03/09/2020]. Available from: https://www.bristol.gov.uk/documents/20182/239297/Section+55+Statement+2015+to+20 16/95fd9b20-7a24-4bb0-afcc-637a81c934b5
- Bristol City Council, 2019a. Full Council – The Mayor's Climate Emergency Action Plan. [Online],[12/07/2020]. Available from: https://www.bristol.gov.uk/documents/20182/33379/Mayor%27s+Climate+Emergency+Act ion+Plan+2019+FINAL
- Bristol City Council, 2019b. Bristol Local Plan Review, Draft policies and Development Allocations. [Online],[20/07/2020]. Available from: https://www.bristol.gov.uk/documents/20182/34536/Local+Plan+Review+-+Draft+Policies+ and+Development+Allocations+-+Web.pdf/2077eef6-c9ae-3582-e921-b5d846762645

- Bristol City Council, 2019c. Bristol Transport Strategy. [Online],[20/07/2020]. Available from: https://www.bristol.gov.uk/documents/20182/3641895/Bristol+Transport+Strategy+-+adop ted+2019.pdf/383a996e-2219-dbbb-dc75-3a270bfce26c

- Bristol City Council, 2019d. Bristol Transport Strategy Consultation Report. [Online],[20/08/2020]. Available from: https://files.smartsurvey.io/2/0/EPN438AS/Bristol_Transport_Strategy_consultation_report_for_website.pdf

- Bristol City Council, 2020. One City Plan. [Online],[12/07/2020]. Available from: https://www.bristolonecity.com/wp-content/uploads/2020/01/One-City-Plan_2020.pdf

- Bristol City Council, n.d. Council use of renewable energy. [Online],[19/08/2020]. Available from:https://www.bristol.gov.uk/policies-plans-strategies/council-use-of-renewable-energy

- Buekers, J., Van Holderbeke, M., Bierkens, J. and Panis, L.I., 2014. Health and environmental benefits related to EV introduction in EU countries. *Transportation Research Part D: Transport and Environment*, *33*, pp.26-38.

- Burch, I. and Gilchrist, J., 2018. Survey of global activity to phase out internal combustion engine vehicles. *Center of Climate Protection: Santa Rosa, CA, USA*.

- Burnham, A., Dufek, E.J., Stephens, T., Francfort, J., Michelbacher, C., Carlson, R.B., Zhang, J., Vijayagopal, R., Dias, F., Mohanpurkar, M. and Scoffield, D., 2017. Enabling fast charging– Infrastructure and economic considerations. *Journal of Power Sources*, *367*, pp.237-249.

- California Energy Commission (CEC) and National Renewable Energy Laboratory (NREL), 2017. EV Infrastructure Projection Tool (EVI-Pro). [Online],[17/08/2020]. Available from: https://maps.nrel.gov/cec-evse/

- Casals, L.C., Martinez-Laserna, E., García, B.A. and Nieto, N., 2016. Sustainability analysis of the EV use in Europe for CO2 emissions reduction. *Journal of cleaner production*, *127*, pp.425-437.

- Cecere, G., Corrocher, N. and Guerzoni, M., 2018. Price or performance? A probabilistic choice analysis of the intention to buy EVs in European countries. *Energy policy*, *118*, pp.19- 32.

- Chen, T.D., Kockelman, K.M. and Khan, M., 2013. Locating EV charging stations: Parking- based assignment method for Seattle, Washington. *Transportation research record*, *2385*(1), pp.28-36.

- Coffman, M., Bernstein, P. and Wee, S., 2017. EVs revisited: a review of factors that affect adoption. *Transport Reviews*, *37*(1), pp.79-93.

- Cook, S., Smith, K. and Utting, P., 2012. Green economy or green society? Contestation and policies for a fair transition(No.10). *UNRISD Occasional Paper: Social Dimensions of Green Economy and Sustainable Development.*

- Cooper, A. and Schefter, K., 2017. Plug-in EV sales forecast through 2025 and the charging infrastructure required. *Institute for Electric Innovation and Edison Electric Institute.*

- Csonka, B. and Csiszár, C., 2017. Determination of charging infrastructure location for EVs. *Transportation Research Procedia*, *27*, pp.768-775.

- Davis, L.W., 2019a. Evidence of a homeowner-renter gap for EVs. *Applied Economics Letters*, *26*(11), pp.927-932.

- Davis, L.W., 2019b. How much are EVs driven? *Applied economics letters*, *26*(18), pp.1497- 1502.

- Delacrétaz, N., Lanz, B. and van Dijk, J., 2020. The chicken or the egg: Technology adoption and network infrastructure in the market for EVs(No.20-08). *IRENE Institute of Economic Research.*

- Department for Business, Energy and Industrial Strategy, 2019. Updated energy and emissions projections 2018. [Online],[02/09/2020]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_ data/file/794590/updated-energy-and-emissions-projections-2018.pdf

- Department for Transport, 2015. Uptake of Ultra Low Emission Vehicles in the UK, *OLEV*. [Online],[20/08/2020]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_ data/file/464763/uptake-of-ulev-uk.pdf

- Department for Transport, 2017. DfT Vehicle registrations by local authority–dataset 0135 end 2017. [Online],[13/08/2020]. Available from: https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01

- Department for Transport, 2018a. The road to zero, Next steps towards cleaner road transport and delivering our industrial strategy. [Online],[14/07/2020]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_ data/file/723501/road-to-zero.PDF

- Department for Transport, 2018b. Road traffic forecasts 2018. [Online],[31/08/2020]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_ data/file/873929/road-traffic-forecasts-2018-document.pdf

- Deuten, S., Vilchez, J.J.G. and Thiel, C., 2020. Analysis and testing of electric car incentive scenarios in the Netherlands and Norway. *Technological Forecasting and Social Change*, *151*, p.119847.

- Dunn, W.N., 2015. Public policy analysis. *Routledge.*

- Eghteabs, C., Ritter, B., Parikh, A. and Lischke, L., 2017. Effects of Color and Threshold on User Perception of Heat Maps. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems*, pp.275-279.

- Eisel, M., Schmidt, J. and Kolbe, L.M., 2014. Finding suitable locations for charging stations. *2014 IEEE International Electric Vehicle Conference (IEVC)*, pp.1-8.
- Eliasson, J., 2016. Is congestion pricing fair? Consumer and citizen perspectives on equity effects. *Transport policy*, *52*, pp.1-15.
- Emrouznejad, A., Ho, W., Grafakos, S., Flamos, A., Oikonomou, V. and Zevgolis, D., 2010. Multi-criteria analysis weighting methodology to incorporate stakeholders' preferences in energy and climate policy interactions. *International Journal of Energy Sector Management*.
- Environmental Commission, 2020. About ECGA. [Online],[31/08/2020]. Available from: https://ec.europa.eu/environment/europeangreencapital/about-the-award/
- European Parliament, 2014. Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure Text with EEA relevance. [Online],[17/08/2020]. Available from: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32014L0094
- Eurostat, 2019. Cities (urban audit). *European Commission*. [Online],[24/06/2020]. Available from: https://ec.europa.eu/eurostat/web/cities/data/database
- Fairley, P., 2010. Speed bumps ahead for electric-vehicle charging. *IEEE spectrum*, *47*(1), pp.13-14.
- Faria, R., Moura, P., Delgado, J. and De Almeida, A.T., 2012. A sustainability assessment of EVs as a personal mobility system. *Energy Conversion and Management*, *61*, pp.19-30.
- Fernández, R.Á., 2018. A more realistic approach to EV contribution to greenhouse gas emissions in the city. *Journal of Cleaner Production*, *172*, pp.949-959.
- Figenbaum, E., 2017. Perspectives on Norway's supercharged EV policy. *Environmental Innovation and Societal Transitions*, *25*, pp.14-34.
- Figenbaum, E., Kolbenstvedt, M. and Elvebakk, B., 2014. EVs–environmental, economic and practical aspects. *Transportøkonomisk Institutt.*
- Ford, A., 2010. Information feedback and causal loop diagrams, *Modeling the Environment, Chapter 9. Island Press,* pp.99.
- Fridstrøm, L. and Østli, V., 2017. The vehicle purchase tax as a climate policy instrument. *Transportation Research Part A: Policy and Practice*, *96*, pp.168-189.
- Go Ultra Low, 2016. Go Ultra Low Cities winner announced. [Online],[28/07/2020]. Available from: goultralow.com/go-ultra-low-cities-winners-announced/

- Go Ultra Low West, 2015. The West of England Go Ultra Low Cities Bid Foreword. [Online],[20/08/20]. Available from: https://democracy.bristol.gov.uk/Data/Cabinet/201604051800/Agenda/0405_5.pdf

- GOV.UK, 2020. Consulting on ending the sale of new petrol, diesel and hybrid cars and vans. [Online],[28/07/2020]. Available from: https://www.gov.uk/government/consultations/consulting-on-ending-the-sale-of-new- petrol-diesel-and-hybrid-cars-and-vans/consulting-on-ending-the-sale-of-new-petrol-diesel- and-hybrid-cars-and-vans

- GOV.UK, n.d. Low-emission vehicles eligible for a plug-in grant. [Online],[28/07/2020]. Available from: https://www.gov.uk/plug-in-car-van-grants

- Grønn Bil, 2015. Statistikk- EVs. [Online],[13/07/2020]. Available from: http://www.gronnbil.no/statistikk/

- Grundt, G., 2016. How Green is Oslo? Urban Development, Green Policies and the Making of a Green capital city. *Green Oslo: Visions, Planning and Discourse*, p.215.

- Hall, D. and Lutsey, N., 2017. Emerging best practices for EV charging infrastructure. *The International Council on Clean Transportation (ICCT): Washington, DC, USA*, p.54.

- Hall, D. and Lutsey, N., 2020. EV charging guide for cities. *Consulting Report.*

- Hannisdahl, O.H., Malvik, H.V. and Wensaas, G.B., 2013, November. The future is electric! The EV revolution in Norway—Explanations and lessons learned. *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*, *IEEE*, pp.1-13.

- Hao, H., Qiao, Q., Liu, Z. and Zhao, F., 2017. Impact of recycling on energy consumption and greenhouse gas emissions from EV production: The China 2025 case. *Resources, Conservation and Recycling*, *122*, pp.114-125.

- Hawkins, T.R., Singh, B., Majeau-Bettez, G. and Strømman, A.H., 2013. Comparative environmental life cycle assessment of conventional and EVs. *Journal of Industrial Ecology*, *17*(1), pp.53-64.

- He, F., Wu, D., Yin, Y. and Guan, Y., 2013. Optimal deployment of public charging stations for plug-in hybrid EVs. *Transportation Research Part B: Methodological*, *47*, pp.87-101.

- Helmus, J. and Van den Hoed, R., 2016. Key performance indicators of charging infrastructure. *World Electric Vehicle Journal*, *8*(4), pp.733-741.

- Hoek, G., Krishnan, R.M., Beelen, R., Peters, A., Ostro, B., Brunekreef, B. and Kaufman, J.D., 2013. Long-term air pollution exposure and cardio-respiratory mortality: a review. *Environmental health*, *12*(1), p.43.

- Holtsmark, B. and Skonhoft, A., 2014. The Norwegian support and subsidy policy of electric cars. Should it be adopted by other countries?. *Environmental science & policy*, *42*, pp.160- 168.

- IEA, 2018a. Renewables. *International Energy Agency.* [Online],[05/08/2020]. Available from: https://www.iea.org/fuels-and-technologies/renewables

- IEA, 2018b. Key energy statistics: Norway. *International Energy Agency*, [Online],[27/05/2020]. Available from: https://www.iea.org/countries/norway

- IEA, 2020a. Global EV Outlook 2020: Entering the decade of electric drive? *OECD Publishing, Paris*.

- IEA, 2020b. Electricity mix in China, Q1 2020. *International Energy Agency.* [Online],[05/08/2020]. Available from: https://www.iea.org/data-and-statistics/charts/electricity-mix-in-china-q1-2020

- Jittrapirom, P., Caiati, V., Feneri, A.M., Ebrahimigharehbaghi, S., Alonso González, M.J. and Narayan, J., 2017. Mobility as a service: A critical review of definitions, assessments of schemes, and key challenges, *Cogitatio*.

- Jochem, P., Babrowski, S. and Fichtner, W., 2015. Assessing CO2 emissions of EVs in Germany in 2030. *Transportation Research Part A: Policy and Practice*, *78*, pp.68-83.

- Johnsen, F.M. and Løkke, S., 2013. Review of criteria for evaluating LCA weighting methods. *The International Journal of Life Cycle Assessment*, *18*(4), pp.840-849.

- Klein, A., Widge, V., Maheshwari, A. and Malik, A., 2018. Climate Investment Opportunities in Cities: An IFC Analysis(No.134204), *The World* Bank, pp.1-176.

- KlimaOslo, 2019. Oslo's Climate Budget 2020: The most important figures. [Online],[20/06/2020]. Available from: https://www.klimaoslo.no/2019/10/29/climate-budget-2020-the-most-important-figures/

- Klöckner, C.A., Nayum, A. and Mehmetoglu, M., 2013. Positive and negative spillover effects from electric car purchase to car use. *Transportation Research Part D: Transport and Environment*, *21*, pp.32-38.

- Kristoffersson, I., Engelson, L. and Börjesson, M., 2017. Efficiency vs equity: Conflicting objectives of congestion charges. *Transport Policy*, *60*, pp.99-107.

- Kwan, S.C. and Hashim, J.H., 2016. A review on co-benefits of mass public transportation in climate change mitigation. *Sustainable Cities and Society*, *22*, pp.11-18.

- Lorenzoni, I. and Pidgeon, N.F., 2006. Public views on climate change: European and USA perspectives. *Climatic change*, *77*(1-2), pp.73-95.

- Lutsey, N., Grant, M., Wappelhorst, S. and Zhou, H., 2018. Power play: How governments are spurring the EV industry. *White Paper*.

- Manski, C.F., 2019. Communicating uncertainty in policy analysis. *Proceedings of the National Academy of Sciences*, *116*(16), pp.7634-7641.

- Melliger, M.A., Van Vliet, O.P. and Liimatainen, H., 2018. Anxiety vs reality–Sufficiency of BEV range in Switzerland and Finland. *Transportation Research Part D: Transport and Environment*, *65*, pp.101-115.
- Mersky, A.C., Sprei, F., Samaras, C. and Qian, Z.S., 2016. Effectiveness of incentives on EV adoption in Norway. *Transportation Research Part D: Transport and Environment*, *46*, pp.56- 68.
- Morlock, F., Mammel, C., Engelhardt, T. and Sawodny, O., 2020. Trip planning for EVs considering the available charging infrastructure. *2020 IEEE International Conference on Industrial Technology (ICIT)*, *IEEE*, pp. 723-728.
- Morrissey, P., Weldon, P. and O'Mahony, M., 2016. Future standard and fast charging infrastructure planning: An analysis of EV charging behaviour. *Energy Policy*, *89*, pp.257-270.
- Nelder, C. and Rogers, E., 2019. Reducing EV Charging Infrastructure Costs, *Rocky Mountain Institute.* [Online],[21/07/2020]. Available from: https://rmi.org/ev-charging-costs
- Nicholas, M., 2019. Estimating EV charging infrastructure costs across major US metropolitan areas. *The ICCT*.
- Nicholas, M. and Tal, G., 2017. In Use Fast Charger Data: Implications for Travel and Usage Projections. *EVS30, Stuttgart.*
- Noel, L., de Rubens, G.Z., Kester, J. and Sovacool, B.K., 2018. Beyond emissions and economics: Rethinking the co-benefits of EVs and V2G. *Transport Policy*, *71*, pp.130-137.
- OECD, 2019. Compare your country – Electricity. *Organisation for Economic Co-operation and Development*. [Online],[30/08/2020]. Available from: http://www.compareyourcountry.org/climate-policies?cr=oecd&lg=en&page=2#
- Open Charge Map, 2020a. Accessing and using Open Charge Map. [Online],[08/06/2020]. Available from: https://openchargemap.org/site
- Open Charge Map, 2020b. About. [Online],[08/06/2020]. Available from: https://openchargemap.org/site/about
- Open Data Bristol, 2020. Home. [Online],[22/06/2020]. Available from: https://opendata.bristol.gov.uk/pages/homepage/
- Oslo Kommune, 2013. EV charging points in Oslo—400 public charging points in 4 years 2008–2011. [Online],[21/07/2020]. Available from: https://urbact.eu/sites/default/files/import/Projects/EVUE/outputs_media/LAP_Electric_ve hicle_charging_points_in_Oslo_Final_01.pdf

- Oslo Kommune, 2016. Climate and Energy Strategy for Oslo. [Online],[21/07/2020]. Available from: https://www.klimaoslo.no/wp-content/uploads/sites/88/2018/06/Climate-and-Energy-Strategy-2016-English.pdf

- Oslo Kommune, 2019. The Car-free Livability Programme. [Online],[24/07/2020]. Available from: https://www.oslo.kommune.no/getfile.php/13319592- 1553857948/Content/English/Politics and administration/City development/Car free city/The Car-free Livability Programme 2019.pdf

- Paddeu, D., 2017. The Bristol-Bath Urban freight Consolidation Centre from the perspective of its users. *Case studies on transport policy*, *5*(3), pp.483-491.

- PayScale, 2020a. City: Oslo. [Online],[19/06/2020]. Available from: https://www.payscale.com/research/NO/Location=Oslo/Salary

- PayScale, 2020b. City: Bristol. [Online],[19/06/2020]. Available from: https://www.payscale.com/research/UK/Location=Bristol-England%3A-Bristol/Salary

- RAC, 2017. Local Authority Parking Finances in England 2015-16. RAC Foundation for Motoring. [Online],[03/09/2020]. Available from: https://www.racfoundation.org/wp-content/uploads/2017/11/Local_Authority_Finances_2 015-16_Leibling_Nov_2016_final.pdf

- Regen, 2019. City of Bristol Carbon Neutrality, CO2 emission baseline and gap analysis. [Online],[01/09/2020]. Available from: https://www.bristol.gov.uk/documents/20182/33395/Bristol+Baseline+Report+April+2019. pdf/76006e21-ab62-fa44-235a-2c5285f1dc2e

- Rietmann, N. and Lieven, T., 2019. How policy measures succeeded to promote electric mobility–worldwide review and outlook. *Journal of cleaner production*, *206*, pp.66-75.

- Rietveld, P. and Stough, R.R., 2005. Barriers to Sustainable Transport: institutions, regulation and sustainability. *Routledge.*

- Romm, J., 2006. The car and fuel of the future. *Energy policy*, *34*(17), pp.2609-2614.

- Sakamoto, N., Niimura, T., Ozawa, K. and Takamori, H., 2016. Robust feedback control for the subsidy policy about plug-in EVs using sliding mode control. *Electrical Engineering in Japan*, *194*(1), pp.10-17.

- Sharma, R., Manzie, C., Bessede, M., Crawford, R.H. and Brear, M.J., 2013. Conventional, hybrid and EVs for Australian driving conditions. Part 2: Life cycle CO^2 emissions. *Transportation Research Part C: Emerging Technologies*, *28*, pp.63-73.

- Sierzchula, W., Bakker, S., Maat, K. and Van Wee, B., 2012. Technological diversity of emerging eco-innovations: a case study of the automobile industry. *Journal of Cleaner Production*, *37*, pp.211-220.

- Sierzchula, W., Bakker, S., Maat, K. and Van Wee, B., 2014. The influence of financial incentives and other socio-economic factors on EV adoption. *Energy Policy*, *68*, pp.183-194.
- Situ, L., 2009, May. EV development: the past, present & future. In *2009 3rd International Conference on Power Electronics Systems and Applications (PESA)*, *IEEE*, pp.1-3.
- Slowik, P. and Lutsey, N., 2017. Expanding the EV market in US cities. *International Council on Clean Transportation (ICCT)*.
- Statista, 2020. Number of licensed cars in the United Kingdom (UK) from 2000 and 2019. [Online],[27/07/2020]. Available from: https://www.statista.com/statistics/299972/average-age-of-cars-on-the-road-in-the-united- kingdom/
- Straka, M., De Falco, P., Ferruzzi, G., Proto, D., van der Poel, G., Khormali, S. and Buzna, L., 2019. Predicting popularity of EV charging infrastructure from GIS data. *arXiv preprint arXiv:1910.02498*.
- Sui, D. and DeLyser, D., 2012. Crossing the qualitative-quantitative chasm I: Hybrid geographies, the spatial turn, and volunteered geographic information (VGI). *Progress in Human Geography*, *36*(1), pp.111-124.
- Sustrans, 2016. A Good Transport Plan for Bristol. [Online], [02/09/2020]. Available from: https://bristolgreencapital.org/wp-content/uploads/2016/01/A-Good-Transport-Plan-for-Bristol-2016-PDF.pdf
- Tagliaferri, C., Evangelisti, S., Acconcia, F., Domenech, T., Ekins, P., Barletta, D. and Lettieri, P., 2016. Life cycle assessment of future electric and hybrid vehicles: A cradle-to-grave systems engineering approach. *Chemical Engineering Research and Design*, *112*, pp.298- 309.
- TfL, 2017. FOI request detail, Freedom of Information. [Online],[03/09/2020]. Available from: https://tfl.gov.uk/corporate/transparency/freedom-of-information/foi-request- detail?referenceId=FOI-2271-1617
- Tietge, U., Mock, P., Lutsey, N. and Campestrini, A., 2016. Comparison of leading EV policy and deployment in Europe. *Int. Council Clean Transport*, *49*, pp.847129-102.
- Van Bree, B., Verbong, G.P. and Kramer, G.J., 2010. A multi-level perspective on the introduction of hydrogen and BEVs. *Technological Forecasting and Social Change*, *77*(4), pp.529-540.
- Vassileva, I. and Campillo, J., 2017. Adoption barriers for EVs: Experiences from early adopters in Sweden. *Energy*, *120*, pp.632-641.
- Viola, F. and Longo, M., 2017. On the strategies for the diffusion of EVs: Comparison between Norway and Italy. *International Journal of Renewable Energy Research*, *7*(3), pp.1376-1382.

- Wagner, S., Götzinger, M. and Neumann, D., 2013. Optimal location of charging stations in smart cities: A points of interest based approach.
- Walker, W.E., 2000. Policy analysis: a systematic approach to supporting policymaking in the public sector. *Journal of Multi-Criteria Decision Analysis*, *9*(1-3), pp.11-27.
- Wangsness, P.B., Proost, S. and Rødseth, K.L., 2020. Vehicle choices and urban transport externalities. Are Norwegian policy makers getting it right? *Transportation Research Part D: Transport and Environment*, *86*, p.102384.
- Wolbertus, R. and Van den Hoed, R., 2019. EV fast charging needs in cities and along corridors. *World Electric Vehicle Journal*, *10*(2), p.45.
- Woodcock, J., Edwards, P., Tonne, C., Armstrong, B.G., Ashiru, O., Banister, D., Beevers, S., Chalabi, Z., Chowdhury, Z., Cohen, A. and Franco, O.H., 2009. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. *The Lancet*, *374*(9705), pp.1930-1943.
- Xi, X., Sioshansi, R. and Marano, V., 2013. Simulation–optimization model for location of a public EV charging infrastructure. *Transportation Research Part D: Transport and Environment*, *22*, pp.60-69.
- Zapmap, 2020. EV connector types. [Online],[21/07/2020]. Available from: https://www.zap-map.com/charge-%20points/connectors-speeds/
- Zeng, L., Krallmann, T., Fiege, A., Stess, M., Graen, T. and Nolting, M., 2020. Optimization of future charging infrastructure for commercial EVs using a multi-objective genetic algorithm and real travel data. *Evolving Systems*, *11*(2), pp.241-254.

Appendix

University of BRISTOL
SCHOOL OF GEOGRAPHICAL SCIENCES

PG Research Ethics Monitoring Form 2019-2020

Research by all academic and related Staff and Students in the School of Geographical Sciences is subject to the standards set out in the Code of Practice on Research Ethics.
It is a requirement that prior to the commencement of all funded and non-funded research that this form be completed and submitted to your dissertation advisor and the School's Research Ethics Committee (REC) (see Ethics Flow Chart). The Advisor and REC will be responsible for issuing certification that the research meets acceptable ethical standards and will, if necessary, require changes to the research methodology or reporting strategy.
A copy of the research proposal which details methods and reporting strategies must be attached. Submissions without a copy of the research proposal will not be considered.
The Ethics process seeks to establish from the form that researchers have (i) thought purposefully about potential ethical issues raised by their proposed research; and (ii) identified appropriate responses to those issues.
Use the Tab key to move between responses and remember to save regularly.

Name: *Daniel Jones* Email address: *si19915@bristol.ac.uk*
Title of research project: *The feasibility of applying Oslo's Electric Vehicle model to Bristol.*
Source of funding if any? *n/a*

---

1. Does your research involve human participants under the age of 18?

No

If YES, please provide further details
n/a

---

2. Does your research involve human participants in vulnerable circumstances?

No

If YES, please provide further details
n/a

---

3. Does your research involve ONLY the analysis of large, secondary and anonymised datasets?

Yes to all 3 (go to Declaration)

---

4. Do others hold copyright or other rights over the information you will use, or will they do so over information you collect?

Choose an item.

If relevant, please provide further details of copyright etc. information
Click or tap here to enter text.

5. If asked, will you give your informants a
    a. written summary of your research aims and its uses?

    Choose an item.

    b. verbal summary of your research aims and its uses?

    Choose an item.

    If NO to either 5a or 5b please provide further details
    Click or tap here to enter text.

6. Does your research involve covert surveillance (for example, participant observation)?

Choose an item.

If YES, please provide further details
Click or tap here to enter text.

7. Does your research involve analysis of social media posts or images?

Choose an item.

If YES, please provide further details
Click or tap here to enter text.

8. Anonymising informants:
    a. Will your informants automatically be anonymised in your research?

    Choose an item.

    If NO, please provide further details
    Click or tap here to enter text.

    b. Will you explicitly give all your informants the right to remain anonymous?

    Choose an item.

    If NO, please provide further details
    Click or tap here to enter text.

    c. Will data/information be encrypted/secured, and stored separately from identification material to maintain confidentiality?

    Choose an item.

    If NO, please provide further details
    Click or tap here to enter text.

9. Will monitoring devices be used openly and only with the permission of informants?

Choose an item.

If NO, please provide further details
Click or tap here to enter text.

10. Will your informants be provided with a summary of your research findings?

Choose an item.

If NO, please provide further details
Click or tap here to enter text.

11. Will your research be available to informants and the general public without restrictions placed by sponsoring authorities?

Choose an item.

If NO, please provide further details
Click or tap here to enter text.

12. Have you considered the implications of your research intervention on informants?

Choose an item.

Please provide full details
Click or tap here to enter text.

13. Are there any other ethical issues arising from this research ?

Choose an item.

If YES, please explain and include how they will be taken into consideration
Click or tap here to enter text.

Declaration

I have read the School's Code of Practice on Research Ethics and believe that my research complies fully with its precepts.
I will not deviate from the methodology or reporting strategy without further permission from my advisor and/or the School's Research Ethics Committee.

Student

Signed D Jones Date *29/04/2020*

Advisor

Signed S. Rodway -Dyer. Date *01/05/2020*

Progress tracker: (dates to be completed by advisor/ethics committee)

A	**Form submission to advisor**	29/04/2020	Choose date	Choose date	Choose date
B	**Clarification requested by advisor**	Choose date	Choose date	Choose date	Choose date
C	**Advisor stage passed**	01/05/2020	Choose date	Choose date	Choose date
D	**Clarification requested by ethics committee**	Choose date	Choose date	Choose date	Choose date
E	**Decision recorded by ethics committee**	18/06/2020	Choose date	Choose date	Choose date
F	**Email sent to student by ethics committee**	18/06/2020	Choose date	Choose date	Choose date