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The potential contribution of e-scooters to sustainable urban transport in Bristol

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Abstract

To meet net-zero targets by 2030, Bristol needs to reduce CO_2 emissions by 88%. So far, scenarios for achieving this goal focus on active transport and electrification of vehicles throughout the city. However, cities in other countries are using 'new mobility' technologies brought to the market by private companies to help reach this target. This study focuses on the electric scooter (e-scooter) which has been hailed as an environmentally and socially sustainable mode of transport. Since the 4th July 2020, e-scooters have been legal as part of a shared mobility pilot scheme in UK cities. The change in the law was brought forward to reduce crowding on public transport during the Covid-19 pandemic. This study takes the form of a policy analysis to explore the successes and failures of e-scooter implementation in cities around the world and how Bristol could learn from these. As part of the policy analysis, an outcomes matrix has been created to evaluate the policy approach that meets the most criteria. The matrix is based on the outcomes from two different scenarios for primary modal shift (from cars or active transport). It is found that the type of modal shift that occurs when individuals start using e-scooters is crucial to their potential contribution to a sustainable transport system. Modal shifts from cars to e-scooters were more likely to occur in United States (US) cities than European ones but this was due to baseline modal shares rather than strong environmental policies. Overall, e-scooters were found to be a positive alternative to cars as part of a holistic approach to the transition towards a sustainable transport system.

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1. Introduction

Following the advice from the Intergovernmental Panel on Climate Change in 2018 that global warming must not exceed 1.5°C, Bristol City Council (BCC; 2019a) declared a climate emergency. It was the first council in the UK to do so and was accompanied by a commitment to become carbon neutral by 2030 (*ibid.*). Globally, the transport sector produces 23% of total carbon dioxide (CO_2) emissions (Sims *et al.*, 2014). Similarly, in Bristol CO_2 emissions from transport make up 25% of the city's total (BCC, 2019b). Despite significant decreases in CO_2 emissions from other sectors, transport emissions have only reduced by 9% in the last 15 years in Bristol (Roberts *et al.*, 2020). Bristol's transport strategy outlines the goals of a less polluting and inclusive transport system and recognises that drawing on new technologies will aid this transition (BCC, 2019b). Although not explicitly mentioned in the strategy, one new technology that has been adopted in other cities around the world is the electric kick scooter (e-scooter). The e-scooter market is already valued at £13 billion and is expected to grow by another 8.5% each year for the next 10 years (Department for Transport; DfT, 2020a).

On the 4th July 2020, the United Kingdom (UK) announced that it would bring forward the legalisation of shared e-scooters as part of one-year pilot schemes (DfT, 2020b). Use of private e-scooters on public streets will remain illegal. The DfT (2020b) stated that local e-scooter trials are hoped to ease demand for public transport during the Covid-19 pandemic and to provide an outdoor mode of transport which enables social distancing. Bristol is among 30 city councils which have displayed an interest in piloting e-scooters (Doward, 2020). Marvin Rees, the mayor of Bristol, hopes that e-scooters will help the city to reduce congestion and air pollution (Grubb, 2020). Bristol's congestion is estimated to be three times the national average which has led to it having some of the slowest traffic speeds of any UK Core City (Bristol Green Capital; BGC, 2015). This is estimated to cost Bristol's economy £600 million per year (*ibid.*).

E-scooters have frequently been hailed as a 'last mile' solution, to link homes or places of work to public transport systems (Gössling, 2020a). They have been praised as more sustainable and less expensive than electric cars due to their compact size, along with other micromobilities (Behrendt, 2018). Micromobilities are human-scale mobility devices that include bicycles but are more commonly used to describe electric devices, such as e-scooters (*ibid.*). The DfT (2020b) has defined e-scooters as electric vehicles with a power rating of maximum 500 Watts, a maximum speed of 15.5 mph and designed to carry only one person. E-scooter users will need to have a valid driving license and operators will need to cover the insurance (*ibid.*). This leaves local authorities with decisions to make on how technologies will be used, what safety provisions will be in place, parking regulations, and drawing up agreements with e-scooter operators on what data is shared (*ibid.*). These policies and regulations are discussed theoretically in the literature review and discussed in practice in the analysis.

Transport strategies to reduce impacts on the climate also have co-benefits which include lower costs of travel, better health, improved safety, and time savings (Sims *et al.*, 2014). Policymakers have, for many years, recognised that there is a need to reduce car-orientated mobility in cities (Bratzel, 1999). When cities have been designed for cars, it disproportionately advantages those using cars and disadvantages other modes of transport, including pedestrians, cyclists, and those using public transport (King and Krizek, 2020). There is a link between increasing CO_2 emissions and inequality within societies (Heffron and McCauley, 2018). They define the 'just transition' as a move towards environmental sustainability that also reduces local and global inequalities. Bristol One City Environmental Sustainability Board (BOCESB; 2020) set out aims to decarbonise the transport sector whilst addressing inequalities in the city. Environmental and social sustainability are core pillars of this study but the two also frequently overlap. Sustainability in the transport sector is complex but at its simplest must meet the needs of the current population without sacrificing the mobility of future generations (Goldman and Gorham, 2006).

This study starts with a literature review (section 2) which addresses the arguments about the environmental sustainability of e-scooters and how they might help or hinder aims to reduce inequality in cities. This is followed by a sub-section on the governance of urban transport systems which is increasingly blurring the boundaries between public and private (Dowling and Kent, 2015). The study takes the form of a policy analysis, which is defined and discussed in the methodology (section 3). It has achieved the aims and objectives set out below and assessed whether a social or environmental approach to the regulation of e-scooters meets the criteria for a sustainable transport system in Bristol, which is highlighted by the outcomes matrix (sub-section 3.1.2). This has been informed by an extensive analysis of six key case studies and their supporting documents. This analysis has been structured by key themes which include the baseline scenario, where e-scooters are not introduced to the city, which is followed by an investigation of environmental, social, and safety policies and regulations. Finally, the study will end with some key recommendations for Bristol to successfully implement e-scooters as part of the sustainable urban transport system and some concluding remarks.

1.1. Aims and objectives

Overall, this study asks whether e-scooters have the potential to aid Bristol in meeting its sustainable transport targets. This includes reaching net-zero emissions by 2030 whilst maintaining a just transition. To do this, the study incorporates the following aims and objectives:

1. To identify and analyse the costs and benefits of e-scooters.
2. To identify successful and unsuccessful e-scooter policies in other cities.
3. To make recommendations for Bristol about how best to implement e-scooters.

2. Literature review

This section will provide a thorough review of e-scooter literature. However, as a new technology there is still relatively limited literature on e-scooters (Lazarus *et al.*, Caspi *et al.*, 2020). Therefore, it will also draw on literature about other shared mobilities, such as car sharing and shared bicycle systems. It will start by considering the potential impact of e-scooters on the environment, followed by the impact on society and transport accessibility. These are formed around the environmental and social pillars of sustainability (Fox and Goodfellow, 2016). The final section refers to the changing governance associated with e-scooters and other shared mobility.

2.1 Environmental sustainability of urban transport systems

2.2.1. Decarbonisation of the transport system

Globally, the transport sector produces 6.7 gigatons of carbon dioxide (CO_2) per year, which makes up 23% of total CO_2 emissions (Sims *et al.*, 2014). It is estimated that by 2050, without intervention, CO_2 emissions in the transport sector could reach 12 gigatons CO_2 equivalent per year (*ibid.*). The Paris Agreement requires countries to keep temperatures well below 2˚C and aims to keep warming close to 1.5˚C (Gota *et al.*, 2019). To reach these goals, it is recognised that greenhouse gas emissions must be net-zero, which means that any emissions produced must be balanced by carbon sinks (*ibid.*). In the UK, CO_2 levels have decreased in every sector since 1990, with the exception of transport (Woodcock *et al.*, 2007). Here, and in other European countries, the fall in emissions per vehicle due to technological advancements has not been sufficient to make up for the increase in miles travelled by car (*ibid.*). Private cars have many negative externalities which are felt at different scales (Tattini *et al.*, 2018). Negative externalities are where adverse impacts to the environment and society are not paid for by the user, often due to the use of public goods (Endes, 2011). In the transport sector, negative externalities at the local scale include congestion, noise, road damage, accidents, and air pollution (Tattini *et al.*, 2018). On a global scale, the primary negative externality is the contribution to anthropogenic climate change due to CO_2 emissions (Tattini *et al.*, 2018).

Internalising negative externalities is often focused on taxes. However, fuel taxes are among the least popular of all taxes (Kallbekken and Sælen, 2011). This explains that although there is consensus between policymakers that transport policies must focus on reducing car dependency in cities, few have had success and car dependency has continued to rise (Bratzel, 1999). Taxes are part of strategies which aim to ‘shift’. ‘Shift’ strategies are about a movement towards low-carbon modes, such as bicycles (Tattini *et al.*, 2018). The other two key strategies are ‘avoid’ which is about mitigating demand by increasing the density of urban structures, and ‘improve’ strategies which are technology-focused (*ibid.*). Gota *et al.* (2019) note that there has been a move away from ‘avoid’ and ‘shift’ strategies in favour of ‘improve’ strategies. An example of this is the focus of many cities on electrification of vehicle fleets. However, ‘avoid’ and ‘shift’ strategies tend to have more public benefits and less negative externalities (Gota *et al.*, 2019). Winters *et al.* (2017) highlight that part of making transport more sustainable is to reduce demand for transport in the first place. This relies on policymakers looking beyond transport, to land use and urban design which locates jobs, schools, and shops within close reach of residential areas (*ibid.*). E-scooters combine ‘improve’ strategies with ‘shift’ strategies due to being a new technology which aims for a modal shift from cars.

2.1.2 Environmental impacts of e-scooters

Shared micromobilities, including e-scooters, have been hailed as low-emission, on-demand public transport which can help reduce pollution and congestion in urban areas (Lazarus *et al.*, 2020). Severngiz *et al.* (2020) assess e-scooters’ environmental impacts using a life cycle analysis method. Life cycle analysis takes into account the raw material extraction, component production, vehicle production, electricity supply, vehicle emissions, and recycling (Severngiz *et al.*, 2020). They find that for all variables included (particulate matter, nitrogen oxide, CO_2 emissions, parking space demand, and traffic space demand), e-scooters perform better than ICE (internal combustion engine) automobiles. Despite this, e-scooters still produce significant CO_2 emissions over their lifetime. In addition, Hollingsworth *et al.*’s (2019) study found that during their lifecycle, e-scooters produce an average of 202g CO_2 equivalent per passenger mile. However, 43% of this figure represents the collection and charging of e-scooters (*ibid.*). E-scooters are often charged by freelancers, often referred to as ‘juicers’, who collect the devices and charge them up at their homes. This leads to ‘juicers’ frequently driving considerable distances to collect e-scooters and means that there is no data on whether they are charged using renewable sources (Masoud *et al.*, 2019). Hollingsworth *et al.* (2019) note that if charging and collection emissions can be reduced that up to 55g CO_2 equivalent per passenger mile could be saved throughout each e-scooter’s lifetime. Severngiz *et al.*, (2020) note that shared e-scooters charged using decarbonised electricity have lower lifetime emissions than privately-owned e-scooters. Furthermore, newer models have batteries which are exchangeable which has mitigated emissions produced from their collection (Fearnley *et al.*, 2020).

The lifecycle analyses are limited by the fact that lifetimes are often much lower due to high usage and vandalism when used as part of a shared mobility system (Hollingsworth *et al.*, 2019). In some instances, e-scooters have only lasted 40 days (Gössling, 2020a). Therefore, Hollingsworth *et al.* (2019) conclude that e-scooters are effective for reducing congestion in cities but do not provide the necessary environmental benefits required to improve the sustainability of urban transport systems. However, models are expected to be more robust in the future which could increase lifetimes and reduce their lifecycle CO_2 emissions (Fearnley *et al.*, 2020).

Further to understanding the lifecycle analysis of emissions from e-scooters, it is important to know what trips they are replacing. For e-bikes, Fishman and Cherry (2016) report that considerable environmental improvements are made if users have replaced trips previously made by automobile. These increases in demand for one form of transport and decreases from another are known as modal shifts (Tattini *et al.*, 2018). Fishman and Cherry (2016) state that emissions are similar to that of bus travel, but that those emissions are primarily related to the production which means there are fewer emissions produced on the roads which leads to lower levels of local air pollution. Tattini *et al.* (2018) note that mode choices are shaped by socioeconomic status, opinion, characteristics of mode, infrastructure, and policy. Severngiz *et al.* (2020) highlight that e-scooter use could lead to increases in demand for public transport and active travel if trips are multi-modal and lead to the creation of more infrastructure. However, they also recognise that there could be decreased demand for these modes as they are replaced by e-scooter trips which would leave demand for private cars the same. The modal shifts that take place dictate whether e-scooters provide an environmentally sustainable alternative urban transport to cars.

2.2 Social sustainability of urban transport systems

2.2.1. Public health and wellbeing

The previous section focused on CO_2 emissions and whether e-scooters contribute to global negative externalities. However, tailpipe emissions which include nitrogen oxide (NO_x) and fine particulate matter ($PM_{2.5}$ and PM_5) are additional local externalities. In 2015, $PM_{2.5}$ was the fifth highest mortality risk factor in the world and in 2016 the associated burden of disease was calculated at 4.4% of global GDP (Glazner and Kheris, 2019). The burden of disease takes into account the sum of mortality and morbidity as well as the cost of those living with diseases (Roser and Ritchie, 2016). This burden is often heaviest on those from low socioeconomic backgrounds (Tonne *et al.*, 2018). In the UK, poorer households are disproportionately impacted by high NO_x concentrations and are also less likely to own a private car, which suggests that there is socio-environmental injustice (Barnes *et al.*, 2019). Electric vehicles, including e-scooters, do not have tailpipe emissions which means they should reduce the burden of disease associated with transport (Carmichael, 2019). Although there are still some particles from braking and tyre-to-road friction (Woodcock *et al.*, 2007), these are likely to be lower for e-scooters than electric vehicles. Glazner and Kheris (2019) found that in cities in Europe, cyclists and pedestrians had less exposure to particulate matter than motorists (Cyclists were exposed to 20% less $PM_{2.5}$, 70% less black carbon, and 90% less carbon monoxide). For pedestrians, these figures were 40%, 300%, and 300% respectively). However, perceptions of air pollution have an influence in modal choice and walking and cycling are associated with high exposure to tailpipe emissions (Marquart *et al.*, 2020). E-scooters have the potential to reduce the amount of air pollution produced in urban areas and are likely to have similar levels of exposure to cyclists, which is less than that of drivers. Therefore, e-scooter use could help to reduce the burden of disease caused by transport, if there is a modal shift away from cars.

Active travel, consisting primarily of walking and cycling, further reduces the burden of disease caused by transport by lowering the risk of cardiovascular disease. It has been found that walking three hours per week reduces the risk of cardiovascular disease by 16% (Winters *et al.*, 2017). These benefits are said to outweigh the risks of injury or exposure to air pollution (*ibid.*). Fishman and Cherry (2016) suggest that there are concerns that e-micromobilities might displace the use of bicycles. Their study focuses on e-bikes and finds that the longer distances travelled, and the fact that some level of physical exertion is still required, means that e-bikes are still likely to lead to an increase in physical activities. However, use of e-scooters does not require physical exertion which means they will not have these co-benefits. Despite this, Fearnley *et al.* (2020) report that e-scooters have the potential to increase social participation and wellbeing due to respondents leaving the house more to make e-scooter trips 'for the fun of it'. Additionally, Severngiz *et al.* (2020) note that if e-scooter use leads to more cycling infrastructure, there could be a modal shift. This further highlights the importance of a modal shift away from cars, rather than active travel.

The safety of e-scooters also requires consideration. Fearnley *et al.* (2020) found that the risk of accident is 10 times higher for e-scooters than for bicycles. This includes accidents and collisions with pedestrians and cars. Woodcock *et al.* (2007) state that traffic danger is a vicious cycle which provides a disincentive for active travel. One way that this circle can be broken is through 'safety in numbers', which has been observed in various cities (Winters *et al.*, 2017). Safety in numbers refers to higher levels of cycling resulting in lower rates of injury due to driver awareness (*ibid.*). However, these could be due to correlations with better cycling infrastructure (*ibid.*). Nello-Deakin (2020) states that there is an abundance of research supporting the building of infrastructure to make cities more attractive for cycling due to positive externalities. Gössling (2020b) argues that adding e-scooters to cities' transport systems provides another reason to divert space away from cars. Separating those using e-micromobility and bicycles from cars is likely to increase perceptions of safety and influence modal choice towards them, whilst simultaneously discouraging drivers.

2.2.2 Accessibility and equity

E-scooters have been praised for filling a gap in access to transport (Gössling, 2020a). Eccarius and Lu (2020) note that they can provide individual transport for those who cannot afford a car. They have also been cited as more accessible than bicycles due to not requiring any cycling skills or appropriate clothing (Caspi *et al.*, 2020). Shared e-scooters solve problems of storage space, ownership, and maintenance costs which further enables access (Shaheen and Cohen, 2019). In addition, they do not require facilities such as showers at destinations which was raised as a concern by Winters *et al.* (2017). Groth (2019) suggests that shared e-scooter systems have the potential to shrink the gap in accessibility between those with private transport and those without it. However, it could lead to a new divide between 'onliners' and 'offliners' due to most shared mobility services requiring the use of a smartphone (*ibid.*). In addition, e-scooters are often associated with areas which already have infrastructure for cycling an areas with high rates of employment

(Caspi *et al.*, 2020). In this instance, inequalities in access to transport are likely to increase. Brown *et al.* (2020) find that e-scooter users are, on average, more likely to be white, affluent, male, and young. Although Fitt and Curl (2020) agree with these findings, they also suggest that shared bicycles and e-scooters still have a higher percentage of female users and users from ethnic minorities than private bicycles. They argue that government regulation is essential to prevent e-scooters from increasing inequalities in access to transport.

Accessibility is often discussed in the context of access to mobility, as in the previous paragraph (Goldman and Gorham, 2006). However, Goldman and Gorham (2006) argue that transport should be seen as mobility for access to services in the city. Therefore, it is essential to consider transport systems alongside land use systems with working towards sustainability goals (Kinigadner *et al.*, 2020). The relationship between land use and transport policies has also been acknowledged as significant by King and Kirzek (2020), with the former relating to the opportunities in a region and the latter about how long it takes to get to those opportunities. King and Kirzek (2020) argue that car-focused urban policies and design have led to urban sprawl, making opportunities inaccessible for those without a car.

Micromobility sharing systems have been promoted as a tool for integrating existing transport systems through what is known as 'last-mile travel' (Parkes *et al.*, 2013). Fitt and Curl (2019) found that over half of respondents used e-scooters as part of a journey with multiple modes. However, Gössling (2020a) found that 30% of e-scooter trips were for journeys of more than 6km, subsequently arguing that e-scooters are not just for short-distance first- or last-mile travel. This presents the potential role of e-scooters to reduce journeys made by car, of which one in four are less than four miles (6.4km) (King and Krizek, 2020). This highlights that accessibility to the city is inextricably linked to CO_2 emissions and that the success of e-scooters lies with a modal shift away from cars. Another reason that individuals might choose e-scooters over cars is that they tend to be faster than automobiles when traffic is congested (McKenzie, 2020). Although there are several positives, Brown *et al.* (2020) state that a major concern with e-scooters is parking. E-scooters blocking pavements present barriers to those in wheelchairs or with visual impairments which makes the city less accessible for these individuals (*ibid.*). However, despite numerous newspaper reports of e-scooters blocking pavements, Brown *et al.* (2020) found that there were few occasions where e-scooters did block pavements and that cars were doing so much more frequently. However, in general, James *et al.* (2019) found that pedestrians perceived their safety to be lower when e-scooters were near them. The success of e-scooters depends on their ability to enhance accessibility of the city rather than hindering it.

2.3 Governance of urban transport systems

Governance is defined by Broto (2017) as the actions or interventions by multiple actors to address a specific problem. It is increasingly recognised that cities play an important role for meeting collectively agreed sustainability goals, such as the United Nations Sustainable Development Goals (SDGs) (Bai *et al.*, 2016). This is confirmed by the city-focused SDG-11 which is concerned with environmental, social and economic functions in urban systems, and declares that there has been devolution of governance (Parnell, 2016).

Aldred (2012) notes that neoliberalism in transport has not been a simple withdrawal of the state. Instead, transport governance is morphing into a system by which the state governs in partnership with non-state actors (*ibid.*). When e-scooters first arrived in cities, they often did so overnight which left little time for city planners to assess their impact on infrastructure and transport systems (McKenzie, 2020). Since then, there has been more collaboration between private e-scooter operators and local authorities. E-scooters are one form of 'mobility as a service' (MaaS), in which private companies provide mobility options, often through smart-phone apps. MaaS has been promoted by those in favour of a 'smart transition'. The smart transition is a theory in which individuals can access efficient and sustainable transport that is flexible and meets their needs (Docherty *et al.*, 2018). However, Docherty *et al.* (2018) argue that there will need to be effective governance to ensure that the smart transition provides more public value to the public, rather than less. Therefore, Dowling and Kent (2015) argue that in the transport sector, the boundaries between public and private are increasingly blurred.

Dowling and Kent (2015) focus their discussion on car-sharing systems, but the principles can be applied to other shared mobility schemes which includes e-scooters. Their paper emphasises that without the local authority, the operator would have no designated parking spaces which would not be as attractive to customers. Conversely, local authorities benefit from the service provided to address negative externalities associated with private car ownership. Similarly, although e-scooters are operated by private companies, they compete for space on public infrastructure with motorists, cyclists and pedestrians (Gössling, 2020a). This backs up Docherty *et al.*'s (2018) argument that the smart transition will require a move away from traditional publicly administered services, to one where there is management of services provided by a range of actors to ensure public value. This idea has previously been referred to as 'new mobility' by Goldman and Gorham (2006). 'New mobility' includes new technologies and restructured governance to provide legitimate alternatives to private cars and influence how individuals plan their activities (*ibid.*). Goldman and Gorham (2006) include shared services and real-time information via smartphones as part of 'new mobility'; both of which are used by e-scooter operators (Lazarus *et al.* 2020). The challenge for local authorities is to maintain a collaboration with private companies to provide a service that is environmentally and socially sustainable.

3. Methodology

Policy analysis has been selected as an appropriate method for meeting the aims and objectives outlined in section 1.1. The method recognises that there are difficulties in answering questions that refer to future scenarios but sets out a framework for how to best attempt to do so.

3.1 Policy analysis

Cairney (2019) defines policy analysis as identifying a policy problem and presenting the possible solutions. Boulanger and Brecht (2005) suggest that at its simplest, policy analysis requires the identification of policy programmes, choosing the criteria of the assessment, assessing the alternatives by the chosen criteria, and making a decision about the most appropriate option. However, problems that occur in society are often difficult to define because solutions cannot be proved before they are applied (Patton *et al.*, 2016). This means that solutions are not guaranteed to provide intended results, and the cheapest solutions are rarely the best (*ibid.*). In addition, policy analysis is inherently uncertain due to the problem of attempting to answer questions about future scenarios (Bardach and Patashnik, 2016).

There are several guides on how to do a policy analysis and each has between five and eight steps (Cairney, 2019; Bardach and Patashnik, 2016). This study has primarily followed the five steps set out by Cairney (2019, n.p):

1. *"Define a policy problem identified by your client*
2. *Identify technically and politically feasible solutions*
3. *Use value-based criteria and political goals to compare solutions*
4. *Predict the outcome of each feasible solution*
5. *Make a recommendation to your client."*

For this research, the meta-problem is that urban transport policy has failed to significantly reduce CO_2 emissions in line with net-zero targets. However, the focus has been narrowed to how a new technology can be best incorporated as part of a more sustainable transport system. Therefore, shared e-scooter systems have been identified as a technically and politically feasible solution. This will be analysed against the baseline of Bristol's current transport policies. Herman (2013) suggests that using a baseline is important for analysing the success of alternative scenarios and is usually included as one of the policy programmes as the 'do nothing' approach. BOCESB (2020) have set out goals for Bristol's transport system that are revolved around environmental and social sustainability. These have formed the structure for the analysis and are clearly presented in the outcomes matrix at the end of this chapter. The predicted outcomes for e-scooters are highly dependent on the final modal mix which is demonstrated by the two scenarios presented in the outcomes matrix. Therefore, this study has deviated slightly from predicting whether the outcomes of policies are feasible, to provide more detailed policy advice about how to achieve the most public benefit from the implementation of shared e-scooter systems. This practical advice takes the form of policy instruments which are about the implementation of policy programmes (Prime Minister's Strategy Unit, 2004). Lastly, the recommendations for decisionmakers in Bristol can be found in section 5.

Browne *et al.* (2018) argue that there are three main approaches to policy analysis. The first is referred to as 'traditional' and works on the basis of policy analysis being an objective analysis on the pros and cons of policy without taking political circumstances into account. The second, 'mainstream', builds on the first to include the process of policy, policy networks, and governance. The last is 'interpretive', which understands policy problems as historically and culturally produced and investigates the assumptions underlying policy framework. Although Browne *et al.* (2018) differentiate between these three approaches, they also note that often a policy analysis will combine more than one approach. This policy analysis primarily takes a 'mainstream' approach and focuses, in particular, on the governance involved in policy implementation. However, it does also draw upon the 'interpretive' approach due to understanding that the history of car-centric policies are still ingrained in the politics of transport planning (King and Kirzek, 2020).

3.1.1 Policy transfer

Policy transfer has been increasingly used by policymakers and frequently forms part of policy analysis (Dolowitz and Marsh, 2000). Policy transfer takes four main forms which include directly copying, transfer of the ideas supporting the policy programme, a mixture of more than one policy, or simply inspiration for a different policy or policy programme (*ibid.*). Dolowitz and Marsh (2000) explain that in a global crisis, for which they reference the economic downturn of the 1980s, but which could as easily refer to the Covid-19 pandemic and subsequent recession, policy actors tend to feel more pressure to engage in policy transfer. This could explain why e-scooter pilots have been brought forwards in the UK. Although Dolowitz and Marsh (2000) suggest that policy transfer is limited between local authorities, since the paper was written there has been an increasing focus on the agency of cities and engagement in city networks such as the C40 Cities. Parkes *et al.* (2013) refer to the process of technologies and policies spreading to other places as 'diffusion theory'. They note that city networks play an important role in addition to the success of technologies and their accompanying policies. However, a significant limitation is that policies that have been successfully implemented in one place may not have the same positive impact in another place (Cairney, 2012).

Policy transfer includes understanding the successes and failures in other cities and analysing whether they will be applicable for the city making decisions about policy (Dolowitz and Marsh, 2000). Therefore, this policy analysis will investigate e-scooter policies and their successes and failures in six case study cities in Europe and the United States (US). The case study cities are Paris, Vienna, Baltimore, Chicago, Portland, and San Francisco. The case studies were chosen primarily because they had accessible documents. To examine the policies in these cities, a document analysis was undertaken. Browne *et al.* (2018) suggest using document analysis as part of mainstream policy analysis. Document analysis requires thorough examination and analysis of content before processing and organising the information into codes and themes to answer central research questions (Bowen, 2009). This project draws on documents from Bristol to understand the baseline scenario and documents from other cities with existing e-scooter policies to analyse the potential outcomes and make recommendations.

3.1.2 Outcomes matrix

The outcome matrix has been informed by the document analysis and the findings from this are discussed in more detail in section 4. The three key policy approaches have been assessed against the baseline scenario in which e-scooters are not implemented in Bristol. Table 1 shows the outcomes matrix for scenario one, in which the modal shift is predominantly made up of e-scooter users who would previously have travelled by car and scenario two, in which the modal shift is predominantly from active travel to e-scooters. The matrix score has been combined with the weightings outlined in Table 2 to provide a total score for each approach. However, for both scenarios, a balanced approach will meet the most criteria (12 in scenario one and 0 in scenario two). However, it still does not fulfil all of the criteria and is likely to be the approach that costs the most to e-scooter operators, and possibly to the council in administrative and regulatory costs.

Table 1: Outcome matrix for scenario one (modal shift predominantly from cars) and scenario two (from active travel) where each approach is referred to as either positive (+), negative (-) or similar to (=) the baseline scenario (e-scooters are not introduced to Bristol). These are used with weightings to provide an overall score between -19 and +19. Weightings are justified in Table 2.

		Scenario One			Scenario Two		
Criteria (and weighting)	**Weighting**	**Environmental approach**	**Social approach**	**Balanced approach**	**Environmental approach**	**Social approach**	**Balanced approach**
Reduced CO_2 emissions	3	+	=	+	-	-	-
Improved access to transport services	3	=	+	+	=	+	+
Reduced local air pollution	3	+	+	+	=	=	=
Reduced congestion	3	+	+	+	=	=	=
Increased health and wellbeing	2	+	+	+	-	-	=
Costs to e-scooter companies	1	=	-	-	=	-	-
Political feasibility	1	=	=	=	+	+	+
Administrative feasibility	1	=	=	-	+	=	=
Total score		**11**	**10**	**12**	**-3**	**-2**	**0**

Table 2: shows the weightings used for the outcomes matrix and the justification for the weight.
Criteria area assigned a weighting between 1 and 3, where 1 is least important and 3 is most important.

Criteria	Weighting	Justification
Reduced CO_2 emissions	3	Bristol has announced that the city aims to reach net-zero emissions by 2030 (scope 1 and 2 emissions) (BOCESB, 2020).
Improved access to transport services	3	A key aspect of Bristol's net-zero journey is for it to be a just transition (BOCESB, 2020). In addition, Bristol has set its own targets within the SDGs and aims to reduce inequalities between communities in the city (Fox and Mcleod, 2019).
Reduced local air pollution	3	Air pollution in Bristol is responsible for 300 premature deaths per year (Fox and Mcleod, 2019). There are also 77% who think that air pollution is a problem locally (BCC, 2019c).
Reduced congestion	3	Bristol is one of the most congested cities in the UK and the cost to the local economy is estimated at £600 million (BGC, 2015). In addition, BOCESB (2020) highlights that roads take up a lot of space in the city and these could provide more public benefit if they were reassigned for housing or green spaces.
Increased health and wellbeing	2	In addition to reducing air pollution, there are other health benefits that can be achieved from some modes of transport. However, this is primarily a co-benefit.
Costs to e-scooter companies	1	There are limited costs to the council, but tight restrictions on e-scooter companies can increase their costs and may lead to their withdrawal from the city if operations become financially unsustainable (CBInsights, 2020).
Political feasibility	1	Important in all policy analyses to ensure that all actors involved support the proposed policy (Bardach and Patashnik, 2016).
Administrative feasibility	1	Ease of implementation, including cost (Bardach and Patashnik, 2016).

The outcomes matrix provides an overview of the potential for introducing e-scooters to meet sustainable transport goals in Bristol. They highlight that the modal shift towards e-scooters is more important than how e-scooters themselves are regulated. However, the complexities of city systems that could impact the outcomes need more consideration (Bai *et al.*, 2018). Although a holistic approach to the transport system is essential, it is still important to understand the details of e-scooter policies so that local authorities can have the best chance of successfully implementing e-scooters as part of a sustainable urban transport system.

3.2. Ethics

This project uses secondary data from open sources which meant that few ethical considerations were required (appendix). However, Cairney (2020) highlights that the ethics of policy analysis is to ensure that rather than solely focusing on the outcomes of policies, inclusion is also considered. Different lenses should be applied when framing the analysis and policy analysts must be wary of their power to present information which may influence the policy outcome (*ibid.*). Therefore, this study addresses two key approaches: environmental and social.

4. Analysis

This policy analysis starts with introducing the baseline scenario in Bristol. This considers whether Bristol is likely to meet its net-zero goals without making changes to the transport system. Due to the changes in UK law, the introduction of e-scooters is inevitable. Therefore, there will be a detailed analysis of whether e-scooter policies in six cities in Europe and the US have met the criteria set out in the outcomes matrix. The policies will be assessed for their environmental and social sustainability, as well as their applicability to Bristol's transport system.

4.1 The 'do nothing' approach

Herman (2013) explains that policy analysis usually begins with what would happen if the status quo remains. In this instance, the 'do nothing' approach would be to continue with national legislation that e-scooters are banned from public roads, pavements and cycleways (DfT, 2020b). This would mean that Bristol would simply not sign up to be a city that pilots e-scooters.

4.1.1 Bristol's current transport strategy

Bristol is the first city in the UK to have published a report on its progress towards the SDGs (Fox and Mcleod, 2019). The report highlights that increases in active travel have led to a reduction in air pollution with $PM_{2.5}$ and PM_{10} now consistently remaining below European Union (EU) recommended levels. However, evidence suggests that NO_x concentrations frequently rise above EU regulation. In a report by the Centre for Sustainable Energy, it was found that despite investments into public transport and active travel leading to a 50% increase in journeys made by bus and a 100% increase in cycling over the past 5 years, there has not been a significant reduction in vehicle miles (Roberts *et al.*, 2019). In addition, CO_2 emissions have only decreased by 9% between 2005 and 2017. To reach net-zero emissions by 2030, Bristol will need CO_2 emissions to decrease by 88% from the 2005 baseline (*ibid.*).

Although alternative policies are not the focus of this policy analysis, Bristol already has several policy programmes in place for the future. These are aimed at addressing the meta-problem defined by this policy analysis, which is that transport policies have, to date, failed to reduce CO_2 emissions in line with net-zero targets. Roberts *et al.* (2019) detail that there are two main routes for decarbonised transport. One is a 'technological approach' which focuses on electrification of Bristol's vehicle fleet. The other is a 'balanced approach' which focuses on modal shifts to active travel to reduce vehicle miles and electrification of the remaining vehicle journeys. Both are shown in Table 3 alongside the baseline (current emissions) and show that air pollution and CO_2 emissions are predicted to decrease drastically. BOCESB (2020) has taken this on board and set a goal to increase active travel and reduce vehicle miles by 40%, with the remaining fleet to be 90% electric by 2030. From the predictions by Roberts *et al.* (2019) this would successfully reduce CO_2 emissions by 88% within the transport sector.

Table 3: Reduction in emissions from future vehicle fleet scenarios in Bristol (adapted from Roberts *et al.*, 2019).

	Baseline	'Technology' scenario (% reduction from baseline)	'Balanced' scenario (% reduction from baseline)
Vehicle milage	1,443 million miles	0	41
Total fleet size	226,690	0	40
NO_x emissions	291 kt	87	92
$PM_{2.5}$ emissions	48 kt	8	37
CO_2 emissions	534 kt	82	88

Swan *et al.* (2020) point out that Roberts *et al.*'s report does not translate the required reduction in vehicle miles into modal share. Roberts *et al.* (2019) simply suggest that target modal shares should be similar to those of Vienna, Berlin, Copenhagen, and Amsterdam. Interestingly, each of these cities has shared e-scooters in operation. Figure 1 shows that the current modal share is more than 50% private car and that this needs to be reduced to 20% to meet net-zero targets according to Swan *et al.* (2020). This is a more substantial reduction than that suggested by the Sustainable Transport Network (2019) and shows that the 'do nothing' approach is not going to meet the sustainable transport targets set out in the Bristol's One City Plan (BOCESB, 2020). In addition, a modal shift will be necessary to combat the city's congestion which is otherwise likely to increase due to expected population growth (Fox and Mcleod, 2019).

Finally, the Bristol One City Plan (BOCESB, 2020) highlights that the city aims to have a fair and just transition which provides new jobs and opportunities as well as improving health and wellbeing. The SDG progress report for the city notes that Bristol's Gini coefficient is 0.4 which suggests that inequality is slightly higher than other UK Core Cities (Fox and Mcleod, 2019). In addition, inequality in Bristol has continued to increase. When relating to the accessibility of transport, only 42.5% of those in the 10% of most deprived individuals reported being satisfied with local bus services in the Bristol Quality of Life survey (BCC, 2019c). This was compared to 48.1% on average. However, those in the most deprived group were more likely to be using those bus services to get to work. Therefore, Bristol needs to improve equality between groups in the city, and accessibility to services and opportunities has the potential to help (Goldman and Gorham, 2006). However, this will require more than simply improving transport services. As has been highlighted in the literature review, this will also require land use policies in which opportunities are made available in those areas of the city which are currently more deprived.

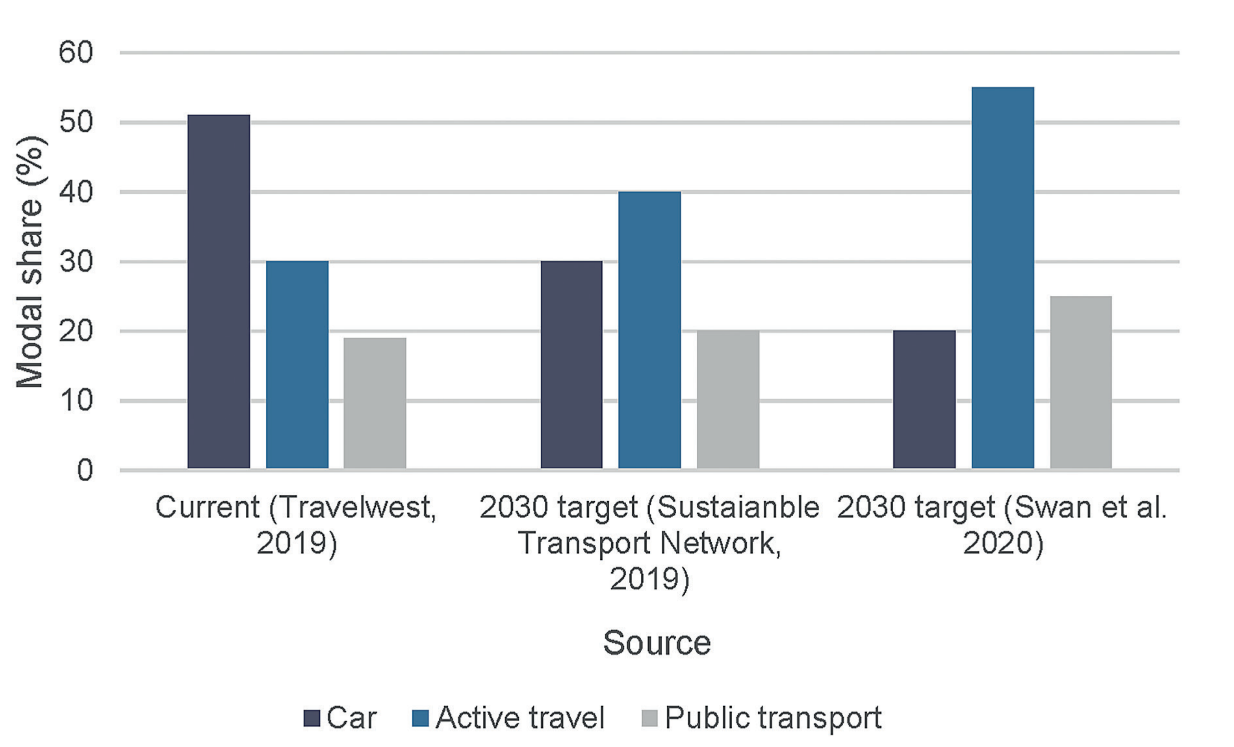

Figure 1: The current modal share of journeys in Bristol and two recommendations for the modal share of Bristol in 2030.

Overall, Bristol would not meet the net-zero goal by 2030 with a 'do nothing' approach. The 'do nothing' approach would also see congestion increase due to population growth and would not address the inequalities in the city. However, there are already policies in place to work towards these targets, and recognition of the important of a just transition. These are important factors to consider when introducing e-scooters as they are likely to influence their success due to the complexity of transport systems and impact on individual modal choices.

4.2 The inevitable introduction of e-scooters

The mayor of the West of England Combined Authority (WECA) stated that e-scooters will be part of plans to provide alternatives to private cars which will reduce congestion, improve air quality, and reduce CO_2 emissions (WECA, 2020). However, as has been highlighted by the literature review, the benefits of e-scooters are more complicated. E-scooters in Bristol, as in other cities, will be privately operated as rental schemes, but private ownership will remain illegal in public spaces (DfT, 2020b). Therefore, Mahoney (2020) recommends in a report from the C40 Cities Network that e-scooters need appropriate regulations to ensure that they provide a sustainable transport service that is beneficial to the public. This section will firstly explore how an environmental approach to regulation of e-scooters might be implemented. Secondly, the same will be done for a socially sustainable approach. These are followed by a short section which considers the possibility of a balanced approach. The final section differs slightly. It will focus on safety regulations which are important in both approaches if e-scooters are to be successful, and was a key theme raised by the document analysis.

4.2.1 Environmental approach

Transport makes up 34% of an average Bristolian's carbon footprint and 17% is directly attributable to private cars (BOCESB, 2020). Many of these journeys are short, and in 2011 44,000 residents reported commuting less than 5km by car (BGC, 2015). This suggests that there is potential for e-scooters to replace these trips due to them frequently being used for short trips (Gössling, 2020a).

Although many cities have adopted e-scooters as part of a transition to sustainable transport systems, few were found to have any policies or regulations directly related to ensuring the environmental sustainability of this mode. However, Paris has recently restricted the number of operators to three. Operators must now tender for one of the permits which are allowed to deploy 5,000 e-scooters (Cenex, 2020). The tenders are awarded based on their abilities to fulfil criteria relating to environmental responsibility, user safety, and management and maintenance (*ibid.*). These changes are the most recent in Paris, following several difficulties which will be explored more in the next chapter. Aside from this, environmental policies have taken a more holistic approach to encourage a modal shift from cars.

In the literature review (section 2.1.2) the uncertainties surrounding the environmental benefits of e-scooters were discussed. The Institute of Transport Economics (ITF; 2020) are still investigating whether lightweight e-micromobilities have a smaller carbon footprint, when considering a full lifecycle analysis, when compared to larger electric vehicles. Once there is more evidence on this, there will be more grounding for analysis on whether e-scooters can contribute to the environmental sustainability of urban transport systems. However, in Bristol only 0.4% of the vehicle fleet is electric (Roberts *et al.*, 2019). The London Cycling Coalition (LCC; 2020) suggest that e-scooters still produce fewer greenhouse gas emissions than fossil-fuel powered cars. However, decisionmakers have sometimes assumed that the modal shift will come from car-use (WECA, 2020). E-scooters still produce more emissions than active transport and public transport (Fishman and Cherry, 2016). Therefore, any environmental gains from introducing e-scooters are reliant on a modal shift away from fossil-fuel powered cars.

A report from Cenex (2020) calculated that a modal shift, comprised of 30% form cars, 50% from active travel, 12.5% from public, and 7.5% that would otherwise not have made a trip, would lead to a 45% reduction in CO_2 emissions. LCC (2020) used worldwide data to calculate that, on average, the modal shift to e-scooters was comprised of 36% from private cars, 37% from walking, 9% from cycling, and 3% from public transport. However, even Lime (2019a), a leading e-scooter operator, reported that on average only 25% of e-scooter trips replaced car journeys. Despite this, the company claims to have prevented 9,000 tonnes of CO_2. However, there is no confirmation on whether this includes a full lifecycle analysis, and this makes up a high proportion of e-scooter CO_2 emissions (Severngiz *et al.*, 2020).

Table 4 highlights that in US cities, the shift from cars is higher than the suggested split from Cenex (2020). However, the opposite was true for cities in Europe. Unfortunately, there was no data available for Vienna, but responses in Oslo and Lisbon found that a shift from cars made up 5% and 21% respectively (Lime, 2019b). This trend was also identified by the ITF (2020). LCC (2020) suggest that the higher modal shift from cars to e-scooters in the US is due to lower availability of public transport. Therefore, adopting US policies to improve environmental sustainability would not be effective. A high shift from active travel to e-scooters has been seen in both continents, but particularly Europe. This leads to higher CO_2 emissions due to active travel not contributing at all. In addition, the co-benefits associated with active travel, such as increased physical activity (Winters *et al.*, 2017), are not met by e-scooters. Therefore, active travel must remain a priority if Bristol is to meet net-zero emissions targets as well as increasing health and wellbeing, as it set out in the Bristol One City Plan (BOCESB, 2020).

Table 4: Modes that respondents would have taken if e-scooters had not been available. A "-" represents no data available. Baltimore respondents were only asked how they normally get to work, but only 25% of e-scooter trips were made to get to work). Sources: 6t Trottinets (2019), Baltimore City Department of Transport (2019), City of Chicago (2020), Portland Bureau of Transportation, 2018), San Francisco Municipal Transport Agency (2019).

City	Private car and ride hail (%)	Walk (%)	Cycle (%)	Public transport (%)	No trip (%)	Other (%)
Paris	8	47	12	30	-	3
Baltimore	69	7	1	18	-	5
Chicago	43	30	7	14	3	3
Portland	34	37	5	-	-	-
San Francisco	41	31	9	11	-	-

In cities that do have e-scooters and where net-zero emissions targets are within closer reach, there are other policies in place. LCC (2020) reference Barcelona and Paris as cities which are using a neighbourhood approach to make cities more walkable. This has been trialled in Waltham Forest in London where roads are closed to through traffic by bollards

(*ibid.*). The scheme has reduced traffic by 16% in residential areas and 5% on surrounding main roads (*ibid.*). In Sofia, 300 car parking spaces have been reallocated as spaces for bicycles and e-scooters which has further disincentivised driving into the centre of the city due to difficulties of finding parking (Cenex, 2020). When e-scooters are paired with more ambitious policies such as these, they are more likely to result in outcomes associated with scenario one (a shift from cars to e-scooters) which provides more public benefit (Table 1). Cenex (2020) stress that these approaches should not be framed as a fight against cars, but a correction of a system that disadvantages those who do not own a car.

Understanding the city as a complex system and taking a more holistic approach to environmental transport sustainability is likely to be the most successful in any city. A holistic approach includes using 'avoid', 'shift' and 'improve' strategies, referred to in the literature review, together as a comprehensive urban transport plan. In Bristol, the Covid-19 pandemic has led to a bringing forward of road closures, such as those on Baldwin Street and Bristol Bridge to reduce traffic in the city centre and encourage safe active travel and social distancing (BBC Radio 4, 2020). However, as was shown by the 'gilets jaunes' movement in 2018, it is important that there are alternatives when ambitious policies are put in place (Nelson, 2020). E-scooters have the potential to provide that alternative and encourage support for the reallocation of road space from cars to micromobilities.

4.2.2 Social approach

The review of literature and the document analysis both revealed that equal access to transport and opportunities provided by cities are key underlying factors of how best to regulate e-scooters. Bristol's One City Plan (2020) highlights that a just transition is an essential aspect of the net-zero targets for the city's transport sector. This aligns with the SDG aim to 'leave no-one behind' in the path to sustainable development (Fox and Mcleod, 2019).

The Bristol Quality of Life Survey (BCC, 2019c) revealed that 77% of Bristolians think that air quality and traffic pollution are problems locally, and 5.8% reported air pollution as a barrier to them leaving their home. Surprisingly, of those in the 10% most deprived, only 67% reported air quality and traffic pollution as problems. This is in contrast to theories highlighted in the literature review that the most deprived are the most exposed to environmental pollution (Barnes *et al.*, 2019). However, the Quality of Life survey is based solely on perceptions and not measurements of air quality. Furthermore, Fox and Mcleod (2019) state that

400 premature deaths per year can be attributed to poor air quality in Bristol. Similarly to reducing CO_2 emissions, local air pollution is a problem that e-scooters can potentially assist with, if the modal shift comes from vehicles with internal combustion engines (ICE vehicles). In addition, if a modal shift comes from active transport, this could lead to increased sedentary lifestyles, rather than decreased (Severngiz *et al.*, 2020). However, only 6% of respondents from Paris said that they walked less as a result of using e-scooters (6t-bureau de recherche, 2019). Sustrans (2020) suggest that Bristol continues to prioritise walking and cycling, but supports the use of e-scooters if it leads to increased demand for cycling infrastructure which they suggest could result in an increase in cyclists.

Another concern for Bristolians, as mentioned above, is access to public transport services (BCC, 2019c). This includes services to their area, but also the cost of those services. There is already significant inequality in the city as highlighted by the Gini coefficient of 0.40 (Fox and Mcleod, 2019). In Portland, the Gini coefficient is 0.48; slightly worse than Bristol's

(Wellbeing in the Nation Network, n.d.). The Portland Bureau of Transportation (2018) found that e-scooters are a relatively expensive mode of transportation. A 19-minute trip was calculated as \$3.85, versus \$2.50 for public transport, or \$1.52 for the city's docked, public bikesharing system (*ibid.*). Although Portland requires e-scooter operators to offer discounts to those on low incomes, there are also discounts for the other two modes stated that still leaves e-scooters as the most expensive option (*ibid.*). Additionally, all companies reported that no users had signed up to the low-income payment schemes. However, local authorities suggested that this was due to a lack of promotion from operators (*ibid.*).

Chicago has a similar scheme and permits are only offered to operators if they provide schemes for those without bank accounts or smart phones (City of Chicago, 2020). This could have helped prevent the gap between 'onliners' and 'offliners' mentioned by Groth (2019). However, the scheme had a very limited impact due to several operators not complying and others not advertising the availability of the scheme (City of Chicago, 2020). Similarly, San Francisco's low-income payment plan was only used for 0.4% of trips, despite 9% of users being eligible (San Francisco Municipal Transport Agency; SFMTA, 2019). In Bristol, 14.9% of respondents stated that they were uncomfortable using smart technologies. Therefore, it would be important not to isolate these people from using e-scooters. These examples highlight the difficulties of improving accessibility of transport when governance systems involve relationships between public and private actors.

A more successful regulation of e-scooters to promote social sustainability is the reallocation of e-scooter fleets. Chicago, Portland, and Baltimore all request that operators place a share of e-scooters in 'equity' zones, which are areas of low household income levels (Baltimore City Department of Transport, 2019). Of the e-scooter fleet in Baltimore, 25% are required to be located in these areas (*ibid.*). In Chicago, redistribution of e-scooters is focused on providing transport in areas currently underserved by public transport systems. In Portland, 100 e-scooters are required to be located in the east of the city at the start of each day (Portland

Bureau of Transportation, 2018). Although rebalancing e-scooters around the city was successful in preventing e-scooter operators from only providing services to affluent areas, operators in Chicago stated that the rebalancing system was environmentally and economically unsustainable (City of Chicago, 2020). This highlights that solely focusing on a social approach can lead to trade-offs for the environment. This is mostly due to the fact that large vehicles are required to rebalance the e-scooters and as Severngiz *et al.* (2020) pointed out, this can make up a significant proportion of e-scooters lifetime CO_2 emissions. A more balanced approach to e-scooter policies might see local authorities requesting that e-scooter operators are distributed to areas of low-income but also require this to be done using fully electric vehicles.

European cities have had less focus on e-scooters as a tool for improving accessibility to transport. This could be because there tends to be less inequality between those earning the most and the least. However, despite having a much lower Gini coefficient than US cities (0.34; OECD, n.d.), Vienna has introduced a system which requires e-scooter operators to spread their fleets of up to 1,500 equally between the central district, districts close to the centre and districts further away which have lower access to existing transport (Moran *et al.*, 2020). In Bristol, 16% of the population live in areas which have been ranked among the 10% most deprived in England (Fox and Mcleod, 2019). This would suggest that policies to ensure e-scooters are available in these areas might benefit these communities. Without intervention from governments, these schemes would not occur which could lead to e-scooters only being provided in affluent areas where there is already high accessibility to transport and opportunities.

LCC (2020) warn that reliance on private operators carries risks, including sudden withdrawal of services which can leave residents without mobility options and further increase levels of transport inequality. Dockless bikesharing services from YoBike in Bristol have already shrunk the perimeter of their operations which no longer include areas of eastern and southern Bristol due to higher levels of vandalism and theft (Cork, 2018). In Manchester, MoBike, another private dockless bikesharing service withdrew their services completely after bicycles were stolen and thrown into rivers (Moran *et al.*, 3030). In the UK, despite e-scooter trials having only recently started, Voi (an e-scooter operator) is already putting identification plates on e-scooters and introducing a 'one strike and you're out' policy for misuse (Paton, 2020). The company reported that vandalism and anti-social behaviour in Coventry and Middlesbrough is already higher than in any other market (*ibid.*). This is not only a concern regarding sudden loss of services due to withdrawal, but is also an environmental concern. If e-scooters have shorter lifetimes due to vandalism, their lifecycle emissions (predominantly from production) will increase (Hollingsworth *et al.*, 2019). This highlights that there are some policies targeted towards e-scooters which are beneficial for both environmental and social sustainability.

Another risk of withdrawal from private e-scooter companies is that even before the Covid-19 pandemic, e-scooter companies were starting to struggle financially and some cities have faced a doubling of fares (CBInsights, 2020). This would mean that some users become outpriced and inequalities in access to transport could potentially increase. This would leave local authorities, such as Bristol, with the choice between withdrawal of the service, subsidising of the service, or taking over of the service. So far, e-scooter sharing systems have not been run by governments, but shared bicycle schemes have done (Parkes *et al.*, 2013). However, shared bicycles have proven public benefits (Nello-Deakin, 2020) which e-scooters are not likely to match. In Bristol, grants from the central government have already reduced by 78% between 2010/11 and 2019/20 down to £45 million (Fox and Mcleod, 2019). Therefore, there would need to be significant public benefit from e-scooters for local authorities to start funding them.

The social approach has some overlaps with the environmental approach. For example, there is recognition that a modal shift will be important to achieve the most public benefit. In this instance, this relates to a decrease in traffic being beneficial for human health. With regards to accessibility to transport in response to inequalities in cities, there have been varying levels of success. This was demonstrated by schemes for those on low incomes and regulations for redistribution. However, they tend to lead to increases in collection and transportation of e-scooters which undermines their environmental benefits (Hollingsworth *et al.*, 2020).

4.2.3 Balanced approach

The outcomes matrix shows that a balanced approach scores highest in both scenarios (a modal shift from cars (score = 12) and active travel (score = 0). A balanced approach would aim to mitigate the environmental trade-offs associated with the social approach. So far, no cities analysed for policy transfer have successfully achieved a balanced approach. However, Paris has recently made changes to policy so that e-scooter operators must tender for permits (Cenex, 2020). This lets local authorities clearly set the terms. Additionally, the limited number of operators makes it easier to manage a productive governance system. Another approach is to charge e-scooter operators a fee for using public infrastructure. This aims to internalise externalities by investing in infrastructure for e-scooters and cyclists (City of Chicago, 2020). In addition, there are constantly new ideas and technologies which quickly spread between cities. POLIS (2020) has suggested that e-scooters could have solar-powered charging points in cities which would reduce the environmental burden associated with recharging them (Hollingsworth *et al.*, 2019). However, it is important that costs to e-scooter operators do not become so high that they suddenly pull out of markets. Overall, the difference in scores between the scenarios stresses the importance of modal shift for achieving Bristol's target's to meet net-zero emissions by 2030 whilst simultaneously reducing inequalities within the city.

4.2.4 Safety policy and regulation

Although safety has not been suggested as an approach, because it is important for all the approaches, it was a significant theme in the documents analysed. In the UK, there have been concerns about the safety of e-scooter users and the impact on the safety of other road users (Tapper, 2020). It has been confirmed by the central government that e-scooters will not be permitted on pavements (DfT, 2020b). However, there is clear support for their use in cycle lanes. Additionally, a recent report from the Climate Assembly UK (2020) stated that 58% of participants 'strongly agree' that there should be investment in cycling and scootering facilities, and a further 17% who 'agree'.

Observations of e-scooter behaviour in Portland found that where bicycle lanes were segregated from the road, rates of e-scooters using the pavements were lower. Where there were no cycle lanes, 39% rode on pavements; this reduced to 21% where bike lanes were present, and 8% when bike lanes were segregated from traffic (Portland Bureau of Transportation, 2018). A similar, but less extreme, trend was found in Chicago. There, 15.2% of riders were reported being on the pavements when there were no bike lanes, which lowered to 10% when they were (City of Chicago, 2020). LCC (2020) suggests that this is because users feel unsafe riding e-scooters directly next to traffic and recommend the reallocation of road space for e-scooter implementation to be successful. This result is the hope of active travel advocates Sustrans (2020) who hope that e-scooters will lead to an increase in cycling infrastructure which could also be used by cyclists. In turn, this could lead to further increases in cycling in Bristol. A survey by Sustrans (2019) found that 82% of Bristolians thought that more segregated cycle tracks would encourage them to cycle more and 70% support building these even if it takes room away from other traffic. If this was the result, it is likely that there would be a significant decrease in negative externalities produced by cars along with the co-benefit of increased physical activity. Therefore, safety is linked to the sustainability of urban transport systems.

Road speed limits are another factor that influence whether e-scooter users ride on pavements. In Portland, 18% of users were recorded as using pavements on 20 mph roads. This increased to 50% at 30 mph, and 66% at 35 mph (Portland Bureau of Transportation, 2018). This highlights that policies focusing solely on e-scooters themselves are unlikely to be satisfactory for their successful implementation. Local authorities will also need to consider wider transport systems. In Bristol, many of the roads are already 20 mph which has contributed to the city's status as one of the most cyclable cities in Europe (Roberts *et al.*, 2019). Keeping e-scooter users safe in cycle lanes or on roads with slow moving traffic is also important for pedestrian safety. Paris suffered from conflict between e-scooter riders and pedestrians after the total fleet quickly increased to 20,000 (Gössling, 2020a). The city has since introduced speed limits of 8 km/h on pavements and 20 km/h on cycle lanes and now has plans to ban their use on pavements altogether, along with an introduction of a €135 fine for doing so (BBC, 2020). In Madrid, e-scooter operators failed to comply with government requirements and were consequently ordered to remove all e-scooters within 72 hours after an elderly pedestrian was killed in a collision (Badcock, 2018). There is a balance of government intervention, operator compliance, and individual behaviour that must be maintained for safety of e-scooters. Without this, it is likely that e-scooters will fail to provide public benefits.

Another concern is the inappropriate parking of e-scooters. Although only 2.7% of respondents in the City of Chicago's (2020) survey reported having a disability, these respondents were more likely to have been negatively impacted by e-scooter parking. The accompanying report suggests the use of 'lock-to technology' which requires e-scooters to be locked to something, usually bicycle infrastructure. However, in Chicago, there is already limited cycle parking (*ibid.*). Therefore, the City of Chicago (2020) has charged e-scooter operators $1 per day to cover the costs of administration and infrastructure. 'Lock-to technology' has already been implemented in San Francisco and there has been a significant reduction in parking complaints (SFMTA, 2019). An alternative could be a step back to a docked system. However, this can result in docks not being placed in areas that most need them (Lazarus *et al.*, 2020). POLIS (2019) suggests that one solution to parking could be a requirement for e-scooters to be docked in dense city areas, but allowed to free-float in other areas so that finding a docking station is not a problem for users. This could be achieved through geofencing techniques. Geofencing could also be used to create parking zones, such as the 107 zones in Santa Monica (ITF, 2020).

Most cities also use geofencing to some extent. Geofencing uses GPS to ensure that e-scooters do not leave a defined permitter, either by ceasing to function beyond the boundary, or charging the user (Moran *et al.*, 2020). Geofencing has been used in Vienna to prevent e-scooters being used in parks, in crowded areas such as cultural landmarks and government buildings, or left in bodies of water (*ibid.*). These areas were defined by local authorities but interpreted by operators which has led to discrepancies between them. Additionally, during Moran *et al.*'s (2020) six month study, operators changed their coverage at least once, with some changing more frequently. Since the study took place, local authorities have set our areas to be geofenced so that individuals are not penalised when using different operators (*ibid.*). This highlights another difficult with private-public partnerships and the importance of clear communication from local authorities.

There are also less technologically-based solutions to the parking conundrum. Washington D.C. and London both use paint to mark out areas where dockless micromobilities should be parked (LCC, 2020). These are currently often marked out on pavements. However, converting on-street car parking would avoid taking space away from pedestrians. Each car parking space can accommodate 12 e-scooters, which makes this a more efficient use of space (Brown *et al.*, 2020). This reallocation of space from cars to other modes has the potential to affect individuals' modal choices.

In Baltimore and Portland, operators are required to provide in-app education about safe and legal operations of e-scooters when a new account is set up (Baltimore City Department of Transport, 2019; Portland Bureau of Transportation, 2018). In addition, helmets are often advised by local authorities and e-scooter companies. For example, Bird (a major e-scooter operator) encourage e-scooter riders to wear helmets by offering discounts if riders take a photo of themselves wearing a helmet (ITF, 2020). However, in practice, the flexibility of the transport mode makes it impractical. In San Francisco, over 18s are no longer required to wear helmets (SFMTA, 2020). In Portland, 2,292 free helmets were distributed to encourage their use, but there is no guarantee of this (Portland Bureau of Transportation, 2018).

In Bristol, 44% of residents are concerned about their safety when cycling, or do not cycle because they feel unsafe. This number is likely to be similar for e-scooter users due to their similar size. To avoid conflicts between different road users it is essential that any approach to e-scooter policy and regulation pays close attention to the safety of all road users. Updates to the UK's Highway Code stress that there is a hierarchy of right of way (DfT, 2020c). Pedestrians have right of way, followed by cyclists then vehicles. E-scooters are likely to be similar to bicycles. However, segregation of road users is the best way to ensure safety and maximise perceptions of safety.

5. Recommendations

The analysis of the successes and failures of the implementation of e-scooters in other cities in the US and Europe, alongside the review of existing literature, have informed the following recommendations:

Safety

Regardless of which approach to implementation of e-scooters is taken, the safety of their use is essential to their success. As has been highlighted by the analysis, cities have struggled with whether e-scooters are safe to use on roads or pavements. Consensus is that where possible they should be used on cycle lanes. To ensure safety of all road users and to gain co-benefits from increased active travel, Bristol should continue to invest in cycling infrastructure and to link up key routes. A more politically and administratively challenging option is to create micromobility streets. These would be closed to through traffic which could further incentivise the modal shift from cars to e-scooters or active travel. This means they provide environmental co-benefits and are more sociable places to live. This option would mean it is important to have services and opportunities located close to households which would require changes to land use policies as well as transport policy. Keeping road users segregated is the best way to increase perceptions of safety, which for cyclists in Bristol are already low and continue to decrease. Although it has not been used in practice, the idea from LCC (2020) about docking in central areas and free-floating in other areas of the city could reduce e-scooter clutter in the centre whilst still enabling freedom to park in other less connected areas of the city so as not to reduce the accessibility of the service.

A balanced approach

The outcomes matrix in section 3.1.2 (Table 1) shows that a balanced approach scores highest against the defined criteria. It is not significantly higher than the other approaches, but it is important that meeting environmental goals does not come at the cost of excluding certain communities in the city. To achieve a balanced approach it is recommended that Bristol requires operators to pitch how they can fulfil both environmental and social sustainability criteria in a similar way to the new system in Paris. For example, it might be that e-scooters are redistributed to areas of the city which have less accessibility to transport, but Bristol could request that this is done by electric vehicles which are charged using de-carbonised electricity rather than relying on 'juicers'. Although a balanced approach meets the most criteria, it is still very unlikely that measures targeted at e-scooters alone are going to lead to a substantial reduction in CO_2 emissions. Reducing emissions in the transport sector by 88% in Bristol, as recommended by Roberts *et al.* (2019) will require a holistic approach to the transport system that continues to reallocate road space away from cars. However, e-scooters provide an alternative mode of transport that might make this reallocation more politically feasible.

Governance

E-scooters, and other MaaS and shared mobility technologies, are part of the change in governance to one where there is collaboration between public and private. Although there are benefits associated with public ownership of transport systems, this has not been done by a city for e-scooters before. Unlike shared bicycles, there are more uncertainties about whether e-scooters have appositive or negative impact on the environment and on societies. Therefore, like other cities, it is recommended that Bristol partners with private e-scooter operators. However, lessons from other cities have highlighted that there needs to be communication and collaboration to ensure e-scooters provide public benefit. It is suggested that during the pilot, local authorities clearly set out their goals to e-scooter companies but also allow e-scooter companies to use their expertise. In addition, it is important that Bristol keeps up to date with future successes and failures in e-scooter policies with city networks such as the Core Cities.

6. Conclusion

The benefits of e-scooters are highly dependent on other factors, most importantly modal shift. For e-scooters to achieve environmental and social benefits, it is essential that they are used to address the negative externalities created by private car use. When a modal shift from cars to e-scooters occurs, the benefits include decreased CO_2 emissions which helps to prevent further warming on a global scale. Secondly, local air pollution and noise pollution are reduced which enhances human and environmental health. In addition, e-scooter hire is cheaper than private car ownership and their dockless nature means they can be found in places which do not currently have good access to public transport. However, these benefits are dependent on a shift from cars to e-scooters. If not, they have the potential to result in more costs to the environment and society. Life cycle analysis has shown that e-scooters still produce a significant amount of CO_2 emissions, especially when compared to active transport. Additionally, if they become too expensive to use or their areas of use become restricted, they have the potential to increase the inequality in transport access.

Cities that have already incorporated e-scooters into their transport systems have had mixed results. In the US, cities have focused on the social approach. This could be because inequality is viewed as more important, or because e-scooters are more likely to have environmental benefits due to shifts from cars to e-scooters because there is a lack of alternative options in cities which sprawl and have limited public transport infrastructure. In Europe, cities have put more focus on the environmental approach. In general, those cities which adopted e-scooters earlier have had more difficulties with their implementation. Paris has already changed regulations and policies several times. However, this is to be expected with a new technology.

The aims and objectives of Bristol as a city highlight its determination to combat climate change, air pollution, and social inequalities within the city. Although e-scooters are a good solution to ease demand for public transport during the Covid-19 pandemic, in the long-term it is important that public transport is still prioritised as a mode of transport over e-scooters. Overall, policies and regulations of e-scooters are unlikely to have substantial effects on Bristol's goals unless the modal shift comes from cars. This will require more than the simple introduction of a new technology. However, e-scooters do provide an alternative mode to private cars and if popular they could influence more radical changes in policy, such as reallocation of street space from cars to micromobilities and pedestrians.

Overall, the potential of e-scooters alone to contribute to a sustainable transport system in Bristol is relatively low. However, their role as a 'last-mile' solution, and their potential to influence decisions about cycling infrastructure, are more significant. This highlights that the modal shift is more important than the e-scooter policy approach, and that it is important for local decisionmakers to take a holistic approach to the transport system.

6.1 Limitations and future research

This study was primarily limited by the limited data available on e-scooters. This is in part because they are a new technology, but also because, unlike other transport systems, they are privately operated. What data there was has been interpreted and analysed to make policy recommendations for Bristol's future shared e-scooter system. This represents another limitation. As highlighted by Cairney (2012), what has been a success, or a failure, in one city may not be successful in another city. This is due to the complexity of cities and the inextricable links between the transport system and other systems within the city (Bai *et al.*, 2016). Lastly, there are inherent uncertainties when discussing the future, particularly during a politically, economically and socially turbulent time with regards to the Covid-19 pandemic (Bardach and Patashnik, 2016).

Future research could take the form of an analysis of policy (Cairney, 2019). An e-scooter pilot trial is due to begin imminently (WECA, 2020). It will be important for the local authorities to monitor the impacts of introducing e-scooters and an analysis of policy will help to determine whether they are successfully contributing towards Bristol's goals for a sustainable urban transport system.

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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: *Georgina de Courcy-Bower*   Email address: *mu19059@bristol.ac.uk*

Title of research project: *The potential contribution of e-scooters to sustainable urban transport in Bristol.*

Source of funding if any? *n/a*

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

No

If YES, please provide further details

Click or tap here to enter text.

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

No

If YES, please provide further details

Click or tap here to enter text.

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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

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.

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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.

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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.

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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

I'm not sure I understand this question – I don't think it would be available to the general public?

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

Choose an item.

Please provide full details

I am still undecided whether I will be asking questions as well as using secondary data.

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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

G. de Courcy-Bower

Date *28/05/2020*

Advisor

Signed

Date *05/06/2020*

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

A	**Form submission to advisor**	Choose date	Choose date	Choose date	Choose date
B	**Clarification requested by advisor**	Choose date	Choose date	Choose date	Choose date
C	**Advisor stage passed**	05/06/2020	Choose date	Choose date	Choose date
D	**Clarification requested by ethics committee**	26/06/2020	Choose date	Choose date	Choose date
E	**Decision recorded by ethics committee**	29/06/2020	Choose date	Choose date	Choose date
F	**Email sent to student by ethics committee**	29/06/2020	Choose date	Choose date	Choose date