Evaluating Compliance to Scotland's Low Emission Zone Policy: A spatial vulnerability assessment

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Abstract

The Cleaner Air for Scotland strategy sets out an ambitious policy to reduce the emission of local pollutants in an effort to improve the health of citizens and to enhance the public realm. This strategy could see the introduction of Low Emission Zones (LEZs) throughout Scotland's urban areas which currently have Air Quality Management Areas in effect. These LEZs may restrict the access of cars which are not compliant to certain emission standards form entering specified districts. If the owners of non-compliant cars tend to populate specific social cohorts, then the restrictions imposed by the LEZs may generate outcomes that are unevenly distributed across society. This paper presents a preliminary social equity analysis of the introduction of LEZs which is conducted through a spatial assessment of the level of vulnerability areas have to this policy. This vulnerability assessment considers three different dimensions relating to the exposure an area has to the policy, the sensitivity an area has to the policy and the adaptive capacity an area has to the policy. To illustrate how these three different dimensions can be applied, a case study of Edinburgh City is presented which highlights the insights that can be generated through the analysis as well as the issues that require further evaluation.

1 Introduction

As of 2017, there are thirty-nine Air Quality Management Areas (AQMAs) in effect across the local authorities of Scotland. These AQMAs are declared by local authorities due to the concentration of particular local pollutants exceeding or likely to exceed the thresholds set out in national and European legislation. These local pollutants cover particulate matter ten, nitrogen dioxide and sulphur dioxide. Each of these substances can lead to negative effects on human health, and are associated with a heightened risk of respiratory illnesses.

In an effort to address these exceedances of local pollutants, the Scottish Government (2015) established the Cleaner Air for Scotland strategy (CAFS). This strategy provides a structure through which to devise and appraise actions that will deliver improvements to air quality levels. As part of the CAFS strategy, a set of options are set out relating to the operation of the transport system, covering the potential introduction of Vehicle Access Regulation Schemes (VARS) which control the entry of certain vehicles into specified areas. One VARS variant which is included as an option regards the implementation of Low Emission Zones (LEZs) which restrict the entry of vehicles that are not compliant to specified European Emission Standards. Privately owned cars could represent a vehicle restricted by a LEZ, with the Department for Environment, Food and Rural Affairs (2016) advising that Euro 4 petrol and Euro 6 diesel thresholds be selected. As of 2016, there were a total of 797,292 privately owned diesel cars not compliant to Euro 6 as well as 385,598 privately owned petrol cars not compliant to Euro 4 registered in Scotland, which equates to 53.3% of the total private car stock. With these figures in mind, LEZs have the potential to impact on the mobility of a large number of Scottish citizens. As a result of this, it is important to consider the social equity implications of introducing LEZs by evaluating the distribution of adverse outcomes the policy may generate across society.

This paper sets out a research project which assesses vulnerability to the introduction of LEZs. This assessment is spatial in nature and combines a series of datasets which are associated with the structure of the car fleet, demographic characteristics of the population, travel patterns and public transport availability to triangulate on the vulnerability of particular areas. A preliminary case study of Edinburgh City is presented in order to illustrate the way in which vulnerability can be practically evaluated and the insights that can generated. The outcomes of this assessment are likely to be of interest to national and local government agencies that are tasked with the appraisal of CAFS options.

2 Background

The CAFS strategy introduces an integrated modelling and appraisal process (illustrated in Figure 1) which is designed to produce and evaluate options through which improvements in local air quality can be pursued. The National Modelling Framework (NMF) covers the use of transport and air quality models to estimate the need for interventions to be put in place in order to address persisting exceedances of local pollutants. The National Low Emission Framework (NLEF) covers an appraisal system through which national and local government bodies can ascertain the appropriateness of different options to particular situations and circumstances.

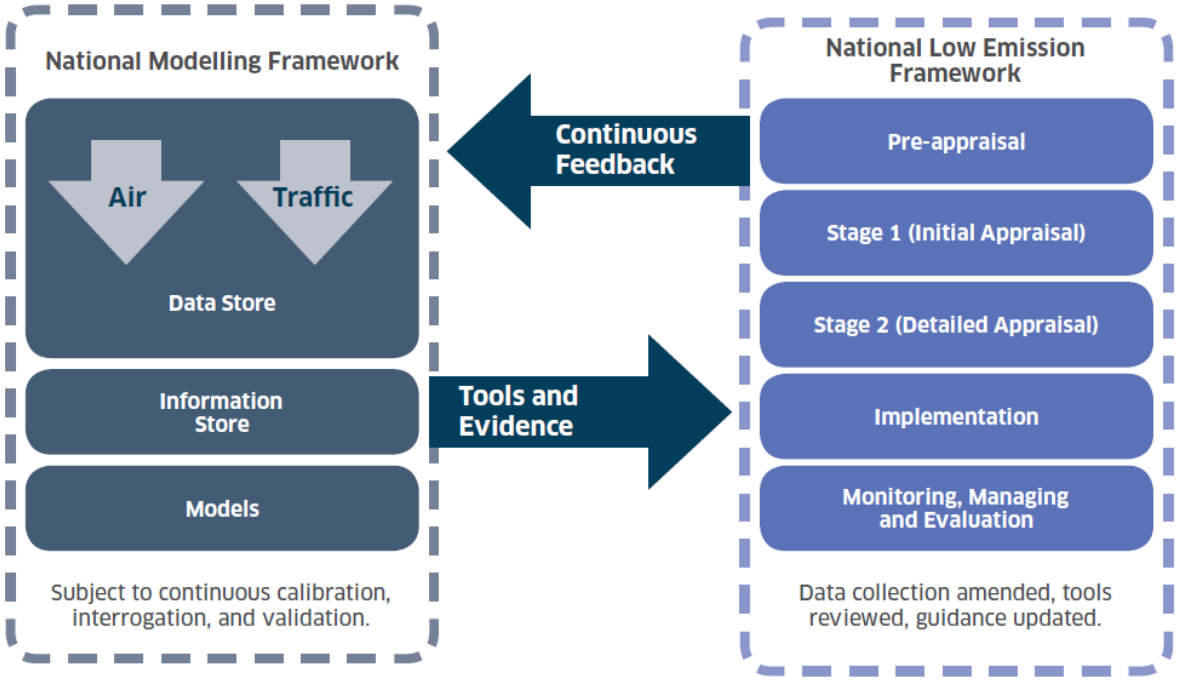

Figure 1: Cleaner Air for Scotland integrated modelling and evaluation framework

The introduction of LEZs represent one of the options included in the NMF-NLEF process. A LEZ could exclude the entry of cars to an area, either entirely or at certain times, based on certain European Emission Standards (such as Euro 6 diesel or Euro 4 petrol anticipated in this paper[1]). These specified areas could cover large parts of Scotland's urban centres. Table 1 provides a summary of the number of private cars which are not compliant to Euro 6 diesel or Euro 4 petrol standard across the four main cities of Scotland as of 2016. These numbers indicate that a significant proportion of private cars are non-compliant, with the highest level of non-compliance observed in Edinburgh City.

Table 1: The number of private cars not compliant to Euro 6 diesel and Euro 4 petrol European Emission Standards by Scottish city

City	Diesel Cars	Petrol Cars	Combined Percent of Fleet
Aberdeen City	28,481	13,842	47.4%
Dundee City	14,681	10,175	49.4%
Edinburgh City	47,852	36,083	51.9%
Glasgow City	51,177	32,055	49.4%

The types of cars registered in an area are effected by a series of factors that are associated with [1] the policy frameworks that regulate vehicle ownership (e.g. circulation taxes and fuel duties), [2] the application environment in which the cars are used (e.g. level of rurality and trip distances) and [3] the demographic structure of the population. This third factor implies that certain cars are owned by certain types of people. It follows that cars that are not compliant to a LEZ standard may be more prevalent amongst certain demographic cohorts. Thus, it is important to consider if this is indeed the case and assess if the cohorts more likely to own non-compliant cars have the capability to adapt to the introduction of a LEZ. Such an assessment is beneficial for two reasons. First, it can be useful in considering if the introduction of a LEZ could potentially generate social exclusion effects, whereby certain groups have their mobility constrained and as a result find their participation in society diminished. Second, such an assessment is required to ensure that the options being considered in the

1 [1] It should be noted that the emission standards that have been chosen are hypothetical and do not represent any agreed standards for LEZ operation

NMF-NLEF process comply with the tenants of the Equalities Act 2010, which stipulates that a policy cannot indirectly discriminate (i.e. have a stronger adverse effect) against groups with protected characteristics (e.g. ethnicity, religion and disability).

3 Methods

3.1 Procedure

The analysis presented in this paper is spatial in nature and considers the vulnerability of the population that are resident in certain areas to the introduction of a LEZ. Three different dimensions are evaluated in the assessment.

Exposure
First, the level of exposure an area has to the introduction of a LEZ is determined. This exposure covers the proportion of an area's privately owned car fleet that is not compliant to the anticipated standards (i.e. Euro 4 petrol and Euro 6 diesel) and the proportion of an area's households that own cars.

Sensitivity
Second, the level of sensitivity an area has to the introduction of a LEZ is estimated. This sensitivity relates to the degree of interaction an area has with the LEZ and is measured by the number of morning peak car trips that are made between the area and the LEZ.

Adaptive Capacity
Third, the level of adaptive capacity an area has regarding access to the LEZ is evaluated. This adaptive capacity is associated with the level of economic prosperity of an area measured by the income domain of the Scottish Index of Multiple Deprivation and the presence of public transport corridors in the vicinity of an area.

In total, the assessment makes use of five separate measurements over the three dimensions to evaluate the degree of vulnerability an area has to the introduction of a LEZ. If an area has a high degree of exposure and sensitivity to a LEZ and has a low level of adaptive capacity to respond, then it would be classified as vulnerable. As such, the assessment acts as a site selection tool and is useful at identifying areas that require further appraisal.

3.2 Data Sources

A series of different publicly available datasets are used in order to conduct the vulnerability assessment. Firstly, the Department for Transport's (2016) vehicle licensing statistics database provides information on the characteristics (i.e. location and emission standard) of privately owned cars licensed for use on Scotland's roads. Second, the National Records of Scotland (2011) census provides details on car availability. Third, the Scottish Government's (2016) index of multiple deprivation provides insights on income levels. Fourth, Transport Scotland's (2017) SEStran Regional Model of the road transport system of the South-East of Scotland provides trip flows by cars between the travelzones of the model.

4 Case Study

A preliminary analysis is presented in this section for Edinburgh City, providing a partial vulnerability assessment for the local authority.

4.1 Exposure

Figure 2(b) summarises the distribution of non-compliant privately owned cars registered across the datazones of Edinburgh City. The rate of non-compliance ranges from under 40% of the local fleet to over 70%, though the majority of datazones fall between 50% and 60% non-compliance. Figure 2(a) geographically locates the rate of non-compliance to illustrate its spatial variation. From the map, it seems that pockets of relatively high rates of non-compliance are spread throughout the city, with a

slight tendency towards the centre and north. Conversely, relatively high rates of compliance are observed primarily in the east end of the city.

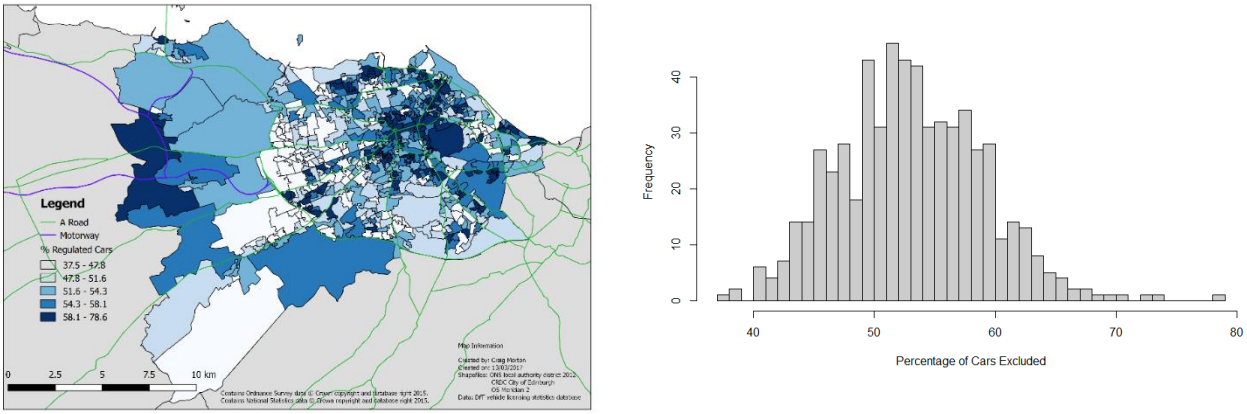

Figure 2: (a) map illustrating the rate of non-compliant cars across the datazones of Edinburgh City (b) the distribution of non-compliance

Figure 3(b) describes the dispersion of household car availability across the datazones of Edinburgh City. A substantial range is present for this characteristic, with values spread somewhat evenly between 30% of households with a car to 90% of households with a car. Figure 3(a) geographically illustrates the variation in car availability, with the city centre and parts of the east end of the city displaying relatively low levels of car access whereas areas towards the south east and north east exhibit relatively high rates. Interestingly, an inverse relationship appears to be present between the rate of non-compliance and the rate of car availability. This relationship is supported by the presence of a significant negative correlation between these two variables (r: -0.529), which indicates that areas that have a relatively high proportion of the privatively owned car fleet not meeting the anticipated LEZ emission standards tend also to have a relatively higher level of households that do not have access to a car.

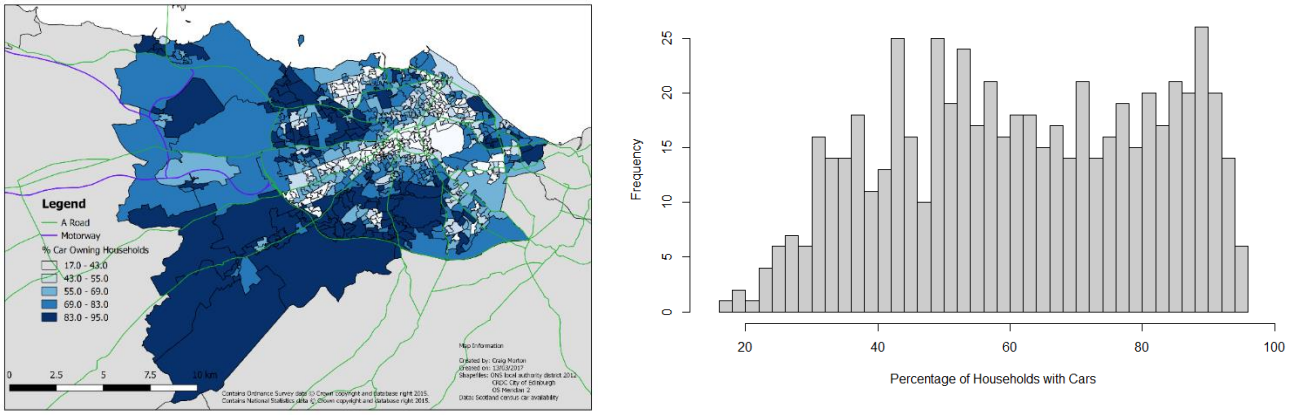

Figure 3: (a) map illustrating the rate of household car availability across the datazones of Edinburgh City (b) the distribution of household car availability

4.2 Sensitivity

In order to consider the degree of sensitivity an area has to the introduction of a LEZ, the analysis requires to know where the boundary of the zone will be located. As of writing, zone boundaries have not been finalised, though there is a general understanding that the zones will need to be of a sufficient scale to be effective in significantly improving air quality within the existing AQMAs. With this in mind, a hypothetical LEZ boundary has been specified in this paper to allow the sensitivity analysis to be

conducted. This boundary is displayed in Figure 4 and covers the central business district of Edinburgh which is currently a site of an AQMA[2].

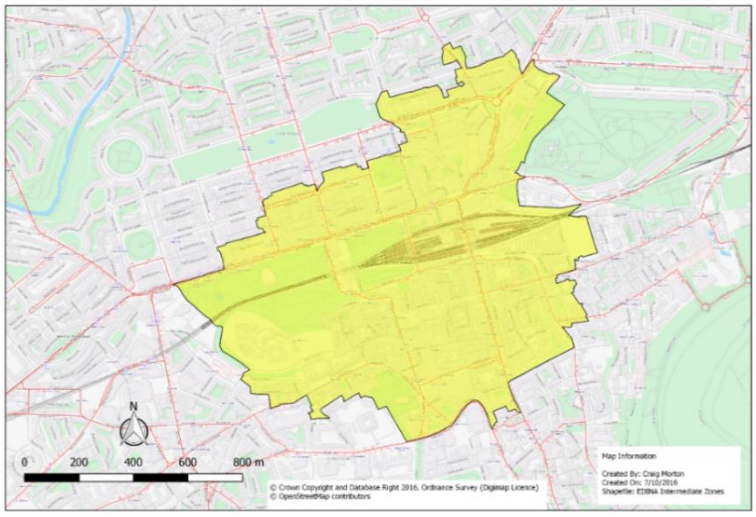

Figure 4: Hypothetical Low Emission Zone boundary in the centre of Edinburgh City

Figure 5 presents a flowmap which displays the morning peak car traffic between the travelzones of the SEStran regional model and the hypothetical LEZ utilised in this analysis. To make the illustration legible, only the highest 20% of flows are displayed. A visual inspection of the figure indicates that the largest flows entering the LEZ are from the wider South-East of Scotland, with the trips tending to originate from the east and north-west of the region. What this implies is that it is areas reasonably distant from the LEZ that have the most interaction by car with it, which may mean that it is regional, as opposed to local, travel that could be most sensitive to the introduction of a LEZ. One implication of this finding is that the analysis of exposure and adaptive capacity needs to be extended from Edinburgh City to the South-East of Scotland region so that the wider effects of this policy can be evaluated.

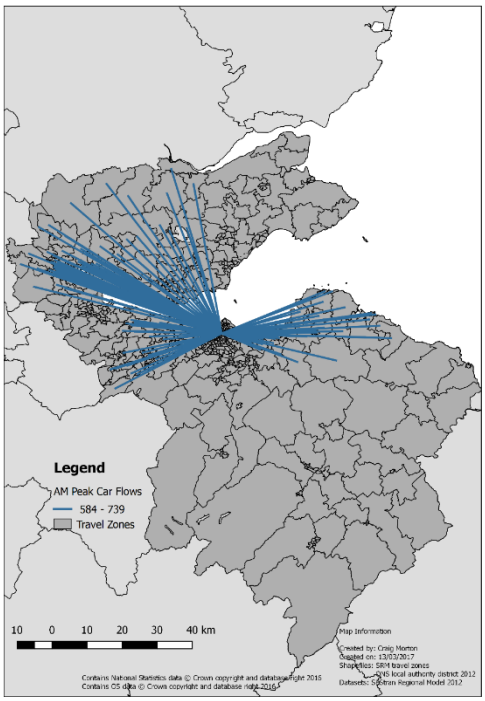

Figure 5: Flowmap of morning peak car traffic between the travelzones of the SEStran regional model and the hypothetical Low Emission Zone of Edinburgh City

[2] It should be noted that the area that has been chosen is hypothetical and does not represent any agreed LEZ boundary

4.3 Adaptive Capacity

Figure 6(b) summarises the distribution of datazones classified as income deprived within Edinburgh City. The measurement exhibits an obvious positive skew, whereby the majority of datazones contain low proportions of income deprived households, with a small number of datazones being the site of relatively high rates on this metric. Figure 6(a) geographically locates this income deprivation, with the analysis identifying pockets of Edinburgh City that are relatively income deprived, such as the north-west and south-east of the city. Interestingly, the spatial variation in income deprivation appears to hold a partial overlap with the variation of non-compliant cars (i.e. areas of relatively high rates of non-compliance tend also to be areas of relatively high rates of income deprivation), with this observation being supported by a significant positive correlation between these two variables (r: 0.385).

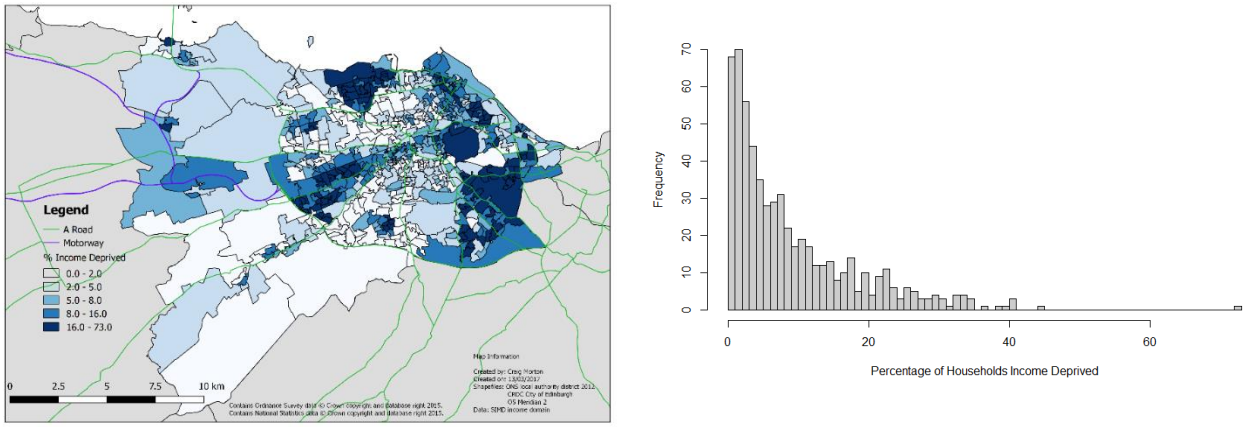

Figure 6: (a) map illustrating the rate of income deprivation across the datazones of Edinburgh City (b) the distribution of income deprivation

Due to the spatial variation in the rate of non-compliance, car availability and income deprivation, the possibility exists for certain areas to score relatively highly on all three of these metrics. This could signify an area of concern, as residents of such an area would have a heightened likelihood of owning a car not compliant to the anticipated LEZ standard and having a reduced ability to purchase a compliant car. The settlement of Kirkliston represents such a case, scoring highly on all three of these metrics. To consider if the residents of this settlement have the opportunity to access the LEZ by an alternative mode, public transport schedules have been interrogated. Figure 7 presents the results of this interrogation, which identified the presence of a direct bus service between Kirkliston and the LEZ operated by First Buses (the 38 route). This finding suggests that Kirkliston residents have the opportunity to travel to the LEZ using public transport, and as a result the possibility of the introduction of a LEZ generating a social exclusion effect on Kirkliston residents is reduced.

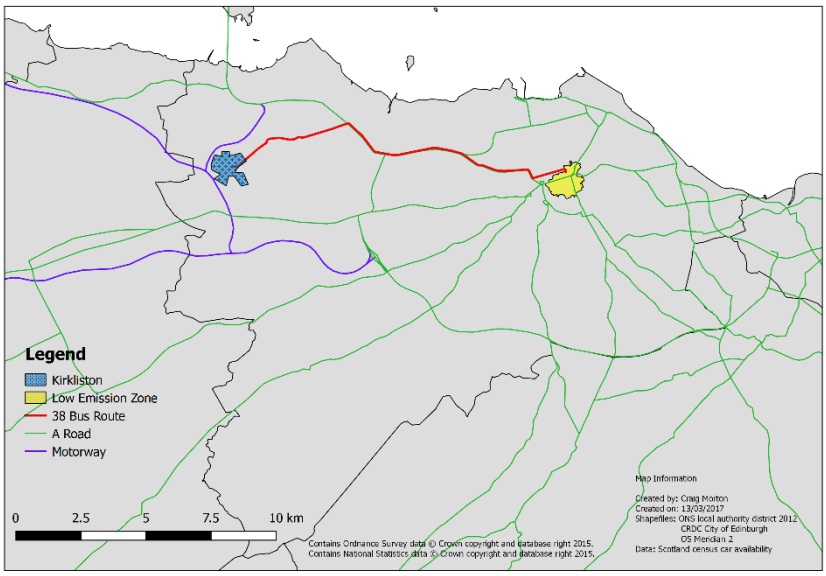

Figure 7: The presence of public transport routes linking Kirkliston and the hypothetical Low Emission Zone in Edinburgh City

5 Discussion and Next Steps

The research presented in this paper represents a preliminary analysis of the vulnerability certain areas may have to the introduction of a LEZ. Taking Edinburgh City as a case study and following a three dimension assessment procedure, areas are evaluated according to their level of exposure to the policy, their level of sensitivity to the policy and their level of adaptive capacity to the policy. This assessment represents a means through which to consider the implications of introducing LEZs on social equity, which assists in identifying areas that may require interventions in order to mitigate any averse outcomes the policy could impose.

As a result of this preliminary investigation, a series of insights can be offered. First, the findings of the sensitivity analysis, which charts the peak morning car flows between the travelzones of the SEStran Regional Model and the hypothetical LEZ, indicate that highest levels of interaction by car occur between the wider South-East of Scotland region and the LEZ. That is to say, it is car trips made from outside of Edinburgh City, and primarily to the east and north-west of the region, that have the possibility of being affected by the introduction of a LEZ. One implication of this is that the vulnerability assessment should be specified at the regional, as opposed to the city level, in order to evaluate the degree of exposure and adaptive capacity that exists throughout the South-East of Scotland.

Second, with a significant positive relationship being observed between the rate of non-compliance and the rate of income deprivation across the datazones of Edinburgh City, it is likely that the residents owning cars that do not meet the anticipated LEZ standards may not have the resources necessary to purchase a compliant car. Such a situation is compounded for areas that have high levels of car availability, implying that their residents actively make use of cars to service mobility needs. As a result, residents that find themselves in this situation could find their existing transport patterns affected by the introduction of a LEZ, and may need to shift to alternative modes in order to access the LEZ. In addition, it is likely that the introduction of a LEZ would lead to an increased rate of depreciation on cars not compliant to the anticipated standard. As areas that have higher rates of income deprivation tend to also have higher rates of non-compliant cars, this implies that the introduction of a LEZ could lead to reductions in the value of assets owned by less affluent citizens.

More generally, the preliminary analysis presented in this paper demonstrates that attempting to evaluate the vulnerability of areas towards the introduction of a LEZ represents a complex undertaking. The multidimensional nature of vulnerability (i.e. exposure, sensitivity and adaptive capacity) and the

different ways in which these dimensions can be measured lead to a situation whereby no single evaluation could cover all of the different issues that are likely to be important. With this in mind, whilst this preliminary analysis will be extended as the project develops, it is important to note that it represents only one means through which vulnerability can be evaluated. Due to this, the use of other methods to evaluate vulnerability should also be pursued in order to robustly appraise the social equity consequences of the introduction of LEZs.

Acknowledgements

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