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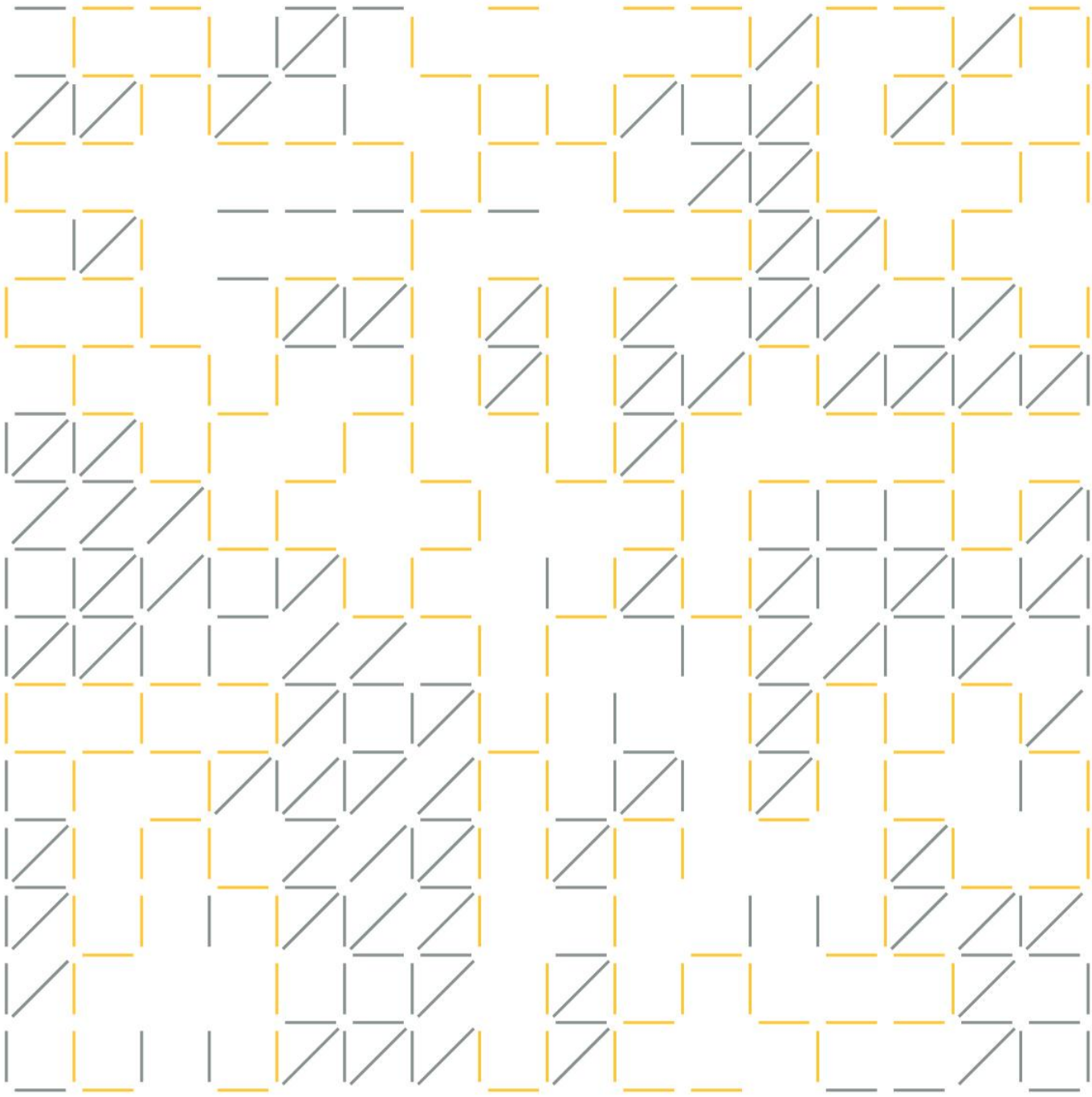

Transport Research Institute. Technical Paper 102

Assessment of demand management measures to reduce road traffic in Scotland: implications for business

November 2022

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1 Introduction

1.1 Background

The Transport Research Institute at Edinburgh Napier University was commissioned by Transform Scotland to evaluate measures to reduce road traffic in Scotland. The aim of the work was to assist Transform Scotland in working with Scottish business NGOs to analyse and discuss the acceptability of road traffic reduction measures to the business community.

The requirement for road traffic reduction measures stems from the Scottish Government commitment in December 2020 to reduce all car traffic kilometres by 20% by 2030 as part of its net zero carbon emissions plan. Following this commitment, a route map to achieving the target was published (Transport Scotland, 2022), with views from the public sought through a consultation exercise, with responses due by April 2022.

The route map presents a framework of four key sustainable travel behaviours to achieve the goal of road traffic reduction: reducing the need to travel; living well locally; switching modes; and combining trips or sharing journeys. Interventions in support of these travel behaviours are also outlined within the route map. Such interventions include changes to planning policy through a revised National Planning Framework (NPF); delivery of safer and more sustainable streets; increased investment in active travel; implementation of Low Emission Zones in cities; investment in public transport, smart ticketing and overhaul of fares; prohibition of pavement parking; development of Workplace Parking Levy regulations and support for car sharing, car clubs and Mobility-as-a-Service (MaaS).

Most of the interventions detailed within the Scottish Government route map seek to improve the quality, availability, affordability, convenience and attractiveness of alternatives to car use. However, the route map recognises the measures are not likely to be sufficient alone in the context that the benefits of car use are at the individual level, whilst the disbenefits tend to be externalised. On this basis, it is anticipated that the so-called 'pull' transport demand management measures outlined in the Scottish Government route map are likely to need to be accompanied by a series of 'push' measures to reflect the negative externalities associated with car use. In this regard, a comprehensive understanding of the advantages, disadvantages and effectiveness of the suite of such measures available to transport policy makers is likely to be vital in effective future policy formation.

1.2 Project Brief

The brief from Transform Scotland was to undertake a study in two parts.

The first part required an evidence review to be undertaken, to identify which measures have been utilised elsewhere to manage effectively road traffic travel demand. The scope of the review comprised both UK and international examples of measures including road pricing, fuel duty, Low Emission Zones (LEZs), car parking strategies and workplace parking levies.

Specific areas of interest were defined as:

- evidence of scheme efficacy;

- scheme context (e.g. urban or rural, strength of public transport etc.);
- drawbacks, issues, benefits and opportunities;
- impacts on other policy areas (e.g. emissions, congestion, productivity, place-making, fairness, effects on different business types); and
- costs of implementation to road users and the state.

Based on the findings of the UK and international scheme review, the second part of the study required an analysis of the likely impact of the measures in a Scottish context, based on pre-Covid travel patterns. Specific areas of interest were:

- which measures are most likely to reduce traffic volumes;
- which areas of Scotland might benefit most from different measures;
- drawbacks or issues for implementation, based on Scottish travel data, along with suggestions for mitigation with emphasis on the business community;
- impact on other policy areas in Scotland; and
- implementation costs, in a Scottish context.

The findings from the two parts outlined above were intended to be used to engage with Scottish business non-government organisations to discuss the acceptability of different traffic demand management measures and to inform future research that may be required in association with such measures.

1.3 Format of Report

The following sections of this report cover the findings under the two parts of the project brief. Section 2 contains the results of the UK and international review of road traffic travel demand management schemes. Section 3 discusses these schemes in the Scottish context under pre-Covid travel patterns. Finally, Section 4 summarises the key findings of this work and suggests further research that may be appropriate for future consideration of such schemes in Scotland.

2 Review of road traffic reduction measures

2.1 Methodology

Case study cities have been selected and an extensive literature review undertaken to gather evidence in relation to the road traffic reduction measures stated in the study brief, along with commentary on associated measures where appropriate. Literature was sourced from academic and professional journals, national and local government reporting, research reports and media coverage. The focus of the areas of interest were grouped into five topic areas, with the topics and typical examples of the issues involved in under each category as follows:

- **Efficacy measures** (e.g. traffic flow, mode share, public transport patronage, economic activity)
- **Contextual factors** (e.g. urban/rural, public transport network strength, socio demographic, employer sizes, emissions standards)
- **Political, social and technological factors** (e.g. public/political acceptance, budgets, enforcement, equality, technology obsolescence)
- **Impacts for policy areas** (e.g. climate, congestion, connectivity, productivity, place-making, fairness on business size, online versus high street)
- **Costs** (e.g. implementation, state, road users)

A full breakdown of all evidence gathered is presented in tabular form in Appendix A, with the findings summarised under each type of scheme in this chapter.

2.2 Low Emission Zones

Low Emission's Zones (LEZs) have been implemented across a wide number of European countries in an attempt to improve air quality in urban areas and bring this into line with European Union standards. In theory, such schemes have the potential to achieve improvements in air quality in city centres, reduce traffic congestion and in some cases, generate significant and reliable revenue for further investment in transport networks. When examining the effectiveness of LEZs however, a major issue is in proving that air quality improvements are attributable to such schemes, as these generally occur against a backdrop of wider emissions reductions programmes in the likes of the private vehicle, road haulage and energy production sectors (Holman et al., 2015). Furthermore, virtually all studies into the topic have focused specifically on air quality measurements, and hence the impact on traffic levels is largely unknown.

In terms of effectiveness, a wide review into multiple LEZs across Europe has revealed mixed results. As an example, it has been argued that LEZs have achieved only minor reductions in both NO2 and PM10 in several European cities (Holman et al., 2015). Furthermore, whilst a 2014 study across 17 LEZs in German cities did attribute PM reductions to LEZs, the actual reductions of NO, NO2 and NOx were all found to be relatively small (Morfeld et al., 2014). Some sources however do point to alternative benefits of LEZs beyond their aims and objectives, such as more public space areas and the

increase in safety of cyclists and pedestrians by virtue of there being fewer cars on city roads (Tarriño-Ortiz et al., 2022).

Overall, whilst LEZs do not widely appear to be driving significant reductions in emissions by themselves, it could be argued they are a part of a continuing range of wider initiatives, all of which are contributing to overall traffic level reductions. As an example, LEZs may have the indirect effect of heightening the issue of vehicle emissions in the public awareness, and hence affect travel behaviour, but we are unaware of any research on this specific issue.

With regards to implementation and bringing forward LEZ schemes, more success appears to have been achieved where there exists an overall tiered national framework, such as the case in Germany, in which local authorities then opt what level to introduce in their respective area, rather than where it is left to individual authorities to determine their own schemes.

In terms of the wider impact of LEZs on the business community, again very little research exists. In one of the very few studies into the topic, prior to its implementation Transport for London (2006) carried out a study into the potential economic impacts of the then proposed LEZ. This exclusively focused on the transport and logistics sectors, but did consider some wider knock-on effects, particularly with regards tourism. In terms of average vehicle operating costs, it estimated these would rise by around 2% per year, but importantly cost increases were not distributed evenly over the period and could be as high as 8% in the early years due to one off compliance costs. As such, cost increases were seen as having a limited impact on employment in the transport and logistics sector in London and the UK. Given the upfront costs of compliance however, it was estimated this would have a disproportionally larger impact on smaller operators.

Despite mixed success and failure to meet EU air quality targets, the trend for further LEZ implementation and expansion appears to be clear, certainly in the short to medium terms, and no evidence has been found to suggest the implementation of such schemes causes any widespread or severe economic downturns (European Commission, 2022). There have however been incidents of strong political and even legal opposition to some schemes, with the case of Madrid in particular representing a high-profile legal challenge that led to the removal of the LEZ in 2021. Nevertheless, this does not appear to indicate any trend as of yet of a demise of such schemes and indeed London's ULEZ was further (geographically) expanded in 2021, and is set to be expanded further in 2023 (London Assembly, 2022).

In virtually all cases considered however, strong questions arise over the extent to which air quality improvements can be attributed directly to the LEZ or would have occurred in any case due to vehicle obsolescence and tightening Euro emissions standards. A second key aspect potentially undermining the effectiveness of LEZs as a policy measure relates to the standards applied. In all cases reviewed, the highest standards identified were Euro 6 for HGVs and Euro 4 for private vehicles, hence in reality, certainly with respect to private vehicles, only a very limited number of vehicles have been affected. As regards HGVs in one example (London), the introduction of the LEZ led to a short-term increase in the rate of vehicle replacement, before trends returned to pre LEZ levels. A final aspect is that not all transport related particulate matter comes from exhaust emissions, and as such LEZs

have no impact on non-exhaust PM emissions from traffic. This aspect has been argued to be an equally or more important emission source (Holman et al., 2015).

All of the research in this area can be identified as short term, hence only the immediate or short-term impacts of LEZs have been researched, and as a consequence this has almost exclusively centred upon the impact on air quality. Issues arising as a result of longer-term impacts, particularly with regards to public perceptions and the general commercial environment, remain largely unknown.

Low Emission Zones – Key Points

+ Some cities have demonstrated small **improvements in air quality** in a short period
+ Implementation best achieved through the specification of **a tiered national framework**
+ **No evidence** found of detrimental economic impacts
+ **Potential of LEZ based measures** (including ULEZs) to reduce traffic volumes **unknown** due to the general low level of standards applied to date**.** The proposed Euro 7 standard (in 2025) may also open up more possibilities for action.

– Implication that any improvements in air quality standards **may have occurred anyway** with **vehicle replacement** over a relatively short time horizon
– Standards applied in LEZs schemes **mainly impact on the road haulage sector**, most private vehicles unaffected
– No or very limited evidence on impacts on **traffic levels, public perceptions** or **wider economic impacts**

2.3 Workplace Parking Levy

Workplace parking levies (WPLs) have been implemented in a small number of cities across the world, most notably in Australia (Perth, Sydney, Melbourne) and the UK (Nottingham). Power is granted to local authorities through primary legislation and associated regulations to apply an annual charge to owners of private parking spaces. In the only UK scheme, this has been limited to workplace parking spaces and only where the number of spaces is greater than ten. In Australia, such schemes have been more comprehensive in coverage and additionally include public off-street parking spaces. The levy may apply across the whole local authority area (Nottingham) or focus only on central business districts and/or specific key employment districts (Australia). No scheme at present requires the cost of the levy to be passed on to the end user; this is at the discretion of the owner of the parking space. The levy may be passed on in whole or in part to the occupier of the space, absorbed by the owner of the space or avoided entirely through decommissioning of the space for other land use.

In terms of efficacy, the direct effect of WPLs on road traffic reduction is very difficult to measure due to exogenous factors. Many WPLs are part of a package of measures, where revenue from the WPL is used to fund a supporting transport package. Isolation of the proportion of a decision to change modes as a direct result of the levy, as opposed to the associated public transport improvements, is very difficult. Specific economic factors such as rapid economic growth of a city (Perth) or implementation of a WPL during a period of rising oil prices (Melbourne) may also potentially mask the underlying performance of a scheme. Nonetheless, all schemes reviewed demonstrated evidence of reduced traffic volumes or congestion, along with increased public transport mode share and/or patronage. Even in the Melbourne scheme, where associated public transport improvements were least apparent, reduced traffic volumes and increased public transport mode share were reported, suggesting at least some direct association with the implementation of the WPL.

A natural issue raised in terms of contextual factors is whether a city considering a WPL has nearby competitors. Being surrounded by the likes of Derby, Nottingham and Sheffield, this was a key consideration for Nottingham, whereas Perth in Western Australia is highly isolated from any competitors, hence the perceived risk associated with implementing such a progressive policy was considerably reduced. Although fear of the economic impact of a WPL scheme may be natural by private enterprises and city authorities, research shows that such concerns appear to be unfounded; a longer-term study of Nottingham for example found it fared no worse economically than key competitor cities with no negative impact on investment (Dale et al., 2014). It is worth noting, however, that all cities that have implemented WPL to date have had relatively high value economies. In Nottingham 90% of the city's GVA comes from the service sector, an indicator of wealth and prosperity in the city as a whole. Perth has been subject to extraordinary economic growth (Richardson, 2010) and the much of the WPL in Sydney was focused on parts of the city associated with high technology and research (Ison and Mulley, 2013). The economic impact of WPLs on areas with lower income levels or lower value industries is less clear.

Gaining acceptance of a WPL scheme by business and the public is critical to its initial implementation. Some businesses are wary of such schemes and may initially threaten relocation, although subsequently such threats have not been acted upon (Dale et al., 2014). The most important factors to business have been suggested to be proximity to customers and the workforce; set against the fact that any WPL is a very small proportion of turnover in this way it can be seen any disincentives are quickly eroded when compared with the costs of sub-optimal business location. It is also worth noting that if the WPL forms part of a package including improved public transport, this can be a significant attractor. For example, in Nottingham revenue from the WPL was used to fund a second tram line which has been associated as a significant factor in attracting new businesses to the city. The hypothecation of revenue to fund transport improvements is also vitally important in securing public support. Not only was this a legal requirement for the scheme in Nottingham under Westminster legislation, it also resulted in the Perth Western Australia scheme receiving an unprecedented level of all-party political support (Richardson, 2010).

Operational factors associated with WPLs include the granting of exemptions to ensure schemes are equitable. Exemptions have been applied in existing schemes to include

disabled users, customer parking and small business. A more challenging area in equitability concerns the transfer of the charge to the end user. It has been claimed that the wealthiest drivers may be the least likely to pay the levy due to being the most likely to be able to recoup the charge from their employer (Hamer et al., 2012a). Further, in some Australian schemes it has been claimed that short stay parking revenue has been used to cross subsidise long stay parking (Hamer et al., 2012b). This potentially undermines scheme objectives by shifting the burden from employees to customers, which may impact retail and leisure in particular. Conversely, implementation of schemes may result in benefits to such businesses through improved urban realm and the redevelopment of car parking for other land uses, as has been the case in Nottingham (Flack et al., 2021).

The costs of WPL schemes are directly related to their size and scope. Critically, an inventory of all available parking across the area of coverage is required and continual monitoring and enforcement is required. In Nottingham where the scheme is city-wide, targeting a smaller number of employers over a certain space threshold minimised costs and made enforcement simpler (Dale et al., 2014). In the Australian schemes, all spaces are monitored but costs are minimised by concentrating on smaller, targeted geographic areas (Ison and Mulley, 2013; Richardson, 2010; Taylor, 2020). On this basis, operating costs can be kept low; for example, first year operating costs in Nottingham were cited as being around 5% of overall revenue. The levy itself in the scheme investigated ranged from £450 to £1,250 per space per annum depending on specific city and area. It is worth noting that the absolute price per space is only one dimension; whether the price is passed on to the end user is arguably equally important in achieving any potential traffic reduction. Nonetheless, at the very least a WPL is a reliable source of revenue for reinvestment in sustainable travel infrastructure, with the scheme reviewed generating between around £10 million (Nottingham) and £60 million (Sydney) per annum. On this basis, potential exists for a general decrease in road traffic, even if not as a direct result of the levy itself.

Workplace Parking Levy – Key Points

+ Appear to have **no significant impact on competitiveness** or economic activity in high value economic locations
+ Not a major consideration in **commercial location decisions** – proximity to customers and workforce key drivers
+ Operationally efficient schemes concentrate on **small geographic areas** or **larger employers only –** small businesses can be exempted
+ **Hypothecation** of revenue important for business and public acceptability
+ Some evidence that **increased public transport patronage/mode share** and **decreased congestion** results from WPL based transport packages overall
+ **Good reliable revenue stream** for investment in sustainable transport
+ Most successful when part of a **package of measures** with public transport improvements

– Very difficult to determine **true traffic reduction** effectiveness of levy itself due to confounding variables (macroeconomic factors, associated public transport improvements etc.)
– **Charges may not get passed on to users**, which may inhibit mode shift and raises equity issues

2.4 Congestion Charging

Congestion charging exists in various forms in a small selection of cities across the world. Cordon-based congestion charging, where vehicles are charged for entering a defined area has been implemented in the cities of Stockholm, Gothenburg, Milan and the central part of Singapore. Cordon pricing was also proposed for the ill-fated Edinburgh and Manchester schemes which both proposed dual cordons around the inner core and outer edge of each city. The second type of scheme is area-based charging. In this case, charges are applied to vehicles driving within a defined area. Unlike cordon charging drivers may be charged if their journey is entirely within the charging area, with no need to cross the cordon itself to incur a charge. London is an example of this type of scheme. The final type of scheme is corridor-based charging. In this type of scheme drivers are charged for the use of specific routes into the city. The prime example of this is Singapore, which uses corridor-based charging in conjunction with the central cordon. The toll lane approach on some US freeways bears some similarities to the corridor-based charge, albeit there are free lanes running in parallel on the same route.

In order to work, congestion charging assumes a large proportion of car drivers are cost sensitive. Increasing the cost of driving decreases the number of drivers choosing to do so, with the scale of the decrease depended on the alternatives available (Eliasson, 2010).

These will consist of switching to a different mode, amend routes and/or destinations chosen or to change the time period of a trip. On this basis, the effects of congestion charging can be complex; the implementation of a charge is not necessarily as simple as exactly the same trip being made by a different mode.

Traffic reduction resulting from congestion charging has been universal. In London, the initial implementation of the scheme resulted in a 33% reduction entering and leaving the zone and an 18% reduction in traffic overall (Metz, 2018). Bus use increased by 40%, suggesting significant mode shift (Bhatt et al., 2008). In Stockholm traffic reduced by 28% at the instigation of the scheme, but there was some drift back over the following months, stabilising at around 20-22% of previous levels. 24% of commuting trips across the cordon disappeared, with most switching to public transport. 22% of discretionary trips by car disappeared, with the main adoption strategies being to either change destination or decrease trip frequencies. In terms of freight traffic, this was found to decrease by 15%, primarily as a result of switching route or by trip chaining.

Gothenburg had slightly more moderate changes with traffic generally stabilising at around a 12% reduction in comparison to pre-charge levels. Traffic volumes on roads that bypass the cordon were found to have increased, ranging from 4% to as high as 26% during charged hours. Nevertheless, travel times on these routes remained unchanged, suggesting sufficient capacity existed to accommodate the increased traffic levels (Börjesson and Kristoffersson, 2015). Overall, car commuting was thought to have decreased by 6%, public transport use increased by 3% and bicycle use by 1.7%. For discretionary travellers however, most appeared to change destination or reduce trip frequency (Andersson and Nässén, 2016). For the scheme in Singapore, very little detail has been made available to researchers regarding changes to mode share as a result of congestion charging. However, changes to traffic volumes are known, with the 1998 Electronic Road Pricing scheme resulting in traffic reductions of 10-15% (Metz, 2018). This is substantially lower than the staggering 75% reduction achieved by the original 1975 scheme, albeit the charges in this case were far higher than could be considered optimal (Walter, 2020).

In contextual terms, each scheme is influenced by unique factors associated with the city in question. In Singapore, cars are perceived as luxury goods and status symbols and the cost of car ownership itself is incredibly high due to a licence bidding system (Chng et al., 2019). Road pricing was also implemented to control traffic levels over a period of dramatic economic and population growth, ultimately resulting in the city becoming one of the most densely populated places in the world. The prime motivation for the London scheme was to reduce traffic levels in the city's highly congested streets. The population of the city is the wealthiest in the UK, which in more recent years has perhaps been counter-productive as it has meant that newer hybrid-electric low emission vehicles (which were exempt from the charge) have been easily attainable (Morton et al., 2017). In the Swedish cities, the prime motivation was to raise finance for infrastructure improvements – including some road improvements.

As demonstrated in the failure of the Edinburgh and Manchester schemes, public and business support in addition to political will are essential to the process of implementation (Rye et al., 2008). In London, a combination of factors assisted in its successful implementation. The political determination of the mayor coupled with a general view

from the public that there was too much traffic played an important part. However, there was also a keen appetite from business to see the scheme succeed through the London First group, to the extent that a High Court challenge by Westminster Council was eventually overcome (Bhatt et al., 2008; Litman, 2005). Gothenburg also managed to successfully harness a range of political, business and environmental organisations through tangible benefits, particularly improved public transport, to be developed in the city as a result of the charge. The success of the Singapore scheme was almost entirely due to a history of strong government control and general compliance by the Singaporean public (Phang and Toh, 2004).

Both the Stockholm and Gothenburg schemes were subject to public referenda. The Stockholm scheme was instigated as permanent in August 2007 after an initial six-month trial period. The result of the referendum produced a 53% majority in favour of the scheme, although this specifically relates to Stockholm city itself. Surrounding local authorities also simultaneously carried out their own referendums, which when combined with the Stockholm vote, produced an overall negative majority, however those referendums were not legally binding. As regards the Gothenburg scheme, the scheme commenced on 1st January 2013. A consultative referendum on the charge was then held in September 2014, with 57% voting against its retention. Despite this, and after a review of alternative policy measures, the city council decided to continue with the charge.

Perhaps one of the key findings from the Stockholm experience is with regard to public opinion. Eliasson & Jonsson (2011) in a wide ranging survey into attitudes to the Stockholm charge one year after its implementation, found an overall level of support in the order 66%, hence significantly higher than the 53% achieved in the referendum. This would suggest changes in attitude (towards positive) after implementation is not simply a short term effect, but based on the limited evidence, potentially continues into the medium term. The main factors influencing these views were found to not only be low car dependence and a high quality public transport system, but of more relevance were opinions on the charges' effectiveness and general environmental views. Putting all of these together, this would suggest that in terms of public acceptability, key factors are an extensive and efficient public transport system, evaluation and wide dissemination of the effects/outcomes of the scheme and finally that any such scheme needs to be seen to be making a difference (Eliasson, 2008).

A mixture of effects on business of congestion charging schemes have been observed. In London, a decline of around 10% in shopping activity coincided with the introduction of the charge (Turner, 2005). Retailers with a high proportion of car-borne customers such as John Lewis cited particular issues, mainly with discretionary shopping at weekends (Quddus et al., 2007). However, several factors such as the SARS outbreak on tourism and the heightened terrorism threat at the time could also explain this fall. More positively, benefits to business were noted as being reduced delivery times within the zone and quicker loading and unloading of vehicles (Bhatt et al., 2008). Economic benefits also included improved access to businesses by other modes, reduced delay for high value trips and an improved local environment. It has also been noted that economic theory suggests congestion pricing should promote higher value activities over lower ones, increasing productivity overall (Litman, 2005). In this regard, criticisms such as the negative effect

shifting of bulky goods retail away from city centres are unfounded, if their removal enables equal or higher value activities in their place.

In Stockholm, a survey into the impact of the charge on retailer revenues comparing eight shopping malls within the zone and twelve outside showed a 7.03% increase in revenues for those malls within the charge zone, but a slightly higher 9.12% increase for those outside of it. Further regression analysis suggested that introduction of the charge did not have an adverse effect on the revenue of malls inside the charge zone (Daunfeldt et al., 2013). The extent to which these results are generalisable to other areas however may be limited by the fact that shopping malls in Sweden are open in the evenings and at weekends, hence introducing a degree of flexibility and making it easy to change shopping habits in order to avoid the charge. A second factor, and perhaps more revealing, is the fact that parking charges in Stockholm are considered to be relatively high, hence even prior to the charge, car access was generally by those on higher incomes and thus less sensitive to congestion charges.

Capital costs and revenue varies by city. In London, initially more than half of the revenue collected was spent on the operation of the scheme (Bhatt et al., 2008), although spend has reduced since with the costs in the last full financial year of operation prior to the global pandemic comprising 36% of revenues (Transport for London, 2019). This contrasts with Singapore, where initial operating costs were only 9% of the original scheme revenue (Phang and Toh, 2004). In smaller cities such as Edinburgh, control of operating costs was seen as critical to the success of the scheme.

Congestion Charging – Key Points

+ **Universal reduction in traffic** of between 12 – 33%
+ Can be seen as beneficial and **supported by business** – particularly where scheme benefits such as transport and environmental benefits can be demonstrated
+ **Improvement in delivery times** within zone
+ **Reduced delay** to **high value trips** within zone
+ **Improved local environment** and opportunity for **better use of space**
+ Increases in **public transport patronage** and **active travel**

– **Effect on retail** difficult to quantify accurately
– Failure to **minimise operating costs** of the congestion charging scheme itself can result in limited funds for transport improvements, limiting potential secondary benefits
– Success at **pre-implementation referenda** challenging – but may improve in time

2.5 National Road User Charging / Fuel Duty

Network-wide Road User Charging (RUC), whilst not perhaps immediately recognised as such, already exists in the form of fixed (vehicle excise duty or VED) and distance variable (fuel duty) components. These duties have been used before to moderate the use of motor vehicles, most recently in the mid to late 1990s as part of the Fuel Price Escalator policy introduced by the Conservative government under John Major and continued by Tony Blair's Labour administration until 1999. The fuel protests of 2000 illustrated the limitation of the willingness of the public and road haulage industry to withstand the cost burden and resulted in the policy's dilution and ultimate demise; from 2011 onwards fuel duty rates were frozen and in 2022 were reduced. From a Scottish perspective, increasing the variable cost of vehicle usage raises questions around equitability particularly in rural areas. In these locations, high car-dependence means that the impact of increased costs can be difficult to avoid through mode change due to limited alternative options. Here, subsidy and support of local shops and services have been suggested as potential requirements of an equitable policy approach (Gray et al., 2001)

Whilst intervention in the cost of motor vehicle use carries political sensitivities, in recent years other events have forced governments to review methods of road user charging. Most recently, in addition to the environmental issues associated with motor vehicle use, a new issue has arisen – that of the reduction and eventual complete loss of tax receipts resulting from the shift from internal combustion engine to electrically powered vehicles. The figures are not insubstantial, with vehicle excise duty and fuel duty comprising approximately 4% of all UK tax receipts in 2021-22 (Parliament. House of Commons, 2022) The Westminster Transport Select Committee has recognised the urgency of reform and has recommended the use of telematics to charge drivers based on distance, vehicle type and congestion. It has also recommended that any scheme should be the sole mechanism for charging, that localised congestion charging and low emission zones should be removed to avoid confusing road users and that the overall scheme should be revenue neutral compared with the current VED/fuel duty arrangements.

Whilst the select committee's solution may ultimately achieve the desired outcomes, a technological solution has not been implemented anywhere to this scale to date and may be challenging. On this basis, others have suggested a simpler system should be adopted consisting of a charge by miles driven per period for all vehicles accompanied by abolition or modification of the existing fuel-duty system for residual internal combustion engine powered vehicles (Corfe, 2022). Such a system would also permit local transport demand management schemes such as congestion charging to remain in place to tackle congestion hotspots. The only disadvantage of a non-telematic, simple system is that it would not permit fully reactive time and congestion pricing and therefore the economic efficiency of the network would not strictly be maximised.

Other countries have implemented RUC schemes in response to economic crises. As a result of reforms required following its post-global financial crisis national debt situation, Portugal implemented gantry-based toll collection on its motorway network in 2011 to cover its public-private partnership financial obligations. In road traffic reduction terms, falls of between 30% and 60% were recorded where the tolls were introduced (Santos and Santos, 2012). However, it is not clear whether these figures represented a true reduction

in traffic or whether vehicles simply diverted to the local road network. If this were the case, researchers have estimated that traffic shifting to such routes may equate to a 10% increase in carbon emissions (Bandeira et al., 2012). Negative impacts in terms of business in low productivity areas has also been identified and it has been suggested that such areas should feature toll-free sections to boost economic output (Amorim et al., 2019).

Spain is also proposing the introduction of a national road tolling scheme. In this case, tolls would be implemented on 12,000km of national state-run high-capacity roads, with further negotiation with regional governments for other key strategic routes (Muñoz, 2021). Charges are yet to be confirmed but suggestions have been made that between €0.03 and €0.05 per kilometre would be required to cover basic road maintenance costs, potentially increasing to €0.13 per kilometre for heavy vehicles. Discounts have been proposed for certain user groups to address equity concerns. Public acceptance of such a scheme is likely to be challenging, particularly as Spain comes from a politically delicate position on road tolling having been unable to renew concessionaires on existing toll routes due to their financial unviability resulting from low usage (Muñoz, 2022). This removal of tolls has also been criticised as undermining public transport recovery in the country following the Covid-19 global pandemic (Cordero and Blanchar, 2021).

Belgium is currently pursuing a national road user charging scheme, following the conversion of its time-based (Eurovignette) to distance-based electronic tolling for vehicles over 3.5 tonnes in 2016. The latter covers motorways, expressways and some local roads and is similar to those covering other central European countries such as Germany, Austria, Switzerland and Czechia. There is evidence that such schemes can result in more efficient fleet use, for example reductions in the number of empty HGVs running on the road network. The proposed scheme in Belgium would see similar technology used to charge all vehicle types, including cars. An eight-week trial was undertaken in 2016 across a representative sample of the country comprising the Brussels city region and surrounding parts of Flanders and Wallonia (de Vos, 2016). The area under test was a polycentric urban rural mix with a dense road network, which could be considered broadly comparable to the Scottish Central Belt. The trial suggested an overall reduction in car kilometres of 5.6% which varied by road type; the greatest reduction was found on urban roads with the least on motorways. In general, the overall reduction was much higher in urban areas (9.3%) than in rural ones (1.4%). Evidence of increases in combined, multi-purpose trips was found along with an increase in walking and cycling. From a business perspective, this would suggest shifts in retail patterns to more local shopping. Despite the trial demonstrating potential positive effects, public acceptance of road user charging remained low, with just under 30% of participants saying they would support a scheme if put to a referendum.

National Road User Charging – Key Points

+ A national road user charging system is likely to be **urgently required** to replace vehicle excise duty/fuel duty in conjunction with vehicle electrification, **irrespective of any traffic reduction targets.**
+ Traffic reductions resulting from road user charging are likely to vary by road type and the urban/rural mix, with **reductions of up to 10% possible**
+ **Business benefits** from road user charging can include more **efficient fleet usage** and **greater uptake of local shopping**
+ A telematic based road user charging system could **maximise the economic efficiency** of the road network, through **reactive congestion-based time and location charging**

– If charges are implemented on certain road types only (e.g. motorways), **true reductions in traffic may not materialise** where local free-of-charge alternative routes exist.
– **Public acceptance** of road user charging is low and traditionally has been highly sensitive when changes are made (e.g. fuel duty protests)
– **Equity issues** are likely to be raised in association with road user charging in **rural areas** where public services are more sparse and public transport provision is low

2.6 Rural Tourism Measures

Congestion charging in rural areas can be more challenging than in cities and conurbations due to the lack of naturally defined physical boundaries and significant generators and attractors of trips. The perception of congestion problems may be far lower and public support for any charge more difficult to secure. However, in certain circumstances, charging can play a part is in relation to the traffic effects of rural tourism. Traffic can be particularly detrimental to environmental conditions in popular tourist areas and as a result may undermine the visitor experience. Mindful of this, charging may bring economic benefits as a revenue stream to support and enhance attractions. For example, charging for vehicular access to National Parks and National Monuments is relatively common in the United States, where just under 28% of the 419 sites charge an entrance fee of between $5 and $35 per vehicle. It is worth noting that these entry fees are not intended as a travel demand management measure specifically; the revenue generated is primarily for the operation and management of the parks. That said, many of the US national parks authorities use some of the revenue to provide transportation for visitors such as shuttle buses and park-and-ride arrangements, so they do have a potential role in road traffic reduction.

An example of a specific road traffic reduction charge was at Zion National Park in Utah. The national park had seen a substantial increase in visitor numbers rising from 1.5 million per year in the 1980s to over 2.5 million a year by the turn of the millennium. The

increased visitor numbers placed significant pressure on infrastructure with congestion and overcrowding a common occurrence. A complete removal of around 5,000 vehicles per day from a 6.5-mile route within the national park was achieved through the provision of parking and a high-quality shuttle bus system. Public acceptance for the scheme was initially restricted but following 10 years of successful operation, the scheme is now well established and generally accepted. It is worth noting whilst in practical terms the shuttle appears to have worked successfully, the research undertaken does not consider the impacts on businesses such as on the gateway town to the region. In addition, the scheme does bring a cost; the original implementation of the system was $28M which included the purchase of vehicles and the construction of a visitor centre. The park is a relatively well-visited one throughout the year; issues of seasonality in visitor numbers and park size may need to be considered in other locations. However, overall, the visitor experience has been substantially improved through reduced waiting times, an improved overall environment and enhanced visitor freedom by making more areas of the canyon easily accessible (Mace et al., 2013).

The potential effect on businesses involved in rural tourism has been referenced in several theoretical studies of road user charging in rural areas. Stated preference surveys of potential schemes in the Dolomites in Italy and some English national parks have shown that if charge levels and/or the quality of associated public transport alternatives is insufficient, then visitors may simply abandon that area and go elsewhere (Scuttari et al., 2018; Steiner and Bristow, 2000). For example, a survey of bed spaces in or around the New Forest National Park found 70% of them being inaccessible by public transport, despite the park being located near to urban high population centres (Smith et al., 2018). Visitors also often have a requirement to carry outdoor equipment such as camping gear. It is also worth noting that the driving experience is often considered part of the attraction of trips to some of these areas and that removing the possibility of driving can have a negative impact, despite the reduction in traffic theoretically improving their environmental attractiveness. In terms of equity, charging for vehicle-based entry to rural attractions has been considered to have a disproportionate impact on elderly people and families with young children.

Road pricing has been discussed for several years in the context of UK national parks. Early literature and reporting were particularly supportive of charging as a measure, specifically to address the ever-growing levels of traffic within them and its impact on the local environment and amenity (Cullinane, 1997) However, since then it has been almost universally rejected by National Park Authority officers on numerous grounds. Domestic national parks tend to have high resident populations with multiple entry points, unlike many international comparators which are often true wilderness areas with a single point of access. In this way, separating the requirements of permanent residents and restrictions on visitors can be problematic both in practical and administrative terms. In the case of the latter, elements of any travel demand management package may be the responsibility of several different bodies, such as the National Park Authority, local authority and Forestry Commission amongst others. Co-ordination is therefore difficult, and policies may conflict (Kendal et al., 2011). Aligned with this, there are arguments that charges are against the philosophy of national parks and can be inequitable. Some argue that charging for their use is inappropriate as such charges may prevent enjoyment of the

land, with disproportionate effects on those on low incomes, for example (Takama et al., 2014).

Whilst in the UK and Scottish context, access charges for national parks appear difficult to implement, options exist at a more localised level. Modelling of the potential effects of local tolls and/or parking charges at and around popular attractions in the Peak District and Yorkshire Dales has suggested that traffic flows may reduce by up to 50% (Steiner and Bristow, 2000; Takama et al., 2014). Such approaches seem to be most associated with the proximity of nearby high population centres, with the biggest effect on modal shift being associated with parking charge implementation for day trips. However, this type of measure has also been associated with visitor number reductions of up to 20%, with potential diversion of trips to other adjacent attractions. On this basis, whilst local environmental improvements may be achieved, the anticipated overall net traffic reduction may not materialise in real terms due to diversion of the problem elsewhere.

Rural Tourism Measures – Key Points

+ Modelling has shown that in theory charging for may **reduce traffic volumes and increase public transport modal share**
+ Can result in **improved local environmental quality** around popular attractions and surrounding areas
+ Most realistic traffic reduction is via **parking charges** for day trips to national parks that are close to urban areas

– In practical terms, rural congestion is not seen to be an issue, therefore **public acceptance highly challenging**
– **Public transport alternatives very difficult to implement** in terms of cost, frequency and multi-agency support
– Requirement to carry outdoor equipment means **mode shift impractical** for many with consequential potential for economic loss
– **Charging for Scottish national park access** compared with international equivalents is **problematic** due to multiple access points and high levels of permanent resident population

2.7 Summary

This chapter has looked at five different approaches to road traffic reduction using transport demand management measures. In many respects, it is difficult to compare the effectiveness of each type of measure directly due to the complex range of contributory and contextual factors involved.

However, an attempt has been made to generalise the strengths and weaknesses of each approach under the five criteria used in this review. Table 1 below illustrates where the evidence suggests a measure might be considered particularly strong in impact (ranging from + to +++) or particularly challenging to implement (from - to ---) under each criteria respectively.

The factors contributing to the scoring can be considered as follows. Efficacy scores the measure's performance against performance metrics, for example traffic flow, mode share, public transport patronage or economic activity. Contextual factors consider the relative ease of implementation when matters such as socio-demographics, public transport network strength and catchment size are considered. Political social and technological factors measure ease of implementation when such attributes are accounted for. Impacts for policy areas score the measure against other policy objectives, such as climate, congestion, connectivity, productivity, place-making and fairness on business size. Cost effectiveness looks at the performance of the measure in terms of car use reduction when compared with the capital and revenue costs incurred.

	Efficacy	Contextual factors	Political, social and technological factors	Impacts for policy areas	Cost effectiveness
Workplace Parking Levy	**++**	**+/-**	**+**	**++**	**++**
Low Emission Zones	**-**	**++**	**+/-**	**+**	**+**
Congestion Charging	**+++**	**+**	**+/-**	**++**	**+**
Rural Measures	**+**	**-**	**--**	**+**	**-**
National Road Pricing	**++**	**+**	**-**	**++**	**-**

Table 1: Strengths and weaknesses of measures against review criteria

The next chapter of this report presents an analysis of the measures identified above in the context of pre-Covid travel patterns in Scotland.

3 Application of measures in Scotland

3.1 Introduction

The previous chapter reviewed five methods that have been adopted as traffic demand management measures with the aim of reducing car traffic on road networks. The case studies reviewed were from a diverse range of geographic locations and comprised urban and rural areas of varying size and population density. Each case was also subject to a range of political, social and technological factors which was likely to have influence on the performance of the measure adopted. Whilst no case was considered directly comparable to the Scottish context, there were some attributes of the schemes examined which may give an insight into how effective they might be if implemented in support of the Scottish Government Route map. This chapter examines these attributes in a Scottish context and suggests possible outcomes of their implementation as part of transport policy in Scotland. Firstly however, a very brief overview/snapshot is given of modal travel patterns in Scotland in 2019, prior to the onset of the Covid-19 pandemic.

3.2 Scottish modal split/travel patterns: a snapshot

Key sources for this sub-section are Scottish Transport Statistics 2020 and the Scottish Household Survey 2020, both of which cover the 2019 calendar year. More recent statistics are available but are heavily affected by the pandemic. In 2019, 72.4% of all Scottish households had access to one car or more, with 71% of all individuals over 17 having a full driving licence, 43% drove every day and 64.4% at least once or twice a week. Of the 49 billion vehicle kilometres driven in Scotland, 40% were on the Transport Scotland operated strategic motorway and trunk road network and 60% on local authority roads. 49% of vehicle kilometres were on rural roads with the remaining 51% in urban areas.

The high level of private vehicle use was reflected in a 65.2% share of all journeys, as opposed to a 22.1% share for walking, 1.2% for bicycles, 7.0% for the bus and 2.3% for rail; note however rail's 'share' would be higher if passenger kilometres rather than passenger journeys was used as the basis for evaluation. Considering the specific case of the journey to work, modal splits were similarly dominated by the car, with a 68.2% modal share, walking with 12.0%, bus 9.6% and rail 5.4%. Average commuting times were 25 minutes by car, 36 minutes by bus and 15 minutes on foot. In terms of urban/rural splits, car use is far heavier in rural areas, with figures relating to the journey to work indicating modal splits urban:rural as car 65.5%:82.3%, walking 5.3%:3.5%, bicycle 3.2%:1.0%, bus 10.6%:2.5%, rail 5.8%:2.6% and taxi/private hire 2.1%:2.0%.

Overall, car travel tends to dominate in Scotland and in comparison to other countries in Europe, whilst car use may be slightly higher, modal splits are not dramatically dissimilar to elsewhere on the continent.

3.3 Likelihood of traffic reduction

All the schemes reviewed resulted in some form of car traffic reduction, except for Low Emission Zones. Here the main impact of such measures appeared to be fleet renewal in the haulage and public transport sectors, with private car traffic left for the most part unaffected. Low Emission Zones are under preparation for implementation in Edinburgh,

Glasgow, Aberdeen and Dundee between 2022-24 after which full enforcement will be undertaken. On the evidence found from other cities, whist these schemes may bring short term benefits in air quality, they seem unlikely to contribute in any significant way to traffic reduction.

Based on the experience elsewhere, it is expected the implementation of Workplace Parking Levies in selected locations in Scotland is likely to result in a reduction in traffic. However, there are some factors which appear to be critical to a successful scheme. Hypothecation of revenue to invest in public transport alternatives is associated with obtaining business and public support. In the case of Scottish cities, this would mean WPL revenue might contribute to schemes such as Edinburgh Tram Line 3 or the Glasgow Metro, for example. Such a combination of push and pull factors is likely to be the most effective approach in traffic reduction. It also should also be clearly apparent that a WPL requires a reasonable amount of workplace parking stock to apply the levy to. To minimise the operating costs, the model applied in Nottingham of restricting the levy to workplaces above a certain threshold of parking seems optimum. On this basis, traffic reduction is only likely to occur in urban areas, and particularly those with a high large employer content.

If congestion charging were to be implemented in Scotland, based on the evidence reviewed Edinburgh would appear to be the most likely location to start. One of the reasons for the support for the London scheme was the acknowledgement that traffic levels in the city were too high. Edinburgh's City Centre Transformation strategy takes a similar view and aims to restrict access to the centre of the city to essential vehicles only. In this regard, congestion charging could be seen as a complementary measure. This would potentially also yield business benefits including improved delivery times, better public transport connectivity and improved public realm. In addition, it would contribute to the city's reputation as a business and tourism destination overall. Edinburgh also exhibits similar characteristics to some of the Scandinavian examples in terms of income levels, public transport network provision and the relatively high level of city centre parking charges.

The level of traffic reduction associated with a National Road User Charging scheme for Scotland would very much depend on the level of charges set. If the current Westminster Select Committee proposal of maintaining the status-quo of a like-for-like replacement of the existing vehicle excise duty / fuel duty combination, then apart from the variable cost of motoring being perhaps clearer to motorists than that on fuel, there is little evidence to suggest any change to habits would occur. However, if differential charging were to be adopted on a time/distance basis, such as the scheme trialled in Belgium, reductions in traffic could be envisaged, particularly in and around urban parts of the country.

Based on the case studies investigated, the rural traffic reduction schemes reviewed such as charging for access to National Parks or attractions is likely to result in moderate reductions in traffic. However, these reductions are expected to be modest and restricted to specific local areas. In many cases journeys will still be made by car but may be truncated through the provision of shuttle buses, for example. The business effects of such measures are unclear, but there is reasonable evidence to suggest that charging may simply result in trips being diverted to other destinations. In a Scottish context, given there is a relative abundance of scenic destinations to visit outwith the two National Park

areas, this would be a considerable risk and it may be that such measures are rendered ineffective in this regard.

3.4 Areas of Scotland most likely to yield positive results

Traffic reduction in rural areas would appear to be very challenging and brings with it equity considerations for measures such as national road user charging. For such concerns to be addressed, significant investment in rural public transport and/or provision and financial support for local services is likely to be required. Considering the business case for this investment, it is highly likely that better returns would be achieved in traffic reduction terms by focussing more on urban and city-region areas. In practical terms therefore, rural areas are unlikely to the best place to target for many reasons; indeed, this is recognised by the Scottish Government Route Map which acknowledges that the contribution to traffic reduction is likely to vary across the country.

Looking at the urban areas of Scotland, the local authority areas of Aberdeen, Edinburgh and Glasgow share similar population levels and economy values to the City of Nottingham and it is suggested could yield similar results to the English city if Workplace Parking Levies were applied. Edinburgh and Glasgow already have long term plans for public transport improvement which could be part-funded from the revenue stream and would assist in securing public and business support. Implementation of levies in smaller towns and cities such as Inverness, Dundee, Stirling and Falkirk for example are more likely to be challenging due to the lower number of large employers and smaller population sizes. In addition, whilst the larger cities are arguably more resilient to competition from elsewhere, smaller authorities may be more vulnerable to competition from non-charging neighbours, particularly in the central belt.

In terms of congestion charging, as previously described Edinburgh would appear to be the most likely city to yield positive results in terms of congestion charging, albeit mainly from a technical perspective. The main barrier to implementation of a scheme in the city is from a political and public support point-of-view, as illustrated by the scheme rejected in 2005. Lessons learnt from that exercise suggests that lack of a political champion, disagreement on scheme objectives, scheme complexity, disjointed city-region governance and lack of clear promotion of benefits were key causes for rejection by the public (Rye et al., 2008). If such issues could be addressed then it may well be that Edinburgh could emulate the success of other schemes such as Stockholm in traffic reduction terms, in addition to providing a useful revenue stream for investment in transport infrastructure.

3.5 Benefits to the business community

The key benefits to the business community are likely to be the potential to move towards a more economically efficient road system. The benefits will depend on the ultimate extent and location of measures adopted, but the closer to a time and distance-based system which is related to the levels of congestion at any particular time, the greater these benefits will be. Specifically, this is likely to take the form of reduced journey times, increased reliability and prioritisation of higher-value traffic. Supplementary effects may include a focus on more efficient fleet usage. In a Scottish context, these effects are most likely to be apparent in and around the urban areas previously described.

Further benefits are likely to be within the urban areas themselves in particular relating to place-making and better usage of urban space. This may include a focus on higher value activities, growth in the tourism and leisure sectors and more accessibility by the labour market using public transport and sustainable modes. If hypothecation of revenue is successfully applied, the introduction of major transport schemes such as new Tram lines in Edinburgh or the Glasgow Metro are likely to increase the attractiveness of these cities as a place to do business in addition to improving the productivity of the existing urban area.

3.6 Impact on other Scottish policy areas

The transport demand management measures outlined in this report are complementary to many areas of current Scottish transport policy, including the National Transport Strategy 2, National Walking Strategy and the Long Term Vision for Active Travel. Transport demand management measures similar to those described are also likely to support a number of local policies, such as planning and regeneration through the potential for reallocation of road space and opening up of development land through provision of new transport links via revenue streams. The concept of 20-minute neighbourhoods through provision of dispersed and decentralised services is rapidly gaining traction and a strongly emerging factor in future Scottish planning policy; to this end transport demand management measures reducing car travel will support this aim.

One constraint to the implementation of the measures outlined here is that devolution may be an issue. Vehicle excise duty and fuel duty are matters reserved to Westminster and it seems likely at present that any replacement scheme will be the same. At present, the Westminster proposal is that drivers should pay no more in future than they do under current arrangements. This raises a political and constitutional question if the Scottish Government wishes to diverge from this and use any new national road charging system as a demand management measure. Furthermore, the Westminster proposal is that congestion charging or LEZ schemes should not co-exist with a national scheme and would ultimately need to be removed. This may have an implication on Scottish transport policy going forward and raises questions over how powers given to local authorities under the Transport (Scotland) Acts might be implemented in future, if so desired.

3.7 Implementation costs

Congestion charging in Edinburgh was shown to have viable business case in the previous 2005 scheme, which targeted a significantly lower transaction cost than London to ensure the scheme could break-even, given the significantly lower charge per vehicle that was proposed. Technological developments such as improvements in back-office systems and digitalisation of enforcement since that time are likely to mean that transaction costs are even lower if a scheme were to be implemented today. The workplace parking levy in Nottingham has successfully covered costs of implementation along with the system operating costs. Based on the findings here, for both congestion charging and workplace levy schemes it would seem that the potential would exist to implement similar approaches in Aberdeen, Edinburgh and Glasgow.

National road user charging, if the telematic-based scheme were to be implemented, is likely to require substantial research and development costs to ensure the technology is proven, followed by roll out of telematic devices to every vehicle on the road network. No definitive cost estimate for implementation of such a scheme is yet available, but it is expected to be considerable. Given the UK-wide and nature of the proposal as a reserved matter it is one that is most likely to be borne by the Westminster Government. However, if some arrangement was reached by way of differential charges applying in Scotland, there may be implications for costs directly attributable to the Scottish Government as a result.

4 Conclusion

4.1 Summary

This report has introduced a series of measures that may result in reduction in road traffic in Scotland and their likely impacts, with a specific focus on the effects on business. The purpose of the report was to enable dialogue and consultation with business NGOs to consider what effects, both positive and negative, such traffic reduction measures may have on the business community. This work was undertaken with a clear view to understanding ways in which any proposed scheme may be optimised.

Key conclusions of this work are as follows:

- All transport demand management measures reviewed were associated with traffic reduction, except for Low Emission Zones where conclusive evidence was not found.
- The most effective schemes are part of a package of measures, comprising the transport demand management itself, combined with complementary transport network improvements.
- Hypothecation of revenue and clear objectives for any scheme are critical to public and business community acceptance.
- No "one size fits all" approach exists, with measures likely to be only appropriate in cities and regions with the appropriate business demographic, for example high numbers of large employers (Workplace Parking Levy) or cost sensitive car drivers (Congestion Charging)
- Transport demand management in rural areas is highly challenging, due to low public acceptance, impracticality, limited public transport alternatives and potential diversion of business to other areas.
- A National Road User Charging scheme is likely to be required imminently to replace Vehicle Excise Duty and Fuel Duty as the shift to electric vehicles accelerates. Opportunities exist with this scheme to contribute to road traffic reduction, albeit current proposals are for a revenue-neutral approach UK wide.
- The transport demand management measures reviewed have the potential to support the Scottish Government's car traffic reduction route map

4.2 Recommendations for further research

The work presented here has provided an overview of the potential results from the implementation of transport demand measures. However, throughout the literature review it was noted that much of the existing research focused on the short term performance of each measure against its key objective, i.e. road traffic reduction or air quality improvement. The specific goal of this study was to assess the implications on business. Whilst the work reviewed on Workplace Parking Levies had some reasonable commentary in this area, overall it was notably lacking when other measures were considered or focused on specific cases where the findings might not be generalised in a Scottish context, such as London.

On this basis, there exists an opportunity for further research in the quantification of the impacts of transport demand management measures on business in general. One of the major challenges in undertaking this is that so few examples of approaches such as congestion charging and workplace parking levies exist internationally. However, the likely

imminent emergence of national road user charging schemes presents a significant opportunity for the implementation of transport demand management in both time and space contexts, as has been demonstrated in pilot schemes such as Belgium. It would seem preferable to embed behavioural change targets through such schemes from the outset. On this basis, it is recommended that further research be undertaken into both the traffic reduction potential and impact on business at the earliest opportunity.

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Appendix A: Literature Summary Tables

Scheme	**Efficacy measures** (e.g. traffic flow, mode share, PT patronage, economic activity)	**Contextual factors** (e.g. urban/rural, PT network strength etc., socio demographic, employer sizes, emissions standards)	**Political, social and technological factors** (e.g. public/political acceptance, budgets, enforcement, equality, technology obsolescence)	**Impacts for policy areas** (e.g. climate, congestion, connectivity, productivity, place-making, fairness on business size, online/hs)	**Costs** (e.g. implementation, state, road users)
Nottingham WPL	• Year 1 review: **no real change** in **journey time**, **car occupancy** or **mileage** but noted may be hidden by underlying economic growth. (Dale et al., 2014) • Longer term review considered exogenous factors and suggested a **reduction in congestion** (Dale et al., 2017b) • **No apparent impact on economic activity** but noted hard to measure (Dale et al., 2014) • Longer term analysis suggests **not having negative impact on investment** (Dale et al., 2017a) • PT travel to work **mode share found to increase** with WPL as one reason, although WPL package included tram line (Dale et al., 2019) • **Suppressed demand** may mean some may also switch *to* car, offsetting WPL benefits (Dale et al., 2019)	• **Location of competitor cities** were a big consideration - Derby, Leicester, Sheffield all close by (Dale et al., 2014) • Targeting **smaller number of larger employers** with >10 spaces minimised costs and made enforcement/compliance easier (Dale et al., 2014) • 90% of city's GVA is in **service sector** (Dale et al., 2017a) • **Improvements to PT** coupled with WPL are **important** (Dale et al., 2017a)	• Pre implementation surveys – 60% of businesses said they would relocate, but this **did not happen** (Dale et al., 2014) • **Good public transport** was seen as key **offset** for WPL in terms of potential inward investment (Dale et al., 2014) • Scheme features range of **exemptions** – disabled, customer, small businesses (Dale et al., 2014) • Some **employers may address equality** – Council passes on WPL at lower rates to PT/low paid staff; Nottingham Uni has similar link between pay and polluting vehicles (Flack et al., 2021)	• Council believed scheme would need to be based on **wide range of policy objectives** to be deemed acceptable (Dale et al., 2014) • Nottingham Trent University **redeveloped car park for other uses** (Flack et al., 2021) • Employers involved in **travel planning** doubled – potential active travel benefit (Flack et al., 2021)	• **Year 1 operating costs** were **5% of revenue** or £362k absolute. Also spent £370k on "supporting businesses" (Dale et al., 2014) • Noted research gap on effect of WPL on **house prices** in city (Flack et al., 2021)

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Perth WPL	• **Continued economic vitality** reported, with grown in employment and commercial floorspace (Richardson, 2010) • A **10% reduction in parking stock** observed after implementation (Richardson, 2010) • **Reduction in all day parking** cited due to increase in parking fees (Richardson, 2010) • **Increased PT mode share** (+27%) and **decreased car mode share** (-17%) (Richardson, 2010) • **Reduced traffic volume** and **increased PT patronage** (Richardson, 2010)	• Perth is **highly isolated** from competitor cities, so had more freedom to **take risk** of WPL scheme (Dale et al., 2014) • Perth **major growth city** – parking bays doubled between 1970s & 1990s (Richardson, 2010) • Covers a relatively **small area of the city** compared with the city region although area of high economic activity (Richardson, 2010) • Fee covers **both workplace and public parking** (Richardson, 2010) • **Free Central Area Transit** scheme provided through WPL subsidy (Richardson, 2010)	• Had **high level of pollical support** – unusually unanimous across all five parties - **hypothecation** thought to be key (Richardson, 2010) • Chamber of Commerce and Industry, Property Council, developers **objected due to competitiveness concerns** (Richardson, 2010)	• **Hypothecation** of revenue important part of policy (Richardson, 2010) • **Urban Design Framework** published following scheme – aim to make streets more attractive for pedestrians (Richardson, 2010)	• **Parking space licence fee** 567 to 598 AUD (2010 prices) (Richardson, 2010) • **30 million AUD per annum collected** (2010 prices) (Richardson, 2010)
Sydney WPL	• **No decrease** in total number of spaces (Ison et al., 2014)	• Limited to **Central Business District** and centres with **high proportion of office space** (Ison et al., 2014) • Some areas are in 'global arc' of **high income** (high technology and universities) (Ison and Mulley, 2013)	• Property Council argued against ability of WPL to **control congestion** (Ison and Mulley, 2013) • Attitude of business **generally not considered key issue** (Ison and Mulley, 2013)	• Revenue primarily used for **PT infrastructure** – interchanges and P&R (Ison et al., 2014) • Spend on **sustainable travel** 'not taken up' (Ison et al., 2014)	• **Parking space licence fee** 740 AUD to 2,100 AUD (2011 Prices) (Ison and Mulley, 2013) • **100 million AUD per annum collected** (2011 prices) (Ison and Mulley, 2013)

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Melbourne WPL	• **Traffic volumes fell 6%** between 2005-09 (Victorian Government, 2010) • **Public transport patronage increased** at a rate greater than population/employment growth (Victorian Government, 2010) • **Long stay parking stock decreased** (2.7%), **short stay parking stock increased** (25%) following implementation of levy (Victorian Government, 2010) • **4% of mode shift** from car to non-car direct result of levy (Victorian Government, 2010)	• WPL is **limited to central area** of city and parking controls beyond diminish (Taylor, 2020) • Levy was applied during period of **rising petrol prices** (60% increase 2005-08) (Victorian Government, 2010) • Implementation coincided with **significant increase** (+25%) **in employment growth** in city (Victorian Government, 2010) • Implementation coincided with **significant increase in PT frequencies** (Victorian Government, 2010) • City centre based **around historical street pattern** retrofitted for car (Taylor, 2020)	• Some **streamlining of administrative issues** was necessary for both the state and users of scheme (Victorian Government, 2010) • Claims of **inequality,** but dismissed as "lower incomes more likely to travel by public transport" (Victorian Government, 2010) • Most drivers thought to **have levy paid by employers** and limited evidence of charge being passed on (Hamer et al., 2012b) • **Wealthiest drivers** appear least likely to pay levy – equity concern (Hamer et al., 2012a)	• **No discernible trend** in NO2/CO levels following introduction (Victorian Government, 2010) • Linkage suggested between **increased short stay** provision and **increased High Street retail activity** (Victorian Government, 2010) • **Higher short stay prices** may be subsidising levy on long stay, which may be negative for retail/leisure sectors (Hamer et al., 2012b) • **Hypothecation** of funds to other transport projects is not clearly visible (Taylor, 2020) • Overall parking policy **inconsistent** – reduced office but increased commercial parking (Pandhe and March, 2012)	• Levy was doubled from 400 AUD to 800 AUD after year 1 (2006) as part of 'phasing in process' (Victorian Government, 2010) • Annual cost **indexed in line** with Melbourne CPI (Victorian Government, 2010) • **Parking space licence fee** 1020 AUD to 1440 AUD (2019 prices) (Taylor, 2020) • Increase in public parking prices **passed on to users** in some cases, but other car park operators struggled (Victorian Government, 2010) • **Long stay parking prices** increased by 11-17%, but then dropped; either way full levy not collected from end user (Hamer et al., 2012b)

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London CC	• Initial implementation led **reduction in car traffic entering/leaving by 33%** and **all vehicles by 18%** (Metz, 2018) • **Small initial decline (up to 10%)** in shopping activity in Central London, mainly discretionary shopping at weekends but may also be associated with **confounding factors** (SARS, terrorism etc.) (Turner, 2005) • Small but statistically significant impact on **physical activity levels** around boundary zone, but may be associated with pull measures (Nakamura et al., 2021) • Association with **house price increases** within the zone at boundary cp outside (Tang, 2016) • **Positive reduction in delivery time** reported for distribution companies (Litman, 2005) • Bus use **increased by 40%** (Bhatt et al., 2008)	• Apparent particular effect on charge for retailers with large proportion of **car-borne customers** – e.g. John Lewis (Quddus et al., 2007) • Population is **wealthiest in UK;** purchase of HEV/LEV to avoid charge more easily attainable (Morton et al., 2017) • LCC discount for zone residents **does not extend to employers/companies** – may incentivise fleet renewal (Morton et al., 2017)	• **Criticised** by some politicians, motorist groups and labour organisations prior to launch, but subsequently **widely embraced following implementation** (Litman, 2005) • **Challenged** (unsuccessfully) in the **High Court** by Westminster Council (Bhatt et al., 2008) • **Significant pre-implementation support** from **large business group**, London First representing 22% of London's GDP (Litman, 2005) • Limited work on **equity** but claimed to have positive benefit due to enhancement of public transport (Bhatt et al., 2008) • Public acceptability associated with widely accepted view (90% surveyed) that there was **too much traffic in London** (Bhatt et al., 2008)	• **Traffic reduction** has remained **broadly the same** since, but **congestion has increased** due to reallocation of road space and urban realm improvements (Metz, 2018) • Substantial and significant **reduction in vehicle accidents** within zone; no evidence of increase outside zone (Green et al., 2016) • London CC positively associated with **hybrid electric vehicle registrations** promoting adoption of LEVs (Morton et al., 2017)	• **Initially £5 per day (2003)**; increased to £8 (2005); £10 (2011); £11.50 (2014) (Metz, 2018) • **Currently £15 per day** 0700-1800 Mon-Fri; 1200-1800 Sat-Sun (TfL, 2022) • **Increases in charges** have had very little impact on traffic, suggesting price sensitivity limited (Metz, 2018) • Scheme set up costs **£161.7 million** (Bhatt et al., 2008) • **More than half of revenue** spent on running the scheme (Bhatt et al., 2008)

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Gothenburg CC	• **Reduction in traffic volume** across cordon of **12%,** but only minor reduction within cordon (Metz, 2018; Börjesson and Kristoffersson 2015) • Increased traffic levels on surrounding streets, but no increase in travel times (Borjesson and Kristoffersson, 2015) • All commuters priced off the road switched to public transport (Andersson and Nässén, 2016) • Discretionary travellers changed destination or reduced trip frequency (Andersson and Nässén, 2016)	• Prime motivation was to raise finance for transport infrastructure improvements (Hysing et al, 2015) • Resistance to the imposition of such charges from strong business interests can be overcome if clear tangible benefits can be seen coming out of the scheme(Hysing, 2015)	• 35% positive attitude before implementation, rising to 43% after, but survey based solely on car owners (Andersson and Nässén, 2016) • Change in attitudes due to status quo basis • Scheme brought about through “coalition” and negotiation between political, business and environmental groups/parties.	• Net welfare loss across all but the very highest income groups, i.e. regressive (West and Börjesson, 2020)	• Raised €72m in first year, opex was €12m.

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Singapore CC	• Initial 1975 scheme had much larger than intended effect – **76% drop in car traffic –** reflecting higher than optimal charges (Walter, 2020) • **Traffic volumes** in central business district **reduced by 10-15%** following 1998 ERP scheme (Metz, 2018) • Noted that little or no work has been done to understand **economic impact** of ERP (Walter, 2020) • ERP system successful in maintaining **satisfactory average speeds** on road network	• **Cost of private car ownership high** through **licence bidding** – so scheme could be considered having **two elements** – high fixed charge for access and low variable charge for use made (Metz, 2018) • **High population and population density** – 5.61 million pop with 7797 inhabitants per km^2 (Chng et al., 2019) • Cars perceived as **luxury goods and status symbols** (Chng et al., 2019) • Road pricing implemented over a period of **dramatic economic and population growth** (Walter, 2020)	• Success associated with **strong government control** and **general compliance culture of Singaporean public** (Phang and Toh, 2004) • Singapore has **long history of priced-based restraint** (Walter, 2020) • **Technology** has progressed from permit based (1975) to ERP (1998) now moving to satellite-based (Walter, 2020)	• **Retailers** expressed concern that charges would **deter customers**, but policy makers claimed that ERP would deter through trips not shopping trips (Walter, 2020) • Effects of ERP offset by **improvements in congestion levels** for residents and businesses, but **18.8% reduction in commercial real estate prices** (Walter, 2020)	• Capital costs of original scheme (1975) S$6.6 million (Phang and Toh, 2004) • Operating and enforcement costs of original scheme only **9% of revenues** (Phang and Toh, 2004) •

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Stockholm CC	• Traffic across cordon **reduced by 20%** and has **stayed stable** at this level (Metz, 2018) • Long term **congestion effects unproven** due to congestion monitoring only immediately after scheme (Metz, 2018) • **15% reduction** in **freight traffic**, either due to route switching or trip chaining (Franklin et al, 2010) • No impact on retailer revenues (Daunfeldt et al., 2013)	• High level and **good quality public transport** provision. • **High parking charges** prior to the CC scheme, hence car access prior to the charge generally by those on higher incomes (Daunfeldt et al., 2013)	• **Referendum** after trial returned an overall majority in favour of retention (53/47), many surrounding areas held non-binding referendums that returned negative majorities, producing an overall negative (47.5/52.5) • Due to geography (water) Stockholm CC area has **a relatively small number of access points** (18). • Research suggests **rising levels of positive public opinion** continued after permanency, estimated at 65% one year after the referendum (Eliasson and Jonsson, 2011)	• **Congestion remains an issue** in Stockholm, although levels significantly decreased • **Funds raised spent on transport infrastructure**, including 25 major road construction/improvement schemes (Swedish Transport Administration, 2011).	• Implementation charge was 1800 MSEK (approx. €180M), which some say was far too high (Hamilton, 2011) • Peak charge 35 SEK (about **£3**) (Metz, 2018) • Charges apply for each crossing, with a maximum daily charge of 105 SEK (approx. £8.50) • 399m SEK raised during six-month trial period

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German LEZs	• Traffic flow, little detail given, generally not assessed, all studies tend to exclusively focus on impact on air quality. • **Contributed to significant reductions** in the amount of particulate matter, effects on nitrogen oxides is less obvious (Holman et al., 2015; Jiang et al., 2017) • Creation of an LEZ or other similar environmental measures provides logistics companies **whose policies include pollution reduction with an immediate competitive advantage** over conventional firms that need to improve their vehicle fleet (Dablanc and Montenon, 2015).	• **Common standards across the country** together with the federal government's scrappage funding scheme helped change the fleet of vehicles in Germany. • Without the introduction of LEZs **the same results may have been observed** but at a slower pace (Cyrys et al., 2014)	• Despite LEZ measures by far falling most heavily on the freight sector, **no research was found** on this whole topic	• No detail found	• No detail found

London LEZ	• **World's largest LEZ**, introduced Feb 2008, covers whole of Greater London, only applies to HGVs • **No real impact on fleet sizes**, and in fact, in Greater London these rose at the national average (Ellison et al, 2013) • **Rate of fleet turnover increased substantially** when zone first introduced (Phase 1), returned to the national average in subsequent years (Ellison et al, 2013), but research pre-dates Phases 2 & 3. • Mixed results re air quality, phase one small reductions in PM (Ellison et al, 2013) v short term increases in PM (Zhai and Wolff, 2021). Higher improvements found in more restrictive phase 2 (Zhai and Wolff, 2021). • Vehicle **operating costs rise on average by 2% p.a**. (TfL, 2006), but includes compliance costs	• Initial standards set at Euro 3, raised to Euro 4 in 2012 and Euro 6 in March 2021 • LGVs (3.5t) at Euro 3 included from Jan 2012 onwards	• No detail found	• **Cost increases would have a minor direct impact on employment** in the transport and logistics sector, but given the upfront costs, suggests it would be smaller operators who would be more affected (TfL, 2006). • Reduction in visitor expenditure impacts from the LEZ likely to be low, **being less than 100 FTEs** (TfL, 2006) • Due to cost of compliance, due to have a larger impact on smaller freight operators (TfL, 2006) • Suggested LEZ may **improve image of London** as a green and clean city, so encouraging tourism, but no evidence presented (TfL, 2006) • Decrease by 8% in the number of small workplaces (0 to 9 employees) in transportation and storage in Greater London between 2008 and 2011 (Thompson, 2009, cited Dablanc and Montenon 2015), but coincides with economic downturn. • Creation of an LEZ reduces the number of transport firms making urban deliveries (Dablanc and Montenon, 2015)	• No detail found
Madrid LEZ	• Achieved NO2 reductions of up to 32% in the first 3 years, with	• No detail found	• 68% stating they were either positive or very positive regarding the	• No detail found	• No detail found

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	no compensatory increases outside of the zone (Salas et al., 2021). • A significant impact on modal share away from private vehicles and towards public transport/active modes (Tarriño-Ortiz et al., 2022), but… • Reported 60% reduction in car users (Tarriño-Ortiz et al., 2022), does suggest a strong response bias in the survey		LEZ (Tarriño-Ortiz et al., 2021), but again a response bias • Wrought with legal and political challenges and, despite strong protests from environmental groups, abolished in May 2021 following a ruling by the Spanish Supreme Court (Cities Today, 2021).		
Scotland LEZs (all Transport Scotland, 2021)	• Consultation exercise with freight and PSV operators	• Strong support for nationally consistent standards	• Questions raised over the feasibility of implementation timelines • Advanced signalling required with respect to future changes to help investment planning	• Concern over the capital costs incurred by businesses when upgrading commercial fleets, particularly for SMEs	• No detail found

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Milan LEZ	• In 2009 found there was **little to no change** in the levels of PM10, PM2.5 and PM1 levels (Invernizzi et al., 2011). This was attributed to the small area of the LEZ and the homogenous levels of particulates across the region. Suggest better to assess black carbon levels to analyse impacts of traffic restriction measures.	• Euro 3/Euro 4 or better	• Controversial	• Replaced by a congestion charging scheme (Area C) in Jan 2012 • Some loading restrictions (time window exclusions) also introduced. • Freight sector had saved €1.3 million in time savings and reliability improvements, but lost €10.8 million in tolls and investment in new vehicles—a net loss of €9.5 million (Danielis et al, 2015, cited in Dablanc 2015)	• No detail found
New Forest Rural TDM	• **Some modal shift** following pull TDM measures (mainly promotion of sustainable transport) (Smith et al., 2018) • **Road pricing** was proposed as part of a long-term plan (Kendal et al., 2011)	• Rural with **nearby urban high population** centres - Bournemouth, Southampton (Smith et al., 2018)	• **Families with young children** thought to disbenefit most – e.g. unable to cycle long distances (Smith et al., 2018) • High levels of **camping and cycle use** – barrier of carrying equipment (Smith et al., 2018) • 70% of bed spaces in or around park **inaccessible by public transport** (Smith et al., 2018)	• Congestion issued had **negative impact on park perception** (Smith et al., 2018) • Biggest potential for mode shift (thought possible parking charge) was in **local day trips** – e.g. dog walkers (Smith et al., 2018) • Road user charging an issue as it is **Local Authority**, not NP authority responsible (Kendal et al., 2011)	• No charges applied to date

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Upper Derwent Valley, Peak District Rural TDM	• Efficacy by stated preference only, but implementation of toll and/or parking charges **likely to result in mode share of car 50-66%** (Takama et al., 2014)	• Rural with **nearby high population centres** – Sheffield, Greater Manchester (Takama et al., 2014)	• Toll thought to have disproportionate effect on **elderly people** (Takama et al., 2014) • Wider question of whether **restricting access to open space** is ethical (Takama et al., 2014)	• Scheme overall would have beneficial localised **environmental benefits** (Takama et al., 2014)	• Charges tested from **20p to £1 for toll** and **50p to £2.50 for parking** (Takama et al., 2014)
Upper Wharfdale, Yorkshire Dales TDM	• Efficacy by stated preference only, but implementation of toll and/or parking charges claimed to result in **potential traffic flow reduction of 50%** (Steiner and Bristow, 2000) • Potential visitor number reduction of **10-20% economic disbenefit,** but may also make **more attractive to new non-car visitors** (Steiner and Bristow, 2000)	• Rural with **nearby high population centre** – West Yorkshire conurbation (Steiner and Bristow, 2000)	• **Hypothecation** of toll to public transport improvement improved public acceptance (Steiner and Bristow, 2000) • Exemptions required **for local residents, disabled and deliveries** (Steiner and Bristow, 2000) • Potential disbenefits from attractions **outwith the scheme becoming more popular** (Steiner and Bristow, 2000)	• Localised **environmental benefit** but potential wider issues of overspill into adjacent areas (Steiner and Bristow, 2000) • Could **generate revenue** for other uses (Steiner and Bristow, 2000) • May result in **diversionary traffic** elsewhere on network (Steiner and Bristow, 2000)	• Charges tested from **50p to £2.50 for toll** (Steiner and Bristow, 2000)

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UK National Parks – Road Pricing	• Road pricing almost **universally rejected** by UK NP officer representatives as being wholly unrealistic on numerous grounds (Kendal et al., 2011) • **Parking charges as a pricing mechanism** more viable, but problematic in implementation (Kendal et al., 2011)	• **300,000 people live within UK NPs**, compared with international examples with are 'wilderness' areas (Kendal et al., 2011) • UK national parks have **multiple entry points** unlike international equivalents (Kendal et al., 2011)	• Traffic problems in National Parks are **not perceived to be 'severe enough'** (Kendal et al., 2011) • For charging to be applied**, PT alternatives needed** – very lacking in NP areas (Kendal et al., 2011) • Charges **'against the philosophy'** of NPs – i.e. may prevent enjoyment of the land – particularly for low incomes (Kendal et al., 2011) • **Overspill parking** on verges and other unwanted areas highly possible (Kendal et al., 2011)	• **Conflict** between National Park's own policy and Local Authority policy – e.g. Hampshire refused to support New Forest RUC (Kendal et al., 2011) • Local authority bus subsidy policy – other areas and routes have **higher priority** over NPs (Kendal et al., 2011)	• Parking charges may be set by various bodies – councils, Forestry Commission, NP authority and **difficult to coordinate prices** (Kendal et al., 2011)

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Dolomites TDM measures	• Efficacy by stated preference only, showing **traffic reduction and mode shift** *if* high quality PT and carefully priced toll used.(Scuttari et al., 2018) • Poor public transport and/or inappropriate toll may result in **loss of visitors** (Scuttari et al., 2018) • **Quota management** – i.e. measures restricted by volume or time of day also may be effective. (Scuttari et al., 2018)	• Mountainous **and single road access routes** to area – passes being of main tourist interest (Scuttari et al., 2018) • Existing **public transport provision reasonable** (Scuttari et al., 2018)	• A **mix of measures** – i.e. carrot and stick - achieves the best results as opposed to a single measure alone (Scuttari et al., 2018) • Paying for access to a road which is **not the attraction itself** may be negatively perceived (Scuttari et al., 2018)	• Poorly performing combinations of measures are likely to cause **abandonment of area and negative effect on business** (Scuttari et al., 2018) • Attraction of some rural routes is the **driving experience itself**. May be possible to extract premium revenue for other transport uses, but on the other hand does not influence (direct) mode share (Scuttari et al., 2018)	• Tolls tested between **€5 to €35;** bus fares **€1.50 to €6** (Scuttari et al., 2018)

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Zion National Park Mandatory Alternative, Transportation Utah	• **Complete removal of traffic** from 6.5mile route within National Park (Mace et al., 2013) • Scheme well received once bedded in (Mace et al., 2013)	• **High quality PT shuttle system** implemented (Mace et al., 2013)	• **Initial public acceptance was restricted**, but after 10 years of operation **now well supported** (Mace et al., 2013)	• **Effect on business** in park gateway town of Springdale requires **further research** (Mace et al., 2013)	• **Transit system implementation cost US$28.1M** including visitor centre (2001 prices) (Mace et al., 2013)
National Road Tolling: Portugal	• **Traffic reductions of between 30% and 60%** on the roads where tolls introduced (Santos and Santos, 2012) • **Further research needed** to determine whether trips reduced or rerouted onto toll-free roads (Santos and Santos, 2012)	• Driven by **post GFC Portuguese debt crisis** (Amorim et al., 2019) • Conversion of previous **shadow toll system** on rural motorways to user pays (Amorim et al., 2019) • Design of motorways had **closely spaced interchanges** compared with normal new-build toll roads (Amorim et al., 2019)	• Used **gantry-based electronic toll collection (ETC)** to reduce booth construction costs as they would be excessively expensive (Amorim et al., 2019)	• In **low productivity** areas, may be appropriate to have **toll-free sections** (Amorim et al., 2019) • Environmental consequence of traffic shifting to local toll-free roads **estimated at 10% CO_2 increase** (Bandeira et al., 2012)	• Payments from tolls are used to **cover PPP repayments by state** to concessionaires (Amorim et al., 2019)

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National Road Tolling: Spain	• Scheme not implemented or studied in detail yet • Proposals expected to be detailed mid-2022, but some doubt due to changing economic climate.	• Tolls to be employed on **12,000km of national state-run, high capacity roads** (autopistas and autovias) (Muñoz, 2021) • Negotiation with **Regional Government** for strategic roads will also occur (Muñoz, 2021) • All tolled roads have state-provided **untolled alternative** (Santos and Santos, 2012)	• On equity, **discounts** proposed for "financially underprivileged groups or regular road users on certain road sections." (Muñoz, 2021) • Public and political acceptance of tolling comes from a **fragile position**, Spain having experienced a financial disaster with previous toll road experiment fatally undermined by property crash (Muñoz, 2022)	• Removal of existing tolls expected to **undermine** post-pandemic public transport recovery (Cordero and Blanchar, 2021)	• No figures confirmed as yet, but **€0.03 to €0.05/km** suggested as sufficient to **cover maintenance** (Muñoz, 2021) • **Variation by vehicle** also suggested, e.g. €0.03/km light vehicles, €0.13/km heavy vehicles (Muñoz, 2021)

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National Road Tolling: The Belgian Road Pricing Trial	• Overall reduction in **car kilometres** by 5.6% (de Vos, 2016) • **Reductions varied by road type**: 7.6% urban, 5.8% rural, 4.2% motorways (de Vos, 2016) • Greater reduction in **off-peak hours** compared with peak (de Vos, 2016) • Considerable difference between **urban** (9.3% reduction) and **rural** (1.4% reduction) in veh kms • Evidence of increases in **combined, multi-purpose trips** • Evidence of **increase in walking/cycling** • Shift to **public transport** harder to represent due to short trial period – believed insufficient to reflect efficient costs e.g. season ticket purchase	• **Patterns of car use** in Belgium **vary by region**: Flanders increasing slightly; Wallonia stable; Brussels city region decreasing • Ratio of average free-flow speed is low and delay per km **high** compared with other European countries • Limited spatial planning has resulted in **urban sprawl** and polycentric situation with limited urban/rural clarity • Sprawl has resulted in **high car dependency**; dense road network; limited possibilities for PT and active travel outside city centres • Time based (Eurovignette) replaced by distance-based national electronic tolling for **vehicles over 3.5 tonnes** on motorways, expressways and some local roads already implemented.	• The three Belgian regional governments agreed to the trial, but not politically binding for permanent implementation • Trial period was eight weeks only so **seasonal factors** not accounted for • Only 26-29% of participants in trial stated they would probably or definitely vote yes in a **road pricing referendum**	• Evidence of **shopping closer to home** – may result in shift in retail patterns, 15-minute neighbourhoods, placemaking etc. • Expectation that **liveability** of residential neighbourhoods will improve along with air and noise pollution reductions and improved road safety • May accelerate urban exodus however – alternative may be to charge **non-urban dwellers only** with cordons	• Costs to car drivers **varied by road type** (urban/motorway/other) **and period** which ranged from €0.025 to €0.09 per km with overnight period free-of-charge

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National Road Tolling: UK	• Scheme not implemented or studied in detail yet • Currently comprises a like-for-like replacement of VED/Fuel Duty, rather than a traffic demand management measure as such.				• Cost to motorists proposed to be revenue neutral with road users paying the same or less that they do under VED/Fuel Duty (Parliament. House of Commons, 2022)

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