The Economic Benefits of Sustainable Urban Mobility Measures
Independent Review of Evidence: Reviews

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EVIDENCE has reviewed a range of material exploring the economic benefits of ‘more sustainable’ mobility-related interventions with potential to be deployed in urban areas. This document brings together the results of the review and analysis of the evidence for each of twenty two categories of intervention, or measure as they are termed here. The ‘Measure Reviews’ contained here will explore the following topics:

Table 1 Themes and measures explored by EVIDENCE

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1 Sustainable mobility describes a set of choices for resolving the travel needs of individuals and organisations in less energy intensive and less polluting ways than at present. This might include different modes of transport, alternative fuels, alterations to infrastructure and the built environment, or changes in behaviours.
Content of the reviews

Each measure review explores source material collected and analysed by the EVIDENCE project, presented in a common format. They consider what material is readily available, and its quality, and then provide an analysis of the results of the various studies and reports being reviewed. This enables the authors to present the key messages relating to the economic aspects of the measure, as well as concise information on the wider benefits that might flow from deploying the intervention and the factors that could help a city to deploy the measure successfully.

EVIDENCE documentation

This document is a companion to the EVIDENCE project report, which presents the overall results of the project. The detail of the review process followed, and how the different interventions have been grouped can be found in the EVIDENCE method, whilst short (one-page) summaries of these reviews are also available, as individual documents and as a combined, single report.

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Measure No.1: Electric Battery and Fuel Cell Vehicles

Activities fostering the use of vehicles that use electricity to power an electric motor.

Cities can encourage use of electric vehicles through their own public procurement policies, regulation (such as “low emission zones”), and local pricing systems (congestion charging and parking policies).

Key messages:

- Electric vehicles currently meet the needs of a range of users - but not yet all users.
- Electric vehicles (EV) can be cost-effective for owners and operators under specific conditions.
- Cost-effectiveness depends on economies of scale. The more vehicles are produced, the more the production costs per unit decrease.
- Any cost benefit analysis (CBA) is heavily dependent on the assumptions used, (for example fuel and carbon costs) and national / local circumstances (such as subsidy levels for example).
- Societal benefits of investments into electric vehicles can be less clear than other technological change in vehicles.
- Electric vehicles can reduce local air pollution, benefitting human health and the urban environment.
- Effects on greenhouse gas emissions will depend on the technology deployed and the source mix for electricity generation.

1.1 Context and background

There are growing numbers of EV on the streets of cities across the world, and the numbers of new electrically-powered vehicles purchased each year are increasing steeply in some nations. In many instances though this is driven by the financial and other support mechanisms available in a country, and at present, EV still only make up a small percentage of the total fleet of vehicles.

EVs are available in different vehicle categories (e.g. electric cars, trucks, buses, bicycles), and cities can further promote the use of EVs through a range of interventions at a local level – consistent with, and supportive of wider national policies.

Potential interventions:

- Purchasing policies to include EV in municipal fleets, or in city-owned public transport.
- Implementations of charging infrastructure.
- Support via regulatory measures (where applicable at city level).
- Local financial incentives.

Other measures that might be used to encourage the use of EV in a city are low emission
Measure No.1: Electric Battery and Fuel Cell Vehicles

zones (discussed in Measure Review No6 Environmental Zones), and pricing measures (No.7 Congestion Charging, No.8 Parking). Some cities are also allowing EV to use public transport lanes (see review No.5 Roadspace reallocation).

This review has considered several different categories of electric battery vehicles, which are described below (the abbreviations are used in the review itself).

**PHEV (Plug-in hybrid electric vehicle):** A duel-fuel vehicle which can either run on electricity or on gasoline/diesel. The vehicle can be plugged in to an electrical outlet to be recharged. Typically with more powerful batteries than HEV these vehicles have a greater range running solely on electricity.

**BEV (Battery-electric vehicle):** Electric propulsion only, relying exclusively on electricity from the power grid.

**FCEV (Fuel Cell Electric Vehicle):** Powered by a fuel cell providing electricity for an electric motor generating energy from a chemical reaction between on-board stored hydrogen and oxygen.

Another term relevant to understanding how EV might play a role beyond just substituting for conventional vehicles is **V2G (Vehicle-to-grid).** This describes how EV may provide services to the power grid, the combined batteries providing a resource to draw on at peak times, feeding electricity back into the system to meet demand – before re-charging at off-peak times. Theoretically this would allow for peaks and troughs in power generation to be smoothed.

Note: Hybrid electric vehicles (HEV) are covered under Measure No2 Cleaner Vehicles, and vehicles that are constantly connected to the grid to draw electricity, such as trams, are also excluded from this review.

### 1.2 Extent and Sources of Evidence

Electric vehicles are subject to on-going research, focussed on technological improvements and externalities. As advanced electric vehicles have been only recently introduced to the market, ex-ante assessments dominate with little ex-post assessment available. The domination of ex-ante assessments may be explained by the novelty of advanced electric vehicles: Experiences on their life time and resale value are not available.

Some case studies evaluate cities’ experiences. These cases provide important information on the feasibility of replacing conventional vehicles with electric ones and their reliability. Some of these studies also provide information on the impacts on externalities. However, they provide little documentation about the methodologies used.

Results are quickly out-of-dated with regard to cost-efficiency or ability to meet user demands, due to rapid technology and price development. Therefore only studies that have been published after 2010 are included in the present analysis.

FCEVs are in a less mature stage than BEVs. ‘Serial fuel cell’ models are not on the market, yet. So hardly any specific evidence was found for fuel cell electric vehicles.

### 1.3 What the Evidence Claims

Studies that examine the costs and benefits of electric battery and fuel cell vehicles usually focus on one or more of the following aspects:

i. **Cost-efficiency** of replacing conventional vehicles with electric ones
ii. Feasibility of replacing conventional vehicles with electric ones

iii. Effects on externalities from motorized road transport such as greenhouse gas emissions, local air pollution and noise

1.3.1 Cost efficiency

Today, acquisition costs are usually higher for electric vehicles than for conventional diesel or gasoline vehicles. However, lower operational costs and other savings or revenues can lead to a higher cost-efficiency of electric ones over the vehicle life time. The overall cost-efficiency depends to a large extent on local circumstances (for example, fuel / energy prices, taxes, and subsidies) and the evaluation perspective: In a societal cost-benefit analysis monetary benefit from the reduction of externalities is usually included, while investors (vehicle owners or operators) usually take only the direct acquisition and operational costs into account.

Christensen and Christensen (2011) conducted a cost-benefit analysis for a BEV and a diesel vehicle in Denmark to compare their cost-efficiency to society and to the private consumer. For the electric vehicle a battery switching technology was assumed. Based on costs of investments, operation, maintenance, environmental impact, refuelling / battery switching time, noise and METB (marginal excess tax burden), the overall life time costs of an electric vehicle were found to be 0.8 per cent less than for a comparable diesel vehicle. From the perspective of the private consumer (accounting only for direct costs and benefits) electric vehicles life time costs are 22% higher than a diesel vehicle.

Noel and McCormack (2014) investigate the cost-effectiveness of a V2G-capable school bus compared to a diesel school bus in an ex-ante assessment. The authors take into account acquisition costs, infrastructure costs, energy costs, V2G-revenues, maintenance costs as well as external environmental and health costs. The study is based on actual prices in the state of Delaware (USA). The cost-effectiveness over the lifetime of the bus (14 years assumed) was investigated. The authors find that one bus would save a school district $6,000 per seat or $230,000 per bus compared to a similar diesel bus. The net benefits for the electric buses are strongly influenced by the revenues from the electricity frequency regulation market. The V2G bus provides electricity storage when connected to the charger and receive compensation for that service. When the revenues from V2G services are excluded, the savings are significantly reduced and the diesel bus might be slightly more profitable. The sensitivity analysis highlighted that the differences in the regulation price for V2G services and the regulation capacity have a significant effect on the overall results. The results were less sensitive to battery replacement costs, diesel and electricity inflation rate or the social costs of CO₂ emissions. Noel and McCormack (2014) also tested the international transferability of the results by adopting diesel costs, electricity costs and regulation price to the conditions in France and Denmark. With $7,852 per seat in France and $8,617 in Denmark the cost-effectiveness was even higher than in the US. Factors such as differences in the electricity generation mix were not taken into account.

Lajunen (2014) investigated energy consumption and the costs and benefits of hybrid, plug-in hybrid and electric city buses compared to a diesel bus on an ex-ante basis. The cost efficiency of the buses was based on the lifetime costs over 12 years including vehicle acquisition, investments in charging infrastructure, operation costs (i.e. fuel consumption and maintenance) and energy storage replacement costs (battery or ultra-capacitor). The vehicles’ salvage value was not included. The impact of different bus technology on local emissions (HC, CO, NOx and PM) was also calculated, but not factored into the life time costs. The study was based on modelled data using the vehicle simulation program ADVISOR and investigated the performance of the different buses in the different test cycles (Helsinki,
Measure No.1: Electric Battery and Fuel Cell Vehicles

Braunschweig, Manhattan, New York and Orange Country). Even though the energy consumption per kilometre varied in the different test cycles, the energy consumption for plug-in hybrid and electric buses was much lower than conventional buses in all test cycles. The study also took into account that due to charging requirements, more buses are needed in a fleet for a specific route. The overall life cycle costs of the different vehicle technologies vary by driving cycle, and in most cycles investigated the hybrid electric buses had similar overall costs to diesel buses. Some differences occurred between parallel and serial hybrid buses, and the all-electric bus had the highest life cycle costs in all driving cycles. The analysis further showed that the life cycle costs varied largely between the different operating routes, thus the authors stress the fact that the vehicle technology should be chosen on the basis of the route. In a sensitivity analysis, the author shows that the life cycle cost of the PHEV and the BEV are highly sensitive to the costs of the energy storage system. It is assumed that costs for batteries will decrease in the future, which would lower the life cycle costs. The life cycle cost only included the direct costs to the vehicle operator, whereas effects on externalities are investigated separately and not included in the cost-assessment (see below). Experience from real life operation is provided by Wiesinger (2013) for all-electric buses in Vienna. The local public transport provider “Wiener Linien” purchased 12 electric ‘microbuses’ for the city centre. The overhead tram power lines were used to recharge the buses. The purchasing costs per bus were 400,000 Euro, which is about twice the costs of a comparable diesel bus. Charging points were installed at each end stations (90,000 Euro per charging point) and at the bus depot (320,000 Euro). Cost savings were expected from lower energy costs and lower maintenance cost (estimated at 8,000 Euro per year). However, cost-efficiency analysis is not provided in the available documents.

Menga et al. (2013) showed the difference in cost-efficiency of electric vehicles from the perspective of society as a whole as well as for an individual owner or operator of a vehicle. In their analysis for the city of Milan, it is shown that electric cars and vans are causing much lower external costs in terms of CO₂ emissions, effects on ecosystems, human health and energy import costs (see below). While the external costs for an internal combustion (ICE) powered car amounts to 5.6 Euro-cent per kilometre, the external costs of electric cars are found to be only 1.4 Euro-cent per kilometre. Similarly, electric vans are more favourable from an external cost perspective (i.e. 2.8 Euro-cent/km compared to 7.6 Euro-cent for a conventional van). In contrast, the total costs of ownership (based on acquisition costs, energy costs, taxes, insurance, maintenance etc.) are higher for an electric van (0.66 Euro/km) than for an ICE van (0.63 Euro/km) as the higher acquisition costs are not fully compensated for by the lower energy costs. Non-energy running costs were the same for both alternatives. However, economic advantages for electric vehicles could result from national or local measures (e.g. tax incentives, access rights).

Results of an ex-post assessment of a trial with electric vehicles for urban freight in London are presented by Browne et al. (2011) and Leonardi et al. (2012). In the trial a local supplier of office supplies replaced its 3.5 tonne diesel delivery vans which transported goods from a suburban depot to customers. Under the new scheme, goods were transported with an ICE truck to an urban consolidation centre to be reloaded to electrically assisted cargo tricycles and electric vans. Data for the studies was collected between December 2009 and July 2010. According to the operator the new distribution system based on electric vehicles had the same operating cost as the previous one based on diesel vehicles (Browne et al. 2011). Costs increases resulting from the operation of the consolidation centre and higher driver costs were balanced by lower vehicle operation costs. Absolute costs are not provided due to
commercial confidentiality. Significant reductions in externalities were achieved (see below). All in all, the different sources of evidence reveal that the cost-efficiency of electric vehicles depends on the perspective and local circumstances. From the perspective of a vehicle operator Christensen and Christensen (2011), Lajunen (2014) and Menga (2013) came to the conclusion that electric vehicles are not cost competitive (yet). Noel and McCormack (2014) expect economic advantages from electric vehicles for the operator. However, in case of Noel and McCormack the economic benefit is based on revenues from V2G. From a societal perspective, electric vehicles can provide an economic advantage due to reduced external costs as Christensen and Christensen (2011) and Menga et al. (2013) revealed. The example of Browne et al. (2011) from London shows that the replacement of conventional vehicles with electric vehicles should not be seen too narrow. Direct comparison of conventional and electric vehicles can mask the potential of electric vehicles in the context of additional changes to transport organisation.

1.3.2 Feasibility

Advanced electric vehicles came on the market relative recently and the technology is still subject to extensive research and development. So besides cost efficiency and sustainability impacts, it is important that electric vehicles can meet the requirements in the proposed field of application. Thus, finding evidence of the feasibility of the application of electric vehicles is of interest in this context as well.

The city of Rotterdam in cooperation with local energy suppliers did an extensive trial of the suitability of electric vehicles for different purposes (City of Rotterdam et al. undated). The initiative was part of pilot projects on behalf of the Ministry of Economic Affairs. The study was conducted between 2012 and 2013, although the vehicles had already been purchased in 2010 and 2011. At this time the electric vehicles purchased were mainly manually converted vehicles. As vehicle and charging technology is continuously evolving, it is expected that even better results would be achieved with vehicles available today. 75 electric vehicles (BEV/PHEV) and 129 charging points were monitored and tested by 100 drivers. Based on the experience during the trial, it was concluded that 60 per cent of the light delivery vans owned by the city could be replaced by fully electric ones. The two local energy suppliers who participated in the trial had larger range requirements, thus only 18 and 27 per cent of their fleet were suitable to be replaced by electric vehicles. The reliability of the electric vehicles was not optimal for the converted vehicles, but the new generation of vehicles provided satisfying reliability and user comfort. The vehicles were charged mainly at work or at home and most vehicles were plugged-in in the early evening.

In their analysis of the potential of electric vans in urban freight distribution in Milan, Menga et al. (2014) revealed that the average daily mileage of delivery vans is 36.8 km, while 95 per cent have a daily mileage of less than 100 km. Thus, all electric vans that are available today would be suitable in most cases from a range perspective.

Wiesinger (2013) showed how electric buses can be successfully integrated in existing system and infrastructure. In Vienna, electric buses are recharged at their final stations by using the existing overhead line system. Each charging process only lasts five to eight minutes. During this time passengers can enter or leave the vehicle. The buses used have a capacity of 46 passengers and a top speed of 62 km/h with a maximum range of 150 km. This scale of bus fits the requirements of routes through the historic centre of Vienna. Some technical alterations in terms of heating for the batteries were necessary to ensure proper operation during wintertime. It was noted that the maximum range would decrease during the Winter to 120 km due to the energy consumption of the heating system.
The example of the London logistics trial with electric vehicles (Browne et al. 2011, Leonardi et al. 2012) revealed that measures should not be looked at in isolation. The integration of an urban consolidation centre in the arrangements made it feasible to cover deliveries with electric tricycles and electric vans in an efficient manner.

All in all, the evidence reviewed would suggest that electric vehicles can already meet the requirements in many – but not all, fields of application.

1.3.3 Effects on externalities

In general, the reviewed studies agree that electric vehicles reduce externalities related to fuel consumption in road transport. Positive effect are reported for greenhouse gas emissions (mainly CO₂) and local air pollutants (Hydrocarbons (HC), Particulate matter (PM), Carbon monoxide (CO) and Nitrogen oxides (NOx)). These emissions have negative effects on the environment, the building structure and human health. It is noted though that merely replacing an ICE vehicle with an electric one will not address other issues such as congestion or land-take for infrastructure (i.e. for roads or parking).

Buekers et al. (2014) investigated the effects on external cost relating to health and environmental impacts from electric vehicle introduction in EU countries. The effects were based on various pollutants that result from vehicle operation (Tank-to-Wheel or TTW) or fuel/electricity production (Well-to-Tank, WTT) and external costs from battery production. The external costs included negative impact on human health (from NOx, SO₂, PM, NMVOC) and on the environment (from CO₂). The results indicated that the introduction of electric vehicles leads to reduction of external costs in 21 of 27 EU countries, when the 2010 electricity mix is taken into account. Annual reductions in external costs from a 5 per cent penetration of electric vehicles are highest in France (98.2 million Euros), Germany (54.3 million Euros) and Italy (48.4 million Euros). In some countries BEV introduction would not be associated with a monetary benefit unless local electricity production changed to cleaner sources. Slight increases in external costs or no effect on external costs were reported for Estonia, Greece, Cyprus, Malta, and Romania. For Poland, where electricity production relies heavily on coal, strong increases in external costs are found. The study further investigates the external costs for a 2030 scenario, with alterations in the electricity production based on current trends. For this scenario, reduction in external cost can be achieved by electric vehicle penetration in all Member States, except Poland and Estonia. All in all, Buekers et al. (2014) provide significant evidence for the reduction in external costs resulting from the replacement of ICE vehicles with BEVs. It is also shown that this effect is highly depended on local conditions especially in terms of electricity production. For a city that is considering measures to foster the deployment of electric vehicles in their SUMP, TTW emission might be of higher relevance than upstream emissions e.g. from electricity production. With tailpipe emissions being zero for electric vehicles, this provides a strong argument for the application of electric vehicles in an urban environment – for example in municipal fleets of service vehicles, or buses for example.

In their cost-benefit analysis of a vehicle-to-grid (V2G) capable electric school bus, Noel and McCormack (2014) also investigate the health and environmental externalities related to diesel and electricity consumption. They calculate that health externalities from a heavy duty diesel vehicle are about $0.08 per mile due to emissions of different pollutants, and based on the local electricity mix in Delaware, they estimate the health externalities from electricity production for an electric bus at $0.0149 per mile. For the environmental externalities Noel and McCormack (2014) take the CO₂ emission of diesel consumption and electricity production into account. $300 of overall benefit of a V2G-electric bus compared to a diesel bus of $6.000 per seat results from the reduction of externalities (see above).
In the ex-ante analysis of different bus technologies, Lajunen (2014) also investigated the effect of plug-in hybrid electric and hybrid electric buses on local air pollutants (HC, CO, NOx, PM). The PHEV lead to 75 to 95 per cent reductions of local air pollutants compared to a diesel bus. The serial HEV led to reduction in hydro carbons of 68 to 92 per cent, and reductions in CO, NOx and PM emissions between 12 and 62 per cent. Reductions were slightly smaller for the parallel HEV.

As reported by Wiesinger (2013), the environmental impacts of the all-electric microbuses used in Vienna were calculated by the Technical University of Graz. In an ex-ante assessment it was found that the busses would lead to significant annual emission reductions compared to the liquid gas buses that were used previously (emission reduction: 5.3 t CO2, 1.7 t NO, 0.06 t NO2). The emission reductions were calculated based on the electricity mix of the local energy supplier, who derives more than 80 per cent of its supply from wind or water. No further details on the methodology of the environmental impact assessment were provided by Wiesinger (2013).

In their assessment of the potential of electric vehicles in urban transport in Milan, Menga et al. (2014) analysed the external costs for the country of electric vehicles compared to ICE vehicles. The monetisation factors for the different pollutants were obtained from CE Delft et al. (2011). The calculations were based on Italy’s electricity mix. The health costs as a result from bad urban air quality were about 1 Euro-cent/km for ICE cars and 0.3 Euro-cent/km for electric cars. Highest health costs were found for ICE vans (about 2.5 Euro-cent/km). External costs from the impact on ecosystems and degradation of buildings were found to be low in all cases. The monetary value of CO2 emissions were 0.8 Euro-cent/km for an ICE car and 0.3 Euro-cent for an electric car. In addition, the study also included energy import costs for the country as external costs. The energy import costs made up about half of the external costs for all vehicle technologies. All in all, it was found that electric cars and vans result in much lower external costs to society than ICE vehicles.

In their societal cost benefit analysis of electric and diesel cars Christensen and Christensen (2011) found that diesel vehicles cause external costs due to emissions of 0.148 DKK/km (about 0,02 Euro/km), whereas emission costs from electric vehicle are 0.003 Euro/km. These results are broadly in line with those provided by Menga et al. (2014). In addition, Christensen and Christensen (2011) also calculated the costs due to noise pollution. Based on an average annual mileage of about 18,000 km, electric vehicles resulted in annual cost from noise of 1.583 DKK (about 212 Euro), while costs from diesel vehicles were 5.203 DKK (about 700 Euro).

The 'before and after' assessment of the urban logistics trail in London revealed positive effects on externalities from the replacement of 7 diesel vans with 6 electric tricycles, 2 electric vans and 1 diesel truck (Browne et al. 2011). Distance travelled per parcel was reduced by 20 per cent, CO2eq emissions per parcel were reduced by 54 per cent. However, electricity was assumed to be entirely from renewable, carbon free sources. As additional benefits to the city, the daytime road space occupation was reduced by 56 per cent per parcel.

According to City of Rotterdam et al. (2014) during their one year trial with 75 BEV and PHEV vehicles more than 700,000 electrically-powered kilometres were driven leading to CO2 emission reductions of 67 per cent and 10 per cent less particulate matter emissions covering the entire chain and taking into account the Dutch energy mix. NOx emissions are reportedly reduced by 100 per cent. However, no details on the methodology and the data basis for emission reduction are given in the available documents. It was revealed that the effects are also strongly affected by outside air temperature (low temperatures lead to higher
energy consumption of EVs), driving style and – in terms of PHEV – charging behaviour. There is strong evidence for a positive effect of the replacement of ICE vehicles with electric ones from a perspective of external costs. However, bodies or private persons that purchase and operate the vehicles do not usually include these considerations in their purchasing decisions, because they do not affect their budget.

1.3.4 Methodologies and caveats

The evidence from the studies outlined above is not particularly comparable. Many studies provide theoretical ex-ante assessments partly based on cost estimate, whereas only limited before-and-after studies are available. The reviewed studies apply different methodologies and take different factors into account. For instance, external costs resulting from noise pollution are neglected in most studies except the work by Christensen and Christensen (2011).

The calculation of emissions from electricity production can introduce some bias in the results for external costs. Most study based their emission calculation based on the national electricity mix. In contrast, Wiesinger (2013) and Browne et al. (2011) calculated emissions based on the mix of the local energy supplier with a high share of renewables. This approach neglects the fact that if one customer obtains a high share of renewables, the share of electricity from fossil sources increases for another customer, as long as no new capacity for renewable energy production is installed. Thus, the emission factor of the electricity mix is a more appropriate basis for the assessment of external costs from electric vehicles.

The monetization factor applied for CO$_2$ can also affect the overall results and varies between the studies cited above: Buekers et al. apply a monetization factor of 20 Euro/tonne, Noel and McCormack use $36/tonne (about 30 Euro/tonne) and Menga et al. (2013) apply a monetization factor of 40 Euro/tonne.

Advanced electric vehicles were introduced to the market very recently and developments are expected in terms of price and energy efficiency and energy storage. Not all studies are based on actual market prices for electric vehicles. For instance Lajunen et al. (2014) estimated the costs for different electrified buses configurations. Furthermore, there is uncertainty concerning the future costs of the battery, which affects the life time costs of an electric vehicle due to the need for battery replacement. For instance, Noel and McCormack assume that battery costs are halved by the year of replacement.

1.4 Lessons for Successful Deployment of this measure

An important aspect that has to be been considered in relation to EVs is that the environmental impact of electric vehicles is largely determined by the electricity mix. Considerable reductions in emissions can be achieved by replacing diesel or gasoline vehicles with electric ones in a country with a high share of renewables, whereas benefits are limited in a country where electricity generation relies heavily on fossil sources. However, benefits to the urban environment and public health from the reduction of on local air pollutants from vehicle tail pipe emissions are independent of the location and thus transferable across cities and countries.

There are also major differences between countries in respect of cost-efficiency for a vehicle owner / operator related to fuel prices. For example, the relation between gasoline / diesel and electricity prices can vary largely between countries. In Germany, the gasoline price (about 0.18 Euro/kwh) is much lower than the electricity price for domestic consumers (0.27 Euro/kwh), whereas in France and Norway electricity is 0.02 Euro/kwh cheaper than gasoline (Mock and Yang 2014). In addition, several countries provide additional monetary incentives
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for electric vehicles such as reduced taxes or subsidies.

Consideration needs to be given to a range of factors that might impact on performance of EVs compared to conventional vehicles. EV performance can be affected by routing, driving style, temperature and traffic conditions, as shown for instance by Lajunen (2014).

Some of the case studies presented here also benefit from specific local circumstances. For example, in Vienna, the existing tram overhead lines could be used for recharging the electric buses. This led to lower charging infrastructure costs and reduced vehicle acquisition costs as smaller battery systems were sufficient (Wiesinger 2013). The results of the EV logistics trail in London are transferable only in a narrow context, when delivery is limited to inner city areas and can mainly be performed by tricycles.

Upscaling of electric vehicle measures can have diverse consequences. On the one hand, bulk orders or higher electric vehicles sales numbers, can reduce the acquisition costs for the individual vehicle and can lead to higher cost-effectiveness of charging infrastructure installation. On the other hand, if a very high number of electric vehicles are charged on a specific location (e.g. fleet depot), effects on the local grid can occur, which require investment in enhanced grid capacity.

Electric vehicles can play an important role in a SUMP, helping to reduce externalities from motorized road transport, in particular EV have considerable potential in terms of road based public transport (i.e. buses, taxies).

In terms of private motorized modes and urban freight, it is important to explore electric vehicles in the wider urban transport context and not as standalone measure. One by one replacement of vehicles neglects the opportunities for additional sustainability effects. To reduce the need to travel and to shift trips to public transport and non-motorized transport need to be prioritized to tackle all transport related issues.

Local authorities such as a city usually have the necessary responsibilities and regulative power to promote the deployment of electric vehicles in the municipal fleet or in public transport. They can also promote private or commercial electric vehicles through (free) parking policies, exemptions from access restrictions, lower or no city tolls, support for the installation of charging infrastructure etc. However, national incentives such as tax policy and energy prices are likely to also play a major role.

Further evidence is needed on the long term application of electric vehicles and the associated effects from real-life examples.

1.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for policies promoting EV:

- **Air Quality:** Although the environmental impact of electric vehicles is largely determined by the electricity mix in a particular country, benefits to the urban environment and public health from the reduction of local air pollutants from vehicle tail pipe emissions are independent from the location and thus transferable across cities and countries.

- **Noise pollution:** A further societal benefit of electric vehicles is reduced noise pollution. Although this benefit is rarely monetised in the evidence, one Danish study found that an electric vehicle driven an annual average distance of 18.000 km would generate an annual cost from noise pollution of less than one third the cost generated by a diesel vehicle.
1.6 Summary

The following conclusions can be drawn in respect of EV at the present:

- Electric vehicle are only cost-effective for vehicle owners or operators under specific conditions. These circumstances will include a range of wider costs (such as oil and carbon), as well as the financial inducements and subsidies available in that location at that time.
- If considering operating costs only, there may already be situations in which operating EVs are more cost-effective than conventionally fuelled vehicles.

Other statements on EVs that can be made with confidence include:

- EVs reduce local air pollution offering benefits for human health and the urban environment
- The overall effect on greenhouse gas emissions of an EV depends on the electricity mix in that location at that time.
- At this time, EVs meet the needs of different – but not all – users.

1.7 References for this Review


Measure No.2: Cleaner Vehicles

Innovations or interventions that aim to improve the environmental performance of vehicles – such as enhancements to engine and vehicle technologies or improved fuels.

Cities have opportunities to improve the environmental performance of fleets of vehicles involved in municipal services – waste collection, public transport etc. They can also encourage moves to more efficient commercial and private vehicles through regulatory and fiscal measures in a city.

Key messages:

- Policy measures such as fleet emission regulations foster economies of scale, and thereby contribute to reducing the production cost of new technologies. This, in turn, supports the consumer’s decision to purchase these technologies.
- For public bodies, implementation of regulatory measures is cost-effective, whereas upfront investments for the purchase of new public transport fleets may exceed direct cost savings occurring over the lifetime of that asset.
- From the perspective of the owner and transport operator, enhancements are cost-effective only under specific conditions, dependent on retail and fuel costs.
- From a societal perspective, the health, built environment and ecosystems benefits of investments into air quality abatement technologies (such as engine enhancements) should outweigh the economic costs. However, such benefits tend to be excluded from benefit-cost calculations of individual users.

2.1 Context and background

The existing vehicles in any city will reflect a range of efficiency and pollution levels. Some of these vehicles, particularly diesel vehicles used in confined inner-city areas may present particular problems in respect of localised air quality problems, and steps to improve their performance could be of particular benefit for a city.

Potential interventions

- Introducing new municipal or public transport vehicles using cleaner fuel (CNG, Biogas)
- Retrofitting existing fleets of vehicles with more efficient and / or less polluting types of motive power, or other vehicle enhancements (for example energy-efficient tyres)
- Encouragement to other transport owners (commercial and individuals) to improve the efficiency of their vehicles (Note: Additional supporting measures for this such as Low Emission Zones are covered under Measure No.6, Environmental Zones).
Whilst cities have the opportunity to address these sorts of interventions specifically in respect of their own fleets of vehicles, it is acknowledged that there will also be significant steps being undertaken at national and international levels to improve the environmental performance of the automotive fleet in general. Accepting and acknowledging this wider impetus, action at a local level to move to more efficient / less polluting vehicles is still seen to have the potential to generate significant improvements on local air quality in a city.

2.2 Extent and Sources of Evidence

As technology continuously advances, and as there are significant and immediate climate change mitigation potentials inherent to such schemes, the implementation of this type of transport intervention (often related to fleet emission regulations) is an area that receives on-going scrutiny.

The selected sources review the costs and benefits of different technologies. As enhancements of engine technologies tend not to be tied on a certain place, many of the sources do not consider local circumstances. The quality of these studies is high, including peer-reviewed articles and studies from independent research institutions, which used appropriate techniques to validate the results. In order to also discuss application on the local level and in SUMPs, the general evidence has been complemented by location specific studies, e.g. CIVITAS evaluation reports. These latter reports are not peer-reviewed.

The selected high quality evidence considers actual data alongside ex ante assessments of manufacturing cost, vehicle lifetimes, and benefits. The results of the selected local ex post evaluations confirm the more general results. The results also fit very well with pure ex ante studies (e.g. cost-abatement assessments), which include a longer time horizon and a wider set of assumptions. However, these pure ex ante studies were not selected for the review, even if their methodology was solid.

The process of evidence collection revealed that the number of pure ex post studies is limited. A reason for this may be that the effects of technologies are of potential interest when they are new. At that point, potential application at a larger scale is of interest, but expected lifetimes of the technology are not yet confirmed.

2.3 What the Evidence Claims

The results of the evidence can be boiled down to a simple message: the less energy consumed per km, the better the vehicle’s environmental performance especially in terms of carbon emissions and health damaging air pollutants.

Further development of engines, chassis, and other vehicle component technologies leads to lower CO₂-emissions, less local pollutants (including black carbon) and less noise. Enhancements of fuels may increase benefits accordingly. Technologies reducing braking distances can also contribute to reducing societal costs by reducing injuries and fatalities. However, energy efficiency improvements for vehicles do not address wider externalities from road traffic such as congestion, consumption of urban space or traffic accidents. In comparison, a shift of short distance trips to walking and cycling or a move to public transport may not only reduce emissions, but also capture wider sustainability benefits.

Economies of scale are crucial to cut costs. Policy interventions such as fleet emission regulations may thus accelerate the development and increase the market share of energy efficient vehicles.

An analysis of a range of potential measures (and associated costs) to reduce CO₂ emissions
Measure No.2: Cleaner Vehicles

from passenger cars was undertaken in 2006. According to this report\(^1\) (using data from 2006), the costs of reaching an average CO\(_2\) emission in new vehicles of 140 g/km by 2008 would involve additional manufacturer costs of €832 per vehicle compared to the 2002 baseline, which translated into an additional retail price of €1200 per vehicle. The manufacturer costs for reaching the 2012 target of 120 g/km were around €1700 per vehicle compared to average costs of the 2008/9 baseline vehicle emitting 140 g/km. This translated into an additional retail price of €2450 per vehicle.

From the consumer’s perspective, additional upfront costs do in many cases not pay back over the vehicle’s lifetime. For example, for the Toyota Prius to be attractive to US consumers, the price of gasoline would have to be more than three times greater than in 2001 (data are used from 2001)\(^2\).

However, a smart combination of existing technologies may also be able to even reduce costs while increasing the benefits described above. For instance, a Dutch study looking at tyres\(^3\) finds that a further penetration of so-called “A-rated” tyres (according to the eco-design directive) would bring about significant energy savings, noise reductions, and traffic safety. Assuming the characteristics of A-rated tyres could be combined into one ‘Triple-A’ tyre, Dutch society would benefit from annual cost savings of nearly one billion Euros (in comparison to status quo). For the end-user, annual cost savings would range from €117 for passenger cars to €2418 for long-haul vehicles.

From a societal perspective, benefit-to-cost ratios (BCR) of enhancements to engine technologies tend to be generally positive. This was also evidenced in a wider cost-benefit analysis (CBA) of the EU’s thematic strategy on air pollution\(^4\), (with supporting measures such as the EURO emissions standards for vehicles). This analysis finds strong benefits for health (mortality and morbidity), materials (buildings), crops, and ecosystems (freshwater and terrestrial, including forests), whilst macroeconomic costs in terms of reduced gross domestic product (GDP) from factors such as spending on abatement equipment are around 0.05% per annum in 2020 (modelling "current" legislation of 2005 vs. thematic strategy).

The World Bank evaluated four diesel emissions control projects (diesel retrofit in Istanbul, green freight plus retrofit in Sao Paulo, fuel and vehicle standards in Jakarta, and CNG buses in Cebu)\(^5\). It concludes that for 2 cases net benefits (health and climate change) were positive and for the other two cases (Cebu and Jakarta) the benefits of black carbon reductions were positive only when assuming a large benefit from black carbon control on the climate in the near term (using 20 years Global Warming Potential or GWP) and a low social cost-of-carbon discount rate.

Studies of the procurement of new engine technologies may not consider a societal perspective, but instead focus on 'financial viability’. Local project evaluations confirm societal benefits (such as lower noise and atmospheric pollution), but evidence on financial viability may be less certain, and not unambiguous.

In Brescia, the purchase of CNG buses was co-funded by CIVITAS. The report on their implementation\(^6\) does not point to conditions, which would strengthen the economic case for the transport operator. In Barcelona, the transport operator was able to establish a strategic partnership with a natural gas company, taking over parts of the maintenance cost. The return on investment was less than 5 years\(^7\).

Apart from the investor’s financial considerations, these two local evaluations report additional benefits: for example, the ease of adjustment to the new circumstances of CNG buses in the public transport fleet\(^8\). Passengers also report that the perceived noise inside
the vehicle is lower than before. Similarly, the extension of the CNG bus fleet in Barcelona found a high level of acceptance. Both drivers and passengers highlighted the decrease in noise, fuel smell and vibrations.

**Methodologies and Caveats**

The analysed evidence mainly uses a combination of ex ante and ex post data. Real data is used as a basis and then complemented by assumptions on market penetrations and technical lifetimes.

Through economies of scale and learning effects, production volumes influence production costs. New technologies become cheaper as more are produced. Some studies in this field estimate costs based on data that are valid for large-scale production of the applied technologies. It appears that costs for current (internal combustion) engine technologies (ICE) may be used as a valid basis to estimate costs and benefits for further short-term developments.

However, it is important to note that even if vehicle technologies are getting more energy-efficient, these effects may be neutralised by growing size and power of vehicles.

Adopting a societal CBA approach, the cost of climate change rather than the oil price may be the crucial factor for the economic viability of ICE enhancements, because in the past, reductions in fuel consumption and increases in fuel prices tended to neutralise each other. A 2007 study found that even in a scenario of high demand and significant supply constraints (growth of 2008 fuel prices by 50%), the fuel consumption component of benefits in a CBA would only increase from 26% to 30%, assuming that fuel consumption remains constant. In turn, the effect of technological change on economic evaluation largely depends on the unit value of GHG emissions.

As the studies have shown, the BCR of ICE enhancement is positive from a societal perspective. However, as the technological improvements are not able to capture wider externalities from individual motorized transport, measures that reduce car traffic may yield much higher BCRs. The costs for sustaining car-based mobility can be enormous for a city, although the cost of transport for the community decreases with rising proportion of trips made by public transport or non-motorized modes.

The factors included in a CBA and the choice of alternatives that are compared can largely influence the results. The reviewed studies do not compare vehicle technology improvements with other measures that aim at reducing individual motorized trips.

**2.4 Lessons for Successful Deployment of this measure**

The results explored in this review are mainly transferable because of the technical character of the options to enhance ICE technologies. For instance, the city of Brescia (Italy) calculated the costs and benefits of investing into a new bus fleet (CNG buses). From the city’s perspective, upfront costs were too high to pay back over the buses’ lifetimes. CIVITAS funding was able to close the gap. Monitoring of the operation revealed presumed benefits such as reductions of local air pollution. This case confirms other studies, which did not consider local conditions.

The 2014 World Bank study summarizes a wide range of black carbon emissions control strategies in OECD countries in North America, East Asia, and Europe from technology (e.g., diesel particulate filters and refinery upgrades) to policy measures (e.g., vehicle emission standards, fuel quality standards, scrappage programs, and tax incentives). These strategies
provide a menu of options that could be considered by developing countries and tailored to the national context. A key characteristic (and lesson) of the programmes implemented in the OECD is the value of national policy road maps for cleaner vehicles and fuels that provide a clear and predictable course for technology and fuel adoption by private and public stakeholders.

The local incentive to implement policy measures fostering the enhancement of ICE technologies may be the reduction of local emissions (noise, NOx, etc.). From a societal perspective, benefits should outweigh the respective cost. Regulative measures such as a low emission zone do not impose significant cost for the public bodies.

2.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for policies promoting cleaner vehicles:

- **Environmental improvements:** Enhancements to vehicles which improve energy-efficiency can help to reduce local air pollution, noise levels and CO₂ emissions, with consequent benefits for human health and the urban environment.

- **Road safety:** Technologies improving safety (e.g. braking distance) also offer benefits in the form of fewer road casualties.

- **Passenger satisfaction:** Another benefit experienced in one study here was that the journey experience improved for passengers on public transport that was converted from diesel to compressed natural gas (CNG) in urban buses. Passengers reporting that the perceived noise inside the vehicle was lower than before. Both drivers and passengers highlighted the decrease in noise, fuel smell and vibrations. Such enhancements could then help encourage increased patronage levels.

2.6 Summary

Whilst it is clear that national (and international) policy, and to an extent consumer demand, is mainly responsible for the longer term enhancements of ICE technologies, local measures stipulated in a SUMP are of supportive character. Through the use of (public) procurement and other local policy measures such as low emission zones (see Measure No.6) it is possible to significantly improve the local air quality as well as contributing to wider uptake of the technologies delivering cleaner vehicles. Cities have a range of options available to them in respect of the interventions they can make to encourage change, and it may be that implementation of regulative measures is a more cost-effective route to pursue initially. On a simple analysis, the expense of investments into new fleets may exceed cost savings occurring over their lifetime, but the local social and environmental benefits for doing so make it worthwhile.

2.7 References for this Review


Measure No.2: Cleaner Vehicles


Measure No.3: Urban Freight

Policy interventions with the aim of reducing the adverse effects of freight vehicle movements in urban areas

Cities can reduce the negative impacts of urban freight distribution through a range of policies: administrative / regulatory (including road pricing), urban planning and governance, infrastructure and modal shift, awareness / information, changing driving behaviour, technology and ITS, supply chain and fleet management3.

Key messages:

✓ Most evidence focuses on Urban Freight Consolidation Centres (UFCCs), showing positive impacts, in terms of cost savings and better service to logistics operators and final customers.
✓ Where cost-benefit analysis (CBA) was conducted, positive values for net present value (NPV) were found, with a range of socio-economic and environmental impacts identified.
✓ UFCCs can be particularly effective if there are congestion and/or pollution problems within the area to be served, or where they are targeted to compact geographical locations, or areas with delivery-related problems
✓ UFCC Interventions are often small-scale with few impacts at city scale.
✓ Better economic assessment of schemes will require greater understanding of supply chain costs and benefits associated with urban freight measures. Commercial sensitivities, the lack of standardized evaluation and the experimental nature of some freight initiatives can make assessment more difficult.

3.1 Context and background

Cities depend upon the efficient and effective transport of goods. However, there are a number of negative social and environmental impacts originating from freight transport in urban environments. These negative externalities include local air pollution, in particular increasing concentrations of NO₂ and Particulate Matter (PM) that are harmful for public health, traffic congestion, accident-related fatalities and injuries due to freight vehicles, noise pollution on road and at delivery locations, and greenhouse gas emissions (in particular CO₂)1.

Conventionally-powered freight vehicles, especially Heavy Goods Vehicles (HGVs), disproportionately contribute to urban polluting emissions considering their relatively low modal share. They also disproportionately damage roadway surfaces due to their weight as compared to cars and other light duty vehicles. Moreover, start-stop operation in urban environments can increase freight vehicles’ fuel consumption by 140%2.
Potential interventions

- Urban freight consolidation centres (UFCC);
- Implementation of environmentally-friendly distribution by low or zero emission freight vehicles, such as bicycles, cargo cycles and electric vehicles; water and tube logistics (i.e. using underground pipelines, see http://www.civitas.eu/content/pipenet-system-city-logistics);
- Route/weight restrictions for HGVs, loading and delivery restrictions (spatial and temporal)
- Freight operator recognition schemes and quality partnership schemes (which can include driver training and best practice sharing) and local delivery plans for buildings, businesses and construction sites.

One of the most studied interventions is the UFCC, which can be defined as a logistics facility that is situated in relatively close proximity to the geographic area that it serves, be that a city centre, an entire town or a specific site, such as a shopping centre, an airport or a construction site, from which consolidated deliveries are carried out within that area. Logistics companies/hauliers with deliveries scheduled for the urban area or site transfer their loads at the UFCC thus avoiding congested urban environments or busy sites. The UFCC operator has the task of sorting and consolidating the loads received from logistics companies and then delivering them to their end-customers, often on environmentally-friendly vehicles, operating on an agreed delivery pattern. A range of other value-added logistics and retail services can also be provided at the UFCC, for example inventory monitoring, product quality checking, consignment unpacking, preparation of products for display and price labelling, management of returns and recycling of packaging.

In addition to the social and environmental benefits in the urban areas where they operate, UFCCs are also expected to provide benefits for the logistics suppliers (hauliers) and end-receivers. The former can typically make deliveries to the UFCC on a wide time window (often 24/7), avoid entering congested urban areas where there might be delivery restrictions and few off-road loading areas, hence saving time and fuel. The latter can benefit through better stock management, faster deliveries, convenient delivery times and added services, such as recycling.

Micro-consolidation is a recently introduced concept to reduce delivery vehicles in urban areas that would only make small deliveries. A more accessible local delivery centre is used instead and the final leg of the journey is completed by electric vehicle, scooter, bicycle or foot.

Examples of organisational type interventions are Delivery and Servicing Plans (DSPs) and Construction Logistics Plans (CLPs).

DSPs are specifically designed for a single or small number of buildings to reduce the number of overall deliveries (through better co-ordination of deliveries and sharing of resources), improve reliability and minimise impact on the surrounding environment. DSPs typically benefit companies through cost savings from reduced delivery charges and reduced disruption. DSPs are relevant because businesses without their own integrated supply chain can often have little knowledge about where the goods come from or how they get to them. Even when such a supply chain does exist it is often managed in isolation, without
considering the wider opportunities of sharing other resources.

CLPs are effectively DSPs for the duration of a construction project and are typically developed as part of a transport assessment. The benefits are similar though added savings through reduced risk of theft and improved security are also important.

3.2 Extent and Sources of Evidence

Although interventions that could be grouped under the ‘urban freight’ measure have been implemented since the 1990s, evaluations of schemes are scarce and very variable in terms of the breadth, depth, validity, reliability and significance of the evidence presented. This is due to various reasons, including the experimental nature of many of these interventions, the lack of consistent monitoring over the duration of the projects, and commercial sensitivity issues that might preclude collection and/or publication of performance data.

The report from the SUGAR project (Sustainable Urban Goods Logistics Achieved by Regional and Local Policies) is useful to understand the range of projects and measures implemented in the European context. The project was funded by the European Regional Development fund in the period 2008-11.

Over 20 items of evidence have been identified for this review through an extensive literature search, however not all can be considered robust. This review presents evidence from a sub-section of these studies, including one review of evidence on urban freight consolidation centres looking at several case studies, 4 peer-reviewed journal papers focused on different measures, and 4 reports from EU-funded projects focusing on 4 different freight demonstration projects. Other relevant sources of background information on urban freight measures have also been considered. The published evaluations are typically carried out during or soon after project implementation and some include Cost Benefit Analysis.

Of all the interventions covered by ‘urban freight’, UFCCs have received the greatest attention in terms of monitoring and evaluation, because of the number of operations existing worldwide which are often supported through public funding, for example through the CIVITAS programme of the European Commission. However, most of this evidence has been collected/produced by the same entity delivering the schemes.

The most comprehensive study of UFCCs, carried out by a team of the University of Westminster for the UK Department of Transport, reviewed 67 schemes across Europe (mostly in Germany, UK, Netherlands and France), US, Canada and Japan, but found some published evidence only on 17 (25%) among them. However, even in these cases the evaluation was found to be relatively limited and with little explanation of the methodology used. This review indicates that: many UFCC trials and schemes that have been terminated do not appear to have been subject to published evaluation that quantifies scheme results; of those UFCC schemes for which quantified evaluation has been identified, only a few provide a single quantified result, usually in terms of changes in vehicle trips, vehicle kilometres, parking time and frequency, total fuel consumed, and vehicle emissions. The review study also stated that it was often unclear whether evaluation results were based on measurement of actual vehicle operations or modelling work (predicted impacts).

3.3 What the Evidence Claims

3.3.1 Freight consolidation and micro-consolidation centres

This review of evidence largely confirms the findings of the most comprehensive review concerning urban consolidation: the existing published results suggest that UFCCs can lead
Measure No.3: Urban Freight

to significant reductions in freight transport activity and associated environmental impacts between the UFCC and the final point of delivery for those goods flows that pass through the UFCC. However, given the often limited scale of such schemes and modest goods throughput at UFCCs, any reduction in transport activity and associated environmental impacts due to the UFCC are, unsurprisingly, marginal in terms of total freight traffic and total motorised traffic in the urban area concerned.

Overall, the 17 UFCC evaluation studies (containing evidence) reviewed by Browne et al. (2005) report: 30-80% reduction in vehicle trips, 30-45% reduction in vehicle kilometres, 15-100% improvement in vehicle load factors, and 25-60% reduction in vehicle emissions. All of these results refer only to the change in transport activity associated with goods handled by the UFCC (i.e. a comparison of the transport activity from the UFCC to the receivers when the UFCC is used and when it is not for those goods flowing through it) rather than the changes in total freight transport operations and impacts in the area covered by the UFCC or the entire town/city.

Several case studies of UFCCs evaluation results are presented as follows.

1. Freight Construction Consolidation Centre, London (UK) 4,5,6

The London Construction Consolidation Centre (LCCC), a two-year trial project operating from 2005 to 2007 with a cost of GBP 3.2 million (EUR 4.7 million), occupied a 5,000 m² facility located in South Bermondsey, approximately five kilometres south of the City of London. Its objective was to serve four major construction sites in the City of London. The partnership comprised Stanhope PLC, Bovis Lend Lease, Wilson James and Transport for London.

Allowing for a rapid flow, on a just-in-time basis, of material from suppliers to site with storage time limited to ten days, the LCCC’s objective was to reduce the number of deliveries going directly to the construction sites, reducing traffic congestion and vehicle emissions. The evaluation results largely indicate that these aims were achieved.

Compared to the trips that would have previously been made, the LCCC resulted in a 15% reduction of materials waste, leading to recovery of re-usable materials on one partner project of approximate value £200,000; increased productivity of the site labour force of up to 30 minutes per day; 68% reduction of the number of construction vehicles delivering to the sites being served by the LCCC and 75% reduction of CO₂ emissions. On average, supplier journey times were reduced by two hours (including loading and unloading at the LCCC). Other environmental benefits were identified, including a reduction in packaging; reduced landfill waste; and better fuel efficiency.

The evaluation reported no incidents of accident. Impacts on safety are not known but the reduction in traffic is thought to have had a positive impact. In terms of financial aspects, the evidence is limited because not enough specific details or comparative data were available on the economic efficiency of the measure.

Strong stakeholder involvement throughout the setting up of the pilot measures has been cited as key in the success of the LCCC. The private sector, Transport for London and construction centres have worked together to design and implement the scheme to ensure maximum efficiency and the highest levels of environmental benefits. The location of the LCCC in relation to the strategic road network and target businesses has contributed to its success, ensuring that users achieve logistics efficiencies when compared to traditional freight delivery methods.

In London, freight consolidation centres are part of the wider London Freight Plan, which was drawn up to support the sustainable development of the region. This plan provides guidance and support for the Mayor of London’s Transport Strategy and will help combine increased
economic performance with the environmental and social impacts of freight transport for London.

2. Bristol/Bath Urban Freight Consolidation Centre (UFCC)

The Bristol/Bath UFCC was set up thanks to three projects funded by the European Commission: CIVITAS VIVALDI (2002-2006); START (2007-2008), funded within the Intelligent Energy Europe programme; and CIVITAS RENAISSANCE (2008-2012). The scheme is currently partially supported through the Local Sustainable Transport Fund (LSTF) by the UK Department for Transport.

Under the RENAISSANCE project in 2010, the services of the Bristol UFCC were extended as an initially free trial to participating retailers in the neighbouring city of Bath, making the Bristol/Bath UFCC the first consolidation operation serving more than one centre.

The centre, managed by the logistics operator DHL, comprises an area of 1,220m² within DHL’s depot in Avonmouth, close to Junction 18 of the M5 motorway 11km northwest of central Bristol. Deliveries from the UFCC into central Bristol and Bath are made using two ‘Smith Newton’ 9 tonne electric delivery vehicles. The scheme includes additional services to retailers, such as pre-retailing, stock management and recycling of cardboard and plastic.

The VIVALDI project recruited 53 retailers in Bristol over its duration, while RENAISSANCE recruited 19 retailers in Bath. At the time of writing, the scheme serves 109 retailers in Bristol and 39 in Bath.

Compared to an equivalent diesel lorry, the electric vehicles used by the UFCC consume 55.7 percent less energy and have no air polluting emissions at the point of use. Vehicle utilisation averaged 65 percent under the VIVALDI project and over 1,000 vehicle km were saved per month, achieving over 70% reduction on delivery journeys. The RENAISSANCE project recorded a 76 percent average reduction in delivery journeys into Bath city centre for the participating retailers, equivalent to 64 delivery journeys avoided per month. However, the impacts on the wider transport system and air quality are likely to be minimal given the small scale of the consolidation operation.

Surveys with users and non-users of the UFCC revealed other positive impacts. According to the VIVALDI project evaluation, deliveries were made on time with no discrepancies or damages. All surveyed retailers said the delivery team had left the delivery area clean and tidy, and retailers who had items collected by the centre said they had been taken at the correct time. Delivery times were generally shorter for users compared to those of non-users. Users stated that participation in the UFCC scheme saved staff time and improved reliability and punctuality of deliveries, whilst creating fewer access problems in the delivery areas.

Bath retailers participating in the RENAISSANCE-funded project, which was offered as a free trial until the end of March 2012, said they were pleased with the service, including recycling of packaging, and that they were satisfied with the contractor DHL and its staff. Although environmental reasons did not appear to be strong motivators for joining, retailers supported the use of the electric lorry. Attitudes towards the fee structure were also positive, as most retailers claimed to have reduced their costs, and gained benefits, by joining the scheme. Those who didn’t take part in the scheme cited several reasons, including perceived costs, satisfaction with current delivery operators and issues with handling the delivered goods.

Users of the scheme were very satisfied with the service and were positive about the demonstration. Eighty-one percent of participating retailers surveyed were very likely to recommend the scheme to other businesses; the other 19 percent were quite likely to recommend the scheme. DHL reported that deliveries were made on time with no damages.
Almost all interviewed businesses confirmed that deliveries were made on time and they experienced no damages to their deliveries, confirming the operator’s reports.

The evaluation of RENAISSANCE reported that the cost of subsidising the scheme reduced from €221,910 in year 1 to €141,083 in year 2 as a charge of £9 per cage and £12 per pallet was made to participating businesses from 1st April 2012 (15 months into implementation). Cost-benefit analysis was conducted by UWE to assess the social net present value (NPV) brought by the UFCC in Bath over a period of 10 years. The analysis compared two scenarios, one without the UFCC or business as usual -- and one with the UFCC. The business as usual scenario considered what would have happened if all the deliveries made with the electric vehicle had instead been made with conventional diesel-powered lorries. Based on the analysis, the measure produces a positive NPV, in other words a net benefit, of £19.251 over 10 years. Sensitivity analysis found that this figure is not significantly affected by small changes in the social discount rate and emissions costs, and remains always positive. Emission reductions contributed the most to achieving the overall positive NPV.

3. Binnenstadservice.nl (BSS), Nijmegen (Netherlands)9

The evaluation document reports that BSS started its services as an urban consolidation centre in April 2008 in the Dutch medium-sized city of Nijmegen, one of the oldest cities in the Netherlands with a medieval city centre situated on a hill. The city centre historical structure is characterised by narrow streets where many small, independent retailers are located. The consolidation centre is located about 1.5 km away where goods can be received and picked up 18 hours a day. BSS uses environmentally-friendly delivery vehicles: an electric bicycle and a natural gas lorry. The mission of Binnenstadservice.nl is to provide logistical services to local inner city stores, regional consumers, carriers and local government. Users were not charged for this service. The objective was to reduce freight vehicle movements in the city centre. BSS users increased from 20 to 98 after one year. BSS received a government subsidy for one year to start business, but since April 2009 it had to operate without any public financial support and seek revenue from additional services to users. According to the evaluation report9, the scheme did not become self-financing. The evaluation used real data on freight vehicle movements and BSS users deliveries and modelled the impacts on air quality, noise and inconvenience for residents in city centre. The evaluation did not find any significant improvement in air quality (measured as concentration of NO2 and PM10) and reduction in noise, due to the overall passenger and bus traffic and the high natural background concentration of PM10 and NO2. However it found a reduction in freight vehicle kilometres, stops and routes in the city centre, as well a reduction in large freight vehicle movements and total loading and unloading activities. If more retailers were participating, BSS would produce more detectable improvements to the shopping environment, traffic safety and residents’ quality of life.

These positive results of BSS in Nijmegen gave rise to BSS franchise initiatives in other Dutch cities.

4. Cityporto Urban Distribution Centre, Padova (Italy)10

The city logistics service “Cityporto-consegne in città” is a 1,000 m² urban distribution centre (UDC) operating in the urban area of Padua, focusing on the local 830,000 m² Limited Traffic Zone (LTZ). The operator is a municipality-owned company called Interporto di Padova S.p.A., which also manages the local ‘freight village’. The deliveries are performed by 8 vans running on Liquefied Petroleum Fuel (LPF) and one electric van, two of which equipped for the delivery of temperature-controlled goods. The service has operated since 2004 and is considered one of the most successful city logistics systems in Italy, replicated in other
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Italian cities and recognised as European best practice. CERTeT-Bocconi conducted an ex-post Cost-Benefit Analysis to evaluate Cityporto in 2006. At the time of the evaluation, Cityporto performed about 60,000 deliveries per year for 45 customers, which in this case are not individual retailers but third-party couriers and hauliers, and also manufacturers and companies operating on own account.

CBA used data collected in the period September 2004 – December 2005. The results show a positive Benefit to Cost ratio (1.66), NPV of 728,500 Euro and beneficial impacts on the environment. As a result of Cityporto operations, reductions were observed in the number of freight vehicle journeys into the city centre (12 saved trips/day) and total km travelled (11,000 km/month saved, 127,000 km in total over the whole monitoring period). Average trip length decreased by 37%, from 34 to 25 km. Reductions in pollutant emissions were also calculated, with the biggest contribution to external benefits provided by reductions in PM10 emissions. The study however pointed out that the overall impact on congestion was negligible due to the limited number of operating vehicles.

Success factors include the location of Cityporto in the freight village, an established logistics platform which was well-known by freight operators; a thorough engagement process with all stakeholders involved to develop an effective framework agreement; and a favourable regulatory context, with access restrictions to goods vehicles in the LTZ of Padua with exemption for Cityporto vans.

5. City of London micro-consolidation centre (UK)\textsuperscript{11, 12}

The evidence is provided by two papers\textsuperscript{11, 12} summarising the before and after evaluation of a trial led by a major stationery and office supplies company in which urban freight deliveries in central London made from a depot in the suburbs using diesel vehicles were replaced in 2009 with the use of an urban micro-consolidation centre located in the delivery area, together with the use of electrically-assisted cargo tricycles and electric vans. This decision was taken as part of the company’s corporate social responsibility in order to reduce the environmental impacts of their delivery operation. The customers receiving the deliveries were all located in the City of London, the historic core of London with an area of 2.9 km\textsuperscript{2}, home of London’s business and financial centre.

The micro-consolidation centre benefitted from the local regulatory and policy context around freight transport. The City of London lies within the Clear Zone Partnership which was used as a testing ground to research, trial, monitor and set best practice for new transport technologies, innovations and physical measures, to be implemented on a local or regional scale. Since 1999 the London Borough of Camden, the City of London and the City of Westminster worked jointly to achieve this. This resulted in the London Borough of Camden making a small financial contribution towards the trial. All the other costs were met by the office supplies company.

The results show that the total distance travelled and the CO2eq emissions per parcel delivered fell by 20% and 54% respectively as a result of this delivery system. However, the evaluation also indicated that the distance travelled per parcel increased substantially in the City of London delivery area as a result of the electric vehicles having far smaller load limits in both weight and volume compared with diesel vans. But, at the same time, the trial system was able to virtually eliminate CO2eq emissions per parcel delivered in the City of London.

The trial proved successful from the company’s perspective in transport, environmental and financial terms. The company therefore decided to continue the operation beyond the end of the trial with it being officially launched during 2010.

The trial demonstrated that even in a supply chain in which goods are already highly
consolidated there is still the potential to achieve further benefits in terms of reductions in total distance travelled and greenhouse gas emissions through additional consolidation efforts and the use of electric vehicles. This is especially true in logistics systems that involve substantial distances between depots and delivery areas. The office supplies company reported that the distribution system used in the trial with its tricycles, electric vans and micro-consolidation centre had the same operating costs as the previous system using diesel vans dispatched from the suburban London depot.

3.3.2 Environmentally-friendly urban freight distribution: water and cycle logistics

1. Beer boat, Utrecht (Netherlands)\textsuperscript{13}

This intervention, supported by the European Commission through the CIVITAS MIMOSA 2008-12 project, consisted of the implementation of a new a zero-emission electrical vessel to transport goods to businesses, bars and restaurants in the historic centre of Utrecht, and the recruitment of new customers and suppliers to increase the potential for water freight distribution. The concept is known as the Beer Boat since the vessel initially transported mainly beer and beverages to catering businesses along the canals. Accompanying measures included vehicle restrictions in the inner city including time windows for freight traffic to deliver goods and a low emission zone.

The Beer Boat started operations in 2010 and at the end of the project was operating 4 days a week, 6 times a day, supplying more than 60 catering businesses. As a result of the MIMOSA electric Beer Boat, in the summer of 2011 the City of Utrecht signed a contract for another electric 'Multi-Purpose Vessel', which replaced the existing boat used for rubbish collection from businesses on the wharves. One of the main drivers for the implementation of the Beer Boat was the shape of the city centre (many canals, dense city centre, most shops, bars and restaurants located along the canals and close to each other) which provided ideal conditions for the services offered by the Beer Boat.

Additionally to the impact and process evaluations, a cost-benefit analysis (CBA) was conducted. The impact evaluation reported emission reductions of the main pollutants and CO\textsubscript{2}, compared to using a diesel boat for the same deliveries. CBA concerned the entire Beer Boat lifespan of 30 years and mainly focused on implementation and operating costs, revenues and emission effects. A positive net present value (NPV) of over €420,000 at a 3.5% discount rate was reported. It was assumed that impacts that were not part of the CBA could have additional positive effects and could further increase the calculated NPV.

Some lessons to be learnt from the implementation of the Beer Boat which are relevant for implementing or further expanding waterborne transport in Utrecht or in other cities include: optimising water delivery schemes and thereby reducing delivery times, adapting renting prices to increase acceptance during start up phases; raising awareness among logistics companies about the potential financial gains and the ease of using water distribution; enforcing further restrictions and/or costs associated with entering the city centre by conventional motorised modes. However, not all freight transport can be shifted to water therefore cities need to consider waterborne freight an element of a more comprehensive and multi-modal urban freight strategy.

2. Cycle logistics (Europe)\textsuperscript{14}

Evidence on the use of other cycles for freight distribution in urban areas is very limited despite the growing interest in cycle logistics especially in Western Europe.

A recent investigation into cycle logistics, which also provided the results of a survey of cycle logistic operators in Europe, indicated that the main areas of application are courier, express
and parcel (CEP) services and the delivery of basic products in catering. The available evidence, primarily gathered from tests carried out by companies in the CEP sector, show a significant potential for cycle freight to carry out deliveries with small volumes and comparably low weights. The provision of space for depots on the edge of city centres is an essential precondition to improve the potential for cargo bike delivery. Another important factor that considerably increases the motivation for cargo bike use in companies in the CEP sector is the considerable cost and inconvenience associated with driving and parking motorised freight vehicles in city centres, often characterised by physical and/or time access restrictions. The survey found that the largest current barrier to a broader implementation is the lack of perception of cargo cycles as a suitable mode of transport and the consequent lack of acceptance by potential customers. In sum, the study estimates that in the medium term cycle freight can form around a quarter of all freight traffic in city centres. In addition, a much greater consideration of the specific demands of cycle freight delivery is required on the part of urban planners.

3.3.3 Evidence on other types of urban freight interventions

Evidence from other types of `urban freight` interventions is very limited.

A study15 into the role and design of urban delivery services used a simulated North American data sample served with three transportation structures: last-mile personal vehicles, local-depot-based truck delivery, and regional-warehouse-based truck delivery. CO2, NOx, and PM10 emissions were modelled using values from the US EPA’s MOVES model and are added to an ArcGIS optimization scheme. Although not a real case study, the findings are relevant to understand how different urban delivery scenarios contribute to emission reduction and motorised vehicle movements, and whether there might be a clash between reducing emissions and easing congestion.

Local-depot-based truck delivery was found to require the lowest amount of vehicle miles travelled (VMT), whilst last-mile passenger travel generated the lowest levels of CO2, NOx, and PM10. While last-mile passenger travel requires the highest amount of VMT, the efficiency gains of the delivery services are not large enough to offset the higher pollution rate of the delivery vehicle as compared to personal vehicles. The practical implications of this research concern the role delivery structure and logistics have in impacting the CO2, NOx, and PM10 emissions of freight transport. Additionally, this research highlights the tension between goals to reduce congestion (via VMT reduction) and CO2, NOx, and PM10 emissions when conventionally-powered freight vehicles are used.

The FREILOT project16, funded as a pilot by the European Commission in the period 2009-2013, implemented a series of freight interventions with the aim to increase energy efficiency in road goods transport in urban areas through four different mechanisms: Traffic management (Energy efficiency optimised intersection control); in-vehicle technologies (Adaptive acceleration and speed limiters); driver behaviour [Enhanced “green driving” support]; and fleet management (Real-time loading/delivery space booking). The participating cities implemented priority for freight vehicles at certain intersections (on certain roads and/or certain times of day) and provided this priority as incentive to the freight fleets which were implementing acceleration, speed limiters and provided eco-driving support to their drivers. In addition, participating cities also provided possibilities to dynamically book and reschedule delivery spaces. The services were piloted in four European implementations: Lyon-France, Helmond-Netherlands, Krakow-Poland and Bilbao-Spain.

The evaluation report indicates that results in terms of fuel consumption and energy efficiency were positive but of modest magnitude, while the fleet management measures led to an increase in the number of deliveries and reduction of illegal parking. Because of the
experimental nature of these interventions and the limitations in data collection and presentation, the evidence base is not yet sufficiently robust.

3.3.4 General considerations about the evidence

Overall, urban consolidation is the area that has received the most attention in terms of monitoring and evaluation, whilst other types of urban freight interventions have received much less scrutiny from practitioners and academics. Therefore significant gaps exist in the knowledge base around urban freight measures that do not involve consolidation centres.

The published evaluations identified typically concern the localised impacts of the interventions, in isolation from total transport activity and its social, economic and environmental impacts in the urban area concerned.

The narrow evaluation scope is likely to be the consequence of several factors, including the challenge of collecting consistent ex-ante and ex-post data especially when commercial sensitivities exist, the lack of standardised evaluation frameworks that are suitable for assessing these types of interventions, and the experimental nature of most urban freight interventions.

These factors impact both on the resources that might be made available for independent and robust monitoring and evaluation, and the scale of the project, which may be limited and unable to produce significant effects.

There is also a need for further investigation into the total supply chain costs and benefits associated with urban freight measures, so that better economic assessments can be performed and more adequate pricing mechanisms identified.

3.4 Lessons for Successful Deployment of this measure

Several considerations can be made in relation to the successful deployment of urban freight interventions. As a consequence of the limited range of findings these are primarily focused on UFCCs.

3.4.1 Geographic scale and location

Concerning urban freight consolidation, the area served by a consolidation centre should not be too large to avoid losing efficiencies associated with centralised distribution. The location of consolidation and micro-consolidation centres in relation to the end-receivers and the strategic road network is very important in determining the effectiveness of the centre.

Environmentally-friendly distribution, for example by cycle and water or by electric vehicles with limited range, also requires a target area that is easily served by these means. The Beer Boat, for instance, performed best in a compact infrastructure, with a dense distribution of clients along the canals.

From the reviewed evidence, UFCCs are most likely to be successful in the following locations: specific and clearly defined geographical areas such as historic town centres, especially those undergoing a ‘retailing renaissance’ and characterised by a transport infrastructure that would be unable to cope with the resultant increase in freight; historic town centres and districts that are suffering from delivery traffic congestion where there is a common interest in improving the street environment, rather than large town-wide schemes.

3.4.2 Users and beneficiaries

In contrast with access restrictions or other types of regulatory measures of a mandatory

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* Browne et al. (2007) provide a detailed description of a proposed evaluation framework for consolidation centres.
nature, voluntary schemes such as consolidation or environmentally-friendly distribution need to secure a substantial user base, such as organisations, logistics companies, retailers and construction companies, to be effective. Market research is useful to identify potentially interested users and to estimate the potential costs and benefits achievable before implementing the measure.

The evidence on consolidation centres, for example, suggests that the major potential beneficiaries from the establishment of UFCCs would be: transport operators making small, multi-drop deliveries; shared-user distribution operations; businesses located in an environment where there are particular constraints on delivery operations; and small independent retailers/organisations, which are not part of a regional/national business with a dedicated and sophisticated supply chain, involving their own distribution centres, and which may be looking for a competitive edge.

To attract users, schemes need to be cost and time efficient and must provide an equal or better service than traditional freight delivery methods. Some of the barriers encountered during the implementation of the reviewed schemes (e.g. the Beer Boat and Bristol/Bath UFCC) were logistical challenges and perception of inconvenience which made recruiting customers difficult. The evaluation of the Beer Boat reported significant difficulties in finding interested transport companies and suppliers, as hauliers were resistant to change their current schemes and delivery patterns. A further barrier was that logistics decisions for chain stores were often made at their headquarters and implemented nationwide. Furthermore, a few logistics companies had already adapted to delivery restrictions or had made investments involving lorry-based delivery. Many clients could only accept/dispatch deliveries at certain times making the Beer Boat delivery route and schedule inefficient with significant waiting time during trips or trips had to be made twice to accommodate businesses different opening hours and staff availability.

Other barriers identified in the available literature include: lack of enforcement of regulations for delivery vehicles not included in the urban freight scheme; organisational and contractual problems that might limit effectiveness; potential to create monopolistic situations, thus eliminating competition and perhaps leading to legal issues and loss of the direct interface between suppliers and customers. Cityporto, for instance, was successful in being regarded ‘impartial’ from the perspective of hauliers. Nevertheless, securing their trust in the ability of Cityporto to successfully complete the delivery to the end customer was found to be a key challenge.

3.4.3 Financial resources

Cost (actual and perceived) is a crucial factor affecting the willingness to join voluntary schemes and to consider implementing a more sustainable form of urban distribution. Whilst the available evidence on urban consolidation suggests that self-financing schemes are not the norm, available CBAs report a positive NPV, or beneficial impact, which might offer a rationale for financial support. The positive financial and environmental experience of the London micro-consolidation scheme might encourage other businesses to explore similar innovative interventions.

3.4.4 Complementary supporting measures

Importantly, urban freight interventions rely on other complementary supporting measures, chiefly in the form of a favourable regulatory environment. Most of the reviewed schemes benefitted from the existence of spatial and/or temporal restrictions, for example a LTZ or LEZ in which loading/unloading operations, or even the access, is allowed only to specific vehicle categories or transport modes.
Other drivers and supporting measures include the identification and development of partnerships early on with key logistics sectors, clients, industries and suppliers; raising awareness about the available urban freight measures and their potential benefits to users, which can increase the number of businesses involved, which in turn makes operations more cost effective and increases environmental benefits.

3.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for policies promoting urban freight interventions:

- **Environmental improvements**: There is the potential to achieve local environmental benefits (air quality and noise) in the areas where goods are being delivered, as a result of fewer vehicles passing through. The improvements in respect of noise can be particularly significant when electric vehicles (or bike-freight) are deployed as last-mile services.

- **Facilitating economic activity**: Provision of UFCC and last-mile delivery services such as bike-freight, can mean that economic activities can now be considered in areas of a city that through poor access, or restrictions on conventional freight vehicles might have not been feasible before. This might have benefits in respect of access to services and goods for the citizens living there, as well as creating employment opportunities.

3.6 Summary

The available evidence on urban freight interventions is growing, especially around consolidation centres, but is considerably limited in breadth and depth, especially in other areas of urban freight policy. Further research needs to address these gaps.

Positive socio-economic and environmental impacts have been identified. In the cases where CBA was conducted, positive values for NPV were found: €19.251 for the UFCC in Bath, €728.500 for Cityporto, Padua and over €420.000 for the Beer Boat in Utrecht. In particular, urban consolidation and environmentally-friendly distribution can reduce harmful emissions and freight vehicle movements in the local areas where they operate. They can also bring considerable benefits to the users of these schemes, such as reduced delivery times and better delivery services. However, these interventions need to be sufficiently scaled up, in terms of user participation, for any tangible effect on air quality and congestion to be measurable at a city level.

According to the evidence, urban freight interventions have the greatest prospect for success if they meet one or more of the following criteria: availability of funding and resources for those schemes requiring initial capital and operational costs not met by operating revenues; strong public sector involvement in encouraging their use through the regulatory framework; partnership working between public and private sectors; significant existing congestion and/or pollution problems within the area to be served; bottom-up pressure from local interests; targeted to compact geographical locations areas where there are delivery-related problems.

Increasing awareness among public and private sector actors of the range of different interventions that could be implemented and their associated costs and benefits (for each stakeholder) is necessary to overcome negative perceptions of sustainable urban freight schemes.
3.7 References for this Review

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Removing, filtering or controlling the flow of vehicles in a street or part of a city with the intention of encouraging other modes (public transport, cycling and walking) and improving the public realm

Cities can limit vehicular traffic by use of physical barriers or signed regulation, allowing exceptions for specific vehicles or groups. They can also exclude vehicular traffic at all times, or at defined times from a particular area (i.e. for pedestrianisation).

Key messages:

✓ Pedestrianisation and access restrictions can bring considerable benefits to towns and cities - although the range of quantitative evidence is limited.
✓ Pedestrianising shopping streets tends to increase retail revenues and the value of property on those streets.
✓ Road closures do not cause ‘traffic chaos’ as critics often fear; drivers adapt their behaviour in ways that are not yet fully understood, but which avoid the worst consequences of congestion.
✓ Benefits include: improvements to the urban environment, reduced traffic in central areas, reduced air and noise pollution and modal shift towards sustainable mobility.
✓ There will normally be some increased traffic on surrounding streets. The extent of traffic displacement depends upon the existence of ‘spare capacity’ on the surrounding streets.

4.1 Context and background

‘Restrictions on through traffic’ [or ‘access restrictions’ for short] refers to situations where vehicular traffic is limited, either physically, or by signed restrictions. In some instances, particular categories of vehicle may still have access, e.g. buses, taxis, local residents or deliveries, even when general traffic is not. Restrictions such as these will affect access to a wider network of streets.

Potential interventions

- Barriers, permanent, or moveable (e.g. rising bollards)
- Legal restrictions, indicated on signs and entailing penalties for infractions.
- Pedestrianisation schemes

Pedestrianisation refers to the exclusion of vehicular traffic at all times, or at defined times each week. The definition does not include temporary closures. Bicycles may or may not be
allowed through pedestrianised streets or plazas. Exceptions may be made for emergency vehicles and deliveries to adjoining properties (these exceptions may or may not be time limited).

Pedestrianisation may be considered a sub-set of access restrictions, although there is a ‘grey area’ between the two, depending on the nature of the restrictions on vehicular access. Where access restrictions do not create pedestrianisation, either:

a) some categories of motor vehicle (apart from deliveries and emergency vehicles)
   e.g. buses may be allowed through and/or
b) barriers may create no-through roads but general traffic may still be able to drive up to either side of the barriers for local access.

Several of the evaluations described below include elements of pedestrianisation and other access restrictions, as part of schemes to remove traffic from a wider area – typically a town or city centre.

4.2 Statement of the Extent and Sources of Evidence

Considering the prevalence of pedestrianisation and access restrictions there is surprisingly little relevant, up-to-date, high-quality evidence available. There are many descriptive case studies available on-line, but these provide very little quantitative evidence on the impacts of such changes. The available quantitative evidence does not generally satisfy the criteria for establishing causality i.e. no-one has proved that pedestrianisation or road closures caused specific changes in travel behaviour or (with one exception) economic impacts. In addition, each study generally considers only limited types of impact e.g. traffic flows or retail spending but not both.

The evidence covered in the item reviews include four peer-reviewed articles, one book\(^1\), one book chapter and three reports from EU funded projects (Civitas and NoiseinEU). The four peer-reviewed articles provide the main evidence on the traffic impacts of road closures and the impacts of pedestrianisation on the retail economy. Of these, two are based on international evidence – much of it from Europe – but these are both rather old: one was published in 1993\(^2\), one in 2002\(^3\), but drawing on evidence going back as far as the 1960s; a chapter in a recent book\(^4\) provides more up-to-date outcome information on one of those case studies. Another article reported on a case study of Oxford in the UK around the year 2000\(^5\). The most rigorous and recent evidence on the effects of pedestrianisation on retail spending was based on a comparison of two streets in Hong Kong\(^6\).

Two of the EU-funded evaluations describe the impacts of pedestrianisation and road closure programmes on the centres of two Spanish cities – Burgos\(^7\) and Vitoria-Gasteiz\(^8\). Finally, an evaluation was conducted on the noise reduction impacts of pedestrianising a single street in Aix-en-Provence in France\(^9\).

4.3 Summary of What the High-quality Evidence Claims

4.3.1 The Impact of Road Closures or Access Restrictions on Traffic Volumes

Two of the sources describe two stages of a project which ran from the late 1990s\(^1\) until publication of the final article in 2002\(^3\). This project remains the most comprehensive study of the traffic impacts of road closures and road capacity reductions available in the published literature. Many other writings have cited it, but none that we were able to review added much to its specific findings in respect of permanent road closures (several publications have
studied the effects of temporary road closures in other circumstances\(^\text{10}\). The study used secondary data collected by local authorities in 10 countries, 6 of them in Western Europe. Most of the data came from the UK or Germany. The road closures or capacity reductions were for a range of reasons. Most of the 63 cases were temporary road closures (the descriptions were not always specific on this); some were capacity reductions due to bus lanes and others were permanent closures due to pedestrianisation of city centres, for example. The aim of the study was to examine the impact of the closures or capacity reductions on vehicles flows on the altered area and on parallel or alternative routes.

A large majority of the interventions were successful in reducing overall traffic levels. Some traffic was displaced onto surrounding roads but not all. Some of the traffic “disappeared”. In 51 of the 63 cases the total volume of traffic in the monitoring area fell. The range was +25.5% to -146.6%. The median reduction was 11% and the mean was 21.6%. The scale of traffic reduction from installing bus lanes was lower than the other schemes, most of which involved actual closures. In a few cases congestion worsened in the short-term but predictions of “traffic chaos” were very rarely fulfilled. There was some evidence that such predictions published in the media may have contributed to traffic reduction, because drivers were warned to avoid those roads. Only two of the interventions were subsequently reversed, due to perceptions that congestion had worsened. Drawing partly on professional opinions, the authors ascribe the disappearing traffic phenomenon to a range of different behavioural responses including: route changes, reduced frequency of travel, more trip chaining, modal shift, changes of destination and in the longer term changes of job or residential relocation\(^3\). A recent book chapter provides more context and longer-term traffic outcomes from one of the cases reviewed in the earlier study – the Cambridge Core Traffic Scheme, which also had further stages in more recent years\(^4\). Cambridge in the UK is a rapidly growing city with a radial road network converging on a historic centre with limited road capacity. It has a ring-road which is mainly two-lane and is bypassed further out on two sides by a motorway and dual carriageway. During the 1990s, the highway authority decided that increasing road capacity to accommodate increasing traffic volumes within the city would not be possible. They decided instead to close roads to through traffic in 6 stages between 1992 and 2008.

Some of the closure points have rising bollards allowing buses, taxis and some other exceptional vehicles through. In other places a permanent physical barrier allows cyclists and pedestrians but not motor vehicles through. Traffic crossing the cordon (on the river which bisects the city centre) fell by 8.4% between 1996 and 2000 (including 3 of the 6 stages)\(^3\). Between 2002 and 2008 (when 2 more stages were implemented) it fell by a further 16%\(^4\). Traffic volumes on the radial routes remained fairly stable, whereas traffic volumes in the surrounding county rose. These falls occurred despite a strongly rising population and rapidly growing economy; average household income grew by 15% above inflation between 2001 and 2011.

Cambridge already had a strong cycling culture and the closure points (which allow bicycles and pedestrians to pass through) provided an advantage in terms of distance to cyclists i.e. journeys by car became longer than the equivalent journeys by bike. The modal share of people cycling to work increased by 6 percentage points from 1991 to 2011.

Methodologies and Caveats

All the above studies drew on secondary data collected by local authorities, over which the authors had neither control nor oversight. The conclusion that some of the traffic “disappeared”\(^3\), depends upon the authorities identifying and correctly measuring traffic on all
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relevant ‘surrounding roads’. No attempt was made to control for other factors influencing changes in traffic volumes (although the more recent book chapter describes several of these factors e.g. population growth and economic growth)\(^4\).

The behavioural explanations offered for the disappearing traffic were largely conjectural (although those behaviours have been observed in other contexts). Two of the explanations – that some people change their destinations or their routes for some journeys implies that measuring traffic on surrounding roads would not capture the total traffic impact. For example, if access through a city centre was made more difficult, some people living in the northern suburbs of a city might stop travelling to destinations in the south of the city. The journey might still be made, but to a different destination. If they decided to travel to another destination in the northern suburbs instead, those journeys would not be captured by the traffic monitoring. Depending upon the layout of roads around the city, some drivers might also change their routes to follow an outer ring-road or a motorway, which would also be excluded from the traffic monitoring.

### 4.3.2 Case studies of pedestrianisation and access restrictions in city centres

There are many descriptive case studies of city centre pedestrianisation schemes available online, including some published by EU bodies\(^1\) and national government bodies\(^2\). Some of these provide useful practical information about the experience of implementing such schemes. Unlike most of the published case studies, the 3 sources reviewed below include quantitative before-and-after monitoring of several indicators. Both evaluations showed significant falls in traffic, within the controlled area and on surrounding streets. Both showed improvements in air quality and one showed significant modal shift in travel to the city centre.

Two evaluations were conducted of pedestrianisation and access restriction scheme for the centre of Burgos\(^7\) and Vitoria-Gasteiz\(^8\) in Spain. The projects and their evaluation were both partly-funded by the EU Civitas programme. Burgos already had a pedestrianised historic centre and recently completed a partial outer ring-road (on 2 sides of the town). The Civitas project expanded the pedestrianised area and removed through traffic from a wider central area of 4 square km. Rising bollards control access to this area, with permits issues to residents and delivery vehicles.

Vehicle, pedestrian and bicycle flows were measured in the area subject to the restrictions from 2000-4 and again after the interventions in 2006/7 and in 2008. Traffic flows on the surrounding roads were also measured annually. Modal share across the city was measured at the baseline, in 2006/7 and in 2008. A sample of 250 residents was surveyed in 2007 and in 2008 to gauge public opinion towards the access restriction measures. Traffic within the restricted area fell by 97%. The pedestrian count rose by 115%. The cyclist count rose even more rapidly but from a very low base (from 30 to 248). Traffic on the surrounding roads also fell very slightly between 2006 and 2007. The modal share of travel by car fell from 36.6% in 2000/4 to 31.9% in 2008. Public transport use rose from 11.9% to 27.2%. The share of journeys on foot fell (presumably many of the increased pedestrians counted in the central areas were arriving by public transport). Only 16% of people surveyed disagreed with the access restrictions in 2007, falling to 14% in 2008. PM10 pollution at the 4 monitoring stations fell substantially; NO2 emissions fell slightly.

The SUMP for Vitoria-Gasteiz aims to establish a limited network of through roads between 'superblocks', in which through traffic is limited. Phase 1 in 2008 introduced the central superblock (which also contains pedestrianised streets) alongside a new tram system. Access to the central superblock was previously controlled by rising bollards. These were
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Traffic flows on 3 affected streets were measured at 3 stages: beforehand (2006), after phase 1, the superblock and tram installation (2011), and after phase 2, the change to number plate recognition (2012). Air pollution and public acceptance were measured in 2011 and 2012. The acceptance survey was conducted by telephone to a random sample of 400 citizens. Most of the traffic reduction (between 60% and 89% on 3 monitored streets) was achieved by the superblock system but the camera-controlled number recognition system removed a further 6 to 8% of the (original) traffic levels. PM10 pollution fell by 7% and NOx by 1% in phase 2. The public were asked to rate their acceptance of the access restrictions on a scale from 1 to 10. The average acceptance level rose from 6.2 to 6.5 after implementation. (More "positive" measures scored higher e.g. the tram system averaged 7.9 in 2012).

The pedestrianisation of Oxford in the UK provided another case study. The pedestrianised zone itself was fairly small - through traffic was removed from a wider area, particularly through the use of bus gates, which allowed buses but not general traffic through. Traffic entering the city centre fell by 17%, whilst total visitor numbers remained stable. Pedestrian volumes in the pedestrianised streets increased slightly. There was a 9% increase in the number of visitors to the city centre by bus, including expansion to park and ride sites, more than compensating for the loss of visitors by car. Retail floorspace reached a record level and retail property rents rose more quickly than elsewhere. There were small reductions in air pollution levels and road collisions.

Methodologies and Caveats

The explanations of methodology in the two Spanish studies were limited in detail. For example, the location of the air quality monitoring stations (in relation to the city centre), the definition of the "surrounding roads" and the methods used to calculate modal share were not defined in Burgos. No attempt appeared to have been made to control for any other factors that might have influenced traffic volumes and air pollution. The Oxford study drew on data collected by the local authority and business organisations, so its robustness would rest on the effectiveness of their methods (which would not generally have been scrutinised by the author).

4.3.3. The Impact of city centre pedestrianisation on visitor numbers and retail businesses

This section draws on one Anglo-German meta-study and a quasi-experimental study of pedestrianisation in Hong Kong.

The meta-study, which was published in 1993, remains the most comprehensive review of evidence on the impact of pedestrianisation (and traffic-calming) on retailing. The article, based on UK and German data, is mainly a meta-study, although it also reports the findings of some primary research. The secondary data included 6 UK studies and 11 German studies; some of the studies covered several towns in each country. The data collected by the different studies spanned the period from 1965 until 1992.

The primary data showed increases in pedestrian flows ranging from 18% to 92%. One measure on one street showed a decline of 3%, where the 'after' survey was conducted before reconstruction was complete. A study of 6 German towns showed that retail turnover increased for 64% of businesses surveyed with the largest concentration (32.4%) reporting an
increase between 5% and 10%. The effect was slightly more positive in the larger towns than smaller towns. Some of the other studies found that there was sometimes a slight fall in turnover immediately following pedestrianisation. In the longer-term, shops on pedestrianised streets tend to benefit, whereas those on trafficked streets nearby tend to suffer. One of the UK studies showed that rents on pedestrianised streets were 80% higher than on vehicular streets, although the change in rents immediately following pedestrianisation in 14 towns was similar to the national trend.

The report describes resistance to pedestrianisation proposals from traders and their representative organisations in several towns, however they “virtually never campaign for the abandonment of a scheme once it has come into operation...traders are often the main people to voice a desire to extend its boundaries or period of operation.”

A quasi-experimental evaluation was conducted of the pedestrianisation of a shopping street in Hong Kong in 2003. Although this raises obvious questions about cultural and spatial differences from European contexts, it is included here because it is, as far as we were able to find, the only rigorous academic study of this question, which enables causal inferences to be drawn.

Both the intervention and control streets are busy shopping streets. The intervention street suffered from overcrowding and conflict between pedestrians at busy times. Since 2003 it has been closed to traffic from 4pm to midnight on Mondays to Saturdays and from noon to midnight on public holidays. On the control street, pavements were widened and traffic calmed but it remains open to traffic. Data was obtained from government sources on the rateable values and physical characteristics of shops for the tax years 1999/2000 and 2008/9. Rateable value, which is an assessment of market rent conducted by the authorities for tax purposes, was used as a proxy, since rents (which are commercially sensitive information) would not be directly available to a researcher. Independent variables were collected for a regression analysis: age, size, frontage, distance from station, corner location and two dummies for the year and the pedestrianised street. Rateable values were already higher on the intervention street before pedestrianisation. They rose on both streets but considerably more on the experimental street. The regression model explained 51% of the variation in rateable values (adjusted $R^2$). After controlling for other factors pedestrianisation added 17% over and above the traffic calming and pavement widening on the control street. The changed environment on the intervention street, with activities such as street theatres and ‘live forums’ led to more noise in the late evening. As a result, the pedestrianisation was shortened, to end at 11pm instead of midnight.

Methodologies and Caveats

The studies reviewed by the meta-study came from a range of sources, including local authorities and a couple of student dissertations. The published article gives only limited information on the methods they used. In most cases, the effects on retail spending depending on self-reporting by businesses, which raises questions about the robustness of the evidence. The studies do not report any statistical analysis controlling for external factors.

There are several differences between Hong Kong and European cities - specifically the much higher population density and lower car ownership in Hong Kong. Whether that would increase or reduce the impact of pedestrianisation on shopping behaviour is not obvious. However, the broad conclusion is consistent with the available European evidence, including the meta-study.
4.3.4 Noise reduction benefits of pedestrianisation

This section is mainly based on a noise evaluation conducted on a single street, la rue d’Italie, in Aix-en-Provence, France, before and after pedestrianisation\(^3\). It also draws on a magazine published by the local authority for its residents\(^4\) and minutes of the city council meetings\(^5\), which provide some broader context on the pedestrianisation programme in that town.

Extending the existing pedestrianised area of the city centre formed part of the programme of the mayor Joissans on her election in 2001. A consultation showed that 60% of the public supported it in principle. It was preceded by an increase in parking capacity of 4,800 judged essential to avoid “killing trade” in the city centre. A smaller area of the city centre had been pedestrianised for many years. A network of minibuses and ‘Diablines’ (slow-moving electric vehicles) serve the central areas.

La rue d’Italie was one of the streets in the newly-extended pedestrian zone. Rising bollards controlled by intercoms allow access for residents, traders and emergency vehicles. A one-hour traffic count and sound measurement was taken before the intervention and shortly afterwards. The number of vehicles moving along the street fell from 155 to 25. Of the latter, 10 were cars (residents or other essential users) with access rights; 13 were motorised 2-wheel vehicles which illegally rode past the bollards (compared to 16, legally circulating before). Average noise level fell by 5 decibels. The contribution of vehicles to total noise levels fell from 56% to 10%.

The city council minutes provide some limited information on the budget (the project was implemented in stages). The cost of installing 34 rising bollards with an intercom and camera linked to a central control point was budgeted at €552,083.

Methodologies and Caveats

The evaluation was conducted on just two days which could have been subject to random variations. The researchers estimate that the fall in noise levels would have been larger (14Db) were it not for building works which were happening in the ‘after’ phase only.

4.4 Lessons for Successful Deployment of this measure

The evidence in this review has mainly come from the UK, Germany and Spain, although the broader Evidence database includes studies from many other countries in Europe and elsewhere. Most of that evidence is descriptive – and favourable towards pedestrianisation and access restrictions. Some of it also describes political conflicts within local authorities and strong opposition (e.g. a study of the removal of through traffic from the centre of Groningen in the Netherlands\(^6\)). This broader evidence base suggests that both pedestrianisation and access restrictions can be implemented almost anywhere – and particularly within Europe. Whether the benefits and costs would vary widely in different contexts is more difficult to assess. The international meta-study of pedestrianisation schemes found that the retail benefits are greater in larger cities than in small towns\(^2\), although this should not be regarded as a universal statement. Both pedestrianisation and access restrictions have been successfully implemented in small towns in many countries.

The main barriers to implementation relate to local opposition, particularly from shop owners and motorists who perceive that road closures will increase congestion, journey times and/or journey distances. Involving stakeholders in scheme designs may help to alleviate some of those concerns, although there is also evidence that brave decisions and successful implementation are the best ways of overcoming opposition.
Cities which embark on a gradual process of pedestrianisation and access restrictions may experience a longer-term decline in urban traffic volumes, coupled with modal shift; this has been the experience of Cambridge and also of Groningen. In the case of Cambridge, those trends accompanied a period of rapid economic expansion and population growth.

### 4.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for policies promoting access restrictions to promote sustainable mobility:

- **Improved street environments:** Reducing traffic levels can lead to the creation or improvement of ‘street life’, through community activities and events such as ‘street parties’.
- **Community cohesion:** More people using streets, and interacting with neighbours and other pedestrians can help create greater social cohesion within a community, in itself reinforcing the more communal street environment.

### 4.6 Summary

Although the range of quantitative evidence is limited, the available evidence, quantitative and qualitative, shows that pedestrianisation and access restrictions can bring considerable benefits to towns and cities. There is some evidence of opposition to such changes – usually stronger before implementation than afterwards – but very few examples of such measures being reversed or judged to have failed. The main advantages are: improvements to the urban environment, reduced traffic in central areas where traffic would otherwise be most concentrated, modal shift towards sustainable mobility and reduced air and noise pollution. Pedestrianising shopping streets tends to increase retail revenues and the value of property on those streets. There may, however, be short-term declines during and immediately after implementation. Shops on trafficked streets bordering a pedestrianised area may also suffer a decline.

Road closures do not generally cause ‘traffic chaos’ as critics often fear; drivers adapt their behaviour in ways that are not yet fully understood, but which avoid the worst consequences of congestion. However, there will normally be some increased traffic on surrounding streets. The extent of traffic displacement depends upon the existence of ‘spare capacity’ on the surrounding streets. The example of Cambridge suggests that (contra to received wisdom) the benefits may be greatest where convenient alternative routes for general traffic do not exist. In those cases, the opportunity for traffic displacement may be very limited – greater modal shift may occur instead. Improvements to the urban environment may have assisted Cambridge’s economic expansion, but the main reasons were unrelated. Although it cannot be proven that removing traffic contributed to economic expansion in Cambridge, the opposite can be stated with some confidence: that removing traffic from the inner areas did not prevent rapid economic expansion, as is sometimes feared.

### 4.7 References

Measure No.5: Road space re-allocation

Re-allocating general traffic lanes for use by other types of road user.

Cities can encourage more efficient or alternative uses of road space by dedicating space specifically for use by public transport, cycles and high occupancy vehicles. They may also narrow carriageways to improve public spaces.

Key messages:

✓ Schemes in which general traffic lanes are re-allocated to alternative uses can be expected to reduce traffic volumes, improve journey times for the modes given additional priority (e.g. bicycles or buses), increase the use of non-car modes and reduce casualty numbers.

✓ However, little credible evidence was identified on the monetized costs and benefits of road space re-allocation schemes. This may be a result of such schemes often forming part of a wider package of measures which are then appraised as a whole.

✓ Journey times for general traffic (cars, vans etc.) may increase, although in some cases road space reallocation has not led to the anticipated increases in congestion. Therefore, it is possible to remove road space and improve conditions for users of other modes and the public realm without worsening conditions for general traffic.

✓ Accordingly, modelling exercises of road space reallocation under different scenarios indicate that benefit-cost ratios for road space re-allocation schemes are likely to be positive in cases where the benefits of increased person throughput or modal shift outweigh the dis-benefits of delays to general traffic.

5.1 Context and background

This measure encompasses Interventions that are concerned with re-allocating general traffic lanes, to alternate transport uses.

Potential interventions

- Reallocation of road spaces to public transport lanes (including provision for taxis, motorcycles and bicycles);
- Reallocation to cycle lanes;
- Reallocation to high occupancy vehicle lanes (including tolled) lanes;
- Carriageway narrowing to improve public spaces.

Road space re-allocation schemes in urban areas may have a number of objectives:

1. To increase the overall people (as opposed to vehicle) carrying capacity of urban networks by: a) increasing public transport or cycle network capacity and b)
Measure No.5: Road space re-allocation

- encouraging a modal shift away from single occupancy car use;
- 2. To reduce traffic levels, congestion and/or improve general quality of traffic flow;
- 3. To improve journey times and reliability for public transport to make journey times competitive with the private car;
- 4. To improve the overall journey experience for cyclists;
- 5. To reduce the number of road collisions and casualties;
- 6. To improve local air quality; and
- 7. To improve the public realm by “taking back” road space to become public space.

Note: This review does not consider access restrictions, or road closures which are dealt with in detail under measure review No4. It also does not include the provision of new capacity (e.g. bus/cycle lanes that are in addition to existing general traffic lanes) as these do not constitute road space re-allocation.

5.2 Statement of the Extent and Sources of Evidence

This measure review has drawn on 13 sources. A meta-study by Cairns et al.1,2 - examining the impact of road space reductions from over 100 case studies around the world - has been used to provide a general context for more detailed case studies of specific road space re-allocation schemes. These interventions were categorised according to whether space has been re-allocated to mixed priority, public transport, cycle only, or high occupancy vehicle lanes. Whilst there is a great deal of evidence on the impact of these different forms of priority lanes, fewer studies were found to have examined the specific effects of re-allocating existing road space to these modes. This was particularly true for high occupancy vehicle lanes, where only one detailed case study was identified.

The review draws heavily on case studies from the UK, though these have been supplemented by examples from Sweden, New Zealand and the USA. It is common for monitoring studies to have been reported by local highway authorities or consultancies acting on their behalf, rather than being based on detailed academic research. A consequence of this is that few studies have applied statistical analyses, limiting the robustness of the findings to some extent. Given that it is usual for local highway authorities to monitor schemes in which road space has been adjusted it has been possible to identify up to date monitoring studies from the last five years. Academic studies are scarcer however. The meta-study dates from 19981 (updated in 20022), while an informative study of bus priority measures, dates from 19963.

With respect to intervention scale, the case studies usually apply to the re-allocation of road space along a single corridor in an urban area. Public transport priority measures may be rolled out on an area wide basis, and the examples reported for Bristol, and Cardiff, UK examine the effects of a series of bus lanes introduced across these cities.

5.3 Summary of What the High-quality Evidence Claims

5.3.1 Impacts on general traffic levels of reducing road space

The meta-study by Cairns et al.1,2 is of relevance to this measure as it included numerous interventions that restricted general traffic lanes to use by a limited number of modes, in addition to road closures (dealt with in detail under measure review four). Monitoring periods varied between one day (single day of closure) and 10 years. A median reduction in overall traffic levels of 10.6% was observed indicating that “in half the cases, over 11% of the vehicles which were previously using the road or the area... could not be found in the...
Measure No.5: Road space re-allocation

surrounding area afterwards”. The study did not control for wider trends in traffic levels or other changes that may have been implemented at the same time as the intervention. Nevertheless, given the large number of case studies analysed, it can be stated with some confidence, that traffic levels can be expected to reduce (by quite a significant amount) if road space is taken away from general traffic.

Single case studies of the following types of road space re-allocation scheme are now presented in sequence:

1. Re-allocation of general traffic lanes to mixed priority routes;
2. Re-allocation of general traffic lanes to public transport;
3. Re-allocation of general traffic lanes to cycle lanes; and
4. Re-allocation of general traffic lanes to high occupancy vehicle lanes.

5.3.2 Re-allocation of general traffic lanes to mixed priority routes

Mixed priority lanes are accessible to multiple modes - including cycling, public transport or high occupancy vehicles – but not to general traffic. Three case studies of interventions in which general traffic lanes were re-allocated to mixed priority use were identified for review:

1. The Lewes Road Scheme, Brighton, UK;
2. The Wilmslow Road Mixed Route Scheme, Manchester, UK; and
3. The Broadway – Union Square improvement scheme, New York City, USA.

1. The Lewes Road Scheme, Brighton (UK, opened in September 2013)

The Lewes Road is a primary radial route connecting a major inter-urban highway to the north east of the city to the city centre. The intervention involved converting one lane of the two-lane general traffic dual carriageway into a bus lane (both northbound and southbound, over 4.5km) and incorporating a widened, continuous cycle lane in both directions. Scheme objectives included reducing traffic volumes and speeds, encouraging greater use of non-car modes, and reducing collision numbers and severity. Traffic surveys were undertaken on neutral days in October and November 2012 and again 12 months later in October and November 2013. The results of the monitoring study are summarised in Table 1.

General traffic flows on the Lewes Road were observed to reduce by 13% and not to increase on alternative routes. However, queue lengths had significantly worsened at one junction and this required a subsequent reconfiguration of signal timings. While car journey times increased in one direction, bus journey times generally improved (with the exception of the evening peak) and this had the desired effect of attracting additional passengers (patronage increased by 7%). An increase in evening peak bus journey times in the northbound direction was attributed to longer dwell times at bus stops (a result of the higher patronage) and the introduction of a lower speed limit. The number of cyclists was seen to increase by 14%. No information was provided on collision rates.

Overall then, it can be said that the re-allocation of road space successfully reduced traffic volumes along the route and encouraged greater use of both cycling and public transport.

Table 1: Lewes Road Scheme, Brighton – Performance Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Impact of intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car journey times northbound</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Car journey times southbound</td>
<td>Increased by 1 min 5 secs in the AM peak and 1 min 28 secs in the PM peak.</td>
</tr>
<tr>
<td>Bus journey times northbound</td>
<td>Reduced by 23 secs in the AM peak but increased by 1 min 29 secs in the PM peak (as a</td>
</tr>
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</table>
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<table>
<thead>
<tr>
<th></th>
<th>consequence of a reduced speed limit and more people boarding the bus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus journey times southbound</td>
<td>Reduced by 1 min 27 in the AM peak and by 19 secs in the PM peak</td>
</tr>
<tr>
<td>Bus passenger numbers on Lewes Road</td>
<td>Increased by 7% compared to 4% city wide</td>
</tr>
<tr>
<td>Cyclist numbers on Lewes Road</td>
<td>Increased by 14% (an additional 298 cyclists)</td>
</tr>
<tr>
<td>General traffic levels on Lewes Road</td>
<td>Reduced by 13% over 12 hour period (~2,300 vehicles)</td>
</tr>
<tr>
<td>Diverted traffic</td>
<td>No significant increases in traffic on possible alternative routes</td>
</tr>
<tr>
<td>Queue lengths</td>
<td>Queue lengths had significantly increased at one junction (in the AM peak), but other junctions were not significantly impacted.</td>
</tr>
</tbody>
</table>

2. The Wilmslow Road Mixed Route Scheme, Manchester (UK, opened May 2004)³. Wilmslow Road is a main radial route between south Manchester and the city centre. As a district high street, it accommodates high volumes of vehicles and pedestrians and had been identified as a collision hot spot, given the potential for conflicts between these two user groups. The scheme involved converting a four lane carriageway into a single lane for general traffic in each direction. The re-allocation space was used to introduce a ‘curvilinear’ road alignment to reduce vehicle speeds. Bus lanes were also provided on the approaches to bus gates at each end of the route, as well as continuous cycle lanes and widened footways in each direction. The main aim of the scheme was to reduce casualty rates, with secondary objectives to reduce vehicle speeds and to improve traffic flow.

- **Casualty rates**: The average annual casualty rate was observed to reduce from 53.3 per year in the three year period before the scheme to 37.8 per year in the three year period following implementation. Whilst this represents a 15% reduction, the analysis did not account for wider area trends and so the reduction cannot be directly attributed to the scheme. The benefits of casualty reduction were estimated at over £0.696m per year.

- **Pedestrian and cycle flows**: Pedestrian footfall increased by 22% (comparing flows measured immediately before and two years after scheme implementation). Bicycle flows also increased from 408 to 1002 on a weekday, but were shown to reduce from 265 to 232 on a Saturday (the time frame of the before and after comparison is not defined). This limited number of observations was not set against wider area trends and again it is not possible to attribute the variation to the scheme alone.

- **Traffic volumes**: The number of motorised vehicles entering the route at each end was observed to reduce by 25% (attributed to the presence of bus gates). No data is reported on whether vehicles diverted to alternative routes.

- **Journey times**: Despite fewer vehicles using the route, journey times, including those of buses increased by up to 60% as a consequence of the capacity reduction (the time frame of the before and after comparison is not defined).

- **Air quality**: Nitrogen dioxide levels were monitored between Dec 2002 and Sep 2003 and between June 2004 and 2005 and were shown to have increased by 41%. This is a significant decline in performance, when set against observed increases.
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of 13% to 47% at other monitoring stations in Manchester. Given the reduction in traffic volumes, worsening air quality was attributed to increasing congestion and slower vehicle speeds, but could also be partially related to potential changes in the number of diesel versus petrol vehicles using the route (not reported).

To summarise the results of this case study, it can be stated that the re-allocation of road space contributed to:

1) improvements in road safety (meeting the main objectives of the scheme)
2) reductions in general traffic volumes and
3) Increases in the numbers of cyclists and pedestrians.

However, whilst the scheme had the desired effect of reducing traffic speed, the absence of continuous bus lanes in each direction had the unintended consequence of compromising journey times for bus users.

3. The Broadway – Union Square scheme, New York City. This scheme involved converting East 17th Street on the approach to the Broadway theatre district, from two-way operation to one way in the westbound direction. The removed carriageway was re-allocated to a floating parking lane which protected a new curb-side segregated bicycle lane. A number of related changes were also made to simplify traffic movements at nearby junctions around Union Square and Broadway. As well as general improvements to the public realm, the scheme was intended to improve safety, reduce vehicle speeds and improve conditions for cycling and walking. The changes were implemented in the summer of 2010 and the New York Department of Transport reported findings from a monitoring study in 2011.

- **Collision rates:** The number of collisions involving injuries reduced from 66 in the year before implementation to 49 in the year after implementation – a reduction of 26%. This was found to be statistically significant and attributable to the scheme after accounting for the variability in traffic collisions over the previous 10 year period.
- **Impact on cycling:** Bicycle volumes were found to increase by 18% (from 1150 to 1362) on a weekday and by 49% (from 372 to 554) on the weekend comparing one month before to one month after data.
- **Traffic speeds:** Traffic speeds on Broadway were found to decrease by 7% from 27mph to 25mph (between 7-9am and 8-10pm) comparing data one month before the scheme to three months after the scheme.

No further data was reported on the longer term impacts on cycling volumes and traffic speed. Nevertheless, in the short term at least, this evidence suggests that the scheme had been successful in improving safety and encouraging cycling in the area.

5.3.3 Re-allocation of general traffic lanes to public transport

The meta-study by Cairns et al. included a number of case studies on the impacts of re-allocating road space to bus lanes. In Bristol, UK, bus lanes were introduced on five corridors between 1991 and 1994. Journey times, bus patronage and traffic flows were monitored before and (three to 12 months) after implementation. Bus journey times were shown to reduce by up to two-thirds, and journey time variability also reduced by up to 89%. General traffic levels had increased by 2.4% along one corridor, although this was set against a general increase in traffic across the city region. Limited data on patronage indicated that passenger numbers had increased by 9% on one corridor and 4% along another. These increases were observed to be greater than the increase in general traffic along the
The study also suggested that separating buses from general traffic can have the effect of reducing journey times for non-priority vehicles e.g. along one corridor, journey times reduced from 8mins to 4mins\(^3\). In two other UK case studies\(^1\), traffic levels were shown to reduce as a consequence of re-allocating road space to bus lanes. Traffic entering Cardiff central area reduced by 4.2% in association with the introduction of several bus lanes between 1994 and 1996 (indicated by a cordon count). In Belfast, traffic reduced by 29% along the Ormeau Road after the introduction of a bus lane (although experts expected some of this to have diverted to alternative routes). Bus journey times were shown to reduce by 20 to 30 seconds while journey times for general traffic increased by two to three minutes on average.

Overall, these case studies suggest that re-allocating road space to public transport lanes can improve journey times and reliability for buses, which in turn increases patronage. In certain circumstances this can be achieved without compromising journey times for general traffic (most probably through a combination of reducing traffic volumes and encouraging greater use of bus services).

5.3.4 Re-allocation of general traffic lanes to cycle lanes

Fowler and Koorey\(^7\) measured the effects on cyclists’ safety of the re-allocation of road space to a cycle lane in Christchurch, New Zealand. The cycle lane reduced the width of the general traffic lanes by 0.6m and 1.4m in each direction. Vehicle speeds and passing distances were recorded three weeks before and six weeks after the cycle lane was introduced. Mean motor vehicle speeds were shown to have decreased by 0.9 km/hr in the peak and 1.5 km/hr in off-peak periods, indicating a safety benefit. However, the passing distance between motor vehicles and cyclists actually reduced by 1.2m after installation of the cycle lane – partly as more cyclists had chosen to use the cycle lane instead of cycling on the pavement (based on a small sample of 95 cyclists using the path).

Nilsson\(^8\) conducted a survey of new cycle lanes (involving re-allocation of road space from general traffic) at various different urban locations in Sweden. In this case, the results indicated that the introduction of cycle lanes did not have a significant speed reducing effect (with reductions on some roads, but increases on others). However, cyclists’ opinions were improved by the introduction of the cycle lanes particularly in relation to safety (as a consequence of having dedicated space on the road).

These insights would suggest that narrowing roads to introduce cycle lanes can have the effect of reducing vehicle speeds in some circumstances. Hence there are potential safety benefits. However, further research is required to confirm under what conditions this is likely to happen and why. While on street cycle lanes are likely to improve cyclist perceptions of the cycling environment, the distance between cyclists and passing vehicles will not necessarily increase given greater perceived certainty in drivers’ minds over vehicle positioning and potential increases in the number of cyclists opting to cycle on street.

5.3.5 Re-allocation of general traffic lanes to use by high occupancy vehicles

The EU “Increase of Car Occupancy” (ICARO) study\(^9,10\) included an evaluation of a 1.5km High Occupancy Vehicle (HOV) lane introduced in Leeds in 1998 (the first introduced in the UK) on a main radial approach to the city centre (costing £585,000 at 1998 prices). The lane permits bus, cycles and high occupancy vehicles (carrying two or more people) and operates in weekday morning and evening peak periods. The scheme was intended to benefit the majority of road users given the observation that one third of vehicles (including buses) carried two thirds of passengers. The following impacts were observed\(^9,10\):
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- **Traffic volumes** initially reduced (by up to 20%) in the period immediately after HOV lane implementation, but later increased beyond the ‘before’ level (likely owing to general traffic growth in the city)
- **Average car occupancy** on the corridor increased from 1.35 (one year before implementation) to 1.51 (four years after implementation)
- **Journey times** for high occupancy vehicles reduced by four minutes (comparing data from one year before implementation to data one year after implementation). Notably, non-HOV journey times also reduced by 1 minute.
- **Casualties** were reduced by 30% in the three year period after implementation.
- **Air quality** was unchanged.

No other detailed monitoring studies were identified on HOV lane re-allocation schemes during the measure review. Dixon and Alexander briefly report on a similar 2+ HOV lane opened on a 1.75km stretch of the A4174 ring road around Bristol (UK) in 1998 (re-allocation road space from general traffic). This contributed to reducing the proportion of single occupancy vehicles from 80% to 70% (though the timeframe was not reported).

Taken together, these insights would suggest that the HOV lane re-allocation schemes can be successful in increasing vehicle occupancies, improving traffic flows and reducing casualty rates.

5.3.6 Evidence on costs and benefits of road space re-allocation schemes

Very little evidence was identified on the monetized costs and benefits associated with the re-allocation of road space (as opposed to the provision of additional public transport, cycle or HOV lanes). Usually such schemes form part of a wider programme of investment in say public transport or cycling infrastructure and are evaluated on this basis. Two modelling studies were identified in the review:

Ang-Olson and Mahendra estimated Benefit Cost Ratios (BCRs) for the re-allocation of a general traffic lane on an arterial route to a Bus Rapid Transit (BRT) lane, based on the modelling of a range of hypothetical scenarios. The calculation of benefits included change in travel time for drivers and BRT users, change in vehicle operating costs for drivers and fares for BRT users, change in emissions and change in crash costs. These were weighed against construction and operating costs over a 20 year appraisal period. A positive BCR of 1.1 was estimated based on an assumed throughput of 40,000 people per day, but BCRs of less than 1 were found at lower and higher traffic volumes. At lower volumes, the number of BRT users was found to be too low to accrue significant travel time benefits while at higher volumes, delays to vehicles following the reduction in general traffic lanes were shown to outweigh the benefits to BRT users. The authors noted that positive BCRs would be expected if other wider economic benefits of BRT infrastructure (e.g. changing land values and economic activity) had been included.

Daniel and Stockton estimated BCRs for seven HOV lanes implemented in Texas (USA). Benefits included reductions in person delay, reductions in vehicle operating costs and reductions in accidents. These were weighed against construction costs and maintenance and operation costs over a 20 year appraisal period. Positive BCRs ranging between 7 and as high as 48 were found for all seven HOV facilities. These were then compared to BCRs for a hypothetical alternative option of providing two additional general purpose lanes. In all cases, the BCR for the HOV lane option was found to be higher than the BCR for the general purpose alternative. On this basis they conclude that HOV lanes can be a more cost effective alternative to general purpose traffic lanes.

In general, these modelling exercise indicate that BCRs for road space re-allocation
schemes are likely to be positive in cases where the benefits of increased person throughput or modal shift can be expected to outweigh the disbenefits of delays to general traffic. Appraising road space re-allocation schemes in isolation from related packages of improvements may produce misleading results, however, if the wider benefits of road space reallocation (in supporting other modes) are not adequately captured.

Methodologies and evidence gaps
Most of the case studies reviewed have tended to rely on reporting the results of before and after surveys which measure performance indicators such as traffic volumes, journey times and casualty rates. In some cases, the context of wider area trends has been qualified, but rarely have statistical analyses been performed to confirm whether the observed trends can be directly attributed to the scheme in question. This is undoubtedly a weakness in the evidence base. A further limitation is that monitoring studies often report quite short term effects (in some cases being limited to a period of several months before or after scheme implementation) and there is limited insight into longer term impacts.

Whilst there are substantial bodies of literature dedicated to bus, cycle and HOV lanes, few sources were found to focus specifically on the effects of the re-allocation of space to such uses (as opposed to the introduction of new lanes which may be additional to general traffic lanes). In particular, very few sources were available on re-allocating road space to HOV lanes and this is an area that certainly demands further research.

5.4 Lessons for Successful Deployment of this measure

5.4.1 Transferability: There are no systematic reasons to suppose that the findings would not be relevant in other locations. In drawing on over 100 case studies from around the world, the meta-study by Cairns et al. offers confidence that restricting road space has the general impact of reducing traffic volumes. With respect to the reallocation of road space to cycle and bus lanes, it is intuitive that providing greater priority to these modes can be expected to improve journey times and increase usage levels. This was confirmed in the reviewed case studies (which are acknowledged to be dominated by UK examples, but also included cases from Sweden, New Zealand and the US) and can be expected in most circumstances. However, an important caveat is that capacity restrictions are likely to reduce speeds and increase journey times for general traffic (and concomitant increases in emissions) and this can have the unintended consequence of delaying buses in cases where continuous priority lanes have not been implemented. The evidence on the extent to which reallocating space to HOV lanes is an effective means of increasing vehicle occupancy and improving traffic flow is weak and this is an area that certainly demands further research.

5.4.2 Drivers / Barriers: Gaining support from the public and other stakeholders is crucial to the successful implementation of schemes that seek to reduce road space for general traffic. The study by Universitaet fuer Bodenkultur suggested that effective consultation and marketing strategies are essential and that efforts should be made to engage with lobby groups (which may be opposed to restrictions in road capacity) including for instance, motoring organisations or local political parties early on in scheme development.

5.4.3 Complementarity: Restricting capacity for general traffic along specific routes within urban areas is likely to require some degree of area wide traffic management. This may include for example reconfiguring nearby junctions to simplify turning movements or restricting access on alternative routes to prevent ‘rat running’. Enforcement, effective signage and scheme marketing are also required. This is particularly the case for novel
schemes such as HOV lanes that may be unfamiliar to drivers. The scheme introduced in Leeds, UK was accompanied by a significant information campaign which involved press coverage, posters, leafleting and advance warning signs on approach routes.

5.4.4 Durability: Poor public support for schemes that appear to be lightly used by buses, cyclists or HOVs (termed “empty lane syndrome”) may result in re-allocated road space later being returned to use by general traffic. This can be avoided by ensuring that there will be a sufficiently visible number of vehicle movements using the re-allocated space during scheme design - For instance, by allowing HOVs to use bus lanes in circumstances where bus services operate relatively infrequently. Where infrastructure changes are maintained, schemes can be expected to have long term impacts. However, as traffic conditions inevitably change in growing urban areas, the initial benefits seen in terms of journey time savings or traffic flow improvements may begin to be eroded over time requiring ongoing programmes of traffic management.

5.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for policies promoting access restrictions to promote sustainable mobility:

- **Environmental benefits:** These can flow from road space re-allocation when reduced volumes of motorised traffic result in air quality and noise reduction improvements,

- **Health benefits:** Reduced traffic volumes could be an encouragement for higher levels of cycling and walking, with resultant health benefits. Reductions could also lead to fewer road casualties.

5.6 Summary

The case studies reviewed demonstrate that schemes in which general traffic lanes are re-allocated to alternative uses can be expected to meet objectives relating to reducing traffic volumes, improving journey times for the modes given additional priority (bicycles or buses), increasing the use of non-car modes and reducing casualty numbers. Successful deployment requires the support of the public and other stakeholders early on in scheme development. Where possible, priority lanes for buses and cyclists should be continuous to avoid delays both to and within general traffic. The introduction of lanes that are unlikely to be heavily used should also be avoided as these are likely to lack public support following implementation.

Little credible evidence was identified on the monetized costs and benefits of road space re-allocation schemes. This may be a result of such schemes often forming part of a wider package of measures (for instance improvements to public transport or walking / cycling infrastructure) which are then appraised as a whole.

The evidence base predominantly consists of reports of simple performance indicators from before and after studies. Whilst performance indicators may illustrate apparent trends, these may not necessarily be directly attributable to the intervention in question. This represents a weakness in the literature and indeed in the approaches used to monitor such interventions. Appropriate statistical tests should be used to identify the effects of interventions independent of other factors. Lastly, very few studies were available on the efficacy of re-allocating road space to HOV lanes and this represents an area that certainly demands further research.
5.7 References


Measure No.6: Environmental Zones

Defining areas of a city as having particular conditions attached to traffic in that area. These might relate to types of vehicle, or to vehicle speed, noise or emissions.

Cities can attempt to address a range of issues using these zones, such as the frequency or severity of road collisions and casualties, levels of active travel (walking and cycling) and the quality of the street environment. They can also reduce levels of emissions from traffic helping to reduce negative effects on human health.

Key messages:
- There is evidence that speed restriction ‘zones’ using road engineering and other physical measures can reduce vehicle speeds, injuries and fatalities. The studies did not find evidence of traffic collisions ‘migrating’ to surrounding streets.
- Compared with speed restriction zones, schemes which rely on sign-only low speed limits are much less expensive to implement on an area-wide basis, although they lead to far smaller reductions in average speed.
- Lower speed zones were found to be cost-effective in areas with high numbers of casualties, but not so in areas which already had low levels of casualties. (Although the study authors did note some issues with the quality of data behind this finding. The UK also has relatively low casualty levels compared to some other nations).
- Low Emission Zones can be beneficial in reducing emissions of harmful pollutants, from transport although there are uncertainties due to other sources of pollution that can affect measurements of air quality.
- Low Emission Zones can help local authorities comply with European limit values and thus avoid fines.

6.1 Context and background

There are a number of zone types that can applied to promote sustainable mobility:

Potential interventions
- Speed restriction zones, which can include engineered or signed-only limits (or a combination). Covering part of a street to a whole area of a city.
- Environmental zones such as low emission zones (LEZ) and noise reduction zones.
- Traffic restriction zones. These include bans on heavy goods vehicles and car-free areas or cities (e.g. residential areas, inner-city and historic areas, retail locations).
Specifically, this Measure Review will cover two distinct forms of low speed restriction, reflecting experience of developments in the UK, and LEZs. An additional study considered in the review relates to a ‘Traffic restriction zone’ in Milan, (Invernizzi et al., 2011), however as this zone essentially operates as a low emission zone it will be treated together with the studies on LEZ. Insufficient material was found to discuss Noise reduction zones in this review, and restrictions on lorry traffic are discussed in Measure No.3: Urban Freight.

### 6.1.1 Speed reduction Zones

Low speed restrictions in a street or across an area of a city are intended to reduce speeds of motor traffic within the areas treated. The aims of such initiatives are to reduce the frequency or severity of road collisions and casualties (Webster & Layfield, 2003, Grundy et al., 2009), to encourage walking and cycling, to promote a more communal street environment (Bristol City Council, 2012, Atkins, 2010) and, arguably, to provide economic benefits from the reduction of casualties (Peters & Anderson, 2012). From a wider perspective, the importance of reducing road injuries reflects the fact that they are seen to be a leading cause of loss of life and disability worldwide (Grundy et al., 2009).

An important feature of speed reduction initiatives as originally deployed in the UK was that the term ‘low speed zone’ specifically implied the use of calming measures such as speed humps and chicanes designed to encourage speeds under 20 mph (32kph). In contrast 20 mph (32kph) limits contained signs and road markings only. This distinction is reflected in the evidence contained in this review, although since 2011 the requirement for UK schemes to be exclusively one or the other type has been lifted and schemes tend to be a mixture of the two. Examining evidence for the two different approaches to lower speed does though provide some insight into the relative benefits achievable in relation to the extent of the intervention being made. In some UK implementations areas or streets with low speed limits and traffic calming elements are also part of ‘Home Zones’, in which roads are (re)designed to facilitate greater and safer use by pedestrians and cyclists.

### 6.1.2 Low emission zones (LEZ)

These are intended to reduce levels of emissions from traffic. The principle dangers in these emissions are negative effects on human health, particularly increased risk of respiratory and cardiovascular disease (Invernizzi et al. 2011, p.3522, Panteliadis et al. 2014). Emissions that are of concern include particulate matter (PM$_{10}$, PM$_{2.5}$, PM$_{1}$, PM$_{0.1}$ and black carbon/soot)(Invernizzi et al., 2011, Cyrys et al., 2014, Panteliadis et al., 2014) and nitrogen oxides, or NOx (NO and NO$_{2}$)(Morfeld et al., 2014, Panteliadis et al., 2014).

In Europe, there is an additional economic incentive for LEZs in as much as they may enable compliance with EU regulations, and thus potentially avoid attendant fines for non-compliance. LEZs can also have the benefit of reducing traffic volume. In 2010 there were 152 cities with LEZs in the EU. Germany in particular has focused on them. In 2010 The EU ‘Clean Air Directive’ (2008/50/EC) was among the strictest legislation about PM$_{10}$ in the world. For this reason many European cities have started to implement schemes to reduce PM$_{10}$ (Wolff & Perry, 2010).

Different countries have different specifications for which vehicles they restrict in LEZs. In Germany, for example, most cars with catalytic convertors are allowed into the zones. Most petrol cars in Germany have these, so the zones restrict mostly diesel cars. However,
Measure No.6: Environmental Zones

different LEZs in Germany have different restrictions for what vehicles can enter (Cyrys et al., 2014).

6.2 Extent and Sources of Evidence

Eleven items were reviewed in total: three examine 20 mph zones, two examine 20 mph limits, five examine LEZs and one examines a traffic restriction zone. All 11 studies are taken from countries in the EU. However there is a focus on the UK and Germany. Five of the studies are on UK schemes and four are based on German schemes. This reflects the literature available. Germany is of particular relevance to LEZs due its widespread adoption of that scheme type. The other two studies are based on data from the Netherlands and Italy. Nine of the 11 studies reviewed were published within the last five years, and three of these were published in 2014. This suggests that environmental zones are a topic receiving ongoing research and that the scheme types and findings discussed in this review are generally up to date.

Eight of the studies are journal papers, likely to have been written by academic authors. Two of the studies are consultancy reports. The remaining study is by a local council reporting on its own scheme (Bristol City Council, 2012). However this report shows a good degree of transparency, providing negative as well as positive findings in relation to their 20 mph limit scheme.

Five of the studies used case studies of single environmental zones. Some of the other studies looked at data combined from a number of zones in one country. Webster & Layfield (2003), Grundy et al. (2009) and Peters & Anderson 2012) all looked at a collection of 20 mph zones across London, UK. Morfield et al. (2014) looked at LEZs in 17 German cities, Cyrys et al. (2014) examine several German LEZs and Wolf and Perry (2010) discuss a more general policy context, although also including a specific focus on Germany. The studies reviewed provide a good level of primary data.

6.3 What the Evidence Claims

Evidence is presented against the classifications introduced above: engineered low speed zones, signed-only low speed limits and low emission zones.

6.3.1 Low speed zones

Two studies reviewed examined 20 mph zones in London (Webster & Layfield, 2003, Grundy et al., 2009). Webster & Layfield found that mean speeds on treated roads were reduced to 17 mph, a reduction of about 9 mph. Every 1 mph reduction of speed is likely to lead to a 5% reduction in collisions causing injury. Hence an important result of this reduction in speed is a reduction in collisions. The zones reduced injury frequency by about 42% and collision frequency by about 53% (Webster & Layfield, 2003). As well as reducing the frequency of collisions the seriousness of injury was also reduced. The zones led to reductions of killed or seriously injured casualties of about 57% (Webster & Layfield, 2003) and the ratio of such incidences to all collisions fell from 0.17 to 0.13. The frequencies of killed or seriously injured casualties were reduced for pedestrians, cyclists, powered two wheelers and car occupants.

Grundy et al. (2009) found that the greatest reduction in road casualties from the zones was amongst young children. They conclude that 20 mph zones are more effective in reducing severity of injury from collision than the total number of collisions. Traffic flows were also reduced by 15% in the zones (Webster & Layfield, 2003).

One concern surrounding 20 mph zones is that they can lead to collision migration. The fear
is that drivers simply reroute in order to avoid the slower zones, and will thus have collisions on neighbouring roads instead. However, Webster & Layfield (2003) and Grundy et al. (2009) found there was little if any collision migration onto neighbouring roads.

### 6.3.2 Low speed limits

Two reports examining low speed areas in Bristol, UK (Bristol City Council, 2012) and Portsmouth, UK, (Atkins, 2010) were considered by the review. Because these 20 mph limits did not include traffic calming measures, it is to be expected that the reductions in speed they lead to will be less than for zones (although potentially providing benefits over a wider area). Bristol City Council (2012) report mean average reductions of 1.4 mph in one pilot area and 0.9 mph in the other. Atkins (2010) reported a mean average reduction of speed across the whole scheme in Portsmouth of 1.3 mph. However, speeds in Portsmouth were already generally low prior to implementation (the mean average speed for roads covered by the 20 mph limits was 19.8 mph, before implementation). In both cities there were greater reductions of speed on roads that had previously had mean average speeds greater than 24 mph. Such roads, in the Portsmouth scheme saw reductions of 6.3 mph (Atkins, 2010).

Both Bristol City Council (2012) and Atkins (2010) report that it was hard to be confident that the 20 mph limit schemes had reduced collisions and casualties. This was simply because the number of collisions within the areas was small and fluctuated. Whether the limits led to more walking and cycling, in turn leading to physical, mental and social benefits is debateable. Bristol City Council (2012) report walking counts increasing by figures ranging from 10 to 36%. Cycling counts increased between 4% and 37%. Atkins (2010) report that the limits in Portsmouth had little apparent impact on modal share.

20 mph limits can have holistic community benefits. The 20 mph limits were generally well accepted by residents and had positive impacts on their perceptions of their area. Bristol City Council (2012) found that after implementation 83% of residents supported the limits. This was an increase from 67% before implementation. 40% of respondents in Portsmouth felt the scheme had led to decreased speeds Atkins (2010). The Bristol scheme was popular in terms of addressing speeding in residential areas which is perceived by residents as one of the most widespread antisocial behaviours (Bristol City Council, 2012). The scheme type can also engender favourable perceptions of greater community: 18% of respondents thought that since limits had been introduced people spent more time in the streets. Similarly, respondents in Portsmouth felt there was a safer environment following implementation.

This evidence suggests that 20 mph zones are more effective than 20 mph limits in reducing speed (Atkins, 2010). However 20 mph limits are less expensive to implement on an area-wide basis. The geographical extent of 20mph limits may be important: If they are consistently applied across a large area than this conveys the message that 20mph is a suitable, normal speed in residential areas. However if they are only applied in small areas, so that a cross city trip encounters a number of different speed limits, than the same message will not be conveyed.

### 6.3.3 Low Emission Zones (LEZ)

Five studies reviewed related to LEZs and a sixth examined a traffic restriction zone that also had the aim of reducing emissions. These studies found that LEZs reduced air quality pollutants of relevance to human health.

The LEZ in Amsterdam, The Netherlands, led to reductions of traffic contributions to concentrations of pollutants (Panteliadis et al.2014). Contributions to NO₂ levels were decreased by 4.9%, NO by 5.9%, PM₁₀ by 5.8%, Absorbance (a soot proxy) by 7.7% and EC (a soot proxy) by 12.9%.
A study into the LEZ in Munich, Germany, found that the zone led to reductions of POC (particulate organic compounds – a component of PM) concentrations (Qadir et al. 2013). The contribution of traffic to the concentrations was decreased by about 60%. However the overall decrease of POC was limited due to other sources of the pollutant type.

An examination of 17 LEZs in Germany found that there was a statistically significant but small (<4%) reduction of NO₂, NO and NOₓ concentrations associated with the zones (Morfeld et al., 2014). The study concluded that the effectiveness of LEZs in tackling such concentrations was still ‘under debate’ (p.2). The study does not focus on PM levels. However it does comment that PM10 mean values had been found to be reduced by the LEZ in Munich by 1% at most.

Cyrus et al. (2014) examined German LEZs in Cologne, Berlin and Munich. Using modelling they estimated reductions of PM₁₀ mass concentrations of up to 10%. However, LEZs were also associated with decreases in traffic-related soot (an important risk to health) of 52%, and decreases of diesel particle emissions of 63%. There were also important reductions of 60% in traffic-related elements of PM₂.₅ in Munich. The study implies reductions of PM₁₀ levels might be affected by meteorology. The study concluded that benefits of LEZs for human health are significant and greater than had been realised when only PM₁₀ mass concentrations were monitored.

A policy based study, with a focus on Germany (Wolff & Perry, 2010), reported that LEZs have been a popular way amongst local authorities and governments for dealing with air pollution concentrations. Germany in particular has implemented many LEZs, and has seen national average PM₁₀ concentrations fall from 24.4 ug/m³ in 2005 to 21.2 ug/m³ in 2008. The number of German cities exceeding the European Limit Values for PM₁₀ fell from 36 in 2005 to 18 in 2008.

Invernizzi et al. (2011) report on a traffic restriction zone in Milan, Italy, that sought to reduce harmful emissions in the city centre area. Traffic restriction zones aim to improve both air quality vehicular congestion. Other European examples are in London and Stockholm. The Milan zone means that drivers wishing to enter have to purchase a ticket, unless their vehicle meets the Euro four standard. The zone differs from a pedestrianised zone as vehicles that are compliant, can enter. Invernizzi et al. (2011) report that PM₁₀, PM₂.₅ and PM₁ concentrations had been found to be unaffected by the zone. However black carbon results suggested that the black carbon contribution to PM₁₀ decreased by 47% and 62% in the traffic restricted zone and pedestrian zone respectively. The study considers that the absence of effect on overall PM₁₀ may be due to the small size of the restricted zone. However, local traffic generally only makes a minor contribution to overall PM₁₀ concentrations (see for example Querol et al., 2004).

In conclusion, as the term suggests, the main aim of low emission zones is to reduce emissions of harmful pollutants. Four of the six studies reviewed suggest that such zones can be successful in this aim. Invernizzi et al. (2011) and Morfield et al. (2014) were less positive in this respect. The prime benefit of reducing pollutants is to reduce threats to human health. Panteliadis et al. (2014) found that the reductions of pollution caused by the zone they studied led to a reduction in EC that would lead to increased life expectancy of around 2 months for those living close to the road measured. However the health benefits of LEZs can be unevenly distributed as concentrations of pollutants such as PM₁₀ can vary greatly even within a small urban area (Cyrus et al., 2014). It is possible thought the greatest benefits from LEZs will be enjoyed by those suffering the worst air quality impacts, thus making the distribution of benefits a fair one.
6.3.4 Nature of Methods

Most of the studies relating to 20 mph zones and limits drew on ‘before and after’ data. The main outcomes measured in these studies were traffic speeds, collision frequency and seriousness of injury from collisions. Bristol City Council (2012) taking a more holistic approach also made walking and cycling counts, noise and air quality assessments, conducted doorstep questionnaires and monitored bus performance. Similarly Atkins (2010) drew on traffic volume data and qualitative surveys investigating support for a 20 mph limit scheme.

A common weakness amongst the methodologies investigating 20 mph zones and limits is that often only two or three years of collision data after implementation are available. This is not a serious drawback when a large number of zones are being examined together (as in Webster & Layfield, 2003 and Grundy et al., 2009) but is more problematic when only one area is being researched as collision numbers are likely to be small and to fluctuate. Bristol City Council (2012) and Atkins (2010) concede that they cannot reach confident conclusions about the effect of 20 mph limits on collision and casualty numbers. The traffic count data used by Atkins (2010) is also questionable, as the data provides a before and after comparison but no control roads (although the 20 mph limit areas are compared with national averages). Hence, Atkins concede that factors such as the economic downturn may have affected the results. For instance, they note that during the time period studied, traffic volumes fell by a greater degree in another UK city, Southampton, than they did in the 20 mph limit area being investigated.

Of the studies examining 20 mph limits and zones, the evidence regarding effects on collision numbers provided by Webster & Layfield (2003) and Grundy et al. (2009) is particularly strong as it covers a large time period and aggregates figures from a number of zones (for instance Grundy et al. covered from 1986-2006, and used data covering 119,029 road segments, a road segment being a stretch of road between junctions) with non-zoned roads acting as controls. Grundy et al. found that their results were robust under sensitivity analysis. The London studies used police data that tends to under-report road injuries, but this under-reporting remains consistent between 20 mph zones and non-zone roads (Grundy et al. 2009).

Two studies comment on the possibility of regression to the mean in relation to understanding the impact of 20 mph zones on numbers of collisions and casualties (Webster & Layfield, 2003, Grundy et al. 2009). This is the idea that if zones are implemented in areas that have experienced unusually high numbers of collisions, it is likely due to natural fluctuation that these numbers would decline in the following years even without the intervention. However both studies conclude that regression to the mean did not affect their findings. In support of this Webster & Layfield point to the fact that many zones they studied were not selected because of high collision rates and the long periods of time after implementation that the data covered.

As mentioned above amongst studies investigating 20 mph zones and limits, Bristol City Council (2012) and Atkins (2010) took a more holistic approach to evaluating success by including qualitative surveys. Good sample sizes were achieved for these, with 1,066 responses being gained to a questionnaire and 1,838 doorstep surveys being completed for Bristol City Council and 1,445 qualitative interviews being conducted for Atkins (2010). For the latter interviews, the sample was stratified by age, gender and ethnicity.

With the exceptions of the German policy focused study (Wolff & Perry, 2010) and Cyrys et al. (2014), the LEZ studies chosen for review used actual data of air pollution measurements rather than modelling. A range of different technologies was used to record the measurements of the different pollutants that the different studies measured. Some of the
studies used measurements from the same location, before and after implementation of the LEZ (Panteliadis et al., 2014 – four years of data in total, Qadir et al., 2013 – three years of data in total). However Panteliadis et al. did not have traffic count data for before the intervention and so state they could not discount the possibility of the reported decreases in air pollution being attributable to decreases in traffic volumes in the area, potentially resulting from the economic downturn for example.

Others did not use before and after measurements but compared simultaneous readings from within and without the LEZ (Invernizzi et al., 2011). Panteliadis et al., 2014 used one measurement station as a control to compare the roadside data against. However, whilst this station indicated background levels as opposed to roadside readings, they concede that it was also in the LEZ and so their findings may have underestimated the effect of the zone. Morfeld et al. (2014) used both before and after measurements (four years of data in total) and also measurements from inside and outside the LEZ, and can be considered a strong methodology in this respect.

A problem commonly reported amongst the studies in accurately assessing the effectiveness of LEZs is isolating the impact of traffic specifically on air quality. This is difficult as pollutant concentrations can be affected by the weather (Panteliadis et al., 2014, Cyrus et al., 2014) including wind (Panteliadis et al., 2014, Invernizzi et al. 2011). The studies generally sought to control for the weather conditions during the measurement period (Morfeld et al., 2014). Season also has an influence on pollution. Winter tends to see higher levels of pollutants than summer (Invernizzi et al., 2011). The effects of traffic also have to be separated out from other sources of air pollution. These can include local sources such as cooking and solid fuel combustion (Qadir et al., 2013), as well as transboundary pollution that originates from sources outside the local area.

Other potential factors that can obscure LEZs effect on air pollution include, ozone concentrations (which reduce concentrations of NOx independently of any reduction in total NOx), school holidays and other temporal variations in traffic, the evolution of lower emission vehicles in general (Morfeld et al., 2014, Panteliadis et al. 2014), residential and business heating (Invernizzi et al., 2011) and construction work and associated heavy goods traffic (Qadir et al., 2013). One of the studies conducted positive matrix factorisation in order to separate out traffic from other sources of pollutants (Qadir et al. 2013). Other studies sought to place the air quality instruments in such places as would minimise the effect of non-traffic sources of pollution (Invernizzi et al., 2011).

The LEZ studies applied a variety of statistical tests to their data including linear regression, multivariate and sensitivity analysis (Panteliadis et al. 2014), positive matrix factorisation (Qadir et al. 2013) and multiple linear and log-linear fixed-effects regression modelling (Morfeld et al., 2014). Morfeld et al. in particular used very thorough statistical methods.

A gap that remains in the evidence regard LEZs is the existence of a number of studies measuring the same specific pollutants: the different studies reviewed focused on a range of different pollutants, so that the overall picture of the effect of LEZs on each specific pollutant lacks corroboration by multiple papers. Such evidence may be available however, with further investigation.

6.4 Lessons for Successful Deployment of this measure

6.4.1 Low speed zones and limits
There are some issues surrounding the transferability and generalisability of the findings of some of the 20 mph studies. Three of the studies into 20 mph zones are based on data from
London. London is by far the largest city in Europe and therefore may not be representative of the traffic conditions in other European cities. However, Grundy et al. (2009) suggest that their evidence from London is relevant to other major cities. They found that the effect of 20 mph zones was similar in inner and outer London areas, and conclude from this that the success of the intervention is little modified by area type.

The transferability of the evidence on 20 mph limits in Portsmouth is questionable. This is because many roads in the city had mean average speeds under 20 mph even before implementation (Atkins, 2010). Average speeds on roads before implementation would be important for authorities in other cities to consider when exploring the use of 20 mph limits. In general, careful consideration and good data should be used when deciding what streets to include in a 20 mph limit area (Bristol City Council, 2012).

The studies examined give some indications of economic aspects of implementing 20 mph zones or limits. Zones, which include traffic calming are more expensive than limits, which only require signage. 20 mph zones could be very expensive to implement on an area wide basis.

Peters & Anderson (2012) focus specifically on the economic impacts of 20 mph zones. They assessed the economic benefits and costs of such zones using two methods: cost benefit analysis (CBA) and cost utility analysis (CUA). These two assessment measures take account of different sets of costs and benefits, including quality adjusted life years as a result of injury, police, local government costs, etc. The main economic benefit of 20 mph zones is in reduction of casualties. Webster & Layfield report that in 2003 each serious casualty in the UK was valued at £134,000 by the Department for Transport.

Peters & Anderson (2012) conducted one-way, threshold and probabilistic sensitivity analyses. They found that in areas of high numbers of casualties, implementation of 20 mph zones was found to be cost effective according to CBA but not by CUA. With CBA the net present value was -£25,500. In low casualty areas neither assessment method found 20 mph zones to be cost effective. Peters & Anderson (2012, p.40) note that their findings should be treated with caution due to the ‘quality, age or absence of reliable data for many parameters’. In addition the UK in general has relatively low numbers of traffic casualties (Grundy et al. 2009). This may affect how representative the UK studies are for other European countries, as calculations of the cost effectiveness of 20 mph zones depends partly on the background rate of collisions (Peters & Anderson, 2012).

The impact of 20 mph limits may be increased if accompanied by supporting measures aimed at generating public support for, and adherence to, the limits. These include communication campaigns, asking businesses and other employers of drivers to encourage compliance and other awareness strategies (Bristol City Council, 2012, Atkins, 2010). Bristol City Council (2012) suggest that for 20 mph limits to be effective, there should be partnership between stakeholders including the local council, the police, local businesses, motoring organisations and cycling and walking organisations etc.

Atkins (2010) report a number of practicalities that should be addressed when implementing 20 mph limits. Challenges encountered in Portsmouth, UK, included limited resources for the design of the scheme, vandalism of the signs and signs ‘cluttering’ some junction. The report also comments that the Portsmouth 20 mph limits were intended to be self-enforcing. It is unlikely that police will be able to enforce area wide 20 mph limits.

6.4.2 Low emission Zones (LEZ)

One political and economic driver of implementation of LEZs comes from the European Union’s Air Quality Directive (Cyrys et al. 2014). [The degree of response to this driver has
differed greatly amongst European countries, however, with many countries still violating EU air quality limits.) The directive addresses air quality with some of the strictest legislation in the world (Wolff & Perry, 2010). It requires measurement of PM$_{10}$ on an hourly basis. There are potential fines for countries failing to meet the air quality limit values. This can result in individual cities facing fines. For instance Leipzig, a city in Germany, faced a potential penalty of 700,000 Euros per day, for failing to comply with limits (Wolff & Perry, 2010). To set against the savings of avoiding fines are the costs involved in implementing and then enforcing the zones (Cyrys et al., 2014). Zones can be enforced by a traffic camera system that reads license plates and automatically issues fines (Panteliadis et al., 2014).

The extensive uptake of LEZs, particularly in Germany suggests that the zones can be implemented on a widespread basis. In 2010, 41 German cities had LEZs (Wolff & Perry, 2010). Countries with high concentrations of air pollution are likely to have air quality plans which provide a helpful context for implementing LEZs (Panteliadis et al, 2014). Thus an obvious driver of LEZ implementation is if a city consistently breaks air quality limit values. For instance Milan, Italy, implemented a traffic restriction zone in response to long periods of high PM concentrations, sometimes reaching daily means of more than 75 µg/m$^3$ (Invernizzi et al. 2011).

This review has in part focused on LEZs, one of the strategies within air quality plans. However air quality plans can also include other complementary measures including ‘traffic regulation, stimulation of public transport usage, ring road utilisation, traffic flow improvement (and) speed limit reduction’ [Panteliadis et al. 2014, p.113].

Some studies highlight issues with public acceptance of LEZs (Wolff & Perry, 2010, Invernizzi et al., 2011). There can be particular issues with inconvenience for residents and businesses located within the zones (Wolff & Perry, 2010). Cyrys et al. (2014) suggest that LEZs can limit some people’s mobility, with some commercial and private vehicles being excluded from the zones (Wolf & Perry, 2010).

LEZs can encourage city residents and businesses to buy vehicles compliant with the LEZ requirements. This means the zones can have an additional benefit for air quality, even outside the boundaries of the zone. However, it does raise issues around fairness as it may be those who cannot afford to buy a new car that are penalised for entering the zones.

### 6.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for Environmental Zones in promoting sustainable mobility:

- **Road safety**: Reducing traffic speeds creates a better street environment, where it is safer for children to play.
- **Health benefits**: Arising from increased walking and cycling due to perceptions of (and actual) improvements to road safety.
- **Environmental benefits – Air Quality**: The main gains from lower pollution in LEZs are for human health, although these can be unevenly distributed as concentrations of pollutants such as PM$_{10}$ can vary even within a small urban area. It is possible however, that the greatest benefits from LEZs will be enjoyed by those suffering the worst air quality impacts, thus making the distribution of benefits a fair one.
- **Environmental benefits - Noise**: Reduced traffic speeds could reduce local noise levels.
6.6 Summary

One strength of the studies reviewed is that they relate to specific case studies, in specific cities for instance, and generally use real world data and measurements. The contemporary nature of the evidence is also a particular strength. As discussed a significant proportion of the studies reviewed used before and after data and/or control data.

Conversely, the small number of studies from countries other than the UK and Germany is a slight weakness in the evidence presented. A gap in the evidence on LEZs is that the studies reviewed did not greatly investigate issues surrounding enforcement of the zones. Another gap in the evidence is that the studies did not tend to discuss the economic aspects of the schemes in detail. The two main economic points that were made are that LEZs can help compliance with European limit values and thus avoid fines, and that 20 mph zones may be cost effective in areas with high numbers of casualties but were not found to be cost effective in areas of low casualties.

The studies present strong evidence that 20 mph zones can reduce vehicular speeds and the attendant injuries and fatalities. The studies did not find evidence of collision migration. 20 mph limits are much less expensive to implement on an area wide basis than zones, but lead to far smaller reductions in average speed albeit this will be over a larger area. The reduction in speed will depend, to a substantial degree, on the average speeds on a road, prior to implementation. 20 mph limits can be considered a way to achieve holistic benefits for an area, both in terms of traffic conditions, and quality of life. The evidence suggests that because of these benefits 20 mph limits can be viewed quite positively by residents. There is a weakness with the evidence of the effect of 20 mph limits on collisions and casualty numbers, due to the small and fluctuating numbers of these in the treated areas. Hence the safety benefits of 20 mph limits, whilst logical given the reduction in vehicle speeds, have not been evidenced with certainty.

Four of the six studies on LEZs suggest that they can be beneficial in reducing emissions of harmful pollutants. These studies had strong methodologies and so this finding can be given some credibility. The other two studies suggested LEZs may not be so effective. One problem with concluding on the effects of LEZs on pollutant concentration is the very localised nature of such concentrations, and the existence of other sources for them, besides motor vehicles. Hence measurements taken in two different places within the same LEZ can yield different results. As discussed weather and season can also influence measurements, although some studies controlled for these factors. Evidence suggests that there can be some issues surrounding public acceptance of LEZs. They have been a strategy that arguably been popular with local authorities. Although take up outside of Germany has not been very widespread. In addition there has been debate about whether citywide or countrywide frameworks can best achieve the aims and deployment of LEZs.

In conclusion, the evidence reviewed suggests that all three types of environmental zone, 20 mph zones, 20 mph limits and LEZs can be viable and beneficial schemes to implement, although the caveats about the evidence reviewed, as discussed above, should be considered.

6.7 References

2. Bristol City Council (2012). 20 mph speed limit pilot areas. Monitoring report.[online].UK:


Measure No.7: Congestion charging

A pricing scheme that can be introduced to charge users to access specific parts of the road network.

Setting a (higher) price to use parts of the road network will discourage some users from driving. This can offer benefits in respect of congestion, journey reliability and environmental factors. It could also reduce pressure for additional capacity on the network.

Key messages:
- The economic effects of the introduction of a congestion charging scheme are influenced by the attractiveness of the city as a destination; i.e. attractive enough to continue to draw sufficient people into the congestion zone to support economic activities.
- Time savings are considered the main benefits for road users, but there is a large variety in the value of travel time savings from congestion charging.
- Economic benefits can also be derived from reduction in CO2 and other emissions, and reduction in road casualties.
- Due to uncertainties in the existing evidence regarding economic benefits, the decision on whether or not to introduce a scheme has been ultimately a political one.
- In the short term, congestion charging reduces car traffic within the charge zone, but effects may diminish over time.
- Congestion charging on its own, without supporting measures such as the availability of alternative modes of transport to the car (with enough capacity), has a low probability of generating substantial benefits.

7.1 Context and background

Congestion charging aims to reduce demand on specific parts of the road network by increasing the cost of using those roads.

Potential interventions
- Pricing schemes that can be introduced to charge users of specific parts of the road network, usually car drivers.
- Typically implemented with a ‘cordon’ of charging points around the area to be managed.

The economic reasoning behind a congestion charging scheme is that demand reduces due to a higher price and that no additional supply is necessary. Less demand means less vehicles on the roads, which should lead to less congestion, shorter travel times and to a reduction of other negative externalities such as emissions and accidents. The
characteristics and aspects of the scheme such as the level of the charge and the time the charge apply might vary, but the underlying principle is the same: to charge users to use a certain part of the network.

Typical objectives of a congestion charging scheme are to: reduce traffic congestion and travel times; increase road safety; decrease other negative externalities of road transport such as noise and pollution and to raise revenue [that might be used to promote alternative transport modes]. In situations where it would not be feasible to introduce new road capacity (such as in historic city centres for example) congestion charging could also be used as a means to manage, or alleviate growth in demand.

Note: Interventions that charge for use of specific corridors (HOV lanes for example, or for the use of infrastructure such as a bridge are not discussed here).

### 7.2 Extent and Sources of Evidence

The reports and papers considered for this measure review focus mainly on the two most important examples of congestion charging operating in European cities: the case of London and Stockholm. There are some other examples studied (i.e. Singapore, Milan and Lyon), but these are only partially analysed and/or modelled in the reports and papers. The fact that congestion charging schemes have only been implemented in a few cities worldwide provides a limitation to the evidence available. All reports and papers that have been analysed have been written after the introduction of congestion charging schemes (2003 in London and 2006/2007 in Stockholm). The majority of the reports date before 2010.

In total 24 academic papers and reports have been analysed. The majority of the papers and reports dealt with the London congestion charging, while only a few discuss the Stockholm example or provide a general analysis of the principle of congestion charging in general. One paper discusses the road-pricing scheme introduced in Milan.

About half of the items reviewed are academic papers, with the other half being project reports. One paper (Bleimeier et al. 2010) presents a meta study about rewarding car drivers for avoiding rush hours. Of the project reports, the majority relate to congestion charging in London, produced by Transport for London, which is the authority responsible for nearly all transportation in London. It is noted that some of the papers and reports are written by people involved in the introduction or implementation of the congestion charging scheme, which might lead to some biases.

### 7.3 What the Evidence Claims

#### 7.3.1 General remarks

The papers and reports mainly describe ex-post analyses of congestion charging schemes, often as a case study including some data analysis. In addition there are a number of papers which discuss a simulation or a theoretical model, which are not based on a specific scheme or intervention. The majority of the reports and papers make use of traffic data and combine these with some assumptions and other research. Very few meta studies have been carried out; the large majority of the reports and papers analysed are project reports. Not all of these project reports do describe factual interventions, for example Souche et al. (2013) and de Palma et al. (2005) carry out modelling studies that do not consider a factual intervention. While some studies focus only on carrying out a cost-benefit analysis (CBA), such as Eliasson (2003), others take a broader perspective into account and put congestion charging in a wider context. The summary of what the evidence claims will be discussed in the rest of
7.3.2 Traffic and travel times reduction

One of the main objectives of the introduction of congestion charging in urban areas is to reduce the level of traffic. By reducing the amount of traffic, ceteris paribus, the level of congestion decreases. Because of the fact that there is less congestion, travel times diminish and travel time reliability increases. This effect is discussed in review documents by Eliasson (2009), Prud’homme and Bocarejo (2005), Rotaris et al. (2010), Buckingham et al. (2010), Transport for London (2008), Evans (2007), Balwani and Arch (2008), Kopp and Prud’homme, (2010).

In general, there are large differences seen in the valuation of time savings. The majority of the reports, papers and analysis use travel time savings as starting point for the determination of the benefits of congestion charging. The tests performed by Raux et al. (2012) show a large sensitivity to time savings and the resultant benefits, which is something that should be taken into account. It is of utmost importance to accurately estimate or calculate the value to time and, if possible to differentiate for various target groups.

Eliasson (2009) values shorter travel times in Stockholm’s charging scheme at 496 mSEK per year (approximately €50 million) and adds another €7.5 million for more reliable travel times. Kopp and Prud’homme, (2010) find a lower value for Stockholm in their analysis and claim that time gains for car users in Stockholm are €19 million a year. Prud’homme and Bocajero (2005) value the reduction in congestion costs for London at €68 million per year. Evans (2007) values total travel times savings at almost 500 million GBP. This is the sum of benefits for both non-business and business travel.

These examples show that there is a large variety in travel time savings, which is dependent on the valuation of time rather than on traffic data (although the latter differs between studies too). Without further research it is difficult to state what the exact value are that should be taken into account, though it seems valid to state that travel time savings are overestimated in some of the studies. This could be considered a major drawback for analyses concerning congestion charging. Santos and Bhakar (2006) suggest that value of travel time savings should not be used to determine the impact of congestion charging, but indicate that generalised costs per trip seems a more valid measure.

7.3.3 Increase road safety

One of the effects of the reduction of traffic is that the number of accidents might be reduced. The indirect effect of congestion charging would be that having fewer vehicles on the road would lead to fewer accidents. Rotaris et al. (2010) values increased traffic safety at 211 mSEK / year (approximately €23 million), but this number also includes some environmental effects. Eliasson (2009) values increased traffic safety at 125 mSEK / year (approximately €11 million per year). There is also an argument that reduced traffic congestion might lead to a higher average speed in the inner-city that, in turn might increase the chance for accidents. Despite this, the overall effect of a congestion charge scheme on road safety seems to be positive.

7.3.4 Reduction of emissions

One of the main effects of traffic reduction is the reduction in vehicles’ emissions. Transport for London (2008) suggests that: “there have been modest beneficial impacts to emissions of key road traffic pollutants”. They estimate scheme-attributable reductions of 2.5 percent to oxides of nitrogen (NOx), 4.2 percent to fine particles (PM10), and 6.5 percent for carbon dioxide (CO2). Evans (2007) claims that substantial CO2 savings are obtained due to the
measure No.7: congestion charging

congestion charging scheme in London. The methodology used to determine these emission savings is relatively similar through all the papers and reports. The reduction in traffic and or kilometres driven is converted to an emission reduction in tonnes, which is converted into monetary terms. Besides that, less traffic reduces the level of congestion, which represents an additional positive effect for the quality of air. In the last two decades, [environmental] sustainability has become increasingly important and therefore it is often mentioned as one of the main arguments concerning the introduction of a congestion charging scheme in urban areas.

7.3.5 Other aspects

Often an increase in the use of public transport within the urban road pricing scheme area is observed. In most cases, this positive effect is associated to the congestion charging scheme, in part related to greater reliability of services. However, often the service levels and frequencies of the public transport are increased in the congestion area as a way to promote alternatives to car use. The increased frequency and quality might of course lead to higher transit even in the absence of a congestion charging scheme. Casemyr (2006) estimates the contribution of the Stockholm congestion charging trial to public transport ridership. The author states that public transport travelling increased by 45,000 passengers to and from the inner city – an increase of six percent compared to the previous year. It’s difficult to distinguish the effect due to the congestion charge and the effect due to the improvement of the public transport system. Eliasson (2009) considers the effect of increased ridership, but does not consistently relate it to the expansion of the public transport network. It is important to try to separate the increase the effect of increased ridership due to the congestion charge from the effect due to the improved public transport system. However, to separate these two effects could be difficult.

Congestion charging can lead to positive net revenue for local government. Both Transport for London (2008) and Rotaris et al. (2010) suggest that the congestion charge scheme might generate positive net revenue for the public finances. However, it would be wrong to consider the public funding benefits solely as benefits on a societal level. Kopp and Prud’homme, (2010) state that “It is money taken out of the pocket of car users, which obviously decreases their welfare and welfare in general.” (although they will benefit from reduced congestion to offset this).

An indirect effect of congestion charging could arise from any positive health benefits that flow from lower emissions. Eliasson (2009) suggests that the emission reductions seen in their study are estimated to 5 life-years saved. Though the effect of a less polluted living environment is proven within academic and business research, it might be hard to prove that these benefits can be derived solely from congestion charging. Indeed, transport accounts for a large part of urban pollution but many other factors have also a role in it.

7.4 Lessons for Successful Deployment of this measure

Two main issues are important concerning the transferability and upscaling of congestion charging. These are the factors relevant for the introduction of a scheme and the factors relevant to the determination of the effects of a scheme.

To introduce congestion charging, strong political commitment is required (and that commitment over the time taken to introduce and see benefits from a scheme). In London, the mayor was by far the major proponent of congestion charging (Buckingham et al. 2010). Besides political support, it is necessary to have a legal framework that allows a local authority to introduce some forms of congestion charging. For example, in order to introduce
the London scheme, an earlier act of parliament was necessary. This is something that should be taken into account when planning to deploy such a measure. Another important aspect to consider, especially in terms of costs for the scheme, is the technology that is going to be used to operate the scheme. Even when the technology is similar, the implementation costs might differ significantly between locations. In Stockholm the implementation costs were relatively low (Eliasson, 2009), mainly because the congestion area is limited to the inner-city island, having only a few entry points. Differences in the implementation costs might have a strong influence on the economic viability of a congestion charging scheme. Hamilton (2011) thoroughly analyses the costs of Stockholm’s congestion charging and finds that, although not necessarily easily achieved, costs could have even been slightly lower.

The economic effects of the introduction of a congestion charging scheme are dependent on various factors. However, two main economic variables are very important, namely the attractiveness of the city and the presence of alternative transport options. If a city is very attractive people are more likely to still come to the city, even though they have to pay. If attractive amenities, facilities or other attractions are located within the scheme zone, people are more likely to come despite the introduction of a charging scheme, than if there are no amenities and the city is not that attractive. Both London and Stockholm have a very strong competitive position in their own regions.

One of the most important aspects however to determine the success of a congestion charging scheme is the availability of an alternative mode of transport. The system is more likely to succeed if there is a good alternative to car use with enough capacity available, and if (as in the case of London for example, there is a strong culture of public transport use). People that avoid entering the charging area can take another route (not applicable for destinations within the charging area), or use another mode of transport. In the London case, there was a very good alternative to going into the charging zone by car, namely going by public transport (Givoni, 2012). The very extensive public transport network in London is a factor that must not be underestimated for the effects of the introduction of the congestion charging scheme. Also in Stockholm, the introduction of the charging zone was accompanied by an expansion of the bus network (Casemyr, 2006). Cities that cannot offer such a valid alternative are likely to experience lower impacts from the introduction of a charging scheme.

An important economic aspect that is not taken into account to any great extent in the material reviewed is the economic crisis that has hit affected many parts of the world since 2007/2008. There may have been effects from this on results in some of these studies due to employment changes, or financial pressures, for example on driving behaviours. This is also the case for variables such as fuel prices and / or taxes. Where these variables experience substantial changes, they are likely to influence results and should therefore be taken into account, which unfortunately is not the case in the large majority of the papers and reports analysed here.

Another aspect to consider in terms of transferability is the fact that a congestion charging scheme is often part of a set of measures, which could include a number of wider, partly social objectives. It usually fits within a pro-environment policy perspective, which might include, but is not limited to, bicycle projects, public transportation expansions, emission measures or active mobility management. These objectives are not necessarily social objectives per se, but might be partly related to social goals. For example, accessible and extensive public transportation for people who cannot afford a car might be a social objective, though it is not solely focused on this issue. Cities or regions that are willing to implement
congestion charging need to take this into account and take these costs and benefits into account. The costs and benefits of a congestion charging scheme might vary if such a scheme is not accompanied by or part of a set of measures.

### 7.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for Congestion charging:

- **Environmental benefits:** Where congestion charging succeeds in reducing traffic, the wider benefits include: improved air quality, noise reduction, health benefits, and an improved street environment.
- **Road safety:** The evidence suggests that congestion charging schemes have had a positive effect overall on road safety, although traffic calming measures may also need to be put in place in parallel.
- **Public transport patronage:** This measure can contribute to increased public transport use (although it is difficult to establish causality as public transport services are often improved as part of congestion charging schemes).

### 7.6 Summary

The context in which any congestion charging scheme is being introduced is important, and will in part determine what economic benefits might be seen. It is also the case that primarily the decision as to whether or not to implement congestion charging remains a political decision.

The evidence collected and analysed shows that congestion charging might have both positive effects (e.g. Eliasson, 2004 and Rotaris et al. 2010) and negative effects (e.g. Prud’homme and Bocarejo, 2005 and Kopp and Prud’homme, 2010). Time savings are seen as the main benefits for road users, but they are often overestimated. As a consequence, where this outcome is being used then it is of the utmost importance to accurately measure and define any time savings, since sensitively analyses show a large dependency on this variable.

Consideration should also be given to the issue of short term versus long term effects. Various papers show that there are short term effects of congestion charging such as reduction of traffic within the charging zone, though it seems that on the longer term these effects diminish. Burris et al. (2004) show that price elasticities decreased on the longer term.

In general, the literature on congestion charging is limited to just a few case studies in the world, which makes it less suitable for generalisation. Next to that, very few meta studies are carried and were thus available for this review. The analyses that have been carried out show that congestion charging is most likely to be implemented as part of a set of measures.

Congestion charging on its own has a low probability of generating substantial benefits. One of the key requirements is an alternative mode of transport with enough capacity, such as public transport. If there is no alternative available or this is not a viable substitute, then the beneficial effects on congestion are likely to be reduced.

### 7.7 References


Measure No.8: Parking Policy

Use of parking policy and parking management as a tool to influence and manage car traffic in and around urban areas.

As most car trips end up in a parking space there is an opportunity to use parking policies that control availability and price in a city to have an effect on managing (car) travel demand.

Key messages:
- Evidence is unanimous on the importance of parking to manage car travel demand in urban areas, with parking issues strongly influencing the decision-making process for travellers.
- Parking management schemes do not usually require large investment (compared with public transport infrastructure), and can be realized in a relatively short time.
- Restrictive parking policy measures (i.e. parking pricing) are not seen to have detrimental effects on the local (retail) economy.
- Effective parking management can actually increase the attractiveness of a city centre and its economic vitality.
- Parking policies can contribute to reducing car commuting. Giving commuters the choice between free parking or its equivalent cash value (‘parking cash-out’ policies) have proved to be very effective in reducing car commuting.
- Parking management, and increasingly technology-based ‘smart-parking systems’, can reduce search time, or ‘cruising’ by drivers looking for parking spaces. This can bring significant benefits in fuel use, air quality and congestion.

8.1 Context and background

Since the 1990s parking policies have increasingly been used as a tool to manage car traffic in and around urban areas in Europe.

Potential interventions
- Traditional parking management controls (pricing / availability of spaces)
- Smart Parking systems.
- On-street parking sensors
- Real-time parking availability and pricing information
- Workplace parking charges

Parking is normally managed at a local level, meaning that local authorities or city administrations make policy regarding parking. Usually a municipal parking policy has four
main aims (Mingardo et al, 2014):

1. To contribute to a better accessibility and mobility of the urban area;
2. To contribute to a better quality of life in the city (mainly a better air quality and quality of the living environment);
3. To support the local economy.
4. To raise municipal revenue.

Compared to other local transport policies parking management has two clear advantages (Mingardo et al, 2015; P&P, 2015, Litman, 2006):

- Parking management interventions do not usually require large scale investments, as might the provision of extra public transport services, and it can be realized in a relative short time;
- Some form of parking management is already deployed in most of cities and towns; this makes the societal acceptability of parking easier than for example the introduction of a congestion charge scheme;

### 8.2 Extent and Sources of Evidence

The reports and papers considered for this measure review refer to a variety of parking policy measures in different cities within and outside Europe. While some of the papers (Shoup, 2005; Litman, 2006; Mingardo et al, 2015) describe the parking policies in general, most of them focus on specific case studies and/or projects (among others: Hagelin and Perone, 2004; Fabusuyi et al, 2013; Guo, 2013; Rye et al, 2006). Most of the papers and articles are peer reviewed and they have all been written in the last 15 years. In total 25 papers and reports have been analysed for this measure review.

Some of the paper presents quantitative evidence of the effects of parking policies. None of the paper includes a complete cost-benefit analysis, but some paper do report on costs or benefits related to the implemented measure. These data could be used to perform a CBA on parking related policies.

### 8.3 What the Evidence Claims

#### 8.3.1 General remarks

The papers and reports mainly describe ex-post analyses of parking policies, projects involving parking or the effect of specific parking measures on traffic and mode shift. Most of the times they include a case study and/or data analysis. There are no papers discussing theoretical models and/or simulations, so almost all the item reviewed are based on a on a specific scheme or intervention.

The majority of the reports and papers make use of data on modal split, parking search traffic, occupancy ratios, car ownership, vehicle miles travelled and related carbon emissions. The rest of this section presents an overview of the evidence that has been reported in the papers analysed.

#### 8.3.2 Reduction in search traffic

One of the major negative externalities caused by inadequate parking management is search traffic or cruising for parking – i.e., when people drive around in search for an available parking space. Cruising leads to not only additional extra pollution, noise and accidents but it also increase the costs for drivers – i.e. extra time and fuel. According to Shoup (2007), “A surprised amount of traffic isn’t caused by people who are on their way somewhere. Rather it
is caused by people who have already arrived”. The city of Amsterdam estimates that residents cruising for parking daily accounts for 50,000 km, which is approximately 18 million km a year (Gemeente Amsterdam, 2013).

Van Ommeren et al (2012) found that cruising might negatively affect other motorists since it may slow down overall traffic. In North America, evidence suggests that on average 30% of urban traffic is cruising for a parking spot and the average cruise time is 8 minutes (Shoup, 2007). While average-searching time does not differ much among different locations within the same town, it does increase sharply when on-street parking becomes free (Shoup, 2005).

Several studies conducted in different cities in North America during several years estimate that between 8% and 74% of traffic flows in urban areas is cruising for parking (Shoup, 2005). The author suggests also that solo drivers are more likely to “search for under-priced curb parking because they cannot split the cost of off-street parking with any passengers” (Shoup, 2005; p. 362). In an experiment in California, he found out that the average occupancy rate of vehicles parked at the curb was 1.3 and of vehicles parked in off-street facilities was 1.7. This suggests that under-priced parking fees tend to allocate scarce urban space (parking) to solo drivers allowing fewer people to visit the city centre.

New technology applied to parking can help drivers to reduce search traffic. For example in the city of Pittsburgh (USA) a technology-based smart parking system pilot project that provides real-time information to the users has proved to be effective (Fabusuyi et al, 2013). A survey among the users reported that 57.2% of drivers needed less time to find a parking space; the magnitude of the reduction varied from 1 to more than 6 minutes less search time. The authors estimate the pilot to have saved 5,746 hours of cruising valued at $117,460 and 2,873 gal gas valued at $10,056.

The SF park pilot project in San Francisco has produced similar results (SFMTA, 2014). The system involve an area where all on-street parking bays are equipped with sensors. These sensors allow the local authority to collect detailed data on parking management and use. Some of the data are used to give real-time information to drivers on occupancy rates and fees (that vary according to the occupancy rate). Detailed data collection and analysis show that parking availability has improved dramatically with the target occupancy rate (60-80%) increased by 31%; cruising for parking has reduced by 43%, with 30% fewer vehicle miles travelled and GHG emissions. Transit speed increased where double parking was reduced and, most important, net parking revenue increased slightly while the average hourly fee rate decreased (SFMTA, 2014).

8.3.3 Reduction in car commuting

Parking policies can have a strong influence on the modal split of commuters, especially when parking management is applied at company sites. Very often, a parking space at the workplace is the crucial factor for employees to use their car for commuting. Surveys in different French and Swiss cities (P&P, 2015) show that employees who have a guaranteed parking space at their working place use their car more than those without a guaranteed space. In Switzerland 81% of employees with a guaranteed parking space drive to work against a 35% of those without a guaranteed parking space. In a survey among employees in three French cities it was found that more than 90% of employees that have a guaranteed parking space use the car to commute; this percentage is halved when employees don’t have a guaranteed parking space.

Parking cash-out policies – i.e. giving commuters the choice between free parking or its equivalent cash value to stimulate alternative modes of travel – proved to be very effective in
Reducing the percentage of commuters travelling by car (Shoup, 2005). The author found evidence for modal split reduction in commuting by car between 5% and 24% in eight case studies in California. Additionally this kind of schemes produce also net economic benefits for employers. Indeed the cost of parking cash out policies is about 2.5% of the capital savings on required parking. As suggested by the author “if the cost of capital is above 2.5% a year, parking cash out thus saves more than it costs” (Shoup, 2005; p. 265).

When local authority apply similar policies, the results can also be quite effective. Nottingham City Council is the first local authority in Europe to have introduced a Workplace Parking Levy (WPL). Employers with more than 10 staff are required to pay the City Council 288GBP (around 350 Euros) per year for each space in use. Many employers pass the charge on to their staff, which then influences travel behaviour (Mingardo et al, 2015). Though there is not yet hard evidence of the effects of the WPL, local authority estimates it to reduce traffic growth in Nottingham from 15% to 8% by 2021 (Hallam and Gooding, 2013).

8.3.4 Park and Ride

In the last two decades, Park and Ride schemes have been implemented in several urban areas in Europe. P&R facilities are usually located at the edge of urban areas and are intended to stop motorists before they enter the inner city. P&R has attracted considerable attention in the scientific literature in the last decade, among others by Merriman (1995), Parkhurst (2000; 2002), Meek et al (2009; 2010 and 2011) and Mingardo (2013). Most of them suggest that this kind of parking facility might also have some negative effects, namely abstraction from public transport (i.e. drivers that would have taken the public transport if the P&R was not available) and extra trip generation. The first vary between 6% in the UK and 45% in Switzerland (Parkhurst, 2000; Guillaume-Gentil et al, 2006).

8.3.5 Effects on the local economy

One of the most delicate issues when it comes to parking policy is the (possible) effect on the urban economy, namely the retail sector. Very often the retail sector has the credo of “no parking, no business” suggesting that parking and car drivers are fundamental for the functioning of the shops in the urban area. Actually, there is no evidence that the most successful shopping centres are those with the most, or the cheapest, parking. On the contrary, effective parking management can actually increase the attractiveness of the city centre, leading to more visitors (P&P, 2015).

In a survey of 1,000 shoppers in Vienna Teller (2008) found that the most important factors for them in choosing where to shop were the mix of shops, and the atmosphere. Parking availability had no significant impact on where people chose to shop. Similar results have been found in the Netherlands: in a large telephone survey (approx. 70,000 people) about people’s shopping behaviour it was found that the most important reasons to choose a shopping area were proximity to home, completeness of shops and completeness of products (Mingardo, 2012).

In the UK, Sustrans (2006) carried out research at two shopping centres in Bristol. Over 40% of all customers travelled less than 800m to the two centers and only 22% came by car – though retailers thought the figure was around 44%. Similar research in Edinburgh City Centre (City of Edinburgh Council, 2006) found around 20% of shoppers travelling by car, whilst retailers thought it was 40%.

8.4 Lessons for Successful Deployment of this measure

As is stated above, parking has an important advantage compared to other policies in terms
of transferability and upscaling, namely the fact that some form of parking management is applied in most cities and towns. This makes the social and political acceptability of parking easier than for example the introduction of a congestion scheme or perhaps an environmental zone. Despite differences in socio-demographics characteristics and in the economic base, most cities follow the same pattern in terms of [development of] parking policy (Mingardo et al, 2015). This is important in terms of deployment, and transferability of interventions as cities can learn from each other.

The extent of the evidence collected in the papers and reports that have been analysed for this measure review give confidence that the findings are transferable to other cities. With the exception of the Workplace Parking Levy (WPL) case, where specific legislation is needed, all other measures and project could be transfer to any European city. Parking policy is almost in every EU country a local matter; cities are able to set up their own policy with almost no interfere from national governments. Exceptions to this are Spain and Poland, where the national government can set the maximum parking fee for on-street parking (Mingardo et al, 2015). However, national governments can play a vital role in educating local policy makers and planners as to the important relationship between parking and traffic and sustainable modes.

A common problem when it comes to the implementation of parking policy is awareness and communication, both from a societal and a political point of view. Especially restrictive parking measures – such as an increase in parking fee and/or reduction in parking capacity – might encounter resistance from some stakeholders. Policy makers must be able to communicate the aim and the effects of parking policy properly to the different stakeholders. For example shop owners are usually against any form of restrictive parking measure but the evidence collected in different cities suggest that they should not be afraid of but, on the contrary, should welcome parking management.

Parking management is a fundamental part of any SUMP (Sustainable Urban Mobility Plan). The (scientific) literature is unanimous in the importance of parking for managing transport demand in urban areas. Virtually any car trip ends up in a parking space; accordingly, the correct management of parking has a strong influence on car traffic and the decision-making process by travellers.

Finally, the evidence of the reports and papers that have been reviewed suggest that evaluation and monitoring of parking policies is essential to ensure ongoing success of the measure. Thanks to data collection and analysis, important pilots can be done and policies implemented. For example, technological improvement (i.e. smart parking systems) can be achieved because the evaluation of the project show the positive results for the city.

### 8.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for Parking management interventions:

- **Improved access:** Greater number of people able to access the area being actively managed. Evidence from North America suggests also that solo drivers are more likely to search for cheaper kerb parking because they cannot share the cost of off-street parking with passengers. Therefore, under-priced parking fees tend to allocate scarce urban space (parking) to solo drivers, which may mean that fewer people can visit the city centre.
• **Environmental benefits:** By reducing the time people spend ‘cruising’ for a parking space, the efficient management of parking brings wider benefits such as improved air quality, reduced casualties, and an improved street environment.

### 8.6 Summary

This measure review has analysed the evidence in 25 reports and papers concerning different aspects of parking. We are confident to say that parking policy is an essential element of a SUMP. Parking management can effectively manage car travel demand both at [company] sites and in the urban area. This review produces important evidence on the effects of parking measure on reduction for cruising and car use in commuting. Additionally, it shows that (restrictive) parking policy measures have no detrimental effect on the local economy. It also points out the possible problems related to the use of Park and Ride facilities.

In the future, thanks to new IT applications in parking (i.e. sensors, automatic number plate recognition and GSM payments) more evidence can be obtained on the exact effects of parking policy. We recommend policy makers to use the data produced by parking management systems – every single transaction involving paid parking is registered somewhere! – in order to produce better monitoring reports. These can be used to increase further the societal and political acceptance of parking measures.

### 8.7 References for this Review

7. Hallam, N. and Gooding, J. (2013), Workplace Parking Levy in Nottingham encourages employers to improve staff travel planning, case study on ELTIS, available online at www.eltis.org
Measure No. 8: Parking Policy


Measure No.9: Mobility management: site-based travel plans

Long-term mobility management strategies deployed at an organisational level, which seek to deliver transport objectives through positive action, and which are articulated by a document that is regularly reviewed.

Travel plans comprise packages of measures put in place to encourage users of a particular site to travel in a more sustainable way.

Key messages:
- By seeking voluntary behaviour change among travellers to a particular site, Travel Plans tend to achieve high levels of public and political acceptability, whilst the inclusion of ‘smarter choice’ measures can make them relatively cheap and swift to introduce.
- The evidence suggests that single-occupancy commute trips to employers with Travel Plans could be reduced by between 4% and 18%, depending on the intensity of surrounding areas.
- Parking restraints and/or financial incentives for giving up parking voluntarily are strongly associated with the degree of car reduction which can be achieved through travel plans, in addition to the improvement of alternative travel modes.
- Often the amount of money spent by an organisation did not relate directly to the degree of change achieved, or the overall ‘end’ level of car use. The more important factor was the appropriateness of the measures and overall strategy.
- Travel planning is affected by the national or regional institutional context in different countries, particularly in the case of workplace travel plans, which can be strongly influenced by labour legislation and tax regimes.
- More significant benefits were seen for the packages of measures including these interventions.

9.1 Context and background

Travel plans relate to an organisation and its various sites. In continental Europe, travel plans are also known as (site-based) mobility management; and in the USA they fall within the broader category of transportation demand management (TDM). Although all have slightly different nuances, the term ‘travel plan’ is used in this review because the majority of the evidence found is from the UK.

The review is divided into two sub-categories: workplace travel plans and school travel plans, as the most comprehensive evidence for site-based travel plans currently concerns travel planning for these two types of organisation.
The main objectives of site-based travel plans have typically been to reduce traffic congestion and improve access on and around particular sites, to reduce the demand for car parking where capacity is limited, and to meet environmental targets. Local planning rules have tended to be an important motivator for the development of travel plans by employers. However, they are increasingly also seen among employers as a means of contributing to wider business or welfare objectives, such as the growth of a business or the health and wellbeing of staff. For schools, they may be seen to have wider potential impacts in fields such as road safety, children’s independence, and citizenship education.

Travel plans comprise a set of voluntary travel behaviour change measures for the individuals involved - i.e. in the case of workplace travel plans, employees are encouraged to travel sustainably, even if the business itself has been required by local planning law to set up the travel plan. This means, for example, ‘re-framing individual travel choices’ with measures such as: improving bus, cycling and walking routes that serve the site; improving on-site facilities (e.g. for cycling); and offering better information about non-car modes, as well as discounts, promotional offers and financial incentives to make alternatives to solo driving more attractive. For schools, measures might additionally include: pedestrian and cycle training for children; ‘walking buses’, special school buses; and activities as part of the curriculum to teach the benefits of sustainable transport.

The voluntary nature of such measures at the level of the individual renders travel plans politically acceptable, whilst the inclusion of ‘smarter choice’ measures can make them relatively cheap and swift to introduce. However, travel planning is affected by the national/regional institutional context in different countries, particularly in the case of workplace travel plans, which can be strongly influenced by labour legislation and tax regimes.

9.2 Extent and Sources of Evidence

Approximately 30 reports/papers which include discussion of workplace and school travel plans are readily available in English. Reports on other types of site-based work plan are not readily available, with the exception of those relating to residential areas; the latter tend to be presented as personalised travel planning interventions rather than site-based interventions, and are therefore reviewed in Measure 10. Eighteen reports/papers containing some degree of evidence were submitted for review. Of these, those providing sufficient detail to qualify as high-quality evidence was limited to 4. The majority of detailed evidence in this review arises from 3 UK datasets, which are used as case studies for this review.

Some reports on workplace travel planning are also available from the USA, Canada, Belgium and the Netherlands, but these do not provide sufficient detail for the quality of evidence to be assessed. Similarly, there are references in the literature to school travel planning in Sweden, Denmark, Belgium, Canada, USA, Australia and New Zealand. Site-
placed travel planning is not limited to these countries. Since 2010, it has been launched at a national level in countries as diverse as Finland, Denmark, France and Japan. Moreover, there is considerable activity in the field of site-based travel planning at the European level; in a 2011 White Paper, the European Commission proposed that large employers in the EU be encouraged to develop corporate/mobility management plans. Several EU data bases, including Eltis, CIVITAS and EPOMM provide a large number of case studies of school- and workplace travel plans, undertaken as part of EU-funded projects, such as the MODERN and GUARD projects supported by CIVITAS. The ‘Online TDM Encyclopaedia’ provides syntheses of commute trip reduction programmes, mainly in North America. The EU COMMERCE project has recently produced a set of pan-European standards for developing workplace travel plans.

Reviews of workplace and school travel planning are undertaken relatively frequently in the UK, partly because in recent years they have featured strongly within packages of measures implemented by local authorities and funded by the UK government’s Local Sustainable Transport Fund.

Meta-studies were not particularly important in reviewing this measure, as most such studies do not provide sufficient detail of the intervention to assess the evidence, unless this is available in separate intervention reports. Thus, the two meta-analyses informing this review mainly re-analyse data from the three UK datasets referred to above.

It is possible that site-based travel planning may be under-represented in the academic literature due to the difficulty of obtaining reliable data on mode-share of travellers to sites such as workplaces and schools. Employers rely on staff surveys for their data, which often achieve a low response rate or are subject to respondent bias, except in rare cases such as Washington State (USA), where the completion of such surveys is required by law.

Most of the high-quality evidence is being commissioned by government (national or local) and undertaken by independent academics and consultants. Evaluations are also carried out by the agencies which undertook the interventions, although this tends to provide weaker evidence. The evidence is presented as project evaluation reports and academic papers, the most recent comprehensive data being from 2010 (the UK Sustainable Travel Towns evaluation); most evidence prior to this (from 2000 onwards) emerges from 2002-2004. The measures to which this evidence relates continue to be implemented.

9.3 What the Evidence Claims

9.3.1 Workplace travel plans

- Workplace travel plans can be successful in motivating behaviour change towards reduction in single occupancy car-use, as long as a comprehensive strategy involving a package of measures is employed.
- Parking restraints and/or financial incentives for giving up parking voluntarily are strongly associated with the degree of car reduction which can be achieved through travel plans, in addition to the improvement of alternative travel modes.
- In the UK examples, the ‘Smarter Choices’ (2004) analysis of 26 workplace travel plans showed an average reduction of 17.8% in the proportion of commuter trips made as a car driver; this is very close to the 18% reduction shown in the analysis of 20 workplace travel plans by Cairns et al. (2010). Independent statistical analysis of these two data sets combined showed a 17% reduction. However, a different dataset from the UK Sustainable Travel Towns evaluation (2010) showed a smaller reduction.
in commuter trips by car: 8.4% across the two thirds of employers who had succeeded in reducing car-use, but only 4.2% across all employers with travel plans. The smaller effect compared with the other data sets was attributed to the lack of ‘push’ factors, notably low levels of congestion in the town in which workplace data were collected (Peterborough).

- As well as achieving dramatic reductions in car use, the 20 organisations examined by Cairns et al. (2010) study had, on average, nearly doubled the proportion of staff commuting by bus, train, cycling and walking.

- Bus use to/from workplaces is boosted in particular by the provision of free, frequent and tailored shuttle bus services. Other factors contributing to high levels of bus use include: relatively cheap fares; ticket discounts; bus stops close to building entrances and/or other on-site bus infrastructure.

- The factors most closely correlated with having high levels of cycling are: high quality off-site access or improved off-site access; increasing available parking for cyclists; having a Bicycle Users Group; and offering a cycle repairs service.

- Factors associated with increased walking include: having high quality off-site access, or improving off-site access to high quality or improved on-site conditions (by increasing the amount of safe crossings, speed restrictions, lighting and traffic calming); allocating funding for walking (including offering financial incentives); and specifically marketing walking to staff, often using health arguments.

- Other ‘success factors’ include: senior management support for travel plans; a dedicated travel plan co-ordinator and/or champion; travel plan targets and a written plan of action; and partnership working with, for example, local authorities and bus operators.

- Persuasive messages about the health benefits of cycling and walking (on its own or combined with public transport use) may offer an effective approach to motivating mode shift amongst employees.

- Medium-length (10-50km) and longer (over 50km) commuter trips offer a large potential ’prize’ in terms of car mileage savings.

- The costs of travel plan measures were calculated by Cairns et al. (2010)\(^6\) showing a median average annual running cost of £47 per full-time-equivalent employee (note that the financial data were collected in 2002). Costs incurred by employers ranged from £2 per full-time-equivalent employee to £431 per full-time-equivalent employee. Surprisingly, the amount of money spent by each organisation did not relate directly to the degree of change that had been achieved, or the overall ’end’ level of car use. The appropriateness of the measures and overall strategy appeared to be more important than actual expenditure.

- CBA was carried out for the totality of the measures evaluated in the UK Smarter Choices\(^7\) and Sustainable Travel Towns reports\(^8\), but not for workplace travel plans in isolation. The Smarter Choices report does however model the relationship between the costs of workplace travel planning and impact in terms of impact on overall levels of commuter traffic (car km saved).

**Nature of the methods**

Changes in employee mode share are measured by comparing survey results from the beginning and end of the monitoring period. Factors which could have influenced mode change (e.g. changes in public transport provision) are also explored ex-post. Qualitative data are collected through interviews with representatives in case study employers and local authority officers responsible for sustainable travel. In the language of the experimental
The value of the evidence on the impact of workplace travel plans reported here has been questioned by some critics of the one-group-pre-post-test design to evaluate smarter choice interventions (notably Bamberg and Möser). The difficulty of identifying suitable ‘control groups’ has been addressed to a degree by using comparable data from sources outside the case study employers/areas to compare the intervention under study with ‘counterfactual’ examples. For example, the Sustainable Travel Towns evaluation used mode share and traffic data for other medium-sized towns, obtained from the UK National Travel Survey and National Road Traffic Estimates, to provide insight into the possibility of attributing changes in travel behaviour to the interventions.

A further systematic weakness is that differences in car use before and after an intervention may only reflect random fluctuation because sample sizes in workplace travel surveys are often not large enough to indicate a statistically significant change – i.e. many studies may lack the statistical power necessary for detecting small to medium effects. Another, related, weakness arises from the lack of independent evaluation at the level of employers, who are usually responsible for administrating travel surveys among their staff to monitor their own travel plans. Thus, even though those carrying out the studies reviewed here are independent, they cannot be certain of the robustness of the data provided to them by employers, or indeed by local authorities.

Another methodological weakness is that those employers collecting data on staff travel are likely to be more engaged in travel planning than the typical employer. Indeed, 20 of the travel plans analysed by Cairns et al. (2010) had been selected on the basis of existing ‘good practice’ in travel planning. This can cast doubt over the representativeness of the findings. Hence, both internal and external validity might be called into question. However, when Bamberg and Möser applied a meta-analysis to the results from 44 travel plans (24 reported in the ‘Smarter Choices’ 2004 study, and 20 in Cairns et al. 2010), they found little evidence of sample bias – and that a different way of analysing the data produces a similar estimate of impacts.

There have been calls for the use of randomised control group post-test designs as an alternative to the methods typically practised to evaluate smarter choice interventions. However, the practical and financial barriers to carrying out evaluations with control groups and large sample sizes cannot be ignored. Indeed, this is a methodologically contested area in which some argue that experimental designs are not only impractical, but also fail to yield the most reliable results, and therefore risk misleading policymakers.

The studies reviewed here do explain the caveats to their findings and present analysis which allow conclusions to be drawn with a degree of confidence as long as careful consideration is given to local conditions and potentially confounding factors which might render an intervention which was effective in one location to be less effective in another.

### 9.3.2 School Travel Plans

- Evidence from both the UK Smarter Choices report and the UK Sustainable Travel Towns report shows that school travel plans can be successful in reducing the proportion of children travelling to school by car. In contrast, a meta-analysis by Möser and Bamberg, which included travel plan examples from the Smarter Choices report, was inconclusive overall on the impact of school travel plans.
- In three UK Sustainable Travel Towns, most schools (between seven and eight out of
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10) demonstrated a decline in the number of pupils travelling to school by car. The overall reduction in car use for the journey to school was between 9% and 17%. Active travel to school increased in all the towns. By comparison, car passenger mode share for trips to school in medium-sized towns also fell between 2004 and 2008, but by a smaller amount of 7% (1.6%-points).

- The Smarter Choice report suggests that, at levels of engagement current at the time, typically 10-40% of schools with travel work will not achieve positive modal shift, 45-50% will reduce traffic by between 0 and 20%, and 15-40% will cut traffic by over 20%, with some schools achieving reductions in traffic of 50% or more.

- The Smarter Choice report also models the cost-impact ratios of with regard to car-kilometres saved through school travel planning measures. Model A assumes that the average cut in car use achieved by the local authorities was 8%; Model B assumes that the average cut in car use was 15%. Cost-impact ratios range from £0.03 - £0.10 per kilometre saved under the more conservative assumption of travel plan effectiveness (model A), or £0.01 - £0.05 with the less conservative assumption (model B).

- However, it should be noted that this method of calculation (employed throughout the report) to some extent ‘disguises’ the up-front investment in capital expenditure needed. For capital spend, the reports assumes that infrastructure spending of £95 per pupil place is required to provide a basic level of safer infrastructure.

- The qualitative research reveals wider perceived benefits of school travel planning, such as: improved road safety (e.g. as more children cycle, the accident rate reduces); children’s health, fitness and independence; improved attendance and ability to learn; community benefits; social inclusion benefits; and greater knowledge of environment and citizenship issues.

Nature of methods

As with the workplace travel plans, changes in children’s mode share are measured by comparing survey results from the beginning and end of the monitoring period. Monitoring data on mode share is obtained from ‘hands up’ surveys and/or School Census returns. Qualitative data are collected through interviews with local authority officers responsible for sustainable travel and representatives of schools implementing a travel plan.

The methodologies applied to the evaluation of school travel can be subject to the same systematic weaknesses as workplace travel plans, with the additional problems that ‘hands-up’ surveys among school children are likely to be especially vulnerable to bias. School Census returns may comprise unreliable data with regard to ‘travel to school’ information, which depends on accurate and timely form completion by parents.

These studies are also likely to over-represent selected ‘best practice’ school travel plan examples, and therefore cannot easily be generalised. Möser and Bamberg contend that this explains the much bigger effect size for the 6 cases they re-analyse from the Smarter Choices study, compared with data from other sources on the impact of school travel plans. However, qualitative research findings from the studies reviewed here serve as a reminder that school travel plan interventions also offer less tangible benefits in addition to those which can be measured and analysed using statistical methods.

9.3.3 The Significance of Workplace and School Travel Plans

As site-based travel plans represent a strategy rather than a measure in their own right, they can only make a significant difference when carried out in parallel with measures such as the improvement of infrastructure and public transport services in areas surrounding the site, as
well as traffic restraints. Travel planning therefore needs to be undertaken in partnership amongst employers and school, local authorities and transport operators. The evidence suggests that overall traffic levels in an area can be reduced when such measures are in place.

9.3.4 Remaining evidence gaps

Although there are many interesting cases of travel planning across the world, readily available, detailed evidence from countries outside the UK is difficult to identify. An evidence gap also remains with regard to sites other than workplaces and schools.

9.4 Findings Relating to Transferability and Upscaling

9.4.1 Transferability

This review has focussed on the UK, but the national and/or regional institutional context plays a strong part in the way that site-based travel plan can be implemented. For example, in some local jurisdictions in the USA, ‘Employer Transport Plans’ became mandatory for all employers above a certain size in the 1980s and ‘90s. Although many such mandatory regulations have since disappeared in response to lobbying from business (Washington State currently has the only state-wide commuting trip reduction ordinance) the USA remains more highly regulated with regard to travel planning than Europe, where the approach is more voluntary. Labour legislation is stronger in continental Europe than in the USA and the UK, which can mean that employee transport issues form part of the ‘social dialogue’. In Belgium, for example, transport allowances form part of collective bargaining agreements between employees and employer, and these can differ between employment sectors. In Belgium, as well as countries such as Denmark, Finland, France, Germany and the Netherlands, commuting costs are considered a tax-deductible expense, whereas in the USA, UK and some southern European countries it is a personal expense.

However, whilst such contextual factors affect the way in which travel planning can be implemented, there are no systematic reasons to suppose that the evidence findings would not, in principle, be relevant in other locations. Indeed the literature review has indicated that site-based travel planning is taking place in many different countries.

9.4.2 Other factors relevant to this measure being deployed successfully

As noted above, specific workplace and school planning interventions cannot be reliably measured in isolation from other mobility-related interventions. For example, the evidence suggests that most UK local authorities see engineering measures as an important part of their work with schools. They are needed as a way of engaging schools, allaying (justified) parental concerns about road safety, maximising the effects of softer measures and locking in long-term benefits. The evidence neither supports nor challenges the view that the ‘locking in’ of mode shift through ‘hard measures’ such as reallocation of road space is essential to the success of travel planning measures, although it is reasonable to assume that this is the case, as the wider literature on smarter choices suggests.

The planning process also continues to provide a stimulus for the travel plan process. Neither can this measure be evaluated in isolation from wider ‘life-choice’ factors. Individual travel for work and school takes place in a much wider context, where factors influencing the relative location of jobs and housing have a profound effect on travel habits. Some best practice in travel planning is attempting to influence these wider issues. For example some employers deliberately aim to employ relatively local staff by undertaking recruitment drives in postcodes close to bus routes serving the site. Some also provide training courses for local
people, to facilitate their employment on the site. One employer reported that, in travel planning work, staff were being allocated to shifts according to postcodes, in order to facilitate the provision of more sustainable travel arrangements. For employers, flexible working and teleworking are two other measures.

In summary, scaling up is likely to be reliant on factors such as:

- Willingness of employers/schools to participate
- Funding
- Use of the planning system
- Restraint measures (e.g. parking management)
- Transport infrastructure/service improvements
- Advertising and marketing

These factors are also likely to be required for travel plans to achieve resilience and durability

### 9.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for site-based travel planning interventions:

- **Health benefits**: Travel plans can encourage the use of more active modes of travel such as cycling, helping to improve the health, fitness and welfare of employees and students.
- **Staff welfare**: Measures taken by employers to improve the experience of the commute can boost the morale of employees, indirectly contributing to staff motivation and productivity.
- **Student / Pupil welfare**: Travel planning at schools may have wider potential impacts in fields such as children’s independence, citizenship education.
- **Road safety**: Reductions in traffic at sites could help reduce road accidents, particularly important around schools.

### 9.6 Summary

Although a number of methodological weaknesses have been discussed with regard to the evaluation of site-based travel plans, the in-depth nature of the evidence reviewed here suggests that we can have confidence in the effectiveness of travel plans in contributing to a reduction in single-occupancy car journeys and increase in use of alternative modes for the journey to work or school, as long as they are undertaken within the context of wider policies and measures which support the use of sustainable modes.

Voluntary behaviour change among individuals requires a combination of `real` mode choices (e.g. availability of public transport and cycling/walking infrastructure) and promotional measures/incentives to encourage people to use them. Disincentives for solo driving such as parking restraints, or `push factors` such as traffic congestion, are likely to improve the chances of success of travel plan measures in terms of reducing car-use. As travel plans tend to focus on the `softer` (and less costly) behaviour change measures, they can only ever be one part of the picture; they require partnership with local authorities, transport providers and other local organisations to achieve success. Although `success` is defined mainly in terms of traffic reduction, travel plans can also offer a variety of secondary benefits, such as health, fitness and welfare of employees and students, as well as community-wide benefits.
It is recommended that future evidence generation attempt to address, as far as is practically possible, some of the selection bias at the level of organisations and individuals providing data, so that greater confidence can be achieved with regard to the robustness of the data (particularly travel surveys), and in the attributing of outcomes to particular measures. However, it should also be acknowledged that in the ‘open system’ of real world travel to school, work and other sites, it may not be possible to establish direct causality. Qualitative research should continue to be used to assist with the interpretation of quantitative findings on site-based travel planning.

9.7 References

Measure No.9: Mobility management: site-based travel plans


Measure No.10: Mobility Management: Personalised Travel Planning (PTP)

Targeted marketing techniques involving the provision of travel advice to individuals, with the aim of encouraging them to make more sustainable travel choices.

An approach which involves directly contacting people with the offer of information, assistance, incentives and motivation, to enable them to alter their travel choices voluntarily.

Key messages:

- Evidence worldwide suggests that PTP projects are successful in reducing both the number of car driver trips and car-driver mode share. Reduction in car driver trips is typically between 8% and 12%, whilst car-driver mode share has typically fallen by around 5-7%.
- Economic benefits have been calculated on the basis of packages of measures, but not PTP in isolation. PTP is most successful when implemented as part of a comprehensive package of sustainable transport measures.
- Recent evidence from integrated UK programmes including PTP have shown Benefit-Cost-Ratios of 1.4 to 4.5, based on economic benefits from reduced traffic congestion.
- PTP can be introduced relatively cheaply and swiftly. The voluntary nature of such measures at the level of the individual renders it politically and publically acceptable.
- Qualitative judgements of residential PTP give confidence that this is a type of scheme which does contribute to increasing the use of sustainable modes, despite a lack of consensus over the scale of impacts.
- Importantly, more significant benefits were seen for the packages of measures including these interventions, and analysis was more commonly seen at this level.

10.1 Context and background

Personalised travel planning (PTP) enables individuals to alter their travel choices voluntarily.

Potential interventions

- Agents visit households to deliver information (and sometimes incentives) that encourage the public to use more sustainable means of satisfying their mobility needs.
- Technique can also be deployed at events or through workplaces and schools.
- Programmes are known by different names (or ‘brands’) in different countries.

It is an example of a voluntary travel behaviour change (VTBC) or travel behaviour modification (TBM) measure. It has been deployed worldwide since the 1980s under a variety of different names. Whilst ‘PTP’ is the most commonly-used term in the UK, it has been
Measure No.10: Mobility Management: Personalised Travel Planning (PTP)

referred to as ‘Travel Blending’ and *TravelSmart* in Australia, ‘Travel Feedback Programmes’ (TFP) in Japan, and as ‘individualised travel marketing’ in the USA within the wider category of Transportation Demand Management. The terminology is further extended by the registered brand names given to particular PTP methods in different countries. Hence, many studies report on projects which used the Indimark® technique, originally developed in Germany by Socialdata Ltd as a tool for promoting public transport, but extended to other countries under the registered trademark of TravelSmart®.

PTP projects have typically been undertaken in residential areas – mainly urban – in workplaces and schools, or at community events. This Measure Review addresses residential PTP, in which households are contacted directly, and to which most of the evaluation evidence relates. Workplace and school PTP projects have been smaller in scale and less well evaluated. As they are generally run in the context of a workplace or school travel plan, they are reviewed in Measure Review No9: site-based travel plans. The exception is one workplace PTP project in Norway, which is included in the current review because the scheme was not part of workplace travel plans.

The scale, objectives and implementation methods of PTP projects can vary considerably. However, the principle outcomes aimed at by most projects are: to reduce the distance individuals travel by car (particularly as sole occupant), reduce the number and proportion of single-occupancy car trips, and increase the number and proportion of trips undertaken by public transport, car-share, bicycle, or on foot. Some also aim to cultivate more positive attitudes to sustainable transport amongst the public, allied to longer term objectives such as: reducing CO₂ emissions; reducing traffic congestion; and reaping health benefits by increasing physical activity levels and community engagement within the population. Some projects also aim for ‘intermediate outcomes’ such as engaging as many members of the public as possible with PTP, or achieving a high level of satisfaction among those who are offered PTP¹. As PTP often forms part of a broader package of measures to increase the use of sustainable transport within an area, it can also serve to increase awareness among the public of other types of measure. It is therefore difficult to evaluate the effects of PTP in isolation from other factors such as improvements to public transport services and cycling infrastructure or more generalised marketing campaigns. Indeed, some of the most detailed evidence in this review emerges from evaluations of packages of measures in which PTP played a major role, but whose outcomes could not be measured separately.

The delivery of residential PTP usually involves direct contact being made with households by travel advisers employed by an organisation (often a consultancy company) contracted by local government. This is the model used in the large-scale Indimark and TravelSmart projects, which typically target over 5,000 households. Contact is made by telephone, by post, or on the doorstep, and may involve a number of further visits, calls or correspondence to interested households. Travel adviser’s survey or discuss with individuals their travel choices, help them identify personal targets or plans for change, and provide information, incentives and motivation to encourage them to change behaviour. Some techniques are more ‘prescriptive’ than others; for example, some methods involve individuals being asked to select what they would find useful from a menu of information, whilst others require travel advisers to assess the individual’s travel needs and motivators (through a short conversation) and then provide the message and information they judge to be most effective for that person. In some projects, community-based social marketing techniques have been used to increase residents’ enthusiasm for travel behaviour change through social support – for example ‘loyalty clubs’, through which people are encouraged to make pledges to change how they travel.
This review also includes a number of smaller-scale projects, often implemented as an experiment or demonstration study, in which delivery methods differed from the more ‘mainstream’ PTP methods described above. For example, in the ‘One-Less-Car’ Demonstration Study in Seattle, travel advisors worked intensively with a small number of households for either 6 or 9 weeks. The households were offered information and financial incentives to help them reduce their car use and try other means of transport. All the participant households owned more than one car, and all agreed not to drive one of their cars at all for the duration of the study. Both the level of engagement required from participants and the provision of a financial incentive, differentiates this project from more typical PTP projects, but highlights what can be achieved in more ‘extreme’ cases. A larger scale example is the EU-funded project: ‘Ad Personam Direct Marketing Programme for Public Transport’, in which a carefully targeted group of 2,521 citizens across 7 European cities received an individual tailor-made travel plan and free use of public transport during a promotional week.

A contrasting example, and one where individuals were targeted via work rather than households, is provided by a field experiment in 6 workplaces in Lillestom, Norway, which aimed to find out whether travel information alone (and with incentives) is sufficient to change travel behaviour in isolation from other factors. Employees in the treatment groups received - usually in their office pigeon holes - either bus information on its own, or bus information plus a free seven day bus pass. However, no interaction with a travel adviser was offered. The contrasting results of these different experiments are included in the findings section below.

10.2 Extent and Sources of Evidence

PTP is a relatively well-evaluated area: approximately 50 items are readily available, many of which synthesise the results of numerous individual case studies. However, a minority of these provide detailed evidence. For the meta-studies, it was not possible to access the original intervention reports, many of which were produced by consultancy companies and were not in the public domain. Forty items were submitted for consideration in this review. Evaluations of PTP projects and the recommendations which ensue continue to receive detailed scrutiny in the research community as the evaluation methods used are strongly contested and have, in recent years, provoked a series of articles which either defend or refute the reliability of the evidence (e.g.5678).

All the items provided were in English, with the most comprehensive reports providing evidence on PTP from projects in the UK, Australia, the USA and Japan. Review papers also show higher level findings from evaluations of the ‘IndiMark’ approach in Germany, Sweden, Austria and Switzerland. PTP interventions are carried out in urban areas, although there is some variety in the size of towns and cities, and the locations of PTP projects within them (e.g. inner, outer and edge-of-town locations).

Much of the original evidence, in the form of individual project reports, has been created by those organisations contracted to deliver the PTP projects (e.g. Socialdata Ltd). This lack of independent evaluation has been one of the criticisms of some of the findings. Other evaluations have been carried out by independent academics or consultants, or directly by local government. The meta-studies have been undertaken by academics and consultants in order to provide independent, comparative analysis of the project data. The evidence is presented as both project reports and academic papers. In the case of the latter, there has been as much discussion of the strengths and weaknesses of the methodology as of the
Some of the projects reported were designed as small-scale pilot studies (with only a few hundred households, or fewer, participating) - particularly those implemented in the late 1990s and early 2000s. As PTP become more established as a behaviour change intervention, projects targeting larger populations became common. For example, the number of households targeted by 23 PTP projects in the UK between 2002 and 2006, ranged from about 2,000 to 30,000, with about 30% to 50% of targeted households participating.

The meta-studies reviewed each report on roughly 20 to 30 individual projects. Most of the interventions described in the current review were carried out since 2000, with the most recent finishing in 2012. By 2009, the ‘IndiMark’ technique alone had been applied in more than 100 pilot and nearly 150 large-scale projects, targeting a total of more than three million people on three continents. PTP interventions remain a popular behaviour change tool and continue to be delivered widely, despite uncertainty about the precise level of their impact.

10.3 What the Evidence Claims

10.3.1 Summary of main findings
The main findings from evaluations of PTP concern changes in the use of different transport modes before and after an intervention: most importantly, changes in car-use. The ways in which ‘car-use’ is measured and reported varies in the different studies, for example, changes in: the number of trips; the proportion of trips undertaken as a car driver (mode share); or the distance travelled by car. Depending on the objectives of the intervention, some studies place greater emphasis on measuring the use of alternative modes. Changes in the use of the car and other modes are generally considered to be the main outcomes of a PTP project, although changes in attitudes to different modes are sometimes also presented. Some of the evidence also includes findings on: PTP interim outcomes, such as scale of delivery of a project; aspects of PTP content and delivery thought to influence outcomes; longer term impacts such as health benefits and CO₂ reduction; and wider benefits of PTP, such as community engagement on sustainable transport issues. The main claims made in the evidence are summarised below, after which methodological issues will be discussed.

10.3.2 Reduction in the number of trips by car (as driver)
An early UK study (2004) had found that PTP reduces car driver trips amongst targeted populations by 7 – 15% in urban areas. A later (2009) comparative study of PTP projects in eight urban areas of England, implemented between 2002 and 2006, found that the relative decrease in the number of car driver trips varied from 4% to 13%, with a project arithmetical mean decrease of 11% (based on 11 PTP projects). These changes were generally consistent across areas regardless of whether the PTP project was the only significant intervention in the locality, or whether it was accompanied by measures to improve non-car options. As with the majority of studies cited in this review, household surveys undertaken before and after the interventions were the main source of data.

The evaluation of the three ‘Sustainable Travel Towns’ in England (2010) found that car driver trips per resident of the three towns together fell by 9% between 2004 and 2008. Car use per head also fell nationally in comparable (medium-sized) urban areas during this period, but by a much smaller amount. However, each of the towns benefitted from a package of measures to encourage use of sustainable modes, and PTP outcomes in terms of behaviour change were not measured separately (discussed further below).
In the USA, nine Individualized Marketing projects ['TravelSmart'] evaluated between 2003 and 2007 showed a decrease in car trips of between 2% and 12.8%, with an average of 8% across the projects.

A 2004 synthesis of previous evaluation surveys of PTP projects in Nürnberg, Germany - run under the Indimark brand - showed an overall reduction in car as-driver trips of 3%. The main objective of Indimark had, however, been to increase public transport use, which rose by 13%. The Nürnberg schemes have been run since 1996, and 600,000 residents had participated by 2007.

‘Community-based social marketing’ approaches to PTP, such as the ‘In Motion’ programme run in Seattle, UAS, from 2004, have shown greater reductions in the number of car trips. A core component of In Motion was inviting participants to pledge to reduce car alone trips; they received rewards for meeting their pledge in the form of weekly travel and local business vouchers. Pledging participants made reductions in car alone trips of between 24% and 50%. The importance of the PTP delivery mechanism is discussed in ‘Assessment of the delivery process’ below. However, in comparing the reductions in car trips quoted here, it should be noted that the ‘pledging participants’ of In Motion were the most active recipients of PTP, whereas the household surveys used in other evaluations typically sample all households across an area where PTP has been offered, regardless of whether respondents participated in PTP or not. Similarly high outcomes were recorded by the EU Ad Personam project, in which 5,507 commuters identified (though an initial survey) as susceptible to changing from car to public transport were given a travel plan and free tickets; 2,521 took up the offer, and a follow-up survey indicated that, of this number, 838 became new public transport users (although the precise meaning of ‘public transport users’ is not defined).

10.3.3 Changes in mode-share

Where the number of trips by car has fallen, the evidence also tends to show a reduction in the share of trips by car as a proportion of all trips. The 2009 study of PTP projects in England showed a decrease in the share of car driver trips of up to 7 percentage points, with a project arithmetical mean decrease of 4 percentage points (based on eight PTP projects whose results take account of the counterfactual). This analysis suggested that switching from car to walking was the greatest factor in the mode shift - the proportion of trips on foot increased by up to 6 percentage points, with a project arithmetical mean increase of 3 percentage points. A meta-analysis of 72 studies covering PTP, travel awareness campaigns and public transport marketing in Europe and Australia, showed a decrease of 5 percentage points in the share of trips undertaken by car.

Similarly, the 2013 evaluation of the ‘Smarter Choices Smarter Places’ (SCSP) programme in Scotland found that the proportion of trips made as a car driver decreased in all of the seven pilot areas. The level of decrease ranged rather widely, from 19.4 percentage points to 1.6 percentage points. Share of walking trips increased in all pilot areas by 14.8 to 21.4 percentage points. Cycling mode share increased in five out of the seven pilot areas, although the proportion of trips made by bus decreased in five of the seven areas. As with the evaluation of other multi-faceted sustainable travel programmes, PTP outcomes in this Scottish study were not measured separately from those of the rest of the programme.

In Australia, six PTP (‘TravelSmart’) projects in Perth between 2000 and 2004 led to reductions in car driving mode share of 4-14%, or 2 to 10 percentage points, with corresponding increases in walking, cycling and use of public transport. In the USA, the ‘SmartTrips’ PTP project in Portland led to drops in ‘car driver alone’ mode share of 4, 5 and 17 percentage
point in three target areas, although an increase in petrol prices was thought to have contributed to some of this reduction. However, a Norwegian study in 2013 did not find evidence supporting the conclusions from previous studies that information-based mobility management programmes reduce car mode share. This was a controlled field experiment, in which the employees of 6 companies were given either bus information on its own, bus information plus a free seven day public transit pass, or neither (control group). Neither of the ‘treatments’ led to significant reductions in the share of trips by car. This project differed from most PTP schemes reported here in that it did not involve any one-to-one interaction with individuals, nor any ‘personalising’ of the content of travel information to the needs of individuals.

10.3.4 Changes in distance travelled by car
There is less evidence concerning changes in the distance travelled by car in areas where PTP has taken place, although this is important in terms of reducing emissions. Just six of the English PTP projects included in the 2009 analysis included results for car distance travelled, but these showed decreases of 8% to 15%, with project arithmetical mean decrease of 12% in car distance travelled in the target areas. In the three Sustainable Travel Towns in England, car driver distance per resident fell by 5%–7% (trips of 50km or less).

An experimental project in Seattle among 86 households (2000–2002), called the ‘Way to Go Seattle: One-less-car demonstration study’ led to a 27% decrease in overall single-occupancy-vehicle (SOV) miles among participants. However, this was a much more intensive programme than the others reported here, in which participants also received financial incentives to reduce their car travel.

10.3.5 Changes in general ‘car use’
The evidence does not always specify the measurements used to define behaviour change. For example, a meta-analysis of PTP projects (‘Travel Feedback Programmes’) in 18 residential areas in Japan (targeting 4,407 people) between 1999 and 2005 provide data on ‘car use change’ and ‘public transport use change’ by aggregating different measurements rather than specifying the precise nature of the change (e.g. distance travelled). This meta-analysis shows a mean reduction in car use of 12.1%, and a mean increase of 38.6% in public transport among the TFP experiments that had control groups. The reduction in car use is similar to the results of PTP evaluations in the UK and Australia, although the generalised nature of the term ‘car use change’ used in the Japanese studies presents difficulties in making specific comparisons.

10.3.6 Changes in attitudes and intentions
Some studies have measured attitudes towards, and intentions to use, the different transport modes before and after a PTP intervention, as social-psychological studies show these to be important factors in the longer-term maintenance of new travel behaviours. For example, in Scotland, attitudes towards walking, cycling and bus travel (except fares) improved after the SCSP programme, although attitudes towards car travel were found to be more complex.

The meta-analysis of Travel Feedback Programmes in Japan showed a 9.6% increase in intention to reduce car use.

10.3.7 CO₂ impacts
Some of the evidence has extrapolated from results on travel behaviour change to estimate indirect impacts. The most frequently cited impact is reduction in CO₂ emissions. Results from 9 studies in Australia suggest that the reduction in car mode share of 4–14%, following TravelSmart programmes, corresponds to a reduction in CO₂ emissions of 0.12–0.39 tonnes.
The evaluation of the SCSP programme in Scotland\(^{14}\) suggested that carbon emissions reduced by a total of 16,400 tonnes per year, or 0.176 tonnes per capita. Ten TFPs in Japan\(^{17}\) (Fujii and Taniguchi, 2006) resulted in a 19% unweighted mean average effectiveness in reducing CO\(_2\) emissions arising from changed travel behaviour.

### 10.3.8 Monetised costs and benefits

#### Costs

Costs cannot easily be compared across the studies because of the different measurements used. However, a recent example is provided by the Sustainable Travel Towns PTP programme\(^{10}\) (2004-2009), which targeted over 90,000 households. Between 41% and 69% of households were successfully contacted, and between 22% and 45% of households consequently received a range of intervention materials to encourage more sustainable travel – a total of 40,927 households across the three towns. The cost of the programme (including contractor costs, materials costs and staff costs but not monitoring) was about £16 per individual contacted, or £25-£29 per individual receiving the materials (assuming 2.4 people per household).

#### Benefits

Only a few recent studies have attempted to place a monetary value on the impacts described above, and these have produced estimates of the financial savings generated by packages of measures (of which PTP formed a part) rather than PTP alone. The Scottish SCSP programme\(^{14}\) was estimated to accrue an average annual financial saving on direct transport expenditure of £62 per resident, equivalent to about £9 million per year across the seven pilot areas. CO\(_2\) reductions were valued at £0.9 million per year using current carbon values, equivalent to £6 per capita. The promotional activities of which PTP formed a part accounted for about one third of the overall programme costs. Health gains from increased physical activity, using valuation techniques which discount future health benefits to the present day, were estimated to be worth £6,150 per 100 population, plus £2,024 per 100 population for healthcare savings, equivalent to £10.6 million across the seven pilot areas; but the estimated health savings using ‘active travel valuation techniques’ suggest a much higher figure of £46 million. In summary, the evaluation of the Scottish SCSP programme\(^{14}\) found that the £14.7 million programme had delivered benefits with a value totalling between £20.5 million and £55.9 million. Although not stated in the evaluation report, this suggests an indicative benefit-cost ratio of approximately 1.4 to 3.8\(^{19}\).

The evaluators of the English Sustainable Travel Towns\(^{10}\) calculated the monetary benefits of the programme by updating a previous estimate made by Cairns et al.\(^{9}\), which related the cost per vehicle kilometre removed from the road network to the UK Department for Transport’s estimate of the marginal congestion cost per vehicle kilometre. By upgrading the 2004 figures for inflation, the average ‘congestion benefit’ of the Sustainable Travel Towns programmes would be about £0.18 per £0.04 of expenditure at 2009 prices, giving a congestion-only benefit-cost ratio of 4.5. As previously noted, this BCR relates to the full package of measures implemented in the towns. However, PTP accounted for the largest share of the revenue expenditure in each town (33%-46%), and revenue expenditure accounted for just under half of all expenditure.

### 10.3.9 Qualitative assessments of PTP

Although little of the evidence claims to present quantitative outcomes and impacts of PTP on travel behaviour in isolation from other measures, most provides a qualitative assessment of other direct benefits accruing from PTP. For example, in Scotland PTP was thought to help make the delivery of the SCSP programme “more dynamic and responsive, recruiting local
people as champions or Travel Club members, and helping to personalise provision and promotion”. The authors concluded, however, that there appeared to be “scope for better value approaches to delivery, working through public service providers, community organisations and business networks, and restricting higher cost household engagement to people who would not be reached through these networks.”

The Sustainable Travel Towns (England) evaluation found that wider benefits were judged to have accrued from PTP with regard to social inclusion, health and quality of life. It was also thought to have contributed to the effectiveness of other measures; for example, in Peterborough, PTP was felt to have ‘push-started’ other transport projects, and there were indications that it may have helped to slow the rate of decline in bus travel. It was also judged that PTP might have contributed to public acceptance of a package of planned walking and cycling improvements.

Participants the One-less-car project in Seattle also reported reduced stress levels, increases in their physical exercise, felt more connected to their community, shopped more at nearby neighbourhood businesses, and enjoyed more quality time with family members.

10.3.10 Assessment of the delivery process

Several studies have identified factors deemed to contribute to the success of PTP projects in meeting their objectives. The implementation of projects is typically contracted out from local government to external consultants with specialist skills and resources to run PTP. The effectiveness of the consultants is clearly key to the success of the projects. Few studies have raised concerns in this regard, although this is unsurprising given that many evaluations have been conducted by the same consultants.

Factors found to contribute to an effective and cost-efficient delivery process in the English PTP projects included media planning, database management systems (to process information requests), and some engagement of bus companies.

The nature and content of the interactions with households also affects PTP outcomes. Repeated attempts to contact householders (e.g. different times of day) was a delivery ‘success factor’ identified in the UK projects. The Australian study cites personal engagement with household members as a decisive factor in securing behaviour change.

The meta-analysis of TFPs in Japan found the setting of ‘behavioural goals’ to be important (e.g. setting a goal or making a pledge to reduce car use by a certain amount). The average car use reduction for seven TFPs that requested goal setting was 20%, whereas that for seven TFPs without explicit goal setting requests was 10%.

Whilst not directly comparable, the findings from Japan are generally supported by those from the two projects in Seattle, where pledges and other commitments formed part of an interaction between travel advisers and householders, and where falls in car use were especially high. Both the Seattle schemes included financial incentives for reducing car use. The field experiment in Norway, which saw no reductions in car-use, also involved the provision of incentives (in the form of free bus tickets) to some participants, but no commitments from these participants were involved, demonstrating that simply providing information and incentives, are insufficient on their own to encourage behaviour change. Social aspects of the PTP delivery process are important to its effectiveness, whether in workplaces or residential areas.

10.3.11 Nature of the methods

The main method used to measure changes in travel behaviour and attitudes in these studies
was the household travel survey, undertaken before, after, and sometimes during the PTP project. Participants in a number of studies were asked to complete travel diaries during the project, and some of the before and after surveys also included a travel diary. The findings therefore rely predominantly on self-reports. Social data uses a branded survey design called KONTIV®: a mail-back technique using a one-day diary for all household members. By 2009, this had been applied across 15 countries.

Some large studies, such as those evaluating the UK Sustainable Travel Towns and SCSP programmes10,14, also drew on a variety of empirical, area-wide data such as: counts of bus passengers; automatic and manual counts of cyclists; manual counts of pedestrians; and automatic and manual vehicle counts. Qualitative evidence was also gathered through interviews with officers responsible for implementation of the programmes and other stakeholders, as well as local residents.

Some of the smaller, more experimental projects (e.g. One-less-car2, and some projects in Australia15) also used car odometer readings and GPS tracking of participants.

10.3.12 Design issues

The sampling frame for the surveys used to evaluate the larger PTP projects (e.g. TravelSmart projects in Australia and England, the English Sustainable Travel Towns, and SCSP in Scotland) covered all residential households in the geographical programme areas, with samples randomly selected and stratified. As previously noted, this means that not all respondents in the ‘after’ survey had actually received PTP advice, although the surveys could have picked up diffusion effects from those who had, to those who had not. However, it would have been informative if results had been available for the two groups separately1.

Evaluations of smaller projects have focused on surveying PTP participants only, before and after a project. The panel approach has the advantage of showing changes which are more easily attributable to the PTP measure. However, panel surveys may introduce errors which are more systematic and less amenable to treatment by statistical analysis. Results can be vulnerable to respondent bias, as those who have made some kind of change are more likely to respond, or to exaggerate the changes in line with the known objectives of the project (the ‘good subject effect’). Whilst household surveys run across a whole area (repeat cross-sectional surveys) may be less likely to suffer from these biases, any changes they show are harder to attribute to the PTP intervention, especially when a range of other measures were being implemented at the same time, as was the case with the most detailed evaluations.

The large-scale PTP evaluations tended to compare results from the project area with those of a comparison area, selected to be as similar as possible to the project area. This constitutes a quasi-experimental ‘two-group pre-and post-test design’. It differs from a randomised control group design (a ‘true experiment’) in that the project area and comparison area are not randomly selected. Generally, independent (random) samples were drawn from the project area and comparison area populations for both the before and after surveys, although partial matched samples and matched (panel) samples were used in some areas. The trend for the comparison area can be applied as a ‘correction’ to the results in the project area to provide an estimate of the ‘counterfactual’, or what might have happened in the event of PTP not being implemented in target area1. However, this type of correcting has led to criticism, given that the circumstances can never be identical across two areas and can lead to exaggeration of the impacts.

In addition to, or instead of, running of household surveys in the comparison areas, some of the larger studies drew on comparable data from national sources, relating to the comparison areas. For example, the Sustainable Travel Towns evaluation drew on household
travel survey data from the UK National Travel Survey, and traffic counts from the National Road Traffic Estimates, to compare the three towns with similar medium-sized towns in England.

Some of the smaller experimental studies refer to the use of control groups, rather than comparison groups. For example, nine of the 31 studies in the Japanese meta-analysis used control groups, and these were given stronger credence in the reporting of the findings. The Norwegian study among employees of 6 companies used an experimental design, with two treatment groups and a control group. Participants were assigned to the treatment and control groups at the level of the company, to prevent diffusion effects within organisations; however they were not assigned randomly. Hence it might be described as a quasi-experimental design, albeit closer to a ‘true experiment’ than most PTP evaluations. This study was designed to address the problem that many evaluations cover a package of measures and cannot therefore provide reliable evidence of PTP effects in isolation from other factors. Whilst the Norwegian experiment showed no effect of travel information and/or incentives on mode use, the ‘treatments’ used differed from the methods employed in typical large-scale PTP project to such a degree that the findings are not easily comparable.

10.3.13 Validity, reliability and significance

The claims made in the evidence with regard to reliability of results and statistical significance of changes in travel behaviour are greater for the larger studies, where larger sample sizes could be achieved. For example, in the Australian studies, nine projects run by Socialdata were considered to have sample sizes large enough to demonstrate statistically significant changes in travel behaviour. Whilst the sample sizes are reported, the statistical methods used are not provided in the available evidence.

The household surveys in the English Sustainable Travel Towns achieved very high response numbers of over 25,000 people and 75,000 trips at the aggregate level, divided into the three towns and two time periods. The sample of people represented 3-5% of the study area populations and was sufficient to provide 95% confidence intervals of around +/- 2% in each town for each date. Although this is claimed to be sufficient to generalise the results to the full population, the changes reported could not be interpreted as emerging from PTP alone, as previously discussed. The English PTP project evaluations compared by Chatterjee included statistical tests on the estimated change in the mode share of car driver trips and showed some level of significance with at least a 90% level of confidence, although there was ambiguity as to whether appropriate sample sizes had been used.

The Seattle ‘One-car-less’ project is an example of a project for which statistical significance was not tested because sample sizes were too small. Despite efforts to include a varied selection of neighbourhoods, housing types, and income levels among participant households, the results could not be generalized to Seattle’s population as a whole. The absence of generalisability also applied to the other smaller projects reviewed.

10.3.14 Critiques of PTP evaluation

Doubts have been cast on the reliability of some of the evidence described above, both methodologically and politically; the latter due to vested interests in the success of PTP projects. Methodologically, evaluations have been criticised for: the use of unrepresentative samples and inadequate sample sizes; incorrect attribution of effects; use of an inappropriate population base; failure to consider longer term effects; and over-reliance on self-reporting. Concerns have been raised about vested interest as a result of the shortage of independent evaluators – hence, PTP schemes have tended to be evaluated by the organisations which deliver them. Policy-makers may also have an interest in PTP
Measure No.10: Mobility Management: Personalised Travel Planning (PTP)

Interventions succeeding because they may appear to increase the use of sustainable transport without requiring major changes to transport policy (described by Morton and Mees as "the promise of something for nothing"). Bonsall concludes that:

"The methods generally used to evaluate PTP schemes, and the forces influencing which results enter the public domain, are likely to have led to a systematic bias in the published results and [...] the real effect of PTP is probably less positive than that which is generally reported".

Others contend that any errors in results can be assumed to be randomly distributed and therefore do not undermine the view that "the case for PTP is made". Ker argues that PTP is required, by critics, to demonstrate that its measurements and the statistical interpretation of its measured achievements are valid, but these critics fail to apply the same standards to their own data and analysis. Moreover, Ker questions whether these statistical 'requirements' are appropriate, given the difficulty of isolating cause-effect relationships in complex systems, the disproportionately high costs of carrying out detailed evaluations, and given that this is an area of public policy where failure does not result in unacceptable consequences.

10.3.15 Evidence gaps remaining

The points raised above suggest there remains a need for the development of evaluation methods for PTP which are both reliable and financially realistic; however, there may be limits as to how far this is possible, given the difficulties discussed. Aside from the inherent weaknesses in the process of gathering evidence, one specific remaining gap in the evidence content concerns the longer-term effects of PTP, which have been considered in only a few studies so far (e.g. 11).

10.4 Findings Relating to Transferability and Upscaling

10.4.1 Transferability

The evidence from Australia, the USA, Japan and Europe is reasonably consistent, suggesting that the same methods to evaluate PTP would yield similar findings in towns and cities across different countries. Clearly, transport alternatives to the car must be available if individuals are to be encouraged to reduce their car use, which is why PTP is more appropriate to towns, cities and sub-urban areas than to rural areas. The lower the quality of the alternatives, the less successful PTP is likely to be. Furthermore, it is also likely that PTP will work better in locations where there is a gap between people’s perceptions of public transport/cycling, and the reality of such alternatives, or where improvements are being made.

The scaling-up of ‘mainstream’ PTP projects like TravelSmart is unproblematic (funding permitted), as the very large projects already run in many cities have demonstrated. The smaller, more intensive demonstration projects, especially those involving the provision of financial incentives, have been more effective but are less conducive to up-scaling due to the costs involved.

‘PESTLE factors’ generally work in favour of mainstream PTP schemes, as they are reasonably cost-effective and not politically sensitive, focussing as they do on voluntary behaviour change. Voluntary behaviour change is enhanced through social diffusion, exemplified by the particular successes claimed by community based social marketing approaches to PTP, such as ‘In Motion’ in Seattle. More passive social diffusion occurs where people simply observe their neighbours using sustainable modes and may feel encouraged to
emulate them. At the same time, this creates positive feedback whereby people may feel more connected with their community as they use their cars less (e.g. 10.2).

10.4.2 Complementarity
The evidence presented here has shown that PTP is often implemented as part of a package of sustainable transport measures; indeed, as already noted, voluntary travel behaviour change away from the car can only occur where alternatives to the car exist, and is more likely where the quality of alternatives is high. PTP can also serve as a useful means of promoting improvements such as better bus services and cycle paths. The success of integrated programmes such as the English Sustainable Travel Towns in increasing use of sustainable modes demonstrate how PTP can complement infrastructure and service improvements. Some of the evidence suggests that PTP can reduce car use even when other improvements are not being made1. However, it is not clear whether sustainable alternatives were already of reasonable quality in those cases, and PTP served to improve individuals’ perceptions, and hence use, of these alternatives.

There is little evidence concerning the durability of the effects of PTP, although it is likely that the ongoing success of behaviour change requires ongoing investment in sustainable modes.

10.5 Additional benefits
As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for personal travel planning interventions:

- **Social inclusion:** Can contribute to social inclusion in a community, through new awareness of ways of reaching services, facilities, and leisure / social activities (and the ability to use them). Also perhaps via increased engagement with others on shared modes of transport (bus, train etc.). In both instances the greater engagement could impact beneficially on the quality of life of participants.

- **Support to sustainable mobility programmes:** Exposure to the PTP process was seen to contribute to the effectiveness and public acceptance of other sustainable transport measures, as well as helping to recruit individuals as ‘travel champions’ in programs. For example, in Scotland, PTP was thought to help make the delivery of an integrated ‘smarter choices’ programme more dynamic and responsive.

10.6 Summary
Evidence from around the world suggests that PTP projects are usually successful in reducing both the number of trips undertaken as car driver, and car-driver mode share. Figures for the reduction in car driver trips are typically between 8% and 12%, whilst car-driver mode share has typically fallen by around 5-7% (but some examples are much higher). The quality of the interactions between travel advisers and householders would appear to be key to the success of schemes; figures higher than these typical ranges were achieved when intensive support was offered, and when people were encouraged to pledge to reduce their car-use either individually or through community-based activities.

However, numerous commentators have concluded that the scale of behaviour change is likely to have been exaggerated. Although it might be argued that we should have confidence in the claims made because of the large number of studies undertaken and the reasonable consistency of findings, there are grounds to suspect that many evaluations have been
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vulnerable to a degree of reporting bias and methodological weaknesses. Such weaknesses
could be addressed through the use of more independent evaluators and greater care in
achieving representative samples and large enough sample sizes (if financially viable). Wider
use of area-wide empirical data such as vehicle counts has been recommended. More
evaluation of the longer term effects of PTP is also desirable, and this might include more
attention to the measurement of attitude change as well as behaviour change. Issues such as
these have been addressed in the most recent studies (yet to be published), so it is possible
that stronger quantitative evidence will shortly appear.

Despite the lack of consensus over the precise scale of impacts, qualitative judgements of
residential PTP give confidence that this is a type of scheme which does contribute to
increasing the use of sustainable modes, particularly when it forms part of a broader
package to improve sustainable transport alternatives.

10.7 References for this review

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Measure No.11: Marketing and rewarding

Marketing / social marketing and rewards-based schemes encouraging greater use of more sustainable modes and travel behaviours.

Interventions focus primarily on brand, image, lifestyle, and benefit, and can be used by cities in conjunction with other ‘physical’ interventions or as stand-alone programs. They are often referred to as ‘soft measures’, voluntary change measures, psychological and behavioural strategies, or mobility management tools.

Key messages:

✓ Marketing ‘campaigns’ appear to deliver their intended purpose successfully, with positive effects seen for interventions relating to road safety, cycling and travel mode.
✓ Individual travel marketing interventions can, by definition, deliver more focused actions.
✓ Reduction in car-driver trips ranging from 5%-15% have been seen from individual travel marketing while the costs are described as ‘low’.
✓ Rewarding schemes for public transport usage are able to increase the number of customers and to achieve high customer loyalty.
✓ ‘Eco-driving’ programmes appear to be a cost-effective way of reducing CO₂ emissions. From a business perspective, eco-driving training can achieve pay back through the induced fuel savings.

11.1 Context and background

The following marketing and rewarding policies and measures might typically be implemented on a local level or as part of a SUMP:

Potential interventions

- Campaigns: Awareness raising/ marketing focussing on different aspects, e.g. active travel or traffic safety, and target groups, e.g. pupils or commuters
- Individualised travel marketing, which is a technique for changing personal travel behaviour through persuasive communication, also known as “voluntary travel behaviour change” (VTBC)
- Rewarding schemes for choosing public transport
- Eco-driving

This measure incorporates a range of marketing / social marketing and rewards-based schemes – whilst initiatives under Measures No.9 and No.10 (which are also seen as soft measures) will be more concerned with delivering travel information. Marketing and
rewarding schemes are seen to be more persuading than travel plans and travel planning.

11.2 Extent and Sources of Evidence

In general, only little information of high quality is available. None of the documents reviewed used a method which is similar to a cost-benefit analysis (CBA). A 2011 study of gaps in knowledge regarding “soft” transport policy measures stated that “future research should also find how to quantify certain benefits inherent to “soft” measures in CBA, i.e. the cost-effectiveness of techniques such as motivational support to set goals of changing travel.”

11.2.1 Campaigns

A study in 2014 of material from school travel campaigns highlighted the ‘striking’ absence of systematic evaluations. The study found that effects most widely reported are the number of participants and various stakeholders’ impressions of the process. There is less knowledge about the long term effects of such schemes.

However, there are a number of (high-quality) meta studies discussing effects of soft measures, partly citing effects of the same projects. A meta study published in 2011 reviewing evaluations of soft transport policy measures discusses the effects of campaigns on car usage. The authors point to methodological weaknesses of the primary sources (see below). Another meta study analyses the effect of road safety campaigns on accidents.

Some in-depth information could also be extracted from ex post evaluations of German campaigns promoting cycling, which had not been cited by the earlier mentioned meta analyses and which give a good indication of the budget which may have to be spent for a successful campaign.

11.2.2 Individualised travel marketing

The effects of individualised travel marketing mainly rely on a 2009 meta study of the effectiveness of their “IndiMark” programme. The IndiMark process uses direct contact with households to identify and meet their individual needs for support, and to motivate people to think about their day-to-day travel choices. This meta study is complemented by findings from the following research experiments:

- An experiment conducted at University of Cagliari, Italy in 2009. This was a cognitive-motivational action facilitated by a GPS device (App).
- An experiment at the University of Tsukuba, Japan in 2008. This was a persuasive communication program to induce public-transport-oriented residential (PTOR) choice. The experiment targeted students, who were in the process of changing their residential location.

11.2.3 Rewarding schemes

The following ex post evaluations have been reviewed:

- Corporate PT pass in Massachusetts, USA
- Free month travel card for Copenhagen car drivers, Denmark
- Reward scheme for better public transportation “Belønningsordningen”, Norway

11.2.4 Eco-Driving

The following evaluations have been reviewed:

- The Dutch national ecodriving programme “Het Nieuwe Rijden”
- The “SAFe and Fuel Efficient Driving” [SAFED] Programme in the United Kingdom
11.3 What the Evidence Claims

11.3.1 Campaigns

Travel awareness campaigns may reduce car usage and accidents in a statistically significant way. A meta-analysis of the effectiveness of soft transport policy measures published in 2008 found that the proportion of trips not conducted by car increased from 34% before to 39% after implementation of the campaign (evaluating the results of 72 studies). A meta-analysis of the effect of road safety campaigns found that the weighted average effect of such campaigns is a 9% reduction in accidents (evaluating the effects of 119 campaigns in 67 studies).

In Munich, the share of cycling increased by four percentage points (from 13.6 to 17.4) in the period between 2008 and 2011. In 2011, the campaign “cycling capital Munich” was implemented, covering a budget of €1.2 million in that year. Sixteen percent of this effect was attributed to the campaign. An evaluation of a campaign in four other German cities, which had an overall budget of €1.2 million (for all the four cities), also showed significant modal shifts. In a representative survey, 26% of respondents indicated to having increased the number of walking and cycling trips on distances less than 5km. The survey was conducted during the campaign’s implementation in 2009.

Travel awareness campaigns vary from relatively general to closely targeted, intensive approaches. The latter tended to achieve higher levels of individual change in car-use reduction. These results fit well with the recommendations from the evaluation of a cycling marketing campaign in Munich that the campaign should focus on specific target groups to be more successful. Equally, the road safety campaign meta analysis concludes that campaigns had a stronger impact on accident reduction when personal communication or roadside media was part of the delivery strategy.

11.3.2 Individualised travel marketing

The results indicate that providing information about sustainable mobility solutions and complementing this with persuasive motivation to act accordingly, may significantly reduce car usage of the participants. The cost of these interventions was described as “low”. Reported estimates of travel-behaviour change achieved by IndiMark have consistently been in the range of a 5% to 15% reduction in car-as-driver trips. Other sources report similar effects.

11.3.3 Rewarding schemes

An evaluation of a ticket subscription mechanism used by Massachusetts Bay Transportation Authority (MBTA) in Boston that offers additional revenue to the transit agency and decreases effective fares for riders found that Corporate Pass customers are using the pass significantly less than their Non-Corporate counterparts. Corporate LinkPass holders use the pass at least 20% less than Non-Corporate LinkPass holders on average, and the disparity in usage increases during summer and popular vacation months. In fact, 47% of Corporate Pass holders are using less than the full “value” of the pass on average, which results in an estimated $4.4 million in additional annual revenue captured from Corporate LinkPass holders, and over $9 million estimated for the entire Corporate Pass program. Furthermore, Corporate Passes generate a steady revenue stream while Non-Corporate Passes have higher fluctuations due to seasonal variability. Additionally, the number of Corporate LinkPasses sold were unaffected by a recent fare rise suggesting (although not definitively proving) that the Corporate Pass may offer some additional insulation to fare increases.
An evaluation was also conducted on the effects of a price promotion in the form of a free month travel card being offered to a random sample of Copenhagen car drivers fulfilling a number of screening criteria. The resulting change in the use of public transportation was measured, compared to a control group, together with a number of possible antecedents derived from previous research. The price promotion led to a significant increase in commuting by public transport: the use of public transportation doubled in the experiment group and a positive effect remained half a year after the intervention.

The effects of a Norwegian government public transport reward scheme providing funds to local municipalities were evaluated in 2007. Most of the money from the "Belønningsordningen" reward scheme has been used to reduce fares and to improve service delivery. Thus passengers benefited indirectly from the reward scheme by e.g. lower tariffs. Between 2004 and 2007 on average €14 million per year has been given to the participating cities in total. As a result, the scheme has facilitated a small increase in public transport in the cities involved. For example in Trondheim funds have been used for financing a 12% tariff reduction in 2004 and a later tariff freeze at the 2004 level, resulting in an increase in the number of public transport journeys per person per year of 2.8% from 2004 to 2006.

11.3.4 Eco-Driving

The evaluation of the nationwide Dutch "Het Nieuwe Rijden" programme provides an overview of the evidence on the effects of raising awareness and encouraging drivers to drive more energy-efficiently. It states some substantial reductions in CO₂ emissions and positive effects on other issues like road safety, traffic noise nuisance and driver stress. The CO₂ emission reduction in passenger traffic achieved as a direct result of the programme is claimed to be 0.22 Mton, plus a 0.10 Mton reduction from freight and public transport. The evaluation emphasises the high cost-effectiveness of the measure: It calculates less than €10 costs per ton avoided CO₂ emissions. For calculations of the cost-effectiveness of Eco-Driving measures the study points out that the government loses revenues as a result. For example, tax-exemption for fuel saving in-car devices and less tax revenues due to the fuel savings themselves. This would result in a mean cost-effectiveness for the government of between €40 / ton CO₂ emission avoidance (including tax-exemption) and €300 / ton (including both tax-exemption and less tax revenues through fuel sales). Only when income losses for the government are not taken into account (which is usually the case for CO₂ reduction projects in traffic and transport), the cost-effectiveness for the government goes up to the beforementioned less than €10 per ton.

Results from the SAFED (Safe and Fuel Efficient Driving) programme in the UK carried out by the Department for Transport also provide evidence. Selected drivers of Heavy Goods Vehicles (HGVs), and later also Passenger Carrying Vehicles (PCVs) like buses and coaches received training on safe and fuel efficient driving techniques by a network of 200 different SAFED trainers. The participating HGV drivers achieved 10% fuel savings, 8 million GBP financial savings and reduced CO₂ by 28,468 tonnes. They also reduced gear changes by 36.9%. For PCVs a feasibility study thus suggested an average of 12% fuel savings per driver, an average 40% reduction in gear changes and a 60% reduction in safety related faults.

11.3.5 Methodologies and Caveats

Evidence found on the effectiveness of campaigns suffers from significant methodological weaknesses. An important problem is the issue of weak quasi-experimental designs that have been used by most of the primary studies on campaigns. For example, due to the lack of control groups, the ‘one group pre-post-test designs’ do not permit strong causal inferences.
This in turn limits the policy recommendations that might be drawn from the results. The Cycling Capital Munich campaign is part of a series of policy measures. The (potential) interrelation between these policy measures or any influence on this campaign coming from the other independent developments was not part of the methodological approach (e.g. by using a control group). The authors acknowledge this fact and develop their own methodology to isolate the campaign’s effects. This methodology assigned stated preferences to responsiveness to certain kinds of policy measures. This approach has never been peer-reviewed.

Evidence about individualised travel marketing is based on using control group data and other statistical tests, and can thus be considered significant. The evidence on rewarding schemes is partly based on using control group data and field experiments and can also be considered significant. The studies on eco-driving did not gauge whether and how long-term effects may occur or not. However, eco-driving training as part of the driving training and test has the potential to reveal long-term effects.

11.4 Lessons for Successful Deployment of this measure

Behavioural changes are easier to achieve if one connects soft and hard measures, i.e. campaigns with physical improvements. Such couplings are easier to achieve if the campaign activity is an integrated part of transport plan, mobility- or health strategy. In particular, supportive hard policy measures are able to increase effectiveness of campaigns and individualised travel marketing. A number of VTBC projects in German cities called “IndiMark” (see above) led to an average increase of 23 additional public transport trips per person and year. When IndiMark was delivered alongside infrastructure improvements, the average increase in PT trips per person per year was more than doubled (+48 trips per person and year).

Some argue, however, that it remains unclear in what ways hard transport policy measures (e.g. cycling infrastructure improvements) impact on the effectiveness of soft policy measures (e.g. cycling campaigns) as well as possible effects in the reverse direction.

Some argue that there is limited understanding about the long-term effects and the associated time-scale of behavioural responses, including what other factors may account for long-term effects. However, the evaluators of IndiMark claim “increasing evidence that behaviour changes generated by IndiMark [individualised travel marketing] are sustained over time”, justifying this by “repeat travel surveys conducted up to four years after”, which had shown “that the behaviour change achieved by the original VTBC interventions – a 14% reduction in car-use – has been ‘locked in’ with a 13% reduction in car-use measured three and four years after the intervention”.

Regarding upscaling of rewarding schemes, the evaluation of the Norwegian scheme to reduce fares point out that although the increase in the number of trips by public transportation due to the free one month travel card is impressive, it needed to be acknowledged that this was an increase from a low level of 5% of commuting trips to 10% and only 7% remained six months after the intervention. The low absolute percentages illustrate the limitations of this measure.

As regards target groups, there appear to be no political, social or economic barriers to suppose that the approaches used are not transferable. As regards other local conditions, there are no systematic reasons to suppose that the evidence findings would not be relevant in other locations. On the contrary, it is argued that persuasive communication programmes
to induce public-transport-oriented residential (PTOR) choice could be implemented at any university, workplace, or housing agency, leading to less car use. The IndiMark programme was successful in three continents. Accordingly, there is no indication that eco-driving may be more successful or less promising under other circumstances than the reported schemes in the Netherlands and the UK.

### 11.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- **Personal rewards**: 'Social benefits' are likely to accrue indirectly from the measures being marketed, rather than the marketing campaigns themselves. Rewards for public transport use may accrue social benefits for the individuals receiving them.
- **Safety Benefits**: Changes in driving styles and approach that follow from promoting Eco-driving may also bring about safety benefits, as well as reduced noise and less stress for drivers.
- **Community benefits**: The mode shift from car to public transport brought about by campaigns has the potential to bring wider air quality and noise benefits to communities.

### 11.6 Summary

In summary, the evidence reviewed here suggests that the following conclusions might be drawn:

- Campaigns can successfully deliver their intended purpose. The effect size depends on several factors such as budget, target groups and delivery strategy. The more focussed an approach, the more successful it is. The exact results of the campaigns on car usage are neither consistent nor reliable.
- Individualised travel marketing is by definition more focussed than campaigns. Participants of such programmes consistently reduce their car-as-driver-trips in the range of 5% to 15%.
- To be effective, marketing and rewarding schemes should also be supported with "hard" policy measures such as infrastructure schemes. This bundling of measures appears to be a successful strategy.
- Rewarding schemes for public transport usage are able to increase the number of customers and to achieve high customer loyalty.
- Eco-driving programmes appear to be a cost-effective way of reducing CO2 emissions. From a company’s point of view, eco-driving training pays back through the induced fuel savings.

Marketing and rewarding schemes as defined in this review do not depend on favourable circumstances. However, they should be shaped to specific target groups to be most effective.

### 11.7 References for this Review

Measure No.11: Marketing and rewarding


Measure No.12: Public transport enhancements

Improvements to existing public transport networks and vehicles in a city.

Cities can encourage greater use of public transport through more reliable, frequent or quicker services, by increasing network coverage, or by making improvements to the quality of vehicles and facilities.

Key messages:

- Quality changes are likely to have a positive effect – albeit more related to existing passengers than those choosing to change their mode of travel.
- Effects of enhancements are likely to be more significant in the longer – rather than the shorter-term.
- Interventions are often delivered as part of a package of changes, making it more difficult to isolate the effects of specific features such as low-floor access or Wi-Fi.
- Increased public transport ridership can be encouraged by low(er) cost travel passes, but this may come at an unsustainable cost to operators and municipalities.
- Success may not be a simple matter of encouraging additional passengers, as this may come at a revenue cost which is not sustainable over time, possibly confounding short-term calculations of cost-benefit.
- ‘Free travel’ can help new services to gain momentum, but free public transport can be a costly policy, particularly if patronage levels increase significantly.

12.1 Context and background

Demand for public transport is a ‘consumer good’ which means that as well as price, a range of qualitative factors, such as, frequency, network coverage, and speed will also influence consumer’s choices. As a consequence this review will cover a wide range of potential interventions which might impact on availability and use of public transport in a location.

Potential interventions

- Additional services, whether that be more frequent running of an existing route, or the introduction of new routes
- Quality improvements (better vehicles, better seats, Wi-Fi etc.)
- More accessible vehicles (for example low-floor vehicles which improve access for elderly, disabled, mothers with children etc.)
- Subsidies (concessionary passes, student passes etc.)
- Fare incentives (lower fares, ‘free fares’, etc.)
- Integrated Ticketing*
To facilitate the use of public transport, operators and municipalities aim to make ticketing systems as easy and attractive as possible. Developing what might commonly be termed integrated ticketing, but also embracing ‘through’ tickets, and ‘cross-ticketing’. In such products pricing structures and information might be made coherent between different public transport operators and potentially valid for all modes in one specific region. Integrated tickets are not necessarily smart (regarding the technology), in fact in many cases they are likely to still be paper-based.

12.2 Extent and Sources of Evidence

There are extensive amounts of evidence available in respect of this particular measure, in part because it covers a wide range of interventions. There is also a longstanding interest from policy makers, planners and academics in what effect changes to public transport services might bring (in both the short and long term), and much material related to this to draw on. In particular there is a strong body of material around ‘elasticity’s of demand’ in response to particular changes. It is the case though that much of the evidence is contained in review documents, is relatively general and generic in nature.

Perhaps the key material which underpins the review is found in body of work addressing elasticities of demand, for example the TRL report from 2004, and the subsequent reviews of similar material (for example from Australia). These wide-ranging review documents have been supplemented here with evidence drawn from specific implementations of additional levels of service, in particular in respect of bus services. This is an area that has received extensive academic interest over the years, and still generates material currently. This extensively-researched knowledge base provides public transport operators with an important baseline from which to consider service enhancements, and to be able to forecast the likely impacts of any change they might make.

Looking beyond enhancements such as additional and more frequent services, attempts have been made to find evidence which considers the effects on likely demand of a range of other improvements to services, whether that relates to the quality of the vehicles themselves, or the facilities they offer. Evidence here may be at a range of scales, from individual routes through to whole networks. It is worth noting that this has not proven to be as straightforward as hoped for, and in fact that it has been difficult to find post-implementation material that explicitly looks at quality of service changes such as installing ‘leather seats’, moving to low-floor buses, or providing ‘free’ Wi-Fi.

The other principal aspect of public transport services considered in this review, and one for which there is a wide range of material available, is ticketing, and more specifically the approach of ‘integrated ticketing’. The evidence on integrated ticketing is introduced via a major review of integrated ticketing systems carried out for the UK passenger transport executives (major urban conurbations) in the late 2000s, which is further illustrated with specific examples of ticketing interventions in a range of European contexts. These types of intervention are being deployed at a range of scales, from individual routes to city-wide (or wider) implementations. It should be noted that smart-ticketing is dealt with in Measure 15, and the ticketing solutions discussed here are reviewed for the role that the intervention plays, not the medium the ticket is deployed on.

Allied to ticketing of course is the fare charged for travel, the primary influence on demand that the evidence relating to ‘elasticity’ focusses on. Although this measure review does not address ticket pricing per se, it does review evidence in respect of ‘free’ travel, in respect of
particular interventions that have set up reduced cost or free services. To that end, concessionary fares in the UK for older and disabled people are reviewed, as are free systems in European countries, and a student scheme from the US which offers a zero marginal cost for use. Although there have been a number of long-running ‘free’ public transport schemes in European countries, there is limited evidence as to the effects and impacts of such schemes. Thus most evidence reviewed here comes from a review paper that considers a number of these schemes, It is acknowledged though that there is a shortfall of evaluation literature around more recent free schemes such as that in Tallinn in Estonia.

12.3 What the Evidence Claims

The evidence reported on here begins by exploring some fundamental econometric underpinnings relating to demand for public transport services. At its most simple, the demand for public transport can be seen to reflect on a range of factors related to the provision of services – not least the price of such services. Having an understanding of how the public might react to price levels in bus, tram and rail has been seen to be an important factor in understanding the benefits to be achieved from using price as a tool to achieve goals in public transport use. Being able to understand the relationships between price and demand levels is particularly important when services are being provided by the state / municipality, with control over subsidy levels, as opposed to more market-orientated environments (such as that experienced in the UK post the 1986 deregulation of public transport for instance).

Some considerable effort has then been invested in understanding the underlying supply / demand relationships in this area, and this has resulted in a significant body of work on the elasticity of demand in response to price, and a range of other factors. This Measure Review will not focus on ‘pricing’ per se, although concessionary and free services will be considered below, but will reflect on other interventions related to public transport provision such as improved levels of service, additional routes, better vehicles, etc. Generic studies have taken place on the elasticity of demand related to these factors, and these will be further illustrated with evidence from specific examples.

The second part of the evidence will look in particular at the area of ticketing and how interventions in this area can make public transport more attractive to passengers. The evidence here is prefaced by an extensive review report undertaken for the metropolitan transport authorities in the major UK cities in 2009. This sets a general context for how a range of ticketing changes can help encourage use of public transport. This then is supported by reports of a number of specific interventions from around the world looking at the benefits of changes to ticketing strategies.

12.3.1 Part I: Extending and improving services:

The 2004 report \textit{The demand for public transport: a practical guide} from the UK Transport Research Laboratory (TRL) set out to provide a comprehensive analysis of the factors that might influence demand for public transport\textsuperscript{1}. It looked to produce quantitative indications of how these factors might influence demand. The resultant study provided an updated set of figures twenty years on from an earlier comprehensive report in this area – drawing on evidence from around the world, and reflecting changes that had occurred in the field of public transport in the intervening years.

Perhaps the most widely estimated effects covered by the report was the impact of changes in price, an area not covered explicitly here in this measure review – aside from the effects of
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free transport which are discussed below. One key factor which the report underlines is that the effects of change can be short-term or long-term, and that often a longer view of impacts will reflect a much bigger change. In fact immediate change may be significantly different to longer-run changes. A later addition to this evidence suggests that in the longer term (over 5-10 years), the impacts of bus improvements on patronage are almost double short run (6-12 months) impacts. These studies on elasticity also highlight that there are differences in (fare) elasticity dependant on factors such as gender, age, journey purpose, peak/ off-peak, PT mode, location etc.

In addition to the (critically important) impacts of price, the TRL report also identifies seven categories of attributes of transport service that determine quality and which can also reflect on levels of demand. These other factors are considered to a greater or lesser extent in this measure review. For the purposes of this review, the element of any public transport intervention that is perhaps key is around ‘service levels’. These can be measured (or described) in several ways, reflecting factors such as frequency of service or the total distance travelled by services. The common approach taken by many studies in this area is to reflect on the total vehicle Kms / Miles travelled. The TRL study, and others that followed, find that at its simplest the elasticity of bus demand (passengers) in relation to vehicle km is approximately +0.4 (short run) and +0.7 (long-run) (based on a range of UK studies). Thus, the more distance covered, the more passengers there will be. Within this headline figure there is variation depending on the context of services (urban/ rural, and day of the week. The study did also look at urban rail interventions where the elasticity of demand may be more sensitive, but found less evidence to consider. Other aspects of service levels also have an impact. For example, longer waiting time at bus stops has an average result of -0.64 (longer waiting times, fewer passengers), whilst additional operating hours had an effect of +1 (although across a relatively limited number of studies).

The implication of the findings on typical short run elasticities is that a decrease in fares of say 10% will increase demand by 4%, an increase in service frequency of 10% will increase demand by around 3.5% and a reduction in in-vehicle travel time of 10% will increase bus patronage by about 3%. Hence the ‘effectiveness’ of bus improvements in patronage terms is driven by the degree to which improvements can act to reduce fares, increase service levels and reduce bus travel time.

There are though limits to the interventions that can be made, and their effects on patronage of public transport systems. For instance, fares cannot be reduced by more than 100%. Hence a bus improvement offering free fares can only ever increase patronage by a maximum of around 40%. Similarly reductions in bus journey times greater than 50% would be unlikely. Hence bus improvements achieving 50% travel time reduction can only ever hope to achieve a 15% growth in patronage. Service levels, however, can be increased more than 100% (although the evidence and common sense indicates diminishing elasticities as service levels increase). This suggests that increases in service level (frequency) might be the measure which might achieve the highest bus patronage growth, assuming money was no object. UK experience has shown that: Improvements to bus frequency demonstrate the greatest proportional and absolute growth in bus use. Typical frequency increases (20-30%) can be expected to deliver patronage gains at around half of the level of service increase.

Service enhancements:

The first specific example of the effects of interventions to increase service levels is taken from Melbourne in Australia in the mid-2000s. In this instance two sets of measures were being undertaken in respect of bus routes. These were broadly classified as ‘mass transit’
and ‘safety net’ enhancements. The former provided additional capacity on what were seen to be premium trunk routes, in order to increase numbers of people using public transport, whilst the latter added capacity to help avoid social exclusion issues in specific communities and at specific times (i.e. weekends). Many of the additional services / more frequent services under the transit enhancements were branded as ‘SmartBus’ routes.

In the year to August 2007, bus patronage grew at a rate of around 4.6% per annum, which was seen to be historically very high. Three quarters of the absolute growth in patronage was attributed to routes that had been added, extended or upgraded over the previous two years. In contrast, routes with unchanged service levels had only grown at an average of 1.3% per annum in the same period. In circumstances that were seen to favour increased bus patronage, the study here finds that this is the case only when routes are operating at a ‘reasonable’ service level. This is suggested to be seven days a week, with half-hourly or better frequencies. Routes not meeting these levels are still seen to be in decline. SmartBus routes are seen to have generated patronage growth over and above any growth in service mileage after 2-4 years – and this is seen to include an element of ‘mode switch’. The increases in service levels to address social transit needs were also seen to be successful, and to be ‘highly likely’ to be reducing social exclusion issues in the many areas of Melbourne that previously suffered from poor mobility.

Although not explicitly covered in this paper, reference is made to an ‘unpublished’ financial evaluation of the wider development program for the public transport network in Melbourne carried out by Metlink (the local public transport marketing body). This was reported to state that the BCR for the expanded local bus services was 1.9, whilst across the full package of changes this BCR rose to 3.0 (about half of which was attributable to congestion cost savings). The evidence made several suggestions as to other factors that might have contributed to the success of the SmartBus corridors / routes. These reflected on wider issues around travel in Melbourne at the time such as levels of congestion, as well as macro-economic factors such as rising fuel prices and mortgage interest rates. Both of these latter factors seen to be influencing commuter location / costs. It is noted that there will be an impact from such factors in levels of demand.

The second example of additional services being implemented is seen in the English city of Winchester. Here a range of interventions around the bus services in the city were taking place, including increased frequency of service on a number of cross-city routes (for example from 4 to 6 buses an hour on one route). Several routes saw changes under the banner of becoming Quality Bus Partnership routes (QBP), and levels of patronage on these routes were compared to ‘control’ routes that were not receiving the same interventions. Results showed increases in numbers of passengers for the two QBP routes, but decreases for a third and the control routes. One of the QBP routes, the X5, experienced a 25% patronage increase from 2002/2003 to 2004/2005, whilst the control routes saw decreases consistent with the average decline in England (outside London) of around 4.5% in bus patronage during the same period. About a quarter of passengers on the X5 used the service more since the changes were introduced. The three most positive influences were the frequency of service, comfort of travel on the new buses and bus traveller information. New users of the X5 stated that frequency of service was the top positive influence in attracting them to use the bus. There was an overall patronage increase on the three QBP bus routes of 12%, meeting the 8% target set in the QBP. The frequency increase for the X5 service would suggest (using the elasticity models derived by Balcombe et al 2004) an increase in use of some 20% - which in effect was 25% here, supported perhaps by the other elements within the package?
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Results show that when user and non-user benefits are taken into consideration, the investment made by both the operator and the local authority to improve these bus services is recovered within 5 years. This is well within the expected life of the new vehicles and, therefore, the investment has been shown to be justified. However, from just the operator's point of view, the investment they have made will take 12 years to recover, which is still less than the life expectancy for the buses of 15 years. One factor cited in the success of the changes on the X5 was that it linked many high density residential areas, with passengers from these estates likely to have no real alternative to the bus. The route also served destinations with high passenger demand such as two major supermarkets, the city centre, the railway station, a business park, and the residential areas at either end of the route.

Reorganising Public Transport services to rationalise them, as well as introducing higher quality vehicles and facilities was an approach used effectively in the CIVITAS Mimosa programme on the island of Madeira. An evaluation of the new 'Green Line' service in the major tourist location of Funchai shows that making such changes can increase patronage whilst also reducing costs and boosting revenue. The changes to service frequency and routes provided an opportunity to not only resolve public transport demands for residents in the tourist quarter, but also provided a new service which hotels and other tourist destinations could promote (and sell tickets for). By deploying new, Euro 5 specification buses, the service was also able to address a range of emission and air quality targets, and accessibility levels that assisted less able travellers. This implementation provides an example of where consideration of existing routes and services offered a new solution which optimised services to allow for growth in patronage at a time when other services on the island were exhibiting decline.

Quality enhancements / improvements:

There are a range of other ‘improvements’ that operators of public transport services could make in order to ‘improve’ the perceived quality of the services – and thereby improve patronage levels. These include improving the quality of the vehicles used, and by offering additional services on the vehicles. This might include Wi-Fi access for example, or better quality seating, or air conditioning for instance. Some of these factors have been tested in the econometric analysis, but there appears to be little independent evidence available to substantiate benefits. Such ‘soft’ improvements are not expected to increase bus patronage by more than a few percent, with air conditioning, CCTV and a smoother ride seen to have the greatest impact, but even then unlikely to be more than 2% for each intervention / measure.

Another improvement in buses in particular is the introduction of ‘low-floor’, or easy access vehicles. In part driven by the need to meet legislative demands in respect of access to transport for the disabled, such ‘accessible’ vehicles also provide incentives for other potential bus users. For example, mothers with small children, or the elderly who might be less able to access vehicles with steps. Low floor buses have been proved to enhance accessibility for wheelchair users, parents with young children, and older people in general. They have led to significant increases in demand for some services (5-10%) although results are seen to vary from place to place. No real effect seen on some early UK routes, although slight increase in demand on one London route. The case study in Winchester also had the opportunity to explore the effects of use of low-floor buses, as these were deployed on the X5 route when service frequency was increased. Although the authors did explicitly look for the effects of the low-floor vehicles there was not a strong impact seen.
**Fares / Subsidies / concessions:**

As noted above, changes to fares on public transport can have well understood impacts on levels of patronage and on revenues for operators. This means that interventions such as subsidies (concessionary passes, student passes etc.) and fare incentives (lower fares, ‘free fares’, free transfer etc.) can be used as tools to boost numbers of people travelling by public transport. As the evidence put forward in the TRL report makes clear though the interplay between passenger numbers and revenue needs to be considered carefully, as does the impacts on alternative routes and networks. Changes need to be made in the context of the fact that there will be short-run (1-2 years) and long-run (12-15 years) effects. The report also cautions that whilst fare increases may improve revenue in the short term, it will likely decrease in the longer-term, and attempts to counter falling revenues with increased fares will eventually fail. To reverse negative trends in patronage levels on public transport will require service improvements, as well as possibly fare reductions.

Completely free public transport may at first sight seem to be an attractive option for encouraging a shift to public transport use. The experience reported on in a review of such schemes is though less affirmative. The review instead suggests that evidence suggests instead that free public transport offers poor outcomes, and comes at a high cost. The TRL report also makes some specific observations on ‘free travel’. Firstly, that there is no convincing evidence that free travel diverts journeys from private cars to public transport, and secondly that offering concessionary fares to certain groups of passengers is likely to result in additional trips being made by those people as opposed to passengers in general.

The main impact seen in the free-fare case-studies considered is a huge growth in patronage, up to 13-fold increase has been reported in a wide review of such schemes, of which a significant section are moving from walking or cycling as their normal mode of travel. Effects on car traffic levels are though marginal and typically any modal shift benefits might be lost after a few years’ traffic growth. Those free public transport schemes which are seen to be successful, are those which have a goal mainly to grow public transport patronage. Other potential benefits around congestion and social and environmental benefits are seen to be best achieved through more targeted measures, or in combination with such measures.

Notwithstanding this general weakness as an intervention, the free travel review does suggest two situations where a free scheme may be appropriate, and effective.

- For promotions of limited duration. So for example, a new service might gain momentum if it is launched with free travel - for a limited time. Such a campaign can, raise the profile of a route, making the population aware of existing public transport following enhancements to the service (or perhaps following a service interruption).
- When the cost of operating a ticketing system and related activities exceed ticket revenues. Free public transport may be a pragmatic solution when the ticket income is very low.

The review also adds a note of caution to those municipalities thinking about introducing a ‘free-fares’ scheme. Free public transport can be a costly policy, particularly if patronage levels increase significantly. If this is the case, then funds that might have been spent on more targeted solutions may be displaced. The review also suggests that there is evidence that free-fare schemes have been abandoned because of high (and rising) costs, and with growing evidence that fare increases have larger effect than similar fare reductions the overall outcome of introducing free fares and later withdraw the scheme can be highly
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Negative. This means that free fare schemes will require broad political support and long term commitment.

Free public transport introduced in the City of Tallinn (Estonia) for registered residents of the city has increased numbers of people using public transport7, although passengers still need to check-on and off the bus using a smartcard. After the first year of this scheme, there was a claimed 6% increase in public transport users in the city, with car use in the city centre reducing by 5%. Whilst the measure is seen as successful, it has increased transport subsidy costs for the municipality, albeit offset in some respects by more local income tax from those registering for the new travel card if they were not already known to city authorities. There is no official analysis of the impacts of the intervention available as yet. Tallinn is one of a growing number of cities and towns that are experimenting with free public transport. Nysa in Poland (population 58,000) allows motorists to travel free on local buses on presentation of their drivers licence and vehicle registration documents. Surveys of passengers have shown additional passengers, and that some people travelling for free had not used public transport previously. Some users were travelling for free who had paid before, but the municipality was absorbing the relatively limited shortfall in revenue, and those who had swapped mode had not been paying for the bus beforehand so made no difference to revenue. Claim were being made about improved air quality, and noise levels in the town centre, as well as reduced numbers of cars. As for Tallinn though, there is no official analysis of the scheme available as yet.

An alternative to making all travel on public transport free is to offer free travel for a group of travellers who may be seen to be mobility disadvantaged. This is the case in the UK, which provides free travel on buses for older and disabled people outside of the morning peak period. Various schemes were introduced in different UK constituent countries (e.g. Wales, Scotland, England) during the early 2000s, culminating in a ‘national’ scheme in England in 2008 which allowed free, or ‘concessionary’ travel across the whole country for those over the age of 60, or who experienced a range of disabilities or health issues. The effect of this scheme on demand for public transport was explored in a report commissioned for the Department of Transport in 20088. The results from the study show that concessionary fare schemes had a significant impact on bus travel of the over 60s, reversing what had been a trend of declining use. In fact, the modelling carried out in the study suggested that without free travel, total bus trips by eligible individuals would have declined by up to 3.0% per annum in cities and a slightly lower rate in rural communities. This would have been almost entirely due to growth in car ownership and driving licence holding amongst those over 60. Instead, trip rates and distance travelled were both seen to increase with the introduction of concessionary travel. As predicted by the report’s authors, the free bus travel results in greater bus use than earlier incentive schemes that made use of half, flat and hybrid fares. The model developed in the report predicts that free fares had the effect of increasing bus travel by eligible individuals in 2008 by 26% in the urban areas and 45% in rural ones relative to the non-concession alternative. This is equivalent on very simple assumptions to a full fare elasticity of -0.47 (urban) and -0.75 (rural). This elasticity represents the change after 2 years, although the author’s expect that over time the elasticity would be greater. Other quantification of the benefits in respect of mobility-exclusion have been less visible, although that is still seen as the primary driver of the policy in the UK. Introducing the concession across the whole population of those over 60 has led to concerns being raised about the cost of the scheme, with the reimbursement to operators in England alone being over £1billion currently. Some attempts are being made to now reduce costs, with higher age thresholds before people
qualify for the pass now in place.

Another option is to offer travel at a zero-marginal cost at the time of travel. Whilst this is effectively how season tickets or travel passes work, there are also subsidised passes which are intended to increase use of public transport. One example of this is found in the study of the ‘UPASS’ at the University of Wisconsin-Milwaukee (UWM) in the US. This pass provided students with unlimited travel on any local bus route at any time, to any place, and for any trip purpose with no additional fare. All students were able to acquire a pass, paying a fee via their tuition fees. Introduction of the new pass was partly driven by parking constraints in and around the University. Approximately 10% of the students who were driving to the university in spring 1994 had shifted to transit a year later, although the largest group shifting consisted of those who had previously walked to campus (28%). In general, the program reduced vehicle trips to campus, increased transit ridership, and reduced the overall impact of vehicles. There was a perception that the parking situation around campus had improved since the implementation of the new pass, with a strong ‘approval’ rating for the scheme from students. Some students surveyed also indicated that the travel pass had influenced their decision to attend the university, their decision as to whether to purchase a car, and had even allowed some to find employment. Several changes had to be made to bus services to accommodate the additional demand. This included additional buses on one route, two new express routes and improved schedules on other routes.

12.3.2 Part II: Ticketing:

Noting the issues and effects above in respect of ‘free’ travel, the other area in which interventions can be made in respect of increasing public transport patronage is around ticketing, more specifically the value and usability of a ticket for passengers. There are a wide range of interventions available, covering what might be termed as ‘integrated ticketing’, allowing access to more than one route and / or mode, as well as options which facilitate travel at minimal marginal costs such as season tickets, or travel cards. For many municipalities, the overarching idea of a multimodal transportation ticketing system is to combine all modes on a single ticket, making the ticketing system as easy and attractive as possible. Such an Integrated Tariff System (ITS) allows users to consider the whole public transit system within a specific area (urban, metropolitan, or even regional), as if it were organized by a sole firm offering a single service.

Integrated ticketing:

The benefit of using an integrated ticketing approach was considered in a major study undertaken in 2009. This literature review identified case studies from major urban areas across Europe, North America and Australia that had qualified and quantified the benefits of a range of integrated ticketing schemes implemented between the early 1980’s and 2008. The review was completed primarily by way of desktop analysis, although this was supplemented by direct contact to some individual agencies and industry associations.

The review identified the following range of benefits of these integrated fare products:

- Increased patronage
- Increases in recorded passenger satisfaction
- Evidence of resulting modal shift; the review notes though that there is limited quantitative evidence to support a link between modal shift and fare integration, although some research they reviewed did suggest an increase in public transport usage.
- Increases in revenue
Measure No.12: Public transport enhancements

- Reductions in transaction and administrative costs
- Social benefits
- Reductions in fraud
- Wider contribution to city life and identity;
- Acquisition of accurate data on passenger behaviour enabling better capacity and network planning; and
- Faster boarding times enabling buses to run more reliably, faster and frequently

Whilst the review identified a wider range of benefits of integrated fare products, the most commonly reported benefit was increased patronage, and it was only in this context that the review found robust evidence in case studies. Some of the specific findings from the review include:

- Drawing on evidence from London, Europe, Australia and the US, the review found increases in patronage in the range of 6% to 20%, with some individual modes experiencing up to 40%.
- There was limited evidence to support increased revenues, with reported increases varying widely from a 1% to a 12.6% increase in total revenue.
- Although some case studies suggested an overall increase in public transport usage, there was limited quantitative evidence to support a link between modal shift and fare integration (the case study considered here was Freiberg in Germany).
- There is some evidence to suggest improved satisfaction from fare integration primary due to increased convenience and fare savings (from UK and US)
- There is limited evidence of faster boarding times as a result of integrating ticketing, with some transport modes experiencing in order of a 10% reduction in passenger in-vehicle time; (From London and US).
- There is limited evidence to suggest that integrating ticketing in isolation has reduced fare evasion. Rather the reduction in fraud has usually been associated with integrated fares as well as a change in fare medium;
- There is only anecdotal evidence to support a reduction in transaction and administration costs from simplified and integrated ticketing.

The report also highlights the following issues with the evidence that they collected:

- The benefits of integrated ticketing are often seen to be significant, yet the post-implementation evidence of these benefits is often not captured and/or reported on in the public domain.
- The evidence that is available can be variable in both quantity and quality, with a focus on patronage levels and revenue for operators. Few studies were seen to have isolated the impact of the introduction of integrated ticket products per se, and in much of the material reviewed it was unclear what effect other factors might have had on observed outcomes.
- The study was focussed on evidence of integrated ticketing whatever the ticketing media (paper, magnetic stripe and contactless smart card).

Ticketing interventions:

As well as the findings of the review noted above, there are a range of ticketing-based interventions that provide evidence of specific approaches that can impact on public transport demand. One area that has received scrutiny is in the use of season tickets, or passes. The impact of the introduction of this sort of intervention has been reviewed in a
range of Swiss cities over the 25 years from 1971-1996\textsuperscript{11}. A feature of these season passes in Switzerland is that they are ‘transferable’, allowing more than one person to use them (although not at the same time of course). Econometric evidence was studied from four Swiss cities (Basel, Bern, Geneva and Zurich) following the introduction of deeply discounted season tickets in the mid-1980s. This was seen to have had a considerable positive impact on public transport use. The passes allowed people to transfer across modes and operator. The introduction led to 8.5% more trips in Basel, and an increase in passenger demand in Bern after the pass was extended to all operators in the city. This was an interesting feature of the scheme in this city, as although 80% of services were provided by one operator it was only when the ‘feeder’ services to the city network were included that use increased.

The authors of the Swiss study suggest that Season ticket innovations are most likely to succeed when the public transport network offers a dense, frequent and fast service, which will offset the fundamental time and cost disadvantages of public transport relative to the private car. In addition, the imposition of complementary traffic restraint measures, such as large scale pedestrianization and central parking restrictions, may also be important in promoting modal change away from the cars. It is noted however that the city of Zurich had achieved high levels of public transport use without substantial pedestrianization.

The use of a ‘travel card’ across the whole transport network in the Madrid region between 1979 and 2001 is also seen to have positive results\textsuperscript{12}, with demand growth rates of 7% to 15% in seen in the long run. This study was not just interested in patronage levels though as it also evaluated the impact on revenue of the introduction of the travel card scheme. The number of passengers using public transport in the region grew from 951 million in 1986 to 1549 million in 2001, with patronage increasing at an annual rate of 2.2%. Results from the study suggest that the introduction of travel cards led to a growth in bus and underground patronage of 3.4% and 5.3% in the short-run, and 7% and 15% in the long-run, respectively. The market share for travel cards in 2001 exceeded 60%. The high market penetration of the low-cost travel card has though had a negative effect on operator revenues. So although the evidence here suggests that a declining trend in public transport ridership can be reversed through a policy based on low cost travel passes and improvements in the quality of services, this may come at the cost of overall revenue.

Finally in respect of integrated ticketing, empirical evidence on the impact on patronage of the introduction of such solutions in an Italian context was considered in a 2009 report\textsuperscript{13}. This study undertook econometric analysis on a panel of 69 Italian local public transport companies over the period 1991-2002. It reviewed the effects of various qualitative features of the service (i.e., average speed, frequency and density), with the ultimate goal of evaluating the shifts in LPT demand due to the provision of an integrated ticketing system. The results show that such systems exerted a demand increase of 2% in the short-run, and up to 12% in the long-run. Three particular features were highlighted for their impacts.

1. **Integrated ticketing for a single trip.** In particular, within the urban networks it seemed to be important to give travellers the opportunity to choose an integrated ticket for a single trip. This is perhaps more relevant to urban areas, and/or travellers making one-off journeys as opposed to commuters who are more likely to buy season tickets. This study estimated the effect of this sort of measure to be around 7% in the short-run and as much as 26% in the long-run.

2. **Zonal Pricing.** The introduction of zonal pricing shows a positive impact of a similar magnitude on demand, since such pricing better discriminates according to users' needs: for example, by increasing the option of short distance/less expensive trips (e.g., by offering different travel cards to be used in the historical centres only rather
3. **Extension of integration beyond the urban area.** This is estimated to induce an immediate shift of demand of 5%, and can, in the long-run, produce an increase of passenger-trips of around 25%. The positive effects seen here are more likely to emerge the higher the quality of the LPT service is, in terms of network density, frequency, inter-modal coordination, and whether other policies to encourage bus use are implemented in parallel.

### 12.4 Lessons for Successful Deployment of this measure

The evidence presented in this measure review has looked at a range of scales of intervention, and in a range of implementation models from full cost subsidy to scenarios where the changes have to be self-financing over standard expectations of commercial return. Changes have ranged from individual routes being modified, through to wider-scale network changes. Key lessons emerging from the evidence include:

- Understanding the underlying elasticity of demand relating to supply and quality of service allows a more nuanced response to changes in service provision.
- Whilst service-level enhancements can be deployed at the level of an individual route with a reasonable expectation of positive change, some of the integrated ticketing interventions seem to be best deployed at a larger scale.
- Political will and funding are required if fare reduction schemes or free travel are offered as a way of increasing patronage levels. Whether the required level of support is justified may well depend on other financial benefits for local/national authorities. For example, in Tallinn, Estonia, citizens were offered free bus travel if they were registered for income tax.
- Public transport enhancements are more successful if accompanied by demand restraints on use of the private car.
- Ticketing integration can become more effective if it is extended beyond the urban area.

It is unlikely that wider scale deployment of ‘free travel’ will find favour outside of the specific circumstances considered above. As has been experienced in the UK with concessionary fares for older people, what may have started as more of a political imperative has now become an expensive, and universal support scheme for a growing part of society, and one which is now exercising political debate as to its long-term viability in a time of reducing public budgets.

Many of the interventions reported on here have explored the factors which have contributed to their success, over and above the intervention itself. In most cases this is some form of restraint, or demand constraints on use of the private car. In general there is little coverage of modal change in the results reported on here, and this would be one area of evidence that would be a useful addition to what is considered above.

### 12.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- **Social Inclusion.** Enhancing public transport can bring social inclusion benefits by providing new or additional services to areas not previously well-served, as well as improving accessibility levels for less able travellers. Free and concessionary fares can also help address affordability issues for some groups in society, again helping them to
access services and facilities, as well as participate in society.

- **Air quality.** Claims are made for improvements in levels of emissions and air quality from moving to newer, higher quality, public transport vehicles.
- **Congestion / Modal shift.** The provision of free travel is claimed to have led to reductions in congestion and some transfer from car use in the cities that have implemented it (although there is limited evidence at present to support this.)

### 12.6 Summary

Much of the evidence presented in this measure review is econometric in nature, and is based on ex-post evaluations of interventions. In some instances this has been undertaken relatively quickly after an intervention has taken place, although there is an understanding supported by the literature that long-run effects are likely to be more significant. In support of this, evidence has been presented here that covers significant periods of time, twenty plus years in a number of instances.

More evidence is needed of the impacts of quality improvements before the impacts of interventions such as Wi-Fi can be clearly articulated, but some effect from these sorts of changes is likely – albeit more related to existing passengers than those making modal change choices.

What the evidence does expose in respect of interventions related to this measure is that there are perhaps competing goals at play, with increased patronage not necessarily the (only) desirable outcome. There are a number of interventions discussed above which will generate increased use of public transport, but this may be at an unsustainable cost to operators / municipalities. Thus success may not be a simple matter of encouraging additional passengers, as this may come at a revenue cost which is not sustainable over time. Understanding the underlying elasticity of demand in relation to a range of factors to do with supply and quality of service allows a more nuanced response to changes in service provision, and allows for a better use of resources.

### 12.7 References for this Review

Measure No.12: Public transport enhancements


Measure No.13: New Public Transport Systems and Networks

New forms of public transport services provided in urban areas

Through the introduction of new forms of public transport, a city can encourage more sustainable travel. Examples of interventions include, bus rapid transit (BRT), light rail (LRT) and ‘flexible’ systems such as demand responsive transport (DRT).

Key messages:

- Light rail (LRT) and Bus Rapid Transit (BRT) systems can increase passenger carrying capacity, increase use of public transport, and deliver land use strategies; e.g. regenerating former industrial areas, intensification around transport nodes or increased economic activity in central areas.
- Bus Rapid Transit (BRT) can meet similar objectives to LRT, but at a much lower cost. It can also be delivered in a much shorter timescale.
- Economic analysis is available for LRT and BRT schemes. For LRT they were more likely to be projections before scheme implementation, with positive benefit-cost Ratios (BCRs) ranging from 2-3. However, no evidence was identified to validate these BCRs post-implementation so they must be treated with due caution.
- Post implementation analysis of BRT schemes produced positive BCRs ranging from 1-3.
- LRT and BRT have a positive effect on land values near stations, but can negatively affect values near routes.
- Urban Demand Responsive Transport (DRT) systems can be an effective means of providing transport to the ‘mobility poor’ at a lower cost than alternatives (such as subsidised single ride taxis). They will normally require subsidy however.

13.1 Context and background

This measure review covers the following types of new public transport systems:

Potential interventions

- Light rail systems:
- Bus Rapid Transit (BRT) systems
- Demand Responsive Transit (DRT) systems.

Note: Personal rapid transit systems (PRT) are not considered here as they are not yet available in every day urban settings (instead being deployed in highly controlled contexts such as airports). Bus network extensions are covered in Measure Review No12.
Light rail systems: The terms ‘light rail’, ‘tram’ and ‘light rapid transit’ are often used interchangeably. In this measure review, the term ‘light rail’ is used to refer to electrified local urban rail systems that are able to run on street but may also incorporate grade-separated (above or below ground) sections, and that have some degree of segregation from general traffic.

Bus Rapid Transit (BRT) systems: The US Federal Transit Administration defines BRT as “an enhanced bus system that operates on bus lanes or other transit-ways in order to combine the flexibility of buses with the efficiency of rail”. The key defining feature of BRT systems is the use of significant sections of fully segregated bus lanes (or busways) across the network. To a greater or lesser extent, BRT systems may also incorporate enhanced safe stops or stations; off board payment systems; high quality and high capacity vehicles operating at a high frequency and the use of consistent branding across vehicles and infrastructure.

Demand Responsive Transit (DRT) systems: DRT (also termed as paratransit in the US) refers to any non-private transport mode that offers flexible, tailored routes and service timings in response to changing passenger demand. This measure review considers urban demand responsive bus services only.

Personal rapid transit systems have not been considered as these are not yet widely available in every day urban settings (instead being deployed in highly controlled contexts such as airports).

13.1.1 Objectives of new public transport systems

Light rail and BRT schemes are intended to provide high capacity, intra-urban (and often, but not always rapid) mass passenger transport. They may be motivated by primary objectives to increase passenger carrying capacity along congested urban corridors and/or to encourage modal shift from private car. A secondary objective may be to improve local air quality and/or to reduce greenhouse gas emissions.

Light rail in particular and to some extent BRT may also be incorporated into broader land use planning strategies to encourage (transit oriented) development along particular corridors and at particular nodes.

DRT schemes are seen as offering a potentially more efficient alternative to subsidised scheduled public transport services, often in rural contexts, but also along lower density lower demand urban corridors. Historically, in urban contexts DRT systems have been most commonly used to provide specialised services for particular user groups e.g. The elderly or the mobility impaired. However, in general public transport network planning, DRT may be used to feed scheduled services, providing a means of serving the ‘first and last miles’ of an inter-urban public transport journey.

13.2 Extent and Sources of Evidence

This review has drawn on 27 items of evidence. Given that the success of large infrastructure schemes like light rail is highly dependent on context (land use planning, economic circumstances and the regulatory environment for example), several meta-studies have been included to cover the required breadth of circumstance. Reliance on a smaller number of single evaluation studies was felt to risk misrepresenting the potential for new public transport measures to be (un)successful. The meta-studies are nevertheless complemented by evaluations of single interventions.
The level of current research activity centred on new public transport systems varies according to the type of intervention under scrutiny. BRT systems are presently an object of great interest, given the growing number of systems being delivered across the world. New light rail systems also tend to attract research interest, given their long term impacts on land use, land values and their immediate impacts on the transport system and travel behaviour. By contrast, there are not many sources on urban DRT systems, not least as a consequence of their being few such systems in existence.

In terms of the currency of evidence, the meta-reviews of light rail systems are now around 10 years old (coinciding with a particular policy interest in light rail in the late 1990s in the UK), but these have been complemented by more recent case studies. Evaluations of urban DRT systems are scarce and the review has relied upon an EU evaluation conducted in 2003 and an evaluation conducted in Manchester, UK in 2005. Evidence on Bus Rapid Transit is more up to date, with sources from the last five years being readily available.

Case studies have been drawn from several European nations, the USA, several South American nations (particularly relating to BRT), South Africa and South Korea. Evaluations tend to have been commissioned by European, national or local governments and conducted and reported by either academics or consultancies. This review has drawn on a balanced mix of evidence from both consultancy and academia.

With respect to intervention scale, the case studies reviewed usually relate to public transport schemes implemented in a single urban area or several urban areas for comparison in the case of meta-studies.

The post-implementation evaluation studies reviewed in the next section have tended not to employ cost benefit analysis. They rely instead on performance indicators to measure schemes against one or more of their objectives. Projected benefit cost ratios for a number of UK light rail schemes (prepared during scheme appraisal) were readily available however, and these are reported later. One meta study of BRT systems was found to include a detailed post implementation cost benefit calculation. No cost-benefit analyses were identified for urban DRT systems.

13.3 What the Evidence Claims

Evidence is presented on the impacts of light rail, BRT and DRT interventions in turn:

13.3.1 Light rail systems

As noted in the introduction, light rail systems may be constructed to meet a mix of objectives including: increasing passenger carrying capacity, improving mobility, achieving modal transfer from the car, improving local air quality, reducing greenhouse gas emissions and supporting land use policies.

1. Passenger demand: Two meta-analyses illustrate the extent to which effectively planned light rail systems can be successful in attracting high numbers of passengers (meeting or exceeding patronage forecasts) and in re-cooping capital costs (see Manchester - UK, Vancouver - Canada, St Louis – USA, table 1).

<table>
<thead>
<tr>
<th>Light rail scheme</th>
<th>Annual cost per passenger</th>
<th>Farebox recovery ratio (%)</th>
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</thead>
<tbody>
<tr>
<td>Patronage Actual / Projected [% difference]</td>
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</tbody>
</table>

Table 1: Light rail outturn annual patronage versus forecast patronage
Factors contributing to the success of light rail schemes, in terms of passenger demand, have been identified (from the meta-studies) as: locating lines in high density areas; high levels of segregation, ensuring integration rather than competition with feeder bus networks (which may be challenging in deregulated regimes), existing high levels of public transport usage, serving areas with strong and growing levels of economic activity and encouraging new development along new lines and at stations. Conversely, absence of these factors can result in failing or poorly performing systems (see Sheffield - UK ), as can serving low income areas (which may already be served by cheaper bus based public transport), poor public relations and negative local attitudes towards a new public transport system.

2. Impact on car use: An overview of the impact of mass rapid transit schemes in the UK, conducted by the Commission for Integrated Transport\(^6\), suggested that light rail systems attract between 2.5% and 20% of passengers from private cars\(^9\). However, modal transfer can be expected to be much larger from existing public transport services - up to 69% of passengers were found to have transferred from other forms of public transport.

As stand-alone interventions, the light rail schemes reviewed by Babalik-Sutcliffe\(^4\), which included systems in the UK and the USA, were generally shown to be *ineffective* in reducing car traffic *overall*. It is argued that additional complementary measures to restrain car use are required to achieve this aim.

3. Local air quality: This is in contrast to a study by Ewing et al\(^7\) which estimated that the extension to the TRAX light rail line in Utah, USA contributed to a reduction in traffic along the light rail alignment of between 7,500 and 21,700 vehicles per day. This estimate is subject to a number of assumptions concerning what traffic levels would have been in the absence of the light rail line and should therefore be treated with caution. Nevertheless, the authors took a central estimate of a reduction of 10,400 vehicles per day to estimate a reduction in nitrous oxide emissions of 16.6 kg per day.

4. Greenhouse gas emissions: Boarnet et al\(^8\) assessed the impact of the new Exposition light rail line in Los Angeles. They estimated that households living within half a mile of a new light rail station reduced their daily average carbon dioxide emissions from motor vehicles by of the order of 30% to 35%. No significant change in carbon dioxide emissions from motor vehicles was observed in households living further than half a mile from a new station.

5. Land use planning: There are several examples of how successful light rail systems have been delivered as part of wider spatial planning strategies. Land use policies in Vancouver were adapted to focus new employment and housing developments around planned SkyTrain stations to stimulate passenger demand. The SkyTrain system was also used successfully to encourage regeneration of former industrial areas of the city\(^4\). Similarly, the Docklands Light

\(^{\text{a}}\) These figures relate to the Croydon, Manchester and Sheffield systems, UK.
Rail (London, UK) successfully catalysed the regeneration of the Isle of Dogs area of East London into a financial centre following the transfer of port activities to a location further down the River Thames. This effect is not universally observed however. After five years of operation, the South Yorkshire Supertram (Sheffield, UK) was found to have had no observable impact on planning application submissions or land uses.

6. Impact on property values: Studies have shown that property values tend to be higher within light rail catchment areas, though again this is not always the case. In their meta-analysis, Hass-Klau et al found residential property prices to be between 3% and 20% higher within light rail catchment areas (external factors are not controlled for in this cross-sectional analysis however). Cervero’s analysis revealed that (all else being equal) apartment prices were typically 17% higher in proximity to the East Trolley light rail line, San Diego (USA). This effect was not apparent along other light rail lines in San Diego, however.

A longitudinal analysis by Yan et al revealed that property prices in the corridor of a new light rail line constructed in Charlotte (North Carolina, USA) were lower before the system was constructed (attributed to being located in an industrial area), but the price differential reduced after the light rail system was introduced. This analysis of temporal change confirms that land values can increase over time as a consequence of the introduction of the light rail system. By way of a contrast, a monitoring study of the South Yorkshire Supertram (Sheffield, UK) indicated that house prices in the vicinity of the new tram line actually fell in the first five years of operation. This was attributed to the disruptive effects of construction. Prices subsequently recovered to be equivalent to other parts of the city and there remained an expectation that over the longer term, prices along the light rail line would continue to inflate.

7. Wider economic impacts: Hass-Klau et al’s meta-analysis of light rail systems in Europe and the USA provided insights into some other general economic impacts over the long term. It should be noted that the following claims are based on quite simple trend observations and the impacts of other external factors have not necessarily been controlled for:

- Rates of household car ownership were observed to be lower and also to grow more slowly within light rail catchment areas. The extent to which this was observed varied quite significantly across case study areas. For example in Montpellier (France), 2+ car ownership fell by 1% in the tramway corridor, but rose by over 3% away from the corridor. This effect was much weaker in the UK case studies. For example, in Manchester (UK), 2+ car ownership grew by 4.7% within the tram corridor, and rose by 5.3% outside the corridor.

- New light rail stops in town centres were found, in some circumstances, to increase pedestrian footfalls in retail areas. This claim is based on limited data from Strasbourg where footfall increased from 88,000 to 146,000 one year after the light rail line opened.

- Light rail connections to city centres were seen to be successful in attracting large employers to city centres and also increased city centre rents which had the effect of attracting higher end retailers (Nantes, France is cited as an example).

8. Cost-benefit analyses (CBA): The post-implementation evaluation studies identified through this measure review did not include cost benefit analyses. However, it is usual for Benefit to Cost Ratios (BCRs) to be estimated as part of scheme appraisal and projected BCRs for a number of UK light rail schemes are presented in Table 2. These are shown to
range between 2 and 2.7\(^b\).

Cervero and Guerra\(^{13}\) estimated monetised social benefits of light rail systems in the USA (based on a calculation of ‘consumer surplus’ rather than BCR) and found that 10 out of the 12 systems tested produced social benefits net of costs. Their calculations compared the present ‘with light rail’ scenario to an alternative ‘without light rail’ scenario and relied on an assumed transfer of passengers to car and a hypothetical bus based public transport system.

Table 2: Projected (a-priori) BCRs for UK light rail schemes

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Benefit-cost ratio</th>
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<tbody>
<tr>
<td>Croydon Tramlink</td>
<td>2.7:1(^{14})</td>
</tr>
<tr>
<td>Nottingham Express Transit Phase Two line</td>
<td>2.47:1(^{15})</td>
</tr>
<tr>
<td>Manchester Metrolink: Oldham and Rochdale line</td>
<td>2.5:1(^{16})</td>
</tr>
<tr>
<td>Manchester Metrolink: Ashton-under-Lyne line</td>
<td>2.1:1(^{16})</td>
</tr>
<tr>
<td>Manchester Metrolink: Airport line</td>
<td>2.6:1(^{16})</td>
</tr>
</tbody>
</table>

9. Deliverability: Given that light rail schemes are amongst the most expensive and difficult local transport intervention to plan, finance and deliver, it is relevant to note that proposed light rail schemes have the potential to fail in the planning stages (at some considerable public cost), given lack of available public finance and/or perceived high levels of risk from potential (private and public sector) investors. In a UK context, this includes highly developed schemes in Leeds, Liverpool and South Hampshire\(^{16}\).

13.3.2 Bus Rapid Transit systems

BRT systems may be implemented to meet similar objectives to light rail schemes but at a lower cost. Objectives typically include increasing passenger carrying capacity, achieving modal shift from the car and/or reducing car traffic, enhancing mobility options, reducing public transport journey times, reducing greenhouse gas emissions, improving local air quality, improving road safety and supporting land use planning strategies. There may also be social equity aims, in for example providing improved transport accessibility to lower income groups.

1. Passenger carrying capacity and impact on car traffic: Two case studies\(^{17,18}\) illustrate the extent to which BRT can deliver high capacity passenger transport. The Istanbul Metrobüş system has a design capacity of 24,000 passengers per hour, but the system has been observed to carry up to 60,000 passengers per hour in peak periods and suffers from overcrowding at stations. It is estimated that the system achieved a 9% modal shift from car use\(^{17}\). Ridership of the Los Angeles County Metro Orange Line BRT system also exceeded expectations attracting 21,828 average weekday boardings (the target for 2020 was 22,000 weekday boardings). 18% of riders had transferred from driving and consequently time spent in congestion on a nearby highway was observed to reduce by 14%. However, BRT travel times were higher than expected - 41 to 50 mins compared to the anticipated 29-40 minutes\(^{18}\). The longer journey times were caused in part by the lack of selective vehicle detection to provide priority at signalised junctions and a need to reduce bus speeds to avoid collisions at junctions.

\(^{b}\) BCRs estimated as part of UK scheme appraisals typically include predictions of investment costs, user benefits (derived from journey time savings) and selected externalities (e.g. impacts on greenhouse gas emissions, congestion, accidents)
2. Journey time savings: Notwithstanding the longer than anticipated journey times on the Orange Line system, 85% of previous transit riders and two thirds of previous drivers reported journey time savings on switching to BRT\(^\text{18}\). Vaz and Venter\(^\text{19}\) report that users of the Johannesburg Rea Vaya system experienced journey time savings of between 10 and 20 per cent. Alpokin and Ergun’s\(^\text{20}\) case study of the Istanbul Metrobüs indicated that passengers saved 50 minutes per day on average (based on the before and after journey times reported by 1000 users of Metrobüs).

3. Greenhouse gas emissions: A meta-study by Embarq\(^\text{20}\) reports carbon dioxide emissions savings of between 27,000 tonnes and 61,000 tonnes of carbon dioxide per year for different case studies (table 3). Note that these estimates are subject to some uncertainty given their reliance on modelling exercises and inherent assumptions.

<table>
<thead>
<tr>
<th>BRT System</th>
<th>Estimated CO(^2) savings (ton CO(^2) / year)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Istanbul Metrobus</td>
<td>61,000</td>
<td>Alpokin and Ergun(^\text{20}) reporting a secondary calculation by the Istanbul Public Transport Authority</td>
</tr>
<tr>
<td>Johannesburg Rea Vaya</td>
<td>40,000</td>
<td>JIKE(^\text{21})</td>
</tr>
<tr>
<td>Mexico City Metrobus</td>
<td>27,000</td>
<td>INE(^\text{22})</td>
</tr>
</tbody>
</table>

4. Local air quality: Turner et al\(^\text{23}\) reported that the Bogota (Columbia) Transmilenio system produced a 43% reduction in Sulphur Dioxide, an 18% reduction in Nitrous Oxide and a 12% reduction in fine particulates\(^\text{24}\).

5. Road safety impacts: The Embarq meta-study\(^\text{20}\) reports that BRT can contribute to a 33% reduction in crashes involving any vehicle type (based on case studies from Latin America and India). The authors note that research on the road safety impacts of BRT is limited however. By contrast, the Los Angeles County Metro Orange Line BRT system initially had a negative impact on local road safety – there were several collisions between cars and buses at junctions when the system began operating. Accidents were reduced by reducing bus speeds at junctions.

6. Land values: Like light rail, BRT has been shown to have a positive effect on land values in proximity to stations, but can negatively affect land values in proximity to busways\(^\text{20}\). Cervero and Kang’s\(^\text{24}\) analysis of a new BRT line in Seoul (South Korea) indicated price premiums in the vicinity of BRT stops of 10% for residential properties and 25% for non-residential properties. Rodriguez and Mojica\(^\text{25}\) conducted a before and after study of an extension to the Transmilenio system (Bogota, Columbia) and identified a 13-14% increase in property prices in the BRT catchment relative to properties outside of the catchment area.

7. Land use changes: Cervero and Kang\(^\text{24}\) also identified that the new BRT line in Seoul contributed to land use intensification – property owners were prompted to convert single-family dwellings into apartments along the BRT alignment.

8. Overall cost-benefit analyses: In considering the combined effects of some of the aforementioned benefits, the Embarq study\(^\text{20}\) reported a post implementation cost-benefit analysis of four BRT case studies (Bogota, Mexico City, Istanbul and Johannesburg). Benefits

\(^\text{24}\) The source of these figures is not clearly reported and it is not clear over what area these reductions applied.
captured include change in travel time, change in vehicle operating costs, change in carbon dioxide emissions, change in exposure to local air pollutants, road safety benefits, and changes in physical activity. Estimates of BCRs ranged from 1.2 (Mexico and Johannesburg) to 2.8 (Istanbul). With this style of cost benefit analysis, travel time savings are shown to make the biggest contribution to benefits. It is also noted that most users of the BRT systems came from lower to middle income groups, demonstrating potential to meet social equity aims. This is in contrast to light rail systems which were observed to be less successful in serving lower income groups.

9. Deliverability: BRT systems may be chosen in favour of light rail alternatives given their lower construction costs and hence anticipated lower risk and shorter delivery time-scales. Indeed the Istanbul system was partly conceived to deliver additional passenger transport capacity across the Istanbul Straits of the Bosporus while a new railway tunnel was constructed. Alpokin and Egrun note that local government was able to fund the scheme without the need for international loans, that fare revenues are higher than operating costs (operating costs are 3.56 USD/vehicle-km while fare revenue is 4.75 USD /vehicle-km) and that the system had started to recover its capital costs after five years of operation.

Light rail and BRT systems: Methods and evidence gaps

It is possible for certain attributes of light rail and BRT systems to be effectively evaluated through simple performance indicators - for example, reporting passenger numbers or journey times following scheme implementation. In meta-studies, descriptive statistics have been used to compare land values or car ownership rates inside and outside of system catchment areas. Such simple observed trends should be treated with some caution as, for example, land values and car ownership will clearly be impacted by other factors such as income or proximity to urban centres. Nevertheless, the results tend to be consistent with studies that have employed more sophisticated regression modelling to examine the impact on land values of new transport systems while controlling for other factors. In this respect, a limitation is that relatively few studies have examined changes in land values after scheme implementation. This is arguably of greater interest than the more common cross-sectional regression analyses which compare land values within and outside of system catchment areas.

Few studies were identified on the impact of light rail and BRT systems on emissions and this represents an evidential need. Studies of emissions that were identified tended to rely on simulation modelling, rather than on observations. The BCRs presented for UK light rail systems are also based on a-priori forecasts. No follow-up studies were identified during the course of this review to examine the accuracy of the predicted BCRs. The results of modelling and forecasting exercises should always be treated with due caution, given their inevitable reliance on assumptions.

The road safety impacts of light rail and bus rapid transit are unproven and this represents a further evidence need.

13.3.4 Demand Responsive Transit schemes

The primary objectives of DRT systems in urban areas are: i) to promote social inclusion by providing efficient public transport access to jobs and services and, ii) to achieve this at a lower cost than conventional, scheduled public transport services. Laws et al. note that there may be a secondary environmental objective to reduce car dependency and congestion by encouraging people to adopt public transport use. Demand responsive services may typically be targeted at the ‘mobility disadvantaged’ including low income, elderly or disabled
groups as well as lower density neighbourhoods with limited scheduled public transport services. It is increasingly recognised that DRT systems may also be able to support some commuter trips between employment and residential zones in (sub)-urban areas that are not well connected by conventional public transport.

There are few evaluation studies of urban DRT systems as services have more typically been adopted in rural areas (where scheduled public transport is less viable). This review has relied upon evaluations of DRT services in Manchester, UK and a study of the DRT systems that were initiated across Europe under the European Commission funded SAMPLUS (System for Advanced Management of Public Transport Operations) programme.

Six DRT services, branded as ‘Local Link’, were rolled out in Manchester, UK in 2002. The evaluation examined a range of policy and operational indicators across the six services, revealing:

**Policy indicators**

- Between 34% and 59% of trips were to ‘target destinations’ (e.g. to health, employment, education)
- Between 75% and 95% of trips were made by users from non-car households while between 33% and 48% of trips were made by users with mobility impairments
- Between 1% and 8% of users would not have made the trip if the service were unavailable
- Between 16% and 66% of users lived outside conventional bus catchment areas

**Operational indicators**

- Subsidy per passenger trip ranged between £4.69 and £68.09
- Average weekly patronage per vehicle ranged between 30 and 260 passengers

To summarise, these indicators demonstrate that DRT services successfully met social inclusion aims, reaching those with limited mobility options and providing access to target destinations as intended. By contrast operational performance varied substantially, conveying small numbers of passengers and requiring quite large subsidies in some cases.

The success or otherwise of a scheme was noted to be most strongly related to the geographic characteristics of the area and the operational characteristics of the scheme. These were found to be more important than the demographic characteristics of the local population. With respect to geographic area, the evaluation report suggests as a guide, that “the optimal size and population density for a successful scheme appears to be 10-15km² and 3,500 people per km² respectively”. Operational success was found to be greater if services were designed to “focus on a few key destinations or clusters of activity”.

The Nelson and Mageean evaluation of DRT services initiated across Europe under the SAMPLUS programme provides insights into the impacts of differing operating contexts (financing, level of regulation, urban structure and service design):

- DRT services were all shown to require subsidy, but less so than alternatives such as conventional scheduled services or single ride taxis.
- An implication of this is that DRT services are more likely to be successful in highly regulated markets, which can provide the high levels of subsidy required. In deregulated environments private operators are unlikely to consider running DRT services without public sector support.
- Subsidy is likely to be acceptable if DRT services are shown to be effective at
fulfilling one or more social requirements.
- Corroborating the findings of the evaluation of the DRT services in Manchester\(^3\), the most successful services were shown to operate across a small area in order to balance route directness with route flexibility.
- Operators were shown to prefer independent travel dispatch centres, which demonstrate economies of scale e.g. external service providers offering booking and route scheduling platforms.

### DRT Systems: Methods and evidence gaps

There is a clear need for further evaluation studies of urban DRT systems. The studies that were identified presented straightforward performance indicators, though these are considered to be fit for purpose. No cost benefit analyses were identified during the course of the review. Traditional cost benefit analysis may not be an effective means of evaluating DRT against social objectives, given the challenge of monetizing some of the more nebulous benefits such as improved accessibility or reduced levels of social exclusion.

#### 13.4 Lessons for Successful Deployment of this measure

13.4.1 Transferability: The meta-studies used in this review intentionally included examples from a range of different urban contexts. These served to illustrate the importance of factors that contribute to the success or otherwise of light rail, BRT and DRT schemes.

Light rail and BRT systems are concerned with delivering high capacity passenger transport. Issues relating to the success, delivery and resilience of light rail and BRT systems are dealt with together first.

13.4.2 High capacity public transport systems

1. Barriers to and facilitators of success: New high capacity passenger transport systems are most successful if they are highly segregated, operate along corridors with high population densities, and serve areas with strong and growing levels of economic activity. Given the relatively large capital expenditure requirements, strong national and local political support is necessary to deliver schemes of this magnitude. Strong and convincing passenger demand forecasts are also required to attract the necessary long term private sector investment. BRT systems are significantly cheaper, lower risk and consequently quicker to implement than light rail systems.

2. Complementarity: Successful deployment is usually accompanied by sympathetic land use policies that prioritise new development in the vicinity of transit stops to stimulate demand. It is also necessary for local bus services to be rationalised and re-organised to feed rather than to compete with new high capacity transit systems. This may be challenging in deregulated markets.

3. Resilience and durability: It is important that land use policies that deliver high population densities and economic activity in the vicinity of new transit systems are pursued and maintained over the long term.

13.4.3 Demand responsive transport systems

DRT systems fulfil a quite different role to high capacity passenger transport systems:

1. Barriers to and facilitators of success: DRT services usually require public subsidy and are most successful in highly regulated environments which are able to provide the
necessary level of financial support. Subsidies are likely to be politically acceptable if DRT services are shown to fulfil important social objectives and that this can be achieved at a lower cost than alternative mobility options (e.g. scheduled public transport or single taxi rides).

2. Complementarity: Services should be designed to complement rather than to compete with existing mobility options, and in particular local taxi markets.

3. Resilience and durability: As Mageean and Nelson\(^2\) suggest a long term view is required in DRT service planning in order to ensure that subsidies can be maintained and that DRT services are given sufficient time to become established.

### 13.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for new public transport interventions:

- **Social Equity**: A comparative study of four BRT systems showed that most users came from lower to middle income groups, demonstrating potential to meet social equity aims. This is in contrast to light rail systems which were observed to be less successful in serving lower income groups.

- **Improved mobility for disadvantaged groups**: DRT systems also offer social benefits such as improved mobility options for disadvantaged groups, for example those without access to a car and living in areas where conventional public transport is less cost-effective.

- **Wider social benefits**: Estimated monetised social benefits of light rail systems in the USA, based on a calculation of ‘consumer surplus’, found that 10 out of the 12 systems tested produced social benefits net of costs.

### 13.6 Summary

#### 13.6.1 Light rail and BRT systems

Overall, there is convincing evidence that light rail and BRT systems can be successful in delivering objectives relating to increasing passenger carrying capacity, increasing use of public transport and delivering land use planning objectives. Evidence on modal transfer and car traffic restraint is less convincing, suggesting that complementary policies are required to meet these aims. Factors that are key to success are: delivering systems along high population density corridors with high levels of economic activity, a high level of segregation from general traffic, and integration with land use planning policies. Absence of these factors can result in highly expensive, failing schemes. A lack of confidence in passenger demand can also lead to projects failing in the planning stages.

Further research is required to generate convincing evidence on local air quality benefits.

**Benefit Cost Ratios**: Projected BCRs for light rail schemes (conducted before scheme implementation) were found to range between 2 and 2.7. No evidence was identified to validate these BCRs following scheme implementation and they must be treated with due caution.

BRT schemes were estimated to have BCRs ranging from 1.2 (Mexico and Johannesburg) to 2.8 (Istanbul) based on a post-implementation analysis.
13.6.2 Urban DRT systems

The evidence base on urban DRT systems is comparatively weak. Nevertheless, the case studies that were available indicated that DRT systems can successfully fulfil social objectives (in particular in providing transport to the mobility poor) at a lower public subsidy than alternatives such as conventional public transport or single ride taxis. Strong support from a public sector body is shown to be a key factor in the long term success of DRT schemes, given that a level of subsidy was required in all cases reviewed. In some circumstances, high levels of subsidy were required given low levels of passenger demand. The most successful schemes served a relatively small geographic area and were targeted towards a focussed set of activity centres.

Benefit-cost ratios: No BCR estimates were identified for urban DRT systems.

It is recommended that further evaluation studies are conducted as new developments in urban DRT emerge e.g. monitoring the development of new innovations such as the uniquely comprehensive KUTSUPLUS system in Helsinki, Finland.

13.7 References for this Review

Measure No.13: New Public Transport Systems and Networks


Measure No.14: Integration of modes

Passenger inter-modality schemes facilitate and streamline journeys that involve use of more than one mode.

Cities can minimise the complexity of combining different modes of transport, helping travellers to use alternatives to the car. Interventions that help to achieve this often focus on the point of transfer between modes.

Key messages:

- The main benefit of Park and Ride (P&R) is to remove car trips out of a city centre, with the potential for economic (e.g. increased retail activity), and environmental benefits.
- The expense and convenience of the P&R site and the overall expense of the service are important factors for success.
- Reducing city centre parking capacity, or increasing the price to make it more expensive are factors that will increase the attractiveness of P&R.
- Improved access to public transport is seen to lead to improved ‘customer satisfaction’. Transfer facilities such as cycle parking and cycle hire are also viewed positively - albeit with continuing debate over how effective they might be.
- Studies of improving access to stations suggest that such improvements can provide ‘good value for money’, better in fact than improving the rail service itself. This is an area of emerging evidence still, so this finding is at present based on a relatively limited number of sources.
- Measures to promote cycle-bus integration could be particularly beneficial for riders with low incomes, as well as increasing the area from which bus passengers can be drawn. Such schemes could offer positive returns for operators, although estimating costs is seen to be problematic.

14.1 Context and background

In effect, a large proportion of all trips include more than one mode. For instance, for able-bodied adults many trips will include a degree of walking; walking to the car or walking to the bus stop. Most of the source documents consulted in this review though have examined inter-modality as the facilitation of the use of two, non-walking, modes in a journey.

Potential Interventions

- Park and ride, where a car or bike is parked to ride a bus, train, tram etc.
- Cycles being taken onto buses (after being used for access, and/or for later travel)
- Links between bus and rail journeys
Where inter-modality is addressed successfully, then well integrated transport networks can be produced. This has led to high bus patronage in cities like Zurich where two-thirds of residents working in the city travel to work by public transport. Mees (2010, p.131).

Note: Whilst an important aspect of inter-modality is ‘integrated ticketing’ (Mees, 2010, p.137) this topic is reviewed in Measure 12: Public transport enhancements, whilst ticketing innovations implemented via new technologies such as mobile phones are covered in Measure 15 e-ticketing.

14.2 Extent and Sources of Evidence

Although documents have been identified in relation to passenger inter-modality, studies documenting the before and after effects of a scheme are much rarer, (although ‘before and after’ behaviour was sometimes hinted at by answers to survey questions.) It is also the case that a large proportion of the evidence identified as relating to inter-modality concerns park and ride schemes.

13 studies were initially selected by the project for this measure, although not all proved helpful on further inspection, due to a lack of relevant empirical evidence. Those that were used were supplemented with documents from other sources. This review draws on 11 source documents in total. All except one are peer reviewed journal articles. For some studies the data has been collected by academics (Cherry & Townsend, 2012). For others the academic has studied data collected previously by other organisations (Givoni & Rietveld, 2007).

No meta-analyses, in the statistical sense, were consulted for the review. One review of a number of inter-modality schemes in Netherlands was useful as it included descriptive statistics relating to the different schemes. Most of the studies consulted used specific case studies, either small scale, such as specific metro stations, or national.

Studies consulted for this measure were from a variety of countries. However, 6 of the 11 were from European countries, and 4 of these were from the Netherlands. It is likely that there is a good body of evidence from the Netherlands because of the richness and diversity of the bike and public transport provision in that country.

The studies consulted were written within the last two decades and many within the last five years. Judging from the dates of the studies consulted, research into passenger inter-modality measures is ongoing. The types of intervention written about are also ongoing. Some of the studies consulted were written shortly after an intervention, such as the study on Park and Ride in Adelaide (Wiseman et al., 2012). Other studies were written long after a scheme had been first implemented (Parkhurst, 1995).

14.3 What the Evidence Claims

Passenger inter-modality is discussed in two contexts, park and ride, and access to rail and bus journeys.

14.3.1 Park and ride

Five items were studied that examined park and ride specifically. Of these, two investigated bus as the ‘ride’ vehicle, one looked at tram and two looked at rail.

Wiseman et al. (2012) suggest that park and rides have numerous benefits. One indicator of these benefits is park and ride’s popularity. The schemes can be politically popular and can
have economic benefits as in effect they can improve the access (including parking) to a city (Wiseman et al., 2012, Parkhurst, 1995). In 2003 in the Netherlands there were 386 park and rides and in 2007 in Great Britain there were over 130 (Parkhurst & Meek, 2014, p.188). As well as being popular with transport authorities park and ride can also be popular with users (Seik, 1997). Overall the evidence suggests that park and ride can achieve high patronage. Wiseman et al. (2012) suggest a specific benefit of park and ride is that it may attract some new users to public transport. It can do this by raising awareness of public transport and by providing a step change: for example car drivers may change to park and ride and then change to public transport only (Clayton et al. 2014).

Perhaps park and ride’s greatest strength is in displacing car trips out of a city centre. This may have city centre economic, ambience and local air quality benefits (although the latter was not investigated in the documents consulted). As Clayton et al.’s (2014) study suggests, reducing car parking and driving in a city centre can be particularly important in towns which need to provide good tourist access whilst preserving an attractive city centre ambience.

Park and ride can replace some car trips. Parkhurst (1995) found that in Oxford 56% of park and ride commuters who had been commuting before the implementation of park and ride had previously used car, in York 70% had. Wiseman et al. (2012) found that 29.8% of park and ride users had previously used car. Specifically park and ride can reduce car trips in the city centres (Wiseman et al., 2012, Clayton et al., 2014).

Some types of park and ride scheme offer better effects on private vehicle kilometres travelled overall than others. Park and rides placed at different distances from the city centre can have different impacts (Mingardo, 2013). Remote schemes (which take the driver from a location near the origin of their trip) can lead to decreases in vehicle kilometres travelled.

However, some types of park and ride, such as periphery schemes, (which can be located at the edge of the destination town and take the driver for the last portion of the trip only) can actually increase car use (Wiseman et al. 2012). Park and Ride can lead to vehicular trips being made that otherwise would not have been taken (Mingardo, 2013, Clayton et al. 2014). Park and ride can also lead to increased car use by leading to modal shift away from public transport (Wiseman et al. 2012, Clayton et al., 2014) and bicycle (Mingardo, 2013). In effect this can mean an increase in car use (and thus an increase in emissions.) Thus Wiseman et al. (2012) found that the park and ride scheme in Adelaide had led to a car use increase of 4.7 car-km/person/day. So it is important to consider the benefits of decreasing car use in the city centre along with the effects on overall car travel (Wiseman et al. 2012).

Another caveat to apply to the benefits of park and ride is that it may reduce travel by active modes. Wiseman et al. (2012) suggest from their findings that the scheme they examined led to a reduction in walking.

Some studies suggest elements affecting patronage levels. Factors which led to increasingly successful implementations of the Singapore park and ride can be divided into those internal to the scheme and those external to it (Seik, 1997). Internal factors included extended parking hours, ongoing journeys on bus being included on one ticket, improved and more numerous car parks, higher financial incentives and improved publicising. External factors included increased charges for driving and parking in the central business district, factors which should be considered when implementing park and ride.

The expense and convenience of parking (Seik, 1997, Mingardo, 2013, Parkhurst, 1995) and overall expense (Wiseman et al., 2012, Seik, 1997,) in relation to other mode options, seem of particular importance to the patronage of park and ride. Other factors included the comfort
Measure No.14: Integration of modes

Reflections on the evidence

None of the items on park and ride included a before and after survey. The studies consulted had been conducted after implementation. Often data collection was by survey. As discussed above a key survey question concerned the mode that had been used previously to using park and ride (Wiseman et al. 2012, Parkhurst, 1995, Mingardo, 2013). This is in effect a ‘before and after’ question: The ‘after’ data is the rider using the park and ride, and the ‘before’ is their stated previous mode. This is key because as discussed above switching from car only trips can be seen positively, but switching from bus or bicycle negatively. The strategy of surveying park and ride users about their previous mode and the location of their trip origin can reveal a lot about the success or otherwise of the scheme. This data can, without great complexity, give estimates to the total change in car travel caused by the park and ride, and associated CO2 emissions.

Of course this data is limited to park and ride users only. It does not capture those who have left park and ride and their reasons for doing so, or non-park and ride users and the reasons why they have never used the scheme. However, Clayton et al. (2014) in effect conducted a park and ride user and non-user (people parking in the city centre) survey and through this were able to draw out different demographic profiles for users and non-users.

Seik (1997) offers evidence of another nature. This evidence is the ‘real life’ level of success (patronage) of a Singapore park and ride. This scheme was a failure at first but its success increased with successive altered reimplementation. Thus Seik (1997) is able to suggest reasons why the scheme became increasingly successful in terms of patronage.

A final method for investigating park and ride behaviour is that of observing behaviour rather than surveying. Mingardo (2013) reports observational research to see whether drivers were parking in park and ride car parks but then walking to their destination.

The nature of park and ride schemes (compared to national rail for instance) means that studies tend to be quite focused geographically, often studying the park and rides serving a specific city.

By surveying present users of park and ride, the data collected in the studies consulted do reflect real-world attitudes and behaviour. The statistical processes involved in the studies on park and ride tend to be reasonably transparent descriptive statistics. (Such as the percentage of people that had used car before park and ride.) Numbers of park and riders surveyed in the studies vary markedly. For instance, Seik’s (1997) sample was n=122, Clayton et al. (2014) surveyed n=721.

The studies adopted different strategies in terms of the time of day that users were surveyed. Perhaps people travelling at different times of day and for different purposes could be better accounted for, by stratified sampling, if a way to do this could be found.

As discussed above, patronage of park and ride services can be influenced by external factors, such as the price of parking in the city centre (Seik, 1997), concessionary public transport fares for older people (Clayton et al. 2014) or public transport provision in areas surrounding the city (Parkhurst, 1995). The importance of these factors is understood through people’s stated reasons for using/not using a park and ride. (Although it is possible that park and ride users might answer tactically if they perceive the ongoing provision of the park and ride is under threat.) The strength of surveying park and ride users (which most of the studies did) is that reasons for choosing that mode can be isolated. Such isolation would
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be difficult to achieve simply by looking at patronage levels.

Although inferences can be made from the above studies about the effects of park and ride on total levels of car travel in a city, an empirical study which measured this total, before and after park and ride implementation was not found. This would be a potential for a further study. Another study could look at park and ride schemes historically and globally looking for correlations between political, economic and transport conditions and patronage. This would involve some wisdom in drawing out the important factors.

The studies consulted have findings that are relevant in other countries/locations. However, the studies indicate that some country specific factors may have been present. For instance Seik (1997) records that in Singapore there were increasing population, income and car ownership combined with very limited geographical space. This led to charging for driving and parking in central urban areas, which increased the park and ride’s popularity. In the case of England, there was a historical favouring of the scheme type and also a concessionary fare for older bus users (Clayton et al. 2014). These factors may support park and ride.

Levels of affluence in the local population may affect patronage of park and ride. This is because one of the main attractions for users of the scheme type is that it can be cheaper than parking in the city centre.

Some of the park and ride schemes that Parkhurst (1995) and Clayton et al. (2014) studied had commenced 20 to 30 years earlier, this points to durability of the schemes.

The studies consulted suggest that important factors for high patronage are the expense and convenience of the associated parking site and the overall expense of the service. It is key to understand that the convenience of parking and expense of using park and ride matter in as far as they compare to other modes. Thus if parking in the city centre is made more expensive, park and ride becomes more attractive (see Seik, 1997).

14.3.2 Access to rail and bus journeys

The second group of studies examined for this measure relate to various forms of access to rail or bus journeys via other modes. (The distinction between these and park and ride are sometimes blurred.) These studies identified different aspects of access. A quick summary is useful:

Brons et al. (2009) and Givoni & Rietveld (2007) sought to understand how important the journey to the rail station is to overall satisfaction with the journey in the Netherlands. Givoni & Rietveld (2007) also discussed the importance of various factors for improving access to stations.

Martens (2007) examined a number of interventions introduced under the Dutch Bicycle Master Plan, aimed at improving bike/rail and bike/bus inter-modality.

Hagelin & Datz (2005) looked at facilities to take bikes on board buses, in Florida, U.S.

Chen et al. (2012) examined factors important to the popularity of bike use as an access/egress mode to metro journeys in Nanjing, China.

Cherry & Townsend (2012) examined Metro/bus interchange in Bangkok, Thailand and how this could be improved.

The studies above more often dealt with access to rail rather than to bus. They found that accessibility to and from railway stations is important and can influence customer satisfaction with the overall journey and hence rail patronage (Brons et al. 2009, Givoni &
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Rietveld, 2007). In addition to being important, accessibility to stations was considered by passengers to be one of the aspects of the Dutch railway needing most improvement (Brons et al. 2009, Givoni & Rietveld, 2007). Givoni & Rietveld (2007, p.362) found that passenger ratings of the access to Dutch railway stations averaged between ‘insufficient’ and ‘sufficient’. Brons et al. (2009) suggest that improving accessibility can provide good value for money, both in terms of increased satisfaction and number of trips and can be more cost effective than improving the rail service itself.

The studies consulted differentiate between the access journey to/from a railway station and the actual transfer from one mode to another at the station. Brons et al. (2009) suggest that the access journey is more important than the transfer facilities at the station.

Some of the studies consulted examine the access of rail journeys, by public transport. Brons et al. (2009) found that connection between rail and other public transport had important and statistically significant effects on customer satisfaction with the rail journey. Without improvements being made, accessing rail by public transport can be problematic. Problems identified in rail/bus transfer in Bangkok included large distances between metro stops and bus stops, difficult boarding conditions for buses, lack of bus timetables and lack of personal security Cherry & Townsend (2012). These are all areas where important improvements could be made.

Some of the studies consulted dealt specifically with accessing rail by bike. Chen et al. (2012) suggest that using cycle to access rail was popular amongst those surveyed in Nanjing, China. However its popularity was variable according to the time sensitivity and purpose of the trip: Bicycle is more likely to be used when the trip is less time sensitive.

For cycle riders, in addition to the cycling access journey to a train station, there is also the task of parking the cycle. Brons et al. (2009) found that unguarded bicycle parking had positive and statistically significant impacts on rail user satisfaction. Martens (2007) also suggests better cycle parking can lead to improved satisfaction and may lead to increased rail use. Martens found improvements of quality and extent of bike parking (along with improvements to ‘walking routes to train platforms’) in five small stations led to an increase of satisfaction of rail users from 5.3 to 7.1, out of 10. The success of the improvements was also attested to by increases in numbers of bikes parked at the stations. Martens reports that 11% of respondents said that better bicycle parking might lead them to travel more by bike and rail. The importance of improving cycle parking on overall trip satisfaction is however contested by Givoni & Rietveld (2007). Chen et al. (2012) report the finding that distance between bicycle parking and station may be an important factor.

Martens studied various other measures to improve bike/bus integration, some of these were more successful than others: An integrated group of measures aimed at facilitating bike-and-ride on a specific transport corridor, through improving the bus priority and adding bicycle parking, resulted in an increase of bus patronage. However, in other pilot schemes Martens (2007) found that facilities like bike lockers were not greatly used. The price for the user of bus/bike schemes should be considered: a pilot scheme to sell a ‘bicycle-bus-bicycle’ product, including bicycle lockers at the bus stops and a travel pass for the bus, was not popular due the price of the product, people preferring to cycle (only) to work and car dependency.

Provision for egress journeys by bike, from either train or bus to a non-home destination, can be beneficial. The two obvious options for how the egress journey can be made by cycle are either to have a second cycle which is left parked near the station, or to hire a cycle. PT-bicycles is an example of a bike hire scheme (Martens, 2007). During 2000 to 2004, this facility
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had been successful, with the number of participating stations rising from 4 to 72, number of users rising to 10,000 and trips rising to more than 100,000/year. Martens’ survey data suggest that PT-bicycles had led to some modal shift. 15% of users had previously been using car.

An alternative to needing two cycles to complete a public transport trip is to take the cycle on board. Hagelin & Datz (2005) found that being able to take bikes on board buses had a number of specific benefits. They found that this facility could be particularly beneficial for riders with low incomes. People using the service tended to use it regularly and long term. The facility can attract new customers and can increase the area from which bus passengers can be drawn. Hagelin & Datz (2005, p.57) conclude that public transport companies can receive returns far greater than their investment through bike on board programs. However, the report also concedes that it is difficult to estimate the costs involved in providing such programs.

Reflections on the evidence

The studies on access to rail and bus journeys did draw on real life attitudes, often using surveys of users’ satisfaction levels. Most of the studies on access to rail and bus journeys did not chart both before and after findings. However they did record patronage and customer satisfaction levels with various access facilities. Martens (2007) was an exception in measuring overall satisfaction with bike/rail journeys before and after a number of improvements were made to facilities. In effect Cherry & Townsend’s (2012) study represents a ‘before’ study, highlighting priorities for change. Whilst Chen et al.’s (2012) study represents an ‘after’ study.

Most of the studies drew on surveys charting customer satisfaction, with their overall journey or with specific facilities. Martens (2007) however also drew on observational data collection of the number of cycles parked at stations. Martens also drew on patronage figures for a cycle hire scheme.

The studies used a range of statistical tests ranging from simple descriptive statistics to Principle component analysis.

The occurrence of accessing rail and bus stations is less geographical focused than park and ride schemes. Thus the issue arises of how representative surveys conducted about access to rail and bus are. Some of the studies involved secondary analysis of national surveys (Givoni & Rietveld, 2007). Other researchers handed out surveys at two or three metro stations (Cherry & Townsend, 2012, Chen et al. 2012). The ability of these stations to represent more general patterns and conditions is questionable. However good sample sizes (n=1784 in total) were achieved.

In general it is hard from the studies to ascertain the link between attitudes to access facilities and actual behaviour. It is difficult to isolate the accessibility factors from other external factors that may affect mode choice.

An absence within the studies consulted is economic study examining the economic cost/benefits of the schemes. However Brons et al. (2009) do suggest from their study that it is when the cost of improving accessibility to stations is considered that improving access to stations becomes desirable compared to improving other aspects of the rail service. The study suggested that accessibility improvements to smaller stations would be likely to be less costly than improving the travel-time reliability of trains, timetables or station quality.

One weakness with the source documents consulted are that they are not numerous or
diverse enough to be representative of the different rail, road and cycling conditions in different countries. Three of the studies are from the Netherlands where cycling facilities are unusually good (Martens, 2007) and where there is a higher density of railway lines and stations than is average in the EU (Brons et al., 2009, Givoni & Rietveld, 2007). Other studies come from Thailand and China where conditions are likely to be different to EU countries.

14.4 Lessons for Successful Deployment of this measure

Key lessons emerging from the evidence include:

- Strong, supportive political will seems to be an important driver of (commercial) success for park and ride.
- The public popularity of park and ride is important; its attractiveness will depend on how it compares with the other modes available to access the city centre.
- Physical proximity is essential for effective inter-modality. The distances between train station/bus stop and bicycle parking or between train station and bus stop, should be small. One ‘must have’ for effective inter-modality is physical proximity. The evidence suggested that the distances between train station/bus stop and bicycle parking or between train station and bus stop, should be small.
- Whilst improvements to train and bus station accessibility can increase patronage this will also significantly depend on the quality of the bus and rail services. Low-quality, expensive, infrequent or poorly routed services and stations that are unattractive will limit potential increases. There is a case made for making investments here into stations that already have high levels of services, and where there are big local populations.
- It is important that efforts are made to inform user and non-user perceptions of accessibility to stations/stops and accessibility improvements. Car users in particular may have a negatively biased perception of the public transport accessibility to train stations.
- For both park and ride and access improvements, it is important to consider which mode trip makers will leave in order to use the improved public transport options. Where possible, pricing and incentives should be used to manage this carefully.

14.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- **Improved access**: P&R can improve access to a city. This can be particularly important in towns which need to provide good tourist access whilst preserving an attractive city centre. This may also help facilitate other changes such as pedestrianisation schemes – with potential benefits for businesses and for air quality in a city centre.
- **Modal shift**: P&R may attract some new users to public transport by raising awareness and by offering a high-quality service which may encourage car drivers to change to P&R and then change to public transport.
- **Customer satisfaction**: Accessibility to and from railway stations can influence customer satisfaction with the overall journey and hence rail patronage.
- **Increased patronage**: Cycle facilities at stations and or related to bus travel may also lead to increased use of these modes by now facilitating a combined journey which previously would not be possible by public transport alone.
14.6 Summary

The evidence base for park and ride draws on studies from contrasting countries around the world. Studies often provide clear estimates of some of the impacts of the scheme, but there are gaps in the research concerning the perceptions of park and ride by non-users, and also before and after studies, in the strict sense. Park and ride schemes can be successful in achieving popularity and patronage where the right conditions are present.

The likely successes and drawbacks of park and ride should be considered before implementing. It is likely that the main benefits of the scheme will be to displace trips out of a city centre, which may have political, economic and ambience benefits. Some types of park and ride, such as remote park and ride can be more effective in reducing overall car travel levels than others.

The evidence relating to rail and bus interchange was often limited, although improved access was seen to lead to greater customer satisfaction, and additional data was emerging through simple usage studies. Transfer facilities such as cycle parking and cycle hire were viewed positively overall, though there was some debate about their effectiveness. More generally studying interchange facilities at rail stations was seen to be challenging, because of the variation in numbers of travellers, station facilities, and in the transport complexity of each location. Whilst the studies consulted did not deal with the economic cost/benefits of improving access in detail, claims are being made that improving accessibility to train stations can provide good value for money, better in fact than improving the rail service itself.

‘Passenger inter-modality’ covers a broad range of scheme types, and so drawing common conclusions across them is difficult. Two key principles of success do emerge though. Firstly, pricing and incentives are important, and influence which modes travellers switch from, and secondly, whilst it is critical that the interchange facilities are high-quality to be successful, the same is true for the journey segments they connect.

14.7 References for this Review

Measure No.14: Integration of modes


Measure No.15: e-ticketing

The introduction and use of new ticketing technologies on public transport systems using what might be generically termed ‘smart ticketing’ or ‘e-ticketing’.

The introduction of a smart ticketing system in a city can improve services to passengers (increasing patronage) and introduce time-saving, marketing and data collection benefits for operators.

Key messages:
- Major cities (such as London and Hong Kong) have implemented e-ticketing solutions that are used by millions of travellers, and smaller scale implementations are commonplace.
- Traveller aspirations in this area are high.
- There are potential cost savings to be made by operators from efficiency gains, fraud reduction and reduced ‘dwell time’ at stops, although there is less clear evidence for increased patronage.
- Initial costs can be high, particularly where none of the necessary infrastructure is already in place. Costs include hardware, software and consultancy for scheme design, with integrated schemes particularly cost intensive, requiring different applications to be connected.
- Cost-benefit analysis (CBA) may struggle to make a positive case in respect of returns from additional travellers alone.
- Implementation of e-ticketing is rarely done in isolation; it is likely that some changes will also occur to ticketing arrangements (pricing, cross-operator, multi-mode) at the same time which may also impact on customer choices.
- e-ticketing technology is developing rapidly – which brings consequent risks of early obsolescence.

15.1 Context and background

This measure considers the range of new ticketing technologies for public transport systems, where the tickets are sold and stored in electronic devices, such as smart cards or a traveller’s mobile phone.

Potential Interventions

- Mobile phone ticketing (m-ticketing)
- Smart card ticketing
- 'Contactless’ ticketing (including contactless cards issued by financial institutions such as banks and credit card companies)

These approaches are generically termed ‘smart ticketing’ or ‘e-ticketing’. Such systems are
now in use around the world, particularly in East Asian countries, but also increasingly in the US, Australia and Europe. Take up varies across European countries, but most have e-ticketing systems in one or more major cities; albeit many of them only launched in recent years. There is limited implementation at national or cross-border level, although steps are being taken to encourage standards, common approaches and potentially inter-operability (certainly in Europe). Some successful schemes (such as the ‘Octopus’ card in Hong Kong) are exporting their technology and approach to other countries, creating momentum behind a particular model of implementation. Further progress in inter-operability is perhaps becoming less of a technical issue, and more of a commercial one.

As noted above, e-ticketing can be delivered on a range of different devices, with the most common in recent years being ‘smart cards’. Alternatives such as contactless bank cards and smartphones are also increasingly being used. The characteristics of the three approaches are:

1. Smart cards: Typically the size of a credit card, technologically simple and relatively cheap to produce. The cards either need to be brought into contact with a reader (contact-based) or the card needs to be placed in close proximity to (within about 10 cm of) the reading device to start the communication process (contactless).
2. Mobile ticketing (or m-ticketing): A virtual ticket held on mobile phones (or other mobile devices), purchased via the phone or mobile internet. Phones can also emulate a smart card.
3. Contactless bank cards: Distributed widely in many countries. Uses the same underlying technologies as smart cards, but use of these cards for transport ticketing involves a different approach to payment – and brings other participants (financial institutions) into the process.

Important underlying technologies include ‘Radio frequency identification’ (RFID) and ‘Near field Communications’ (NFC). RFID ‘tags’ embedded in devices can process data or communicate with other RFID tags and are compatible with existing contactless smart card infrastructure. NFC is a more advanced form of RFID technology that also permits short-range communication between electronic devices. NFC is able to emulate RFID readers and tags, allowing it to also potentially use earlier infrastructure.

A wide range of potential benefits are claimed for e-ticketing.

For travellers:

- They are simpler and more attractive than paper based systems.
- They can potentially be used across modes and across operators – again simplifying travel.
- They promote a more reliable service, quicker (less dwell time as drivers no longer deal with cash, or as many cash transactions in systems that accept both means of payment)
- They provide easier access to tickets and the potential to ‘manage’ an account online. Tickets may now be sold through a wider network of outlets, or through ‘recharging’, or online. This may help some user groups (e.g. elderly people or people with reduced mobility). Tickets can also be targeted at different specific groups, such as schoolchildren, students, families, tourists, visitors etc.
- E-ticketing can facilitate ‘fare-capping’, ensuring the best price for trips across a day is calculated automatically.

For operators:

- They can remove or reduce the costs of handling coins and banknotes, as well as helping
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reduce the costs of on-bus security, and opportunities for fraud.

- They offer the potential for tailored marketing and more appropriate ticketing products, better adapted to the needs and travel patterns of each person. Smarter-ticketing also provides the opportunity to collect more detailed data on the behaviours of passengers across routes and networks, which can help operators and municipalities optimise networks, and provide services that better match customer demand.
- More passengers are attracted to public transport as a consequence of all above, and the more modern image created of public transport modes.

There are then a range of choices for those looking to introduce systems to replace paper-based ticketing on public transport, with consequences in respect of cost, implementation partners, risk (with respect to the technology), and customer take-up. However, there are other factors to consider. For example, it would not be feasible to move to use of contactless bank cards as payment mechanisms in a transport system if there was not widespread use of such cards in that location. Similarly if mobile phone based ticketing was used. There are also choices to be made about where such a system might be deployed, across a city (or part of), or a wider implementation across a region. Consideration needs also to be given to interoperability with wider schemes or initiatives.

Evidence related to integrated ticketing (across operators and modes and in respect of pricing reform) is covered in Measure 12.

15.2 Extent and Sources of Evidence

Smart-ticketing is now in use in locations ranging from towns to city-regions, and in some instances across a national transport network (e.g. OV-chipkaart on the rail network in the Netherlands). Thus implementations are being used by thousands in some locations and many millions in others (e.g. the 'Oyster' card in London or 'Octopus' in Hong Kong). However, there appear to be relatively few items of evidence that purely evaluate the implementation of e-ticketing (smart-ticketing or m-ticketing), and as such it is difficult to corroborate the potential benefits claimed above.

In some instances new forms of ticketing have been implemented at the same time as changes to the ticketing and pricing regime, making it difficult to unravel the effects of the individual components of the change. It is also the case that in some instances these ticketing technologies are still very new, and limited evaluation of the impacts / results of these alternatives appears to have been undertaken to date.

There are though a limited number of studies and reports which have compared the implementation of such systems in cities and regions across the world. Within the EU there have been many cities within the CIVITAS programme which have deployed ‘smart ticketing’, and there is some evidence available from these interventions. These might relate to specific routes within a city, or a more widespread implementation. CIVITAS has also provided summary reviews of such measures across a range of cities in its programme. There is also some material looking at the cost-benefit analysis of smart ticketing, particularly from a US context, although also exploring some European implementation. In respect of peer-reviewed literature, there appear to be relatively few sources available which evaluate implementations of this technology.

This measure review has taken material from the wider studies / reports as a starting point, and added to it specific examples from CIVITAS and the academic literature. Whilst the review material considers experience from around the world, the more specific evaluations
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have in general come from Europe.

15.3 What the Evidence Claims

15.3.1 General reviews of e-ticketing

Drawing on the experience of interventions carried out in the EU funded CIVITAS programme a ‘Policy Note’ on ticketing suggests that there are some common factors that help to make moves to e-ticketing successful. Amongst these are developing a ticketing system that is ‘user-friendly’ and simple to use, and that where appropriate a standard technical architecture should be used. The tasks that will need to be undertaken in order to successfully implement an e-ticketing solution are discussed. Experience from the CIVITAS II programme suggests that the introduction of a new ticketing system would take about two years. Up to 16 months preparation and 2-10 months to implement. The policy note also considered complementary measures, interventions which could be undertaken in parallel with the introduction of e-ticketing which could enhance success factors. Those seen to be most appropriate include:

- Offering other services to public transport users via the same e-ticketing mechanism, to make the tickets more attractive to users, and potentially to increase use of other transport modes. Examples include access to car-sharing and bike sharing as well as cultural and leisure activities.

- Offering discounted prices on other transport interventions if using the new ticketing mechanisms, for example for bike-sharing or park and ride schemes in a city,

- Introducing journey and travel planning tools and ticket purchase ‘apps’ alongside the ticketing itself. Perhaps particularly relevant for m-ticketing solutions delivered on smart phones. Such tools help passengers find the right route, real-time information on departures, means of access, and provide the means to easily purchase appropriate tickets.

In a second review document, this time produced by transport consultants Aecom, the work undertaken in the European Commission’s "Study on Public Transport Smartcards" is documented. This considered the development of smart card fare payment systems across Europe and the rest of the world and specifically the benefits of such schemes to regular travellers, as well as exploring how smartcards might address the perceived and actual barriers to irregular travel. Using a questionnaire to quiz 20+ schemes around the world (including those in Hong Kong, Seoul and London). The report noted that the delivery of smart-ticketing schemes had been achieved through a variety of organisational approaches. These included models with one central scheme provider, or a network of stakeholders (operators, authorities, technical etc.), partnerships between public transport operators and local government(s), and some cases where a private company had taken primary responsibility. The number of (public transport) operators within a single scheme tended to be no more than 10, although it was possible for more established schemes to accommodate upwards of 40 individual operators. Funding had come from a range of sources, individual PT operators, local/regional government authorities, private shareholders or PFI arrangements. Parties involved in the development, implementation and operation of integrated smart ticketing normally fell into the following groups: Transport authorities; transport operators; standards bodies; equipment suppliers; service suppliers; and public transport users. The exact nature of the stakeholders involved, the role they play and how they collaborate between each other varied significantly between the schemes researched.
This report suggests that the main drivers for implementation for operators were efficiency gains and fraud reduction, whilst for passengers the goals were for a simple ticketing system that could cover all modes of public transport. In general, smart-ticketing was seen to be more reliable, convenient, faster and easier to use than conventional ticketing, delivering a better overall product allowing users to travel more freely. The report concluded that these forms of ticketing may well remove some barriers to travel for irregular and unfamiliar travellers, but that operational as well as technology change is required to achieve all of the proposed benefits. More effective use of the data generated by the cards would be one way of better understanding what some of these changes might be.

The 2014 report from the Science and Technology Options Assessment (STOA) project of the European Parliamentary Research Service (EPRS) focussed not just on the implementation of e-ticketing, but more specifically integrating access to touristic sites into systems. In its review of the current status of e-ticketing solutions the report finds that finance, complexity and technology issues have so far hindered a wide scale implementation in Europe, and that technology is developing at a faster pace than decision cycles. It suggests that successful e-ticketing solutions in cities such as London and Hong Kong were subject to particular conditions that allowed schemes to develop well (for example subway stations were already gated reducing infrastructure costs). Initial set up costs are seen to be relatively expensive (e.g., hardware, software and consultancy for scheme design), with integrated schemes particularly cost intensive, as different applications need to be connected.

In a report for the UK Department of Work and Pensions that focussed on the wider benefits of the use of smart-cards in the UK, it was noted that such technology may create efficiencies for a municipality in respect of delivering travel services, for example concessionary bus travel for older and disabled people. It might also contribute to image and reputational benefits for the area, from being seen to embrace new technologies. It was though noted that the UK case studies explored in the report had not typically attempted to conduct a full cost-benefit analysis or evaluation of costs of their schemes in a systematic way so no clear conclusions as to the economic factors relating to the introduction of such wider smart-card schemes had been made.

Issues of value for money were though considered in a US report in 2008. This reviewed three smart-card based implementations in the United States. It was noted that each scheme created different costs and benefits, depending heavily on the public transport characteristics of the given region (e.g., whether a single operator or multiple operators are involved, government subsidy structures, existing ticketing infrastructure, etc.). Adopting smart ticketing was seen to be an expensive process, involving purchase of new equipment and revision of fare collecting systems, whilst the benefits were harder to quantify. The main beneficiaries of the smart-card systems were identified as the individual operators and passengers, with individual transit operators and multiple agencies bearing the majority of the deployment costs. The authors noted in the report that there were (at the time) relatively few cost-benefit evaluations of ticketing systems such as this in the US. The studies reviewed are also critiqued for a lack of rigour, and for not having any consistent application of accepted cost / benefit methodologies. Reasons given for this include problems in quantifying benefits, and the variety of organisational structures and political contexts found in the studies. The report concludes that smart ticketing solutions (in these instances smart cards) offer great potential, but that none of the three cases they considered managed to quantify the benefits clearly. They also find that while the underlying studies were informative, they were not comprehensive or generalizable.
15.3.2 e-ticketing specific studies

Considering more specific studies, some evidence can be found in evaluation studies produced by cities engaged in various European sustainable mobility programs, such as CIVITAS. Whilst a number of e-ticketing solutions have been deployed through this mechanism, relatively few evaluation reports were both available and suitable for consideration here. In the main this was because the intervention was still in the process of implementation at the time of review, the evaluation had taken place immediately after the implementation without sufficient time to properly explore any change, or a package of measures had been introduced making it difficult to isolate results to any specific measure. Two CIVITAS interventions that have been considered are in the Danish city of Aalborg, and the Portuguese city of Coimbra.

In Aalborg\(^6\), smart card ticketing was deployed in a specific corridor only - a route between the University and city centre. The move was in response to falling public transport use along the corridor, but was also linked to a wider set of plans in respect of use of travel cards in Denmark. The evaluation studied both passenger statistics and acceptance issues to do with the new mode of ticketing. Results suggest higher passenger satisfaction levels, and higher than forecast growth in passengers. This was though an instance where a number of measures were introduced at the same time, so it was difficult to correlate the effects of e-ticketing specifically. Other measures included additional promotion, use of biofuels on the buses and 'on-trip' traveller information. Problems were encountered trying to also integrate taxi use onto the card, and delays in the wider national e-ticketing scheme were also an issue. Lessons learnt in Aalborg included:

- It can take a long time to implement e-ticketing, so it is important to ensure that schemes are flexible to adjust to evolving technology.
- It is important to have a clear data collection strategy, with data well managed.
- It is important to start with a pilot, to gain experience in a small part of the system (for operator and customers).
- When multiple suppliers are involved, it is important to have a clear specification and clear allocation of responsibilities. Involvement of drivers is key, as they are the first contact with passengers.

In Coimbra\(^7\), smart card ticketing was introduced to public transport services, and to park and ride facilities. The goal was to increase passenger numbers and increase use of park and ride. Cost-benefit projection (looking forward over 15 years) forecast a payback of 5-6 years, compared to the costs of the existing ticketing systems. Actual results showed a small increase in PT users (1-2%), and 10% increase in park and ride use 9 months after the implementation began. Suggesting perhaps an over-optimistic forecast of potential benefits in this instance. As for Aalborg, a range of measures were implemented at the same time making it harder to isolate specific correlations in results, even though the evaluation did attempt to isolate the effects of e-ticketing in the passenger survey used as the basis for their review. Deployment of the scheme was held up by financial issues. Lessons learnt were that technical design of the system was important, and that by using the same standards as systems in the Portuguese capital Lisbon, technology and systems could be cheaper than for a bespoke delivery. Adopting an ‘open’ system also meant a range of suppliers could tender, again with potential to reduce cost.

The implementation of e-ticketing in Trondheim\(^8\) (using smart cards called ‘t:card’) was part of a regional scheme. The intention was to provide a single card (using a single ‘contract’) which customers could use for buses, trams, and regional coaches operated by 10 public
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Transport operators in and around Trondheim. The scheme was reviewed using social cost-benefit analysis of data after 12 and 24 months of operation (using a 10 year CBA). The scheme is seen to be profitable from a socioeconomic point of view, with an NPV of $32.5 million and a benefit to cost ratio of 1.96. (The study notes that transportation expenditure in Norway usually struggles to deliver a positive NPV at all). After more than three years of operation, approximately 90 percent of all trips were paid for using the t:card. Incentives to use the card include discounts compared to cash, with further reductions if using monthly passes. This study also considered boarding time for passengers, with time savings of 6.8 seconds per passenger compared to those using cash. The scheme had again faced delays - this time due to technical complexities and some legal issues with suppliers.

Several ‘pilot’ studies were carried out in the Netherlands in advance of the nationwide OV-chipkaart scheme. One of these was the Tripperpas smart card study which ran for 2 years on urban buses in Groningen. Passengers who used Tripperpas as well as non-users were surveyed at regular intervals over the length of the study. Some 4000 of the cards were issued (the population of Groningen is 180,000). Results suggest that the people most likely to use the card were aged 25 to 64, using the bus primarily for work or shopping. Reasons cited for use included ease of use and convenience. Some technical issues were experienced which were often quoted as a source of irritation by those surveyed, with the percentage of respondents who had experienced some kind of technical disruption associated with the check-in or checkout procedure using the card reader reaching 61% in the final survey. It was thought an element of this might be poor handling by cardholders – perhaps suggesting more advice should be given. Other lessons learnt included poor customer understanding of the ‘best price’ guarantee (fare-cap) implemented on the card, and that students (some 30% of the non-users surveyed in this university town) already had a travel pass, and thus had no reason to use the new one. Many users also regarded the lack of immediate, transparent information on what they had been charged as a negative feature of the scheme compared to the previous ticketing mechanisms.

In a study undertaken by the Dutch Ministry of Transport in 2006, the potential impacts of implementing a nationwide public transport smart card (later to be called the OV-chipkaart) were explored through a socioeconomic cost benefit exercise. The study considered impacts on a range of stakeholders, and also conducted a range of sensitivity tests on the results. The overall forecast was for a positive NPV, with operators getting the best benefit, followed by passengers. The effects of smart card introduction were estimated against the situation where existing ticketing continued, and also made allowances for probable societal and public transport changes. The smart card technology was assumed to have a life of 15 years, before the underlying technology became obsolete. The results of the exercise were that the NPV of overall benefits would be E3.5 - E4.2 billion, whilst costs would range from E2.7 - E3.0 billion, meaning a surplus of E0.4 - E1.5 billion. This study then suggested that the scheme was a profitable investment for the Netherlands. Operators would reap the most benefits (E0.4 - E0.9 billion) from nationwide implementation, and passengers as a group would also benefit substantially. The scheme would be most favourable to larger operators, as a high proportion of the costs involved in the smart card project are fixed. In urban areas, the costs involved in equipping all vehicles with smart card apparatuses are relatively high, and they must be recovered from trips of short average lengths. Operators of railways and metro systems would be able to use smart cards to facilitate the introduction of a closed station system, thereby achieving more reduction in fraud and higher fare revenue gains. Looking at partial implementation in the sensitivity test suggested that all of the alternatives examined would render less favourable outcomes than implementation of smart cards on a national
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scale.

In a further ‘forward-looking’ study for the city of Budapest in Hungary, a wide range of ticketing options (including e-ticketing) were compared to the current paper-based system by the Centre for Budapest Transport (BKK)\textsuperscript{14}. The study determined that a system based on contactless cards (including in addition contactless Bank Cards), would provide the optimum solution for public transport in the city, addressing a range of problems including fraud. The formalized feasibility study was prepared in accordance with the methodology required for EU co-financing and included a cost-benefit analysis to support its analysis (although this is not included in the published English-language report).

As well as the evidence on implementation of e-ticketing systems, there is also relevant evidence which considers the problems of using cash on buses as a payment mechanism. As has been noted above, the opportunity to reduce ‘dwell time’ at a stop whilst passengers board can have significant benefits for journey time, and in reducing the variability of journey time. In a study carried out on bus routes in Zurich\textsuperscript{11}, it was seen that onboard ticket sales involving cash reduced reliability. Up to 20\% of the total trip time could be spent on ticket sales (for the routes studied here), but actually the most significant problem was the variability in time spent in the ticket sales process. This variability made it difficult for schedule planners to develop accurate and reliable schedules, which was seen to increase costs and reduce service efficiency. The authors of the study suggest that the results give weight to strategies that will reduce onboard ticket sales (although they propose that the best situation is to eliminate onboard ticket sales whenever possible). In a further study\textsuperscript{12} looking at the issue of dwell time, but this time located in Vancouver Canada, fare payment methods are seen to have a ‘substantial effect’ on dwell time and thus schedules. The study finds that different payment methods showed a statistically significant positive effect on dwell time, with cash payment having the highest effect, and ‘no fare’ presented showing the lowest effect on dwell time. Paying in advance of travel, and the use of e-ticketing solutions are recommended in response. Tirachini\textsuperscript{13} (2013) also explored the effect of a range of ticket sales and validation approaches on a number of bus routes in Sydney Australia. Using observed data and a modelling approach it was established in this study that moving from cash-based paper ticketing to e-ticketing solutions could make a difference not only to dwell time and reliability, but also to the numbers of buses and drivers needed to operate a route. In some circumstances changing the method of ticketing (to contactless cards) could offer greater benefit than implementing bus priority initiatives onto a route.

15.3.3 Reflection on methods used in studies

The ‘review’ documents / reports appear to have a greater focus on desk-based study, and in some instances of submitting questionnaires to cities deploying smart ticketing as a means of collecting data. Most of the individual studies seem to have tried to execute some form of cost-benefit analysis using their own national guidelines, or those provided by CIVITAS.

Aside from this a range of methods have been used, including surveys / interviews / focus groups with passengers and drivers, as well as a range of modelling techniques. Other studies have looked at passenger numbers, cost of operation etc. In general the methods used in evaluation seem to be valid, and have attempted to determine benefits in areas of importance for that intervention.

15.4 Lessons for Successful Deployment of this measure

The fact that e-ticketing systems have been implemented in a range of cities and locales
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across the world over recent years would suggest that there such systems could be implemented in most cities, and at a range of scales. The case studies considered here do though point to several factors that are important when thinking about deployment at smaller scale, and the potential scale of finance required for larger scale implementations.

There seem to be some common issues to be overcome in respect of the technology used (especially during the requirements definition phase of any intervention), as well as funding (sometimes a significant level required) and political support. There do not commonly appear to be public acceptance issues with the new technology, although the example of the "tripperpas" and poor understanding of the proposed fare cap perhaps highlights the need to ensure effective communications with travellers.

Other measures that can be seen as complementary, and helpful in respect of improving customer acceptance, include 'ticket simplification' and 'integration' of ticketing across operators and/or modes. These sorts of changes can not only help to promote public transport options, but also help provide incentives to encourage the move away from cash and/or paper-based ticketing. The introduction of e-ticketing also potentially opens the door to other add-on services using the same payment mechanisms. So for example, access to other modes of transport such as bike hire or car-share schemes. It also provides operators with a rich source of data about travel habits and behaviours, and potentially a marketing tool – possibly facilitating personalised solutions in some cases.

One factor that is evident in some of the studies considered here is that this is an area where technology is changing and evolving, and it is important to be realistic about the lifetime of any solution being implemented, and what might be done to make the most of the technology deployed. Factors such as ongoing maintenance and availability of support for hardware and software need to be considered and planned for. As was seen in the Coimbra example, there is also an imperative to think about wider technical strategies for e-ticketing, at regional and national (EU?) scales. Economies of scale may flow from adopting technologies and standards already in use, or planned at these larger scales.

Experience from the CIVITAS II programme¹ suggests that the following factors are also relevant when thinking about wider and more extensive implementation:

- Gaining political support,
- A willingness from operators to accept the new approach (particularly resolution of revenue sharing issues),
- Ensuring sufficient finance to deploy e-ticketing,
- Resolving the interaction with other systems (where necessary),
- Making sure that any approach is legal (particularly if multi-operator) and there is common purpose and engagement between all the relevant parties in the implementation process.

15.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- **Delivery of additional services**: The introduction of e-ticketing opens the door to other add-on services using the same payment mechanisms, including access to other modes of transport such as bike hire or car-share schemes.
- **Information on travel behaviours**: E-ticketing provides a rich source of data about travel habits and behaviours, useful in better planning of services, and in understanding existing
(and potentially future) transport demand

- **Promotional opportunities:** Data collected from e-ticketing solutions can also provide operators (and cities) with a marketing tool – and the opportunity to deliver more personalised travel solutions to travellers, increasing use / patronage of systems.

### 15.6 Summary

Various forms of e-ticketing are now found in cities worldwide. Major cities such as London and Hong Kong have implemented solutions that are used by millions, and smaller scale implementations are commonplace. For municipalities looking to make the transition to such a solution there is plenty of guidance, and explanation of the processes and potential benefits achievable. What is less apparent is simple and clear evidence of benefits specifically attributable to this intervention. This might be for several reasons. Firstly, implementation of e-ticketing is rarely done in isolation. It is likely that some changes will also occur to ticketing arrangements (pricing, cross-operator, multi-mode) at the same time which may also impact on customer choices. It is also the case that technology has been developing rapidly in the ticketing arena, and studies five or ten years ago may be restricted in what they can say about current technologies, costs and traveller aspirations.

Evidence does seem to suggest though that there are potential cost savings to be made, in particular for operators, and that e-ticketing solutions also provide a valuable new source of data for planners and operators alike. What is less clear is if they increase passenger numbers.

Initial costs for this sort of intervention can be high, particularly where none of the necessary infrastructure is already in place, and as evidenced here, pure cost-benefit analysis may struggle to make a positive case in respect of returns from extra travellers, so it will be important to also think of benefits from addressing issues such as reduced dwell time, fraud, image, marketing, cross-selling etc. when considering implementation of some form of e-ticketing. The magnitude of costs will also be related to whatever the existing system of ticketing is, and how much of a change the e-ticketing solution will require (for example whether a city is moving from a paper-based or an earlier form of smart ticketing system).

In terms of economic evaluation, it appears that in many instances there has been no systematic evaluation of costs in schemes, or attempts to carry out a full cost-benefit analysis. Where CBA has been applied (in the US examples considered here for instance) approaches are seen to be either inconsistent or techniques used not widely accepted. The evidence from Trondheim does though suggest that when wider socioeconomic benefits are quantified, then positive benefits can be seen.

### 15.7 References for this Review

Measure No.15: e-ticketing


13. Tirachini, A. 2013. Estimation of travel time and the benefits of upgrading the fare payment technology in urban bus services. *Transportation Research Part C 30 239–256*

Measure No.16: Traffic Management and Control

Applications of technology that help to manage the movement of people in urban areas.

These interventions can help flows around city transport networks. They include urban traffic control systems (UTC), traffic signals that respond to specific modes (e.g. buses or cyclists), the use of cameras to protect dedicated lanes or manage junctions and variable message signs (VMS) providing dynamic instructions to vehicles.

Key messages:

- Urban Traffic Control systems (UTC) can be expected to improve network efficiency by reducing delays to vehicles. This can have additional benefits in reducing fuel use and emissions (although evidence here is limited).
- Economic benefits are calculated mainly on the basis of time savings. These savings may be specifically for public transport users, cyclists, or for general traffic.
- Providing priority to public transport or bicycles through UTC can contribute to significant journey time savings without compromising journey times for other road users.
- Automatic systems to monitor bus lanes and signalized junctions have been shown to improve journey times, reduce infringements and reduce collision rates at junctions.
- Investment payback periods for bus priority measures are seen to range from 3 months to 2 years in the examples reviewed.
- Variable Message Signs (VMS) can divert some traffic (although they are less likely to be effective in heavily congested networks).
- VMS has the potential to contribute to time savings in public transport corridors, but evidence is currently limited here.

16.1 Context and background

This measure considers a range of interventions that are concerned with the management of vehicles, and travellers on transport networks – particularly traffic on the road network.

Potential interventions

- Urban traffic control systems (UTC), that focus on maximising the throughput on the network – helping to reduce congestion and thus pollution
- Traffic signals that give priority to, and respond to specific modes (e.g. buses or cyclists),
- Cameras used to enforce the protection of dedicated bus / cycle or high-occupancy lanes or used to manage junctions to ensure free-flow
- Variable message signs (VMS) which can provide dynamic instructions to vehicles (for example highlighting congestion, alternate routes, parking availability etc.)
In more detail, these systems are:

1. **Urban Traffic Control (UTC) systems**: UTC systems are linked and coordinated networks of traffic signals. Traffic flows on junction approaches are monitored in real time and signal timings are continuously optimised across the network (according to traffic conditions) through a centralised processing algorithm such as SCOOT (Split Cycle Offset Optimisation Technique). UTC systems are often set up to minimise delay to motorised vehicles. However, they may also be optimised to minimise fuel consumption and to reduce emissions or to provide selective priority to public transport or cyclists.

2. **Selective vehicle detection at traffic signals**: Various types of ‘Selective Vehicle Detection’ (SVD) system can be employed at signalised junctions to provide additional priority to cyclists or users of public transport. These systems operate by detecting bicycles, buses or trams on the approaches to stop lines (usually through inductance loops for cyclists or the use of GPS tracking systems in the case of public transport) and then either re-call or extend green times. The objective is to minimise the delay to cyclists or public transport at junctions without significantly compromising journey times for other road users.

3. **Enforcement of bus lanes using technology**: Bus lane infringements (parking violations for example) can have a serious impact on bus reliability. Highly visible automatic detection systems (cameras with automatic number plate recognition for example) can be installed to discourage drivers from entering the bus lane. The objectives of such systems are to reduce infringements and to improve public transport journey times and reliability.

4. **Camera enforcement at signalised junctions**: Similarly, cameras may be installed at signalised junctions to reduce red light running and collision rates.

5. **Removal of traffic signal control**: Proponents of ‘shared space’ style traffic management (see measure 22) argue that ‘over control’ of traffic at junctions, through the incremental introduction of signals, can have the unintended consequence of increasing delay to pedestrians and vehicles. In certain circumstances, the removal of traffic signals may meet objectives to increase junction efficiency (reducing delay to all road users) and to improve the urban environment (through the removal of unnecessary street furniture).

6. **Variable Message Signs (VMS) in urban areas**: VMS may be employed in urban areas to warn drivers of incidents, delays or to provide comparative information on journey times (on alternative routes or modes in the case of park and ride). The objective is usually to influence route choice in some way to reduce congestion, delays and to improve overall network efficiency.

### 16.2 Extent and Sources of Evidence

This review draws on 19 sources which, in the main, report on the impacts of a single intervention employed in a case study city. The single case studies have been supplemented by two meta-studies\(^1\) to illustrate the wider applicability of the findings. One meta-study reports on the impacts of bus priority\(^4\) at traffic signals across 24 cities around the world, while the second\(^2\) provides a comparative review of VMS system trials conducted in eight European cities. Indeed, seven of the sources have been generated by various EU funded programmes, which either commissioners a literature review or alternatively field trials of one of the traffic control measures identified in the introduction. While the majority of the cases consequently relate to an EU city, results from the USA, Japan, New Zealand and Australia are also discussed. Evaluation reports have typically been authored by academics or consultancies (and published on EU programme websites such as CIVITAS.eu) or
alternatively results have been reported in academic journals or conference papers. Sources from the last five years were readily available, but the review has also relied on some good quality evidence from academia which is now over ten years old, particularly in relation to VMS and bus priority at traffic signals.

16.3 What the Evidence Claims

The review presents evidence in relation to the types of intervention defined in the introduction.

16.3.1. Urban Traffic Control systems and fuel consumption

UTC systems are often set up to minimise delay to vehicles by extending green times where there is highest demand and by using signal offsets along arterial corridors to create ‘green waves’ (where successive junctions provide green as traffic approaches) to maintain flow. However, they may also be optimised to minimise fuel consumption and to reduce emissions. In theory, fuel consumption can be reduced by tuning signal timings to limit the need for drivers to stop at junctions, reducing delays and encouraging moderate speeds to be maintained along links in the network.

Stevanovic et al evaluated new methods of optimising signal timings to reduce emissions using observed data on traffic flows through a network of 14 signalised junctions in Park City, Utah, USA. Their method of evaluation was based on micro-simulation modelling of signal timings rather than on observations in the field. Nevertheless they estimated that employing signal timing optimisation algorithms that specifically seek to reduce fuel consumption, could be expected to contribute to a 1.5% reduction in fuel consumption overall.

A field evaluation of an Adaptive Traffic Signal Control System implemented in Aalborg, Denmark (along a 1.7km section of the ring road which included eight junctions), found that fuel consumption was reduced by 2.45% overall (based on calculation rather than on observation). This was attributed to smoother driving and a reduction in very low speeds.

Overall, UTC systems have been shown to be highly effective at managing capacity – improving traffic flow and reducing delay. For instance, an installation of SCOOT in Toronto across a network of 75 junctions was shown to achieve an 8% reduction in travel time, a 22% reduction in vehicle stops, a 17% average decrease in vehicle delay, a 5.7% reduction in fuel consumption, and a 5.0% reduction in carbon monoxide emissions.

Perrett and Stevens performed a cost benefit appraisal of UTC systems in UK cities. They estimated a benefit-cost ratio of 7.6 over a five year appraisal period based on the introduction of five new systems in medium sized cities. Their analysis included time savings, changes in vehicle operating costs and changes in pollution costs.

An important caveat, however, when considering UTC systems in the context of Sustainable Urban Mobility Plans is that signal optimisation across networks is intended to make the system more efficient overall for motor traffic, and hence encourages more motor traffic use. This can be counter to sustainable mobility objectives.

16.3.2. Bus priority at traffic signals

Some have suggested that UTC systems tend to be configured to minimise delay to general traffic, when they should instead be optimised to meet the more socially equitable objective of minimising overall delay to people. A consequence is that those choosing not to travel through urban areas by private car may not be afforded an appropriate level of priority at signalised junctions. To address this issue, various types of ‘Selective Vehicle Detection’
system can be employed at signalised junctions to provide additional priority to users of public transport.

The International Association of Public Transport (known as UITP) commissioned a review of ‘Bus Priority at Traffic Signals around the world’ in 2008. The impacts of SVD systems installed in 24 cities (mainly within Europe, but also including Japan, New Zealand, Australia and the USA) were collated. The following impacts were observed:

- Delay savings of between 3 and 11 seconds per bus per junction;
- Travel time reductions of between 2% and 25%; and
- Patronage increases of up to 42%.

The level of benefit derived was noted to be constrained by the overarching policy framework rather than on the technical capability of SVD systems per se. For example, in some cities, the level of priority afforded to buses at signals was limited by wider objectives to maintain capacity for general traffic. The examples reviewed in Europe were shown to repay their investment costs within three to 16 months of operation.

Hill et al\textsuperscript{8} evaluated the application of bus priority at junctions along a single corridor in Cardiff, UK using the SCOOT UTC system. Three configurations were compared: SCOOT with no bus priority, SCOOT with priority enabled for all buses and SCOOT with priority enabled for late buses only. Journey time savings of 3% were observed under priority to late buses only, rising to 4% under priority to all buses. In peak periods, journey time savings were shown to increase to 14-15% under both scenarios. Associated delays to general traffic were not found to be significant.

The EU commissioned INCOME (INtegration of traffic COntrol with other MEsures) project\textsuperscript{3} evaluated priority measures for buses in four European cities (London (UK), Gothenburg (Sweden), Turin (Italy), and Piraeus (Greece)). The implementation of bus priority at junctions through UTC systems was shown to reduce journey times by four to 10% in London, five to 15% in Gothenburg and three to 16% in Turin. Other studies of sites with lower flows\textsuperscript{9} were shown to generate journey time savings of up to 80%. Economic appraisals of the trial sites indicated pay back periods of less than two years.

Gating: UTC systems can also be used to improve journey times for buses by holding traffic at signals outside of central urban areas and then gating traffic into the central area at a rate than can be accommodated by the network. The objective is to improve flow through space limited central areas by moderating traffic throughput. Bus lanes are required on the approaches to gated junctions to avoid buses being delayed in queues. A trial of a gating system implemented in Twickenham, UK demonstrated a statistically significant journey time saving of 13% for buses. Delays to general traffic as a consequence of the scheme were not found to be significant.

16.3.3. Enforcement of bus lanes using technology

The city of Bologna, Italy identified parking infringements in bus lanes as a major cause of delays to public transport, as well as contributing to wider congestion problems (through for example, illegal parking along narrow city roads)\textsuperscript{10}. A mobile camera system with Automatic Number Plate Recognition (operated by the police department) was installed along two bus routes in 2008 and 2010. The system was shown to contribute to an 80% reduction in parking in the bus lane along one route. The reliability of bus journey times consequently improved (indicated by a reduction in journey time variability), particularly during the highly congested Christmas period (December). Journey times also reduced by five per cent along one route.
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16.3.4. Bicycle priority at traffic signals

1. **Green waves**: Signal offsets along arterial routes can also be optimised (through UTC systems) to generate ‘green waves’ for cyclists. In this case, offset times (between green aspects at successive signals) are calculated using average cycle speeds as opposed to average vehicle speeds. Stopping is a major penalty for cyclists (given the effort involved in regaining momentum) and the objective of green waves is to reduce the number of stops along a link and to reduce delay. A similar affect can be achieved at isolated junctions by installing inductance loops at junctions to detect approaching cyclists. Cyclists are then given a green signal as they approach. Ryding\(^1^\) (cited in Knight et al\(^1^\)) evaluated a ‘green wave’ system of 13 interlinked signals in Copenhagen. Average cycle speeds were shown to increase by 5km/hr resulting in a saving of 2.5 minutes over the link. The number of stops required was also shown to reduce (by up to a maximum of six stops). Journey times for other vehicles were only found to increase slightly by (four seconds).

2. ‘All green’ stages: ‘All green’ stages for cyclists (where all other traffic movements are halted) have been employed to reduce potential for collisions between cyclists and other vehicle types. Wolfe et al\(^1^\) (cited in Weighland\(^1^\)) evaluated a junction in Portland, USA and found that 78% of cyclists crossed the junction illegally before the introduction of an ‘all green’ stage (implying a safety risk) and this reduced to 4.2% after the introduction of the all green stage. A cost benefit analysis of a similar configuration in Davis, California (USA)(by Korve and Niemeier\(^1^\), cited in Knight et al\(^1^\)) indicated that the safety benefits outweighed the costs associated with increased delays to other vehicles.

3. **Priority in inclement weather**: There have been trials in the Netherlands of detection systems to give additional priority to cyclists at traffic signals in wet weather. The objective is to reduce the need to stop and to reduce traffic signal violations by cyclists in inclement conditions. Evidence is limited, but an evaluation of the Dutch trial by Harms\(^1^\) (cited in Knight et al\(^1^\)) indicated significant reductions in both delays to cyclists and the number of cyclists running red signals during wet weather.

4. **Gating at junctions**: Gating can be employed to hold general traffic behind cyclists (waiting in advanced stop reservoirs) at junctions. This provides an opportunity for cyclists to enter junctions ahead of other vehicles and reduces the chance of conflicting movements (e.g. left turning vehicles conflicting with cyclists heading straight on in a UK context). A cycle gate was installed at Bow Roundabout in London - a collision hot spot. Although a detailed evaluation was unavailable, Transport for London\(^1^\) reported that “the eastbound cycle early-start has been effective in reducing the risk of conflict with vehicles turning left”.

5. **Push button controlled bicycle and pedestrian (Toucan / Puffin) crossings**: Bicycle and pedestrian phases are commonly used to provide opportunities for non-motorised users to negotiate road crossings. In cases where crossings are staggered, pedestrian / cycle signals can be offset such that users receive a green phase immediately on entering the central reservation to reduce delays to non-motorised users. Alternatively, staggered crossings can be replaced with single crossings. Maximum wait times for pedestrian / cyclists green phases (on requesting a crossing) can also be pre-programmed into signal controllers to minimise wait times at the roadside. Whilst such initiatives have been documented in good practice guides\(^1^\), no evidence was identified on their effects.

16.3.5. Camera enforcement of signals

Signalised junctions may be enforced through the installation of cameras (either...
automatically through ANPR or through manual monitoring of data feeds). The objective is usually to reduce collision rates at junctions. An evaluation of a system implemented in Bologna, Italy\textsuperscript{18}, demonstrated a 21% reduction in collisions and a 28% reduction in injuries at signalised junctions after installation of enforcement cameras (comparing the 2008 baseline year to 2011 when the full system had been rolled out). A cost benefit analysis was performed to quantify the benefits of these collision and injury reductions. Sensitivity tests indicated potential Net Present Values for the scheme of between 36,000,000 and 51,000,000 Euros over a 17 year appraisal period.

\textbf{16.3.6. Removing traffic signal control}

It is suggested that, in certain circumstances, the removal of traffic signals may increase junction efficiency and improve the urban environment (through the removal of unnecessary street furniture). This was demonstrated in trials conducted in Portishead and Bristol, UK\textsuperscript{19}.

The Portishead trial involved switching off signals at a quite complex, heavily trafficked junction (handling 1500 pcu/hr) for a period of four weeks (in 2009). Queues and delays were shown to reduce by 50% and the increase in capacity led to a growth in demand of 20% to over 2,000 pcu/hr. Average pedestrian crossing times were also shown to reduce by 20%. The success of the trial led to the signals being permanently switched off. Similar results were observed at one week trials conducted at two low traffic, high pedestrian flow junctions in Bristol city centre. Queues and delays were observed to reduce by between 30% and 40% and pedestrian crossing times also reduced. However, at one location in Bristol, two thirds of survey respondents felt that the junction was safer and easier to use under signal control.

\textbf{16.3.7. Variable Message Signs in urban areas}

Variable Message Signs (VMS) may be employed in urban areas to influence route choice in some way to reduce congestion, delays and to improve overall network efficiency.

Chatterjee and McDonald\textsuperscript{2} reviewed evidence from VMS field trials implemented in the late 1990s across eight European cities (Valencia (Spain), Southampton, Bristol and London (UK), Lyon and Toulouse (France), Turin (Italy), and Piraeus (Greece)). Trials were sponsored by the EU under the ‘Transport Sector of the Telematics Applications’ programme. The VMS systems were evaluated through a survey of drivers passing VMS signs to measure their awareness of information and responses to this, monitoring traffic flows on VMS routes and potential diversion routes and the use of simulation modelling.

In cases where just one VMS sign was installed, only one third of passing drivers noticed the information. This increased to 89% of drivers in cases where several signs were available along a route. VMS information was found to be legible to drivers, particularly if simple text (rather than symbols) was employed. 80% of those noticing the information reported being able to read and understand it. With respect to driver responses to VMS information, on average, 13% of drivers reported changing route (ranging between 0% and 31%). These self-reported results were supported by the monitoring of traffic flows on the VMS routes and expected diversion routes. On average 11% of traffic passing a VMS was shown to have diverted (based on monitoring conducted in 13 corridors across London, Piraeus, Southampton and Turin). By contrast, only 1% of drivers were found to have switched from car to park and ride in Bristol when VMS showed comparative journey times. Thus VMS must be viewed only as a complementary measure in the development of successful park and ride schemes. With respect to the impact on network journey times, it was only possible to measure changes in journey times along VMS routes in one city (Piraeus, Greece). On street measurement of six routes indicated a 16% reduction in travel time on average (ranging
between 11% and 23%), suggesting potentially significant network efficiency gains through the use of VMS. No empirical evidence was available on safety or environmental impacts.

VMS systems were employed in Gothenburg, Sweden, to divert general traffic away from main public transport corridors. The objectives here were to improve journey times for buses in heavily congested conditions in Gothenburg. The systems were evaluated using simulation modelling only. In Gothenburg, VMS were estimated to re-route up to 200 vehicles an hour away from the public transport corridor, contributing to an estimated 21% reduction in delay.

16.3.8 Methodologies and evidence gaps

1. UTC systems and emissions reductions: There is limited evidence on whether UTC systems can be optimised to reduce emissions as well as minimise delay across networks. The studies reported here mainly rely on simulation modelling rather than field measurement. It would be beneficial to conduct field trials which monitor air pollution levels over a period of time with and without emissions reduction algorithms.

2. Bus priority at traffic signals: The studies reviewed here have tended to report simple before and after bus journey times. Potential confounding factors (such as network wide changes in traffic conditions) have not been controlled for. However, the commonality in results from a wide range of cities gives confidence that such measures can be expected to improve journey times for public transport. A methodological improvement would be to use control sites (with no priority at signals) and to conduct appropriate statistical tests to identify whether the treated sites show significant improvements when set against the control sites. This also applies to the limited number of simple studies reviewed for enforcement of signals and bus lanes, and the removal of traffic signals.

3. Bicycle priority at traffic signals: Techniques to provide priority to bicycles at traffic signals are not widely used and this is reflected in a relatively weak evidence base. Further research on the specific management of bicycle traffic using traffic signal control is warranted.

4. VMS signs in urban areas: The review of field trials conducted in European cities is now over ten years old (and reports on trials conducted in the late 1990s). This study also relied on limited field data on how traffic volumes alter on VMS routes and diversion routes. No data was provided on environmental or safety impacts and this represents an evidence gap. Up to date field trials would be beneficial to identify the role of VMS in urban traffic management given recent advances in mobile technologies (with traveller information applications), and flexible, shared transport systems.

16.4 Lessons for Successful Deployment of this measure

16.4.1 UTC systems

Transerability: There are no systematic reasons to suppose that UTC systems, which are now widely used, will not be effective in other urban areas.

Drivers / Barriers: The implementation of UTC is often motivated by a need to improve traffic flow as congestion increases in urban areas i.e. They increase the capacity of space constrained networks in central areas, often to accommodate travel by private car. Care therefore needs to be taken that UTC systems are not designed to prioritise the movement of private cars at the expense of the more general objective to accommodate the movement of people through cities. In this respect, it has been demonstrated that UTC systems can be
tuned to prioritise other modes at junctions.

**Complementarity:** In Aalborg, the development of a UTC was in part motivated by wider planning policies to regenerate a central area which saw the reduction of a four lane city centre road to a two lane road with consequent transfer of traffic to a nearby inner ring road. The UTC was able to increase capacity of junctions along the inner ring road to cope with the additional traffic. Hence UTC can be effectively used as part of a sustainable urban mobility policy in combination with road capacity reduction measures.

**Durability:** As UTC systems increase network capacity for private vehicles, it is likely that initial efficiency gains will tend to be eroded over time if traffic levels continue to increase. This emphasises the importance of using UTC in combination with ongoing policies to encourage the use of non-car modes in densely populated urban areas.

### 16.4.2 Removing traffic signal control

**Transferability:** The limited evidence on removing traffic signal control reviewed here indicates that this can be an effective means of improving junction efficiency for all users. However, this is likely to be highly context specific and further research is required to identify under what circumstances such measures are likely to be effective. Related interventions are considered in further detail in measure review 22.

**Drivers and barriers:** Strong public support was an important factor in the delivery of the trial and later permanent removal of signals in Portishead, UK. Conversely, a lack of public support, or a perception that removing signals will reduce safety (particularly for pedestrians, as demonstrated in Bristol), may limit the appetite amongst planners to implement a longer term strategy of signal removal.

### 16.4.3 Selective vehicle priority at traffic signals and enforcement

**Transferability:** The review of bus priority at traffic signals around the world confirms that such measures are likely to be effective in most contexts. Similarly, although the evidence base is less comprehensive, measures to increase priority to bicycles at traffic signals can also be expected to improve conditions for cycling.

**Drivers and barriers:** However, the extent to which bus or bicycle journey times are improved may be constrained by overarching policy frameworks for traffic control which set limits on the extent to which traffic signals are allowed to favour public transport or bicycles over general traffic. Systems of priority are most effective where networks are not already congested. In heavily congested conditions, it may not be possible to provide selective priority at signals as this will worsen the situation for all road users.

**Complementarity:** Bus or cycle lanes on approaches to traffic signals are required for priority measures at traffic signals to be effective. Absence of dedicated lanes will mean that buses or bicycles become delayed in general traffic queues, significantly limiting the extent to which priority at signals can have an impact on overall journey times. Automated enforcement of bus priority measures can be effective as long as cameras are highly visible and penalty notices are efficiently served to maintain credibility amongst drivers.

### 16.4.4 Variable Message Signs in urban areas

**Transferability / Upscaling:** The European field trials reviewed by Chatterjee and McDonald indicated that VMS systems are more likely to be effective if several signs are installed across a network. Single signs are less likely to be noticed and hence have little influence
Measure No.16: Traffic Management and Control

Drivers and Barriers: The success of VMS systems in alleviating congestion on specific routes is clearly dependent on the availability of capacity on alternative routes. Attempts to divert drivers through VMS will not be effective in heavily congested networks. Signs also need to be positioned sufficiently upstream of ‘major decision points’ in the network.

Complementarity: VMS systems are reliant on good real time data on traffic flows across a network in order to reliably estimate journey times on competing routes. Thus complementary traffic monitoring systems are required. VMS systems may themselves be used as a complementary measure to other interventions such as park and ride (displaying comparative journey times for example). In such circumstances, VMS can be expected to be effective in raising the profile of the park and ride, but are unlikely to deliver a significant modal shift in their own right.

Durability: Signs should be shown to be updated regularly to give drivers confidence in the reliability of information.

16.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- Reducing traffic in city centres: By improving capacity via UTC in some areas, it is possible to reduce capacity in others, providing support for other measures aimed at reducing traffic in city centres.

- Road safety: Enforcement cameras at signalised junctions have been demonstrated to reduce collisions and injuries, and dedicated phases for bicycle traffic at signalized junctions to reduce conflicting movements, making the environment safer for cyclists.

- Encouragement for alternatives: VMS can be a useful profile raising measure when used in conjunction with other measures such as park and ride.

16.6 Summary

- UTC systems can certainly be expected to improve network efficiency in terms of reducing delays to vehicles. However, there is limited evidence on the extent to which UTC algorithms can be optimised to reduce emissions. The estimated 1.5% fuel reduction reported here relied on simulation modelling rather than on field observations.

- Further research is also required to identify under what circumstances the removal of traffic signals is likely to improve junction efficiency and perceived safety for all road users.

- Where UTC systems and traffic signal controls are used to provide selective priority to public transport or bicycles, they can be expected to contribute to significant journey time savings (of for example between 3 and 11 seconds per bus per junction), without compromising journey times for other road users. They are most effective in uncongested conditions and must be deployed in conjunction with priority lanes on approaches to signalised junctions.

- Providing dedicated green phases for cycle traffic at signalised junctions has been shown to reduce conflicting movements, making the environment safer for cyclists.
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- Systems that automatically monitor bus lanes and signalised junctions have been shown to reduce infringements, improve journey times and reduce collision rates at junctions.

- The success of VMS systems is typically measured in terms of the extent to which they encourage drivers to divert to less congested routes (or modes). Where several, well positioned signs are installed, VMS systems can be expected to divert around 11% of traffic (though this estimate is based on monitoring conducted in the later 1990s along 13 corridors in London, Piraeus, Southampton and Turin). They are unlikely to be effective in heavily congested networks and should be seen as a supplementary, profile raising measure when used in conjunction with park and ride. Updated field trials would be beneficial to identify the role of VMS in urban traffic management given recent advances in mobile technologies (with traveller information applications), and flexible, shared transport systems.

16.7 References for this Review


Measure No.16: Traffic Management and Control


Measure No.17: Travel and passenger information

Improved information for trip-makers in advance of travelling or whilst making a journey.

Information about travel options, mode and route choices as well as timetable and ticketing data can be provided by cities to help travellers find alternatives to the car. Increasingly this might be via online or phone-based resources. Operators and municipalities can also make use of ‘real-time’ data to inform travellers.

Key messages:
✓ The provision of travel information (especially real-time), is desired by travellers.
✓ Access to travel information can be most valuable to users when uncertainty is highest (e.g. for buses more than trains, and for more congested cities).
✓ The economic implications of information provision were generally viewed positively, although not quantified rigorously.
✓ Some passengers would be willing to pay a higher price for bus services that included real-time information.
✓ Deploying travel information via the internet can be less expensive than options such as public screens, and can benefit users before they reach a stop or station.
✓ It is inconclusive as to what extent provision of information on its own may affect patronage or potentially modal shift.
✓ Moves to deploy more information via the (mobile) web may exclude those who cannot access the technology (i.e. smartphones).
✓ Reducing perceived waiting time with real-time information would be less expensive than increasing public transport frequency.

17.1 Context and background

This measure is primarily focussed on the provision of static (timetables, routes, prices etc.) as well as dynamic (expected arrival, delays etc.) information on public transport services to passengers.

Potential Interventions

- Travel information (timetables and journey planning), online and on mobile devices.
- Real-time information (RTI) on public transport services, online on mobile devices and at bus stops / railway stations / public locations (for example shopping malls).

In the past, many of these services have been provided in the form of paper timetables, or printed information at stops. This is increasingly being supported, or replaced, by electronic services – particularly those delivered via the mobile internet to smartphones.
Measure No.17: Travel and passenger information

Through providing information services, operators and cities are looking to addresses a range of issues, including improving passenger satisfaction and journey comfort, and encouraging intelligent and informed travel behaviour. In some instances, the aim is to give reliable and up to date travel information for the benefit of drivers (with the intention of minimising congestion / pollution, or optimising parking). Travel information may arguably also be used to encourage modal shift, in particular through multi-modal information which allows travellers to construct complete (end-to-end) journeys across a range of modes.

Some studies consulted for this review investigate RTI for public transport. This information can be conveyed to the user via at-stop or on-board displays or via web-based and phone technologies (including telephone calls, texts or apps.) It can also be conveyed via touch screens although this method is not covered in this review. The review also examines websites that provide multi-modal travel information. Some of this information is based on real-time data, some is static (based on bus timetables for instance). Most of the interventions reviewed here provided information for public transport users only. Two multi-modal websites that also include information for car drivers were exceptions to this.

17.2 Extent and Sources of Evidence

This review considers eleven items of evidence, mostly academic journal articles, but also three reports and one conference paper. Two of the reports are for the EU CIVITAS project, the other was a European commission report for the Trans-3 project. Items that review specific interventions were available for this study, so that the inclusion of meta-studies or literature review articles as items has not been necessary.

One item refers to on-board screens on buses, three relate to at-stop/station RTI screens, and others to web / phone based RTI provision. Another source compares at-stop displays and phone based provision whilst others refer to multimodal travel information websites. In terms of scale, the interventions generally cover a city or part of a city. One of the website interventions covers a region.

Five of the items reviewed were published in the last 5 years and report on recent interventions, suggesting that research and development in this field is ongoing. It is likely that the advancement of smartphones and other technologies will ensure the topic receives ongoing attention. Many of the items related to apps and other up to date media. However some relate to technologies that may now be slightly out of date. The CIMTAS (2) report from Aalborg suggests that keeping up with technological development was difficult whilst developing a travel website. Caulfield & O’Mahony (2009) studied methods for receiving RTI (SMS and telephone call centre) that are arguably already out of date, for some users, due to the development of smartphones.

17.3 What the Evidence Claims

17.3.1 Real-time information (RTI)

Lehtonen & Kulmala (2002) investigated user satisfaction and behaviour in relation to the provision of electronic displays showing RTI at 15 bus or tram stops in Helsinki, Finland. The study found that generally the passengers found the displays useful (66% of tram users and 78% of bus users), understandable and easy to notice. Some (13% of tram users and 20% of bus users) also reported using public transport more as a result of the displays. Due to this success, Helsinki city transport decided to further extend the deployment of at-stop displays.
Caulfield & O’Mahony (2009) assessed the relative popularity of receiving RTI from at-stop displays, and by phone (SMS or ringing a call centre). They found that riders preferred to get the information from at-stop displays.

A number of the studies focused on passenger satisfaction with the information provision. Politis et al. (2010) found that 83% of those interviewed were satisfied with the RTI provided by at-stop displays and 94% were satisfied with its reliability. RTI displays can also be housed on public transport vehicles. (CIVITAS 1) reports on the addition of on-board monitors giving information about upcoming stops and RTI about routes passengers might want to connect with on disembarking. They found 88% of respondents liked the displays, 87% liked the news and weather information that the screens also displayed and 90% thought them an improvement to the service.

Increasingly, RTI has become available through the (mobile) internet and phone devices of the individual traveller. Watkins et al. (2011) investigated bus information provided through website, telephone, text and apps. They suggest that web or phone based provision has an advantage over at-stop displays, in that it can advise on bus times before the user has reached the stop, thus minimising their wait at the stop. Tang & Thakuriah (2012) examined longitudinal data which suggested that the roll out of RTI (received through web or smartphone) across most bus routes in Chicago led to slight increases in bus patronage. Brakewood et al. (2014) also examined the effect of provision of RTI for bus, via website and mobile apps. Their study found that satisfaction with the length of wait for, and with the punctuality of, buses improved after the introduction of such information provision.

The studies reviewed here highlight two major benefits concerning RTI for public transport users. These are the reduction of the frustration surrounding uncertainty about arrival and departure times, and the reduction of actual and perceived waiting times. With regard to reducing frustration, Caulfield and O’Mahony (2009) collected findings in their questionnaire that identify some of the problems that RTI can ameliorate: They found 80% of all users were frustrated by uncertain arrival times of public transport vehicles, 69% were frustrated by not knowing if their desired vehicle had departed and 70% were frustrated by not knowing departure times. Brakewood et al. (2014) found that the frustration and anxiety that bus users had felt previously was reduced by the availability of RTI.

The evidence suggests a second major benefit of RTI for public transport users is that it can reduce their actual and perceived waiting time. This is important as delays that occur before the arrival of the vehicle that have the most damaging effect on public transport passenger satisfaction. Thus the main benefit of reducing actual and perceived waiting time is that it can improve the journey experience for the public transport user. With regard to actual waiting time: Watkins et al. (2011) found decreases of around 2 minutes, whilst Brakewood et al. (2014) found that RTI led to a decrease of actual waiting times of 1.5 minutes on average.

In addition to reducing actual wait time RTI appears to also reduce the perceived wait: Dziekan & Kottenhoff (2007) found at-stop information lead to a decreased perceived waiting time of 20%. Watkins et al. (2011) found that bus riders who were not provided with RTI perceived their wait to be longer than it actually was, whereas those who have such information did not. Those bus riders without RTI perceived their wait time to average 9.9 minutes, for those with it the figure was 7.4 minutes (a reduction of about 30%) (Watkins et al. 2011).

17.3.2 Multi-modal websites

Enei (2014) examined two regional level travel information websites in Italy, providing
The study assumed that the websites would lead to 5% modal shift. The resulting positive economic and other effects of this shift are outlined in the study.

(CIVITAS 2) reported on improvements to two transport information websites covering the city of Aalborg. Coverage comparing modes was improved and flow information and option of personalising site pages were added.

Rapp (2003) reported on a website covering Basel that sought to inform the modal choice of trip makers with route planning, estimation of travel time etc. It was a multimodal site covering car, bike, park and ride and other modes. It took account of real-time parking and driving conditions. 70% of visitors to the site gave it a positive rating and 85% thought it useful.

17.3.3 Modal shift

A question that emerges from the above studies is whether the provision of real-time information can lead to modal shift. There was a variety of conclusions drawn on this, with some studies suggesting modal shift can result. Lethtonen et al. (2002) report that their findings suggest that displays at stops/stations might affect modal shift and lead to increased numbers of trips on services. Enei (2014) bases his analysis of the benefits of a travel information website on the assumption, taken from literature, that the website would be likely to create a 5% shift from car to public transport. Enei concludes that travel information sites can support other policy objectives, such as achieving modal shift. As described above Tang & Thakuriah (2012) found that real-time information provision led to modest increased in bus patronage.

By contrast, (CIVITAS 2) found no detectable modal shift resulting from the travel websites reported on. However they suggest these findings were complicated by the economic crises. The study concludes that information does not, on its own, change travel behaviour, but that it can play a supporting role in reaching of intelligent modal decisions by trip makers, if they are forced into changing mode by factors such as extreme congestion. In conclusion on this question the achievement of modal shift through information provision appears a credible possibility. The usefulness of such provision in supporting other efforts to achieve modal shift seems more certain.

A final question regarding the evidence reviewed is whether real-time information might create a greater improvement for some modes than for others. Caulfield and O’Mahony (2009) found that rail users were less frustrated by uncertainty than bus users. As frustration increases, real-time information becomes more valued, suggesting that bus users would find more value from the additional information than rail users.

17.3.4 Economic benefits

The economic implications of information provision were generally viewed positively by the studies. Dziekan & Kottenhoff (2007) suggest reducing perceived waiting time through RTI would cost only a fifth of the resources needed to increase the tram service studied itself (see also Watkins et al. 2011). Tang & Thakuriah (2012) suggest that due to increasing connectivity, the benefits of RTI may outweigh the costs. Politis et al. (2010) found that some passengers would be willing to pay a higher price for bus services that included real-time information. Caulfield & O’Mahony reached the same conclusion through their stated preference survey. On this basis Politis et al. (2010) calculated that if 30% of passengers were willing to pay 0.65€ rather than 0.50€, the costs of the investment for the information
provision would be regained in less than a year. The study also concluded that the annual economic benefits of the provision would be twice the investment cost.

Evidence pointed to the fact that the cost of providing RTI can vary significantly according to the media through which it is communicated. For example, Watkins et al. (2011) consider that information provision through websites and apps is much cheaper than at-stop or on-board displays. However CIVITAS (1) suggests that even on-board displays did not lead to the local authority increasing operating costs, although there may have been some extra costs for the contractor. Whilst it is likely that provision through web and smartphone would be cheaper than at-stop displays, this may lead a ’digital divide’, with those who cannot afford a smartphone and/or mobile internet access, and who may depend on public transport, being unable to reach the information. Similar issues may also arise in respect of the ability to use these devices in segments of the population most likely to be reliant on public transport, such as the elderly.

Several studies looked to quantify increased patronage as a consequence of improved information systems, for instance does RTI provision lead to more people taking the bus? Tang & Thakuriah (2012) addressed this issue, but could only use overall bus ridership levels that, as they concede and attempted to control for, could be affected by a large number of internal and external factors, (weather, economic climate etc.). As a consequence, they could not answer questions about who had started using the bus due to information provision and why. Brakewood et al. (2014) also attempted to address the same issue, using an experimental design. Here it was found that bus riders in Tampa tended to depend on the mode and had no alternatives (with around 56% not having a driving license). This could explain perhaps the findings that the improved experience from RTI provision failed to lead to increased patronage in their experimental group.

Notably, Enei (2014) stands out amongst the studies reviewed as being the most focused on economic costs and benefits. Examining the potential economic effects of regional travel information in Italy, including environmental savings, accident savings, air pollution savings etc. he concluded that the websites would lead to savings in external costs of about €18 million annually. However, this figure was based on the assumption that the websites would lead to a 5% modal shift, an assumption that was based on other literature rather than primary data. A final economic factor to mention in relation to the studies is that some of the findings were complicated by the impacts of the economic crises (CIVITAS 1, CIVITAS 2).

17.3.5 Nature of methods

Four studies sought to gain data about at-stop or on-board screens:

Lehtonen & Kulmala (2002) conducted before and after surveys to assess customer attitudes to the introduction of at-stop real-time displays. The after surveys were conducted roughly 6 months after the improved bus and tram services had begun operating. Similarly CIVITAS (1) conducted surveys to measure ‘acceptance’ levels of on-board real-time information screens, before and after their implementation.

Dziekan & Kottenhoff (2007) comment on two case studies. For the first, in The Hague, they asked tram users about their perceived waiting time before and after the introduction of at-stop real-time information. There was also an observational study in Sweden, observing the percentages of people running in subway stations according to whether displays showing the timing of the next train were switched on or off.

Politís et al. (2010) used a system similar to a willingness to pay measure. They asked
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passengers the proportion of the fare price that they considered paid for real-time information provision, and their satisfaction regarding the service.

Some studies examined the effects of web and phone based information on public transport users:

Watkins et al. (2011) compared bus users with RTI on their smartphones with those who did not have it. Watkins et al. achieved this by asking people waiting at bus stops for their perceived wait time and also by observing their actual wait time.

Tang & Thakuriah (2012) used longitudinal data spanning an 8 year period, during the roll out of bus RTI across Chicago. They controlled for a number of internal and external factors to examine the effect that real-time information had on patronage. This methodology is different to the others in investigating overall ridership levels of buses rather than user satisfaction.

Brakewood et al. (2014) conducted a before and after behavioural experiment into the provision of real-time information by website and app. This included experimental and control groups. Real time was only given to the experimental group. The ‘after’ data were gathered about three months after real time information had been introduced to the experimental group.

Caulfield & O’Mahony’s (2009) study differed to the others by recording neither actual travel behaviour nor actual customer satisfaction. Instead they conducted a stated preference survey in which respondents were asked to choose between three ways of accessing real-time public transport information. The importance of the benefits of these ways was measured by stated preference in relation to increases in fares and reductions in waiting time. A number of factors that can influence an individual’s willingness to pay for real-time information were also examined. The methods employed by the studies examining general travel information websites will be discussed under the next heading.

The studies have a wide variety of sample sizes, many of which were appropriate. As examples of the variety, Lehtonen & Kulmula (2002) surveyed 412 tram passengers and 528 bus passengers, Brakewood et al. (2014) used a sample of 268 with 110 in the experimental group and Enei (2014) used data reporting 37,000 hits to a website.

The studies used a variety of statistical tests including simple descriptive statistics (Lehtonen & Kulmula, 2002, Dziekan & Kottenhoff, 2007, CIVITAS 1, Rapp, 2003) linear mixed effects model (Tang & Thakuriah, 2012) and a nested logit model structure (Caulfield & O’Mahony, 2009)

In conclusion a wide range of methodologies and methods were used. The methods chosen were generally suitable to the studies’ aims. Most of the studies were aimed at investigating different aspects of user satisfaction and perceptions rather than users’ travel behaviour. A particular perception of interest was that of waiting time at stops.

17.3.6 Strengths / weaknesses in the methodologies

All of the studies reviewed can be considered to provide high quality evidence, with some caveats. The 11 items reviewed have good quality methodologies, and the varying methodologies used across the studies complement each other. In general it can be assumed that the questionnaires and other methods used captured real world attitudes. It is also likely that most of the projects achieved findings that would have been replicated, had the research been repeated with the same methodology and population.
Some studies used particularly effective and comprehensive ways of achieving comparisons between information provision and non-provision. For example Tang & Thakuriah (2012) compared bus routes that had real-time information added both to other routes that did not have information and also to those same routes, previous to receiving it. Watkins et al. (2011) used teams of two researchers, one asked those waiting for buses for their perceived waiting time, the other observed their actual waiting time. A similarly impressive methodology was employed by Brakewood et al. (2014) who used both before and after data as well as experimental and control groups.

A key indicator used for the studies investigating the success of traveller information websites was the ongoing numbers of hits the websites received (Enei 2014, CIVITAS 2, Rapp, 2003). The success of the websites was also measured by surveys into awareness of the site (CIVITAS 2) and questionnaires investigating user appraisal (RAPP, 2003). Researching websites has the advantage that the way in which the user has used the site, for instance the trip origin and destination they have entered, can be recorded (Enei, 2014). As Enei concedes this obviously does not correlate perfectly to actual behaviour, a user can enter an origin and destination for a potential bus journey but then not make that journey in real life.

There were also some weaknesses in some of the methodologies reviewed. These included that not all the studies included before and after studies. In addition, some of the studies had some minor biases in their samples. For instance Lehtonen & Kulmala (2002) report that females were overrepresented in their study and Brakewood et al. (2014) state that their sample group under-represented bus users of a lower income, respondents without car, African American users and those under 18. Caulfield & O Mahony (2009) report their sample of office workers was not representative of the whole Dublin population.

Another study, (Politis et al., 2010) used a measure similar to willingness to pay that can in some aspects be misleading. For example they suggest their finding that people made 34% extra bus journeys because of the information was likely to be unrealistic, and reflected a general positivity about the information provision. Brakewood et al. (2014) raise the possibility that some of their results may have been influenced by affirmation bias: the motivation for the respondent to write the response desired by the researcher. It is easy for the passenger respondent to indicate in satisfaction surveys that they value real-time information, they might do so both because of affirmation bias and in order to encourage a more widespread provision of real-time information in their city.

It could be argued that different responses would be gained if respondents had to prioritise such information against other improvements or added expense. For instance passengers surveyed by Lehtonen & Kulmala (2002) suggested they would support RTI being more widespread on the bus network but not if some bus routes had to be sacrificed in order to fund the improvements. However, counter to this objection, Politis et al. (2010) found that males valued the provision of information at 22.2% of their bus fare and females at 26%. They thus conclude if real-time information provision was paid for by an increase of fare of 5-10%, this would not significantly decrease patronage.

17.4 Lessons for Successful Deployment of this measure

The range of case studies illustrated here gives confidence that implementation of similar schemes in other cities are feasible, and that benefits are transferable. The case studies use a range of methodologies and highlight technologies like bus stop displays and smartphone apps, which could be applied in all European cities. One element of travel information that
might vary from country to country and which might introduce an extra element of complexity is the number of languages in which the information is provided. For instance travel websites in Basel had to include 3 languages (Rapp, 2003).

Provision of travel information is seen to be particularly helpful where and when road conditions are unpredictable. For example (CIVITAS 2) suggests that congestion in the city of Aalborg is not too bad under usual conditions and traffic conditions are fairly reliable. Hence the use of a travel information website was not as high as it might be in cities with more congestion. Extreme weather may be another source of unpredictability which again favours the deployment of information / RTI. The evidence suggests that under such conditions use of travel information websites can increase significantly (CIVITAS 2, Enie, 2014). More specifically, the CIVITAS 2 report proposes that the dramatic increase in people accessing the travel websites in that study during a period of extreme weather, showed that people were aware of the web-based information, and knew that they could access it when they needed it.

Effective marketing was seen as important to maximising information use by a number of the studies here, making the public transport user aware of the information that is available, as well as informing non users of public transport of services available - which can become more relevant perhaps in situations of disruption / extreme weather.

Information provision needs to be accessible and understandable for the user. For example, CIVITAS (1) comment that on-board display screens had to be timed so that everybody could read the information before the screen changed and Brakewood et al. (2014) found that some of their participants found smartphone apps hard to access. Consideration needs to be given to the technology used (for passengers and for operators), and it is recommended in the CIVITAS (1) report that a flexible system that can adapt to IT advances and trends is used. They also suggest making the RTI data available to private companies who can disseminate it – this can also reduce costs for an operator / city. Consideration also needs to be given to the cooperation that might be needed between different technology suppliers in order for systems to work effectively.

17.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- **Modal shift**: Some studies suggest that provision of travel information can help encourage modal shift, with one forecast suggesting 5% shift from car to public transport. This would lead to accident and air quality benefits. Reports from actual interventions indicate a much more modest effect.

- **Improved passenger satisfaction**: The evidence suggests a second major benefit of real-time information for public transport users is that it can reduce their actual and perceived waiting time. This is important as delays that occur before the arrival of the vehicle have the most damaging effect on public transport passenger satisfaction.

17.6 Summary

There is strong evidence in the studies reviewed that the provision of travel information, especially real-time information, is desired by trip-makers and can improve satisfaction with journeys. Providing real-time information is a good way to improve the experience of public transport users. It can achieve this both by removing frustration surrounding uncertain
arrival and departure times, and by reducing actual and perceived waiting times at stops. An important decision to reach is whether information provision will be via public screens or web and phone. As discussed above, the latter may be cheaper, and can benefit the rider even before they reach the stop or station, but may exclude those, for instance, who cannot afford smartphones.

A theme in this review is that travel information can be most valuable to the user when uncertainty is highest. Examples given include that information may be more valued for bus services than rail if the former are perceived as more unreliable. It may also be more valued in cities where congestion is heavy and unpredictable and when extreme weather occurs.

Most of the studies suggest that in terms of improving user satisfaction, travel information, including real-time information can be significant in its own right, without necessarily being part of a package of other measures.

As discussed above it is inconclusive from the studies reviewed to what extent provision of information, as a solitary measure, may affect modal shift. There were a variety of conclusions on this, a greater number of studies suggested modal shift does result than does not. The likelihood of achieving, or the degree of, modal shift is increased if the measure is introduced as part of a package of measures that might for example also include improved bus priority, (Lehtonen & Kulmala, 2002) fare prices (Politis et al., 2010) or increased quality of service (Tang & Thakuriah, 2012).

The PESTLE analysis conducted suggests that information provision can be positive economically and that whilst there can be issues surrounding changing technology, these were overcome, in the interventions studied.

For two reasons there can be a good level of confidence about the evidence reviewed. Firstly most of the items refer to a specific intervention and draw on specific and primary data. Secondly there is a good range of data collection methods, spanning from before and after studies with control groups, to stated preference and from observational research to longitudinal data collection.

A gap in evidence remains regarding the degree to which improved information can lead to new users opting for public transport use. In addition, more information about the economic benefits and costs of information provision needs to be gleaned. As Tang & Thakuriah (2012) demonstrate the influence of information provision on ridership levels is hard to isolate accurately

17.7 References for this Review

4. CIVITAS (2)(date unknown – approximately 2012) Modernising Travel information in Aalborg. Archimedes project. Measure number 09 [online]
Measure No.17: Travel and passenger information


Measure No.18: New models of car use

Shared use of cars (or other vehicles), to reduce the volume of traffic, and to improve access to mobility.

Shared use can include multiple uses of individual vehicles belonging to an operator or to a ‘club’, or multiple people travelling in a vehicle sharing a journey. Potential benefits for a city include fewer vehicles travelling and reduced demands on parking.

Key messages:
- There is strong evidence of positive effects of Carsharing schemes on vehicle kilometres travelled, CO2 emissions, car ownership, the incidence of driving alone and the numbers of vehicles on the streets.
- Free-floating Carsharing seems to have additional important advantages for larger urban areas (related to parking and one-way journeys), although evidence here is limited at present.
- Carshare schemes are run on both profit and not-for-profit bases. The proliferation of carshare schemes across the globe, often run by private companies, suggests that they can be commercially viable.
- Carshare schemes will be more expensive to operate in cities where parking spaces are expensive.
- Carsharing offers users financial advantages in comparison to owning a private vehicle; e.g. avoiding maintenance costs and unpredictable repair bills.
- Carpool schemes can reduce congestion, parking demand and fuel use/CO2 emissions. However there is the possibility of induced trips replacing these.
- The evidence reviewed does not give a clear indication of economic benefits to societies and municipalities of carpooling, instead focusing on benefits for the individual user.

18.1 Context and background

This review will look at a range of interventions that are aimed at providing access to the benefits of individual mobility, without some of the negative elements of such mobility. In particular it considers interventions known as carsharing and carpooling. It should be noted, that these terms (and that of ridesharing) can have different and similar meanings depending on the country they are deployed in.

Potential interventions
- Cars (and sometimes other vehicles) provided by an operator and used by a range of individuals when they have a need for a vehicle. Can be a not for profit operator, a commercial entity, or even a motor manufacturer.
- Systems whereby those making journeys with spare capacity in their vehicle can offer
that space to others (sometimes in return for payments). New entrants in one area of this market are highly technology driven, for example rideshare providers such as Uber and Lyft.

- Both types of scheme may be implemented for individuals, or through workplace-based schemes.

A carsharing scheme is one in which a number of cars are owned by an organisation. The organisation then rents the vehicles to members of the scheme. The terminology for carsharing is complicated as the term means different things in different countries. In the UK ‘carsharing’ refers to individuals sharing their personally owned vehicles whereas ‘car clubs’ refer to organisationally owned cars being rented out. Outside of the UK however ‘carsharing’ is the term applied to organisationally owned cars being rented out, and carpooling or ridesharing refers to individuals sharing personal, non-organisationally owned, vehicles. For this review the non-UK definition of carsharing and carpooling will be used.

This review includes studies on two types of carsharing. These are station-based carsharing, and free-floating carsharing. In station-based carsharing, the rented car has to be returned to the parking space from which it was taken. Hence the vehicle must be used for there-and-back or circular journeys. By comparison in free-floating carsharing the car can be left at any location, within a prescribed urban area (Firnkorn & Muller, 2011). In effect this means that the rented vehicle can be used for a one-way journey. This is beneficial because otherwise carsharing can be unappealing when the user wishes to travel only a short distance but then stay at the destination for some time (Ecoplan, 2012). Other features of free-floating schemes are users not having to prior book to use a car, no fixed costs (i.e. users only pay if and when they use a vehicle), and real-time GIS information showing the present location of available cars (Firnkorn & Muller, 2011). Firnkorn & Muller suggest that evidence relating to station based and free-floating carsharing should to some extent be considered separately as findings relating to one may not necessarily apply to the other.

Carsharing patronage in Europe has expanded rapidly in recent years. In 2015 it was reported to stand at more than two million, having increased from 75,000 in 2005 (Dings, 2015). It is a measure that can be used to address the adverse effects of excess private vehicles on roads. This means it can address ‘social, environmental and land use issues’ Klinevicius et al. (2014 p.54). While reducing the car use of many of its members, and reducing vehicle kilometres driven overall, it can also provide a degree of car mobility for those on lower incomes, unable to afford private car ownership.

Carpooling is a form of ridesharing (Chan & Shaheen, 2012). It has been defined by Macdonald et al. (2010, p.3) as ‘the practice whereby individuals combine to share private vehicles for specific journeys.’ Thus the vehicles aren’t hired from a central organisation. Ridesharing also contains vanpooling (Chan & Shaheen, 2012). Vanpooling is where a larger vehicle is used for the shared journey. Vanpooling groups are often financially self-sufficient, although can be subsidised by employers.

Carpooling has different forms (Chan & Shaheen, 2012, p.94). These include ‘acquaintance-based’ carpooling in which family members, friends, or known colleagues may share a trip. ‘Organisation-based carpooling involves the trip maker joining a carpooling organisation, either through becoming a member or through using a website. This may include the trip maker traveling with different people and in different vehicles, on different days. ‘Ad hoc’ ridesharing is when the trip makers are not familiar but does not require membership of an organisation. It often takes the form of ‘casual carpooling.’ Carpooling is often associated with commute journeys although it can be used for other types of journey.
18.2 Extent and Sources of Evidence

Fourteen items were examined for this review. A reasonably wide literature base exists on the topic of carsharing. There is less academic work on carpooling. Seven of the fourteen studies reviewed are journal articles and two are conference papers, written for the Transport Research Board meeting. Four reports are also included, two of which were written on behalf of transport authorities, another on behalf of a British motoring organisation and a fourth was part of the E.U. CIVITAS project.

The items reviewed cover a range of studies, ranging from overviews to investigations of specific interventions: Three studies on carsharing were on solitary schemes, two looked at carsharing within a specific city, three looked at carsharing at a national level, one looked at the whole North American continent and one was a general overview. Of the documents on carpooling, one was a report on carpooling in a number of cities. Another was to investigate the possibility of an area wide carpooling scheme. A third was a stated preference study and the fourth was a review of carpooling in the U.S.

Within Europe, two of the studies on carsharing were based in Germany, two in the UK, and one was based in Sweden and written in Swedish. Outside of Europe, carsharing has been particularly popular, and researched, in North America. Hence two studies reviewed were based in San Francisco, U.S., one was based in Montreal, Quebec, and one was based on the North American continent in general. Of the studies into carpooling, one was based in Australia, one in the U.S., one in Portugal and one across European cities.

Of the fourteen studies reviewed, ten were published in the last five years. Two were published last year. This suggests that carsharing and carpooling is receiving ongoing research, although there may be more being conducted on the former. Free-floating carsharing is a relatively recent development, and as yet there has been little data collection and research in relation to it. It is likely that such research will continue to arise in the coming years. The studies reviewed provide current research and related to contemporary forms of carsharing and carpooling.

18.3 What the Evidence Claims

18.3.1 Carsharing

Cervero & Tsai (2004) conducted a study on carsharing in San Francisco, U.S. They compared the impacts on travel demand and car ownership levels, amongst carshare users and non-users two years after implementation of a carshare. The study reported on the mileage that users travelled by different modes. 6.5% of their trips and 10% of their vehicular miles were travelled in the carshare cars. One caveat on the reduction of car use by carshare members is that this reduction may be less noticeable at traffic peak times of day (although it may be that car sharers may become more likely to commute by bus or cycle). They also found that 50% of trips that used car share cars had previously been on public transport, walking or cycling. 18% were previously made by driving.

Ter Schure et al. (2012) also focused on car sharing in San Francisco. In that city, many residential developments are required to provide carshare facilities. The study compared the travel behaviour and car ownership of those living in developments with carshare to those in developments without carshare.

Klincevicius et al. (2014) assessed the effects of carsharing on household car ownership in
Montreal, Quebec. They used a different methodology to most of the other studies as will be discussed below. They found that where there are a higher number of carshare vehicles within a 500 meter radius of a household there is a lower chance of car ownership.

Three of the studies reviewed are reports using mainly fact finding and qualitative strategies. These are Integrated Transport Planning Ltd (2004), Cairns (2011) and Ecoplan (2012).

Integrated Transport Planning Ltd (2004) is a report investigating carsharing in the UK, using qualitative interviews. Most of the carsharing schemes the report includes were in rural areas, although one was in London. Qualitative insights include general feelings of the carsharing schemes being a success and members viewing carshare as providing access to a car without the drawbacks of ownership. Members interviewed reported selling their private vehicles. One of the reported attractions of carshare was having access to vehicles of different sizes. The schemes studied varied, some were considered a success financially whilst others had very low take up and were not economically sustainable.

Cairns (2011) also provided an overview of carsharing in the UK. She reports that there had been ‘exponential growth’ (p.11) in the popularity of carsharing schemes in the UK. According to Carplus data there were around 32,000 members of carsharing schemes in 2007 in the UK. By 2010 the figure had risen to 146,000 members.

Ecoplan (2012) produced a report to provide a basis for decisions around what level of support should be given to carsharing schemes in Sweden. The research included interviews with four car sharing companies and with other stakeholders. The study is an overall investigation of carsharing but with a focus on Sweden.

Litman (2000) conducted a general international evaluation of the potential of, and barriers to, carsharing. The study concludes that carsharing is a beneficial alternative to private vehicle use if less than 10,000 km (6,000 m) are driven annually.

Two of the studies reviewed examined free-floating carsharing specifically, as defined above (Firnkorn & Muller, 2011, Schmoller et al., 2014). Schmoller et al. (2014) examined booking data of free-floating carshare cars in Munich and Berlin, Germany. They found increasing bookings of the cars, during the study period, due to increasing numbers of members. They comment that free-floating carsharing addresses two problems with station-based systems. These are that in free-floating systems cars can be booked spontaneously, without reservations, and that one way trips become possible. The latter advantage is particularly important as their data suggested that only around 10% of trips made were round trips.

Firnkorn & Muller (2011) examined free-floating carsharing in Ulm, Germany. The study used survey respondents’ predictions of their own behaviour given differing scenarios. They found indications that the scheme was popular. Almost 10% of residents in Ulm signed up to the scheme, although not all of these were active users. More than 25% of respondents stated they would forgo purchasing a car if the scheme was offered permanently. Firnkorn & Muller conclude that free-floating carshare is able to interest a greater share of people than station-based schemes.

Martin & Shaheen (2011) focused specifically on effects of carsharing on Greenhouse gas emissions (GHG) across the North American continent. The study found that car sharing leads to a net decrease in GHG emissions and vehicle kilometres travelled.Whilst a majority of households taking up car sharing increased their emissions when joining carshare, a minority decreased their emissions. The decreases tended to be of greater magnitude than the increases, to the extent that the overall effect of carsharing was a decrease in emissions. This finding is supported by Litman (2000). Martin & Shaheen (2011) used two measures of
the effects on emissions. The ‘observed’ impact included the observable changes in household driving behaviour. The ‘full’ impact took account of wider effects on behaviour, such as car purchase being forgone because of carshare membership. Statistically significant reductions of the mean emission level were found using both measures. ‘The mean observed impact is -0.58 t GHG/year per household, whereas the mean full impact is -0.84 t GHG/year per household’ (p.1074). Cervero and Tsai (2004) also suggest that GHG emissions would be reduced by carsharing, partly because of the carshare vehicles having lower emissions than average vehicles, although their study is less specifically focused on this specific outcome of carsharing.

Firnkorn & Muller (2011) used scenarios to estimate CO₂ emissions resulting from a free-floating carshare scheme. Even the worst case scenario resulted in a net reduction of CO₂. They estimate that the effect on CO₂ emissions of the scheme would be average reductions of between 312 and 146 kg CO₂/year per weighted average car-sharing user. The study suggests these results are similar to conventional car sharing schemes. However it also comments that the free-floating scheme type would be more popular than a conventional station-based scheme and thus would have greater benefits. The reductions in CO₂ that Firnkorn & Muller (2011, p.1526) predict lead them to suggest that ‘the difference between the emissions of car2go’ [the carshare company] ‘and public transport is small enough to rethink the paradigm that public transportation is invariably superior to cars in environmental terms’.

Firnkorn & Muller highlight cold starts of engines that lead to high levels of harmful emissions compared to normal running. Thus if the periods between use of the carshare cars are small, emissions will be lower than if everyone used their own vehicle and let it cool between journeys. Firnkorn & Muller (2011) concede that they did not take account of the CO₂ emissions involved in setting up and maintaining the infrastructure of a carshare scheme.

Having briefly introduced the separate items reviewed and having discussed impacts on CO₂ emissions, some common trends within the evidence, across the studies on carsharing, will now be summarised. The evidence reveals positive trends regarding the effect of carsharing on total distances travelled in cars, car ownership, numbers of cars being effectively removed from the streets, mode use of carsharers and reductions of drivers driving alone.

The evidence suggests that carsharing can reduce vehicle kilometres travelled overall. Martin & Shaheen (2011) found that mean vehicle kilometres travelled per year decreased by 27%. They note that carshare member tended to drive very small distances in carsharing vehicles. Ecoplan (2012) cite the International Energy Agency as suggesting that carshare users reduce their annual mileage by about 3,000 miles on average after joining a carshare. Cervero & Tsai, (2004) also found carshare users overall mileage was found to be reduced by joining carshare. They suggest that this may be due to a number of outcomes of carsharing, including reduced car ownership and more selective car use in general. Integrated Transport Planning Ltd (2004) suggests that carshare members tend to minimise their use of the carshare vehicle as they have to pay for each individual journey. Showing similar evidence of low mileage, Cairns (2011) reports that on average carsharers made five or six car driver trips of less than 25 miles per month. This was compared to an average of 56 such trips for non-carshare drivers. Litman (2000) similarly concludes that carsharing tends to reduce vehicle use by 40 to 60% due to the low fixed costs but high variable costs involved in using carshare vehicles. It can be observed that this proportion of fixed to variable costs is different for private vehicle use, where there are high fixed costs. Hence one of the problems of private vehicle use, which is ameliorated by a switch to carshare, is owners tending to maximise their mileage in their vehicle in order to get the best value from their investment.
As noted above, one reason for a reduction in total distance driven by carsharers includes impacts on car ownership. The studies reviewed suggest that carsharing can be associated with lower levels of car ownership. Ter Schure et al. (2012, p.96) suggest that carshare members had ‘significantly lower levels of vehicle ownership than non-members did.’ They found the average member household owned 0.47 vehicles per household while for non-members the figure was 1.22, more than twice as many. Cervero and Tsai (2004) found that around a third of carshare users had reduced the number of cars owned by one or more. Two thirds reported that during the two years since carshare implementation they had opted not to purchase another car. Similar behaviour is reported by Cairns (2011). She found that 85% of respondents reported not owning a car after joining a carshare, compared to 63% prior to joining. 25% reported giving up a privately owned vehicle during the membership and 30% reported forgoing buying a vehicle that they would have purchased if not for being carshare members. Similar results were found by the various datasets that Cairns reports on.

A potential outcome of some carsharers reducing car ownership is that one carshare vehicle may replace numerous privately owned vehicles on the streets (Another reason may be that carsharers drive less than car owners who are not members.) Cervero and Tsai (2004) estimate that the 74 vehicles in the scheme they examined had probably removed more than 500 vehicles from the local area. That is about seven private vehicles removed for every carshare car. A scheme investigated by Ecoplan (2012) suggested that each carshare vehicle replaces between ten and fifteen privately owned cars.

As well as reducing car use and ownership, carshare use is associated with generally desirable modal behaviour. Ter Schure et al. (2012) found that there were statistically significant differences in the mode used for commute between carshare members and non-members. 83% of members used non-auto modes for their journey to work compared to 70% of non-members. 43% of carshare members took public transport compared to 23% of those without. Cairns (2011) found that members walked, cycled and used public transport more than the population in general. Some of those interviewed by Integrated Transport Planning Ltd (2004) also reported using walking and public transport more having joined a carsharing scheme.

Carshare may also affect incidence of driving alone. Ter Schure et al. (2012) found that carshare members were 40% less likely to drive alone for trips than non-members. Cervero and Tsai (2004) suggest that members’ overall mileage may have been reduced after joining carsharing due to more journeys being made with more than one person in the car (i.e. combining different trips).

Carsharing would not be popular unless it offered benefits for the customer. Litman (2000) suggests that carsharing can be attractive by avoiding the need for maintenance of a privately owned vehicle and unpredictable repair bills (see also Ecoplan, 2012).The main benefit for the customer though is likely to be financial advantages of membership, in comparison to owning a private vehicle. These will depend on the amount of transport that the individual needs a car for (Ecoplan, 2012). Environmental concern may also be a motivator (Integrated Transport Planning, Ltd., 2004).

Very few disbenefits of carsharing schemes are revealed in the studies reviewed. One logical disbenefit is that whilst carsharing is more environmentally beneficial than private vehicle ownership, it is less beneficial, from environmental, street ambience, road safety and public health perspectives than walking and cycling, which it may in some instances replace.

Other issues are mentioned in relation to small scale rural carshare schemes. These include
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the difficulties of finding staff to administer the scheme who have the prerequisite skill sets and also making the scheme financially viable (Integrated Transport Planning Ltd, 2004). However evidence suggests that financial viability in urban areas is less problematic. A key factor for the economic sustainability of a station-based scheme is that each car should be patronised by a sufficient number of householders in its vicinity.

In conclusion on the main findings on carsharing, the evidence suggests a number of strong benefits of the intervention type. These benefits apply to the global environment (CO₂ and other emissions) the local society (reductions in numbers of vehicles driving in the city) and the individual member (reduced hassle and expense from reduced private vehicles owned.)

18.3.2 Carpooling

Macdonald et al. (2010) report on a number of carpool interventions carried out in European cities as part of the CIVITAS project and comments on their success levels. Across eight cities, five (Burgos, Krakow, Debrecen, Potenza and Preston) involved the introduction of a new car pooling system whilst three (Stuttgart, Toulouse and Norwich) involved the expansion or adaptation of an existing carpooling scheme.

The carpooling interventions included: facilitating carpooling amongst students or educational institutions (Debrecen, Krakow, Norwich) using or creating website or web-based tools (Burgos, Debrecen, Krakow, Norwich, Potenza, Preston, Toulouse) and promotion, marketing or advertising (Burgos, Debrecen, Krakow, Norwich, Potenza, Preston, Stuttgart). The cities reported beneficial effects of the interventions. These were expressed in various formats: Norwich reported 304 tonnes of CO₂ being saved, Preston reported an average reduction in emissions of 7.7g of CO₂ per shared journey and Toulouse reported 0.338kg of CO₂/km for a medium sized car being saved. Krakow reported that fuel consumption had been reduced by 32% (although the document comments this figure should be treated with caution). Norwich reported savings in car running costs of £99,369 (estimated from the vehicle miles saved).

A number of cities reported increases in average car occupancy following the intervention. In addition there were increases in total numbers of people using the carpool system. These increases varied greatly by city: increasing up to 1,800 in Toulouse and 1,700 in Stuttgart, but only up to 34 in Potenza. The different cities reported people’s attitudes to carpooling in relation to the intervention. In Burgos the percentage of people willing to share their own vehicle rose from 57% to 87%. In Krakow, awareness of carpooling increased from 34% to 66%. However, in Krakow, interest in carpooling did not vary as a result of the intervention and in Stuttgart, awareness of carpooling declined during the researched intervention period. Overall though, Macdonald et al. (2010) conclude that in each city the intervention achieved its aim of successfully establishing or increasing a carpooling facility.

Correia & Viegas (2011) used a stated preference survey in Lisbon, Portugal, to examine carpooling. They tested whether there was a level of trust needed for carpoolers seeking matches. They suggest that sharing a car with a non-acquaintance can be a barrier to take-up. This can be reduced in if the carpool is organised by an employer, so that the other trip-maker is a colleague. Correia & Viegas also examined the importance of being able to join different carpooling groups for a user whose schedule has changed. They suggest that carpooling systems can be inflexible, particularly when users want to change their destination or timing of trip. This problem can mean only a small percentage stay with carpooling long term.

Chan & Shaheen (2012, p.96) give an overview of carpooling in the U.S. They suggest that
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carpooling can be claimed to have a number of 'societal benefits' such as reduced CO2 emission and energy use, amelioration of traffic congestion and reduced demand for parking. However, they conclude 'the magnitude of such benefits is unclear.'

DeGruyter (2006) investigated the potential for a CBD (central business district)-wide carpooling scheme in Melbourne. He reports on a survey that preceded the possible intervention. The proposed intervention was addressing the problem that carpools specific to individual employers would not be effective in a CBD area, full of small shops etc. Thus an alternative would be to have a joint carpool for the companies in the area. 6% of workers in the area said they would be very interested in the carpool, 23% said they would be slightly interested. Almost half of the staff who would be interested in the carpooling were in lower as opposed to higher paid jobs. More women than men were interested in the scheme.

The extent to which carpooling schemes may reduce total vehicle kilometres travelled is debatable. Whilst shared car trips may be longer than individual journeys (in order to pick up fellow travellers) this will not lead to as many vehicle kms travelled as if each trip maker made a separate car journey (Degruyter, 2006). However Degruyter also notes that some new carpoolers may switch from public transport. In the case of the Melbourne CBD he examined, the survey responses suggested that because most of those surveyed who were interested in the scheme presently used public transport, the overall result of the scheme would be likely to be an increase in total vehicle kms travelled.

A common theme in the studies examined is that carpooling can have both attractive and unattractive aspects for the individual user. Attractive elements can include the idea of reducing congestion and pollution (DeGruyter,2006), reducing personal travel costs (both financial and travel time, Chan & Shaheen, 2012, DeGruyter, 2006), the potential of increased social interaction (DeGruyter, 2006), reduced stress of driving the commute (Chan & Shaheen, 2012) and the enjoyment of priority parking, subsidised parking costs, use of high occupancy vehicle lanes and other incentives (Chan & Shaheen, 2012, DeGruyter, 2006).

Potentially unattractive aspects for the user include a lack of journey flexibility in carpool arrangements, personal safety concerns, having to rely on fellow travellers, not wishing to interact socially during the commute (Chan & Shaheen, 2012, DeGruyter, 2006) and the time spent collecting fellow travellers (Correia & Viegas, 2011, DeGruyter, 2006). So some elements of carpooling work towards and some against, the popularity of the scheme type. Discussion now turns to the nature and quality of the research methods used to reach the above findings.

18.3.3 Nature of research methods – Carsharing studies

This section will discuss two main approaches of generating data used by the study: comparing before and after behaviour and comparing the behaviour of carshare members and non-members. It will then discuss some of the strengths of the methods used, and then some of the weaknesses, before drawing brief conclusions.

An obvious strategy when seeking to understand the impacts of carsharing schemes is to compare members with non-members. This can be done in two ways: those who are presently members can be compared with those who presently are not members. Ter Schure et al. (2012) and Cervero & Tsai (2004) took this approach. Ter Schure et al. (2012) compared those who were members of a carshare through their residential development with those who had no such facilities. Alternatively the behaviour of those who are presently members can be compared with their behaviour before they became members. Cairns (2011) and Martin & Shaheen (2011) took this approach. Cervero & Tsai (2004) measured changes in
members’ behaviour in their first two years of membership and also compared this to a control group of non-members. This in effect used both approaches.

It could be argued that the method of comparing members’ behaviour to non-members does not prove a cause and effect between membership and altered travel behaviour. It may be that those who carshare are less likely to drive as far or are more likely to use other modes for reasons other than their carshare membership. This issue is maybe less of a factor in the surveys comparing before and after behaviour. This method may contain its own biases though due to its component of self-report.

The methodologies used included a number of strengths. One of these is the collection of data from large samples of carshare members. For example, Martin & Shaheen (2011) used a survey of 6281 responses, Cairns (2011) drew data from around 5,000 survey responses, Ter Schure et al. (2012) used 298 survey responses, Cervero & Tsai (2004) used around 500 survey responses, and Firnkorn & Muller (2011) used 308 responses. Martin & Shaheen (2011) and Firnkorn & Muller (2011) record efforts to make their samples representative.

Another strength in the evidence reviewed is the range of methods by which it was gathered. This range included, surveying members about their travel behaviour, qualitative fact-finding investigation, using computerised booking data and using census level information.

The majority of the studies were peer reviewed and, when using statistics, used appropriate methods. These included simple descriptive statistics and chi-square tests (Ter Schure, 2012), Binomial logit models (Cervero & Tsai, 2004), sensitivity analysis and paired t-test (Martin & Shaheen, 2011), cluster analysis and linear regression models (Schmoller et al. 2014) and multiple regression models (Klincevicius et al. 2014).

Perhaps the main weakness of a number of the studies reviewed is that they relied on surveying carshare members’ attitudes and self-reported behaviour. Klincevicius et al. (2014, p.49) suggest that this reliance may lead to bias as it may involve the members’ ‘interpretation and speculation and may not correspond to measurable effects overall in the city.’ There is the impression that some of the fact finding reports, such as Integrated Transport Planning Ltd. (2004), were researching people who were particularly positive about the scheme type.

However, not all the studies relied on surveying carshare members. Klincevicius et al. (2014) sought correlations between levels of car use and household characteristics at a population level, using census data, and behaviour and car ownership data. Another exception was the study by Schmoller et al. (2014). They used computerised booking information of a free-floating carshare system. This information consisted of start and end times of journeys, journey duration and lengths and the location of start and end points.

Other weaknesses also exist in specific studies reviewed. For instance one carshare scheme researched by Integrated Transport Planning Ltd (2004) had only 34 members, so drawing conclusive evidence about behavioural changes was difficult for this case. However, that scheme was only one of a number investigated in the report.

Other data was drawn that might have had motivation for bias. For instance Cairns (2011) used data from an organisation that is aimed at supporting rethinking car use. However, this study also drew on data gained from other sources. Similarly (Ecoplan, 2012) drew data from carshare companies, that might have motivation to be biased.

Although a number of the studies did rely on self-reported behaviour, this information has the strength of relating, theoretically, to actual or real-world behaviour. An exception was the...
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study by Firnkorn & Muller (2011), which asked participants for predictions of their behaviour given different scenarios. This data might be considered of slightly less worth in this respect than the reports of actual behaviour.

Some of the studies discounted members who didn’t use the carshare vehicles, despite being members (Martin & Shaheen, 2011). This is understandable in terms of focusing on members whose travel behaviour is actually affected by involvement in a carshare. However it would seem important that research into carsharing should recognise that a proportion (Martin & Shaheen, 2011, estimate 15 to 40%) of those joining carshare never or rarely use the carshare vehicles. Other studies concede that their respondents may have been more likely to be those using the carshare more regularly (Cervero & Tsai, 2004).

Isolating the effects of carsharing on behaviour can be difficult because of other factors that may influence the trip maker (Klincevicius et al. 2014). For instance, Firnkorn & Muller (2011) concede that their study did not take account of seasonal variation. Integrated Transport Planning Ltd (2004) suggest that carshare uptake may depend on local economic conditions, which can be difficult to understand. Some studies did seek though to take account of factors affecting behaviour such as weather and demographics (Schmoller et al., 2014) and moving house (Martin & Shaheen, 2011.)

In conclusion caveats that must be applied to the evidence have been outlined. The largest being that a number (although not all) of the studies rely on the self-reported behaviour of carshare members. Despite this, due to the range of methodologies and the consistency of the finding that carsharing can provide benefits while causing few disbenefits, the conclusion that carsharing is a measure with important positive potential can be held with some confidence. This positive verdict on carsharing would seem, from the studies reviewed, to be rationally generalisable to locations other than those researched.

There are some gaps in the evidence surrounding carsharing at present. Two studies on free-floating carsharing have been summarised. However, the literature base on this form of the scheme remains small. It is likely to increase in coming years, as the scheme type has been successful. Another gap in the research is a before and after study which compares individuals’ (actual rather than self-reported) travel behaviour before becoming involved in carshare and then after they have become members. This is due to the obvious difficulty in predicting who, in the future, will join carsharing schemes.

18.3.4 Nature of research methods – Carpooling studies

A strength in the evidence reviewed concerning carpooling is that it represents a range of approaches: from surveying to reports on figures of membership, and from a stated preference study to an historical overview. However the nature of the data collected in relation to carpooling is weaker than that relating to carsharing and contains greater gaps. One of these gaps is that the evidence often focuses on the benefits of, and attitudes towards, carpooling for the individual user rather than the local authority or society as a whole. The effects of carpooling for the local area, in terms of congestion, economic impacts etc. is not greatly quantified in the evidence reviewed.

Macdonald et al. (2010) use data from carpooling interventions in 8 European cities. The strength of this data is it draws on empirical data gathered after the interventions had been implemented. It includes total number of carpool users, results from surveys asking for people’s attitudes to the carpool schemes, and comments about the scheme implementation in each city. Correia & Viegas (2011) obtained a good number of respondents for their survey (N=996.) However a weakness with it the data is that it is stated preference, rather than data
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on real behaviour. Chan & Shaheen (2012) do not provide empirical data, but provide an overview of carpooling using other sources. Degruyter (2006) collected survey data on people’s attitudes to carpooling in a CBD, prior to an intervention.

18.4 Lessons for Successful Deployment of this measure

18.4.1 Carsharing

It is possible that evidence provided by research can be accurate for the location studied but is not legitimately generalizable to other settings. For carsharing though, most of the evidence suggests the scheme type could benefit other cities and countries than those covered in the research. It should be conceded that many of the studies examined schemes in countries where carsharing was becoming widespread, such as Germany and the U.S. Some of the study areas are particularly conducive to carpooling. For example Cervero & Tsai (2004) question whether their findings in San Francisco would be generalizable elsewhere because the city has ‘congested streets, limited and expensive parking, good public transit options, numerous non-traditional households and a fairly socially progressive population’. It could be argued though that these urban characteristics are quite common in many European cities and thus the findings from San Francisco may be relevant to much of Europe. Overall it is likely that the positive effects of carsharing found in the cities and countries researched could be replicated in other cities and countries. Firnkorn & Muller (2011) suggest that free-floating car-sharing could become a widespread solution to mobility problems in the future, provided some technological and organisational problems were sorted out.

The range of studies shows that carsharing can be organised at a range of scales, from small urban schemes to large international companies. However very small rural schemes may have problems with financial sustainability.

Most of the evidence reviewed suggests that carsharing is significant as a measure in its own right. However it would be unusual for members to rely purely on carsharing for their transport needs, carsharing tends to be part of a multi modal lifestyle (Ecoplan, 2012). Thus the scheme may be most effective alongside effective provision for public transport and active travel. The review now examines the characteristics of carshare within a PESTLE analysis (which summarises political, economic, social, technological, legal and environmental factors).

The studies reviewed suggest a range of different interactions between relevant political bodies and carshare schemes. A shaping political factor surrounding carshare schemes can be that of parking (Ter Schure et al. 2012). Cairns (2011) suggests that in the UK, carshare schemes sometimes rely on local authorities for the provision of parking spaces. She also notes that local authorities can help to promote the schemes and can make use of them, as an organisation, themselves. Supporting carshare can be attractive to local authorities if they wish to create local areas that are walkable and which support public transport (Ter Schure et al. 2012).

Carsharing schemes relating to residential developments have been required of developers by some local authorities (Cairns, 2011, Ter Schure et al. 2012). However, Ter Schure et al. add that including residential based carsharing facilities can be attractive for developers, even when not legally required.

Political bodies and other organisations may be motivated to investigate and aid carsharing
due to concerns over GHG emissions. The positive impacts of carsharing on these emissions have been discussed above.

Economically, the contemporary proliferation of carshare schemes across the globe, often run by private companies, demonstrates that they can yield profit. Some schemes are run on a profit and some on a not for profit basis (Ecoplan, 2012). As a caveat to the economic viability of carshare, Integrated Transport planning Ltd (2004, p.110) found that one small rural scheme they investigated was not proving to be economically sustainable. This was due to outgoings (including repairing office equipment and work on parking places etc.) outweighing income. However, the rurality and small scale of this scheme should be stressed. It is much easier to achieve sufficient membership and income in dense, urban areas, and a London scheme investigated in the same report was found to be economically successful.

Ecoplan (2012) suggest that the cost to the carsharing organisation will depend to a great degree on the location of the car parking space. In this respect cars will be more expensive to run in larger cities where parking spaces can be expensive (unless local authorities help in this respect, as discussed above). If as Ecoplan (2012) suggest one carshare vehicle replaces seven private vehicles, this suggests that carshare could theoretically release valuable land that otherwise would be needed for parking. This effect is intensified by carshare cars often being smaller than average, thus allowing more to be parked in a given space (Firnkorn & Muller, 2011). It has been argued that this release of land could help create more liveable streets (Litman, 2000). It is likely though that in many cities the demand for parking so outweighs the provision available, that any extra land would quickly be used up by latent demand for parking.

Schmoller et al. (2014) report that the carsharing they examined received greater use on Saturdays than other days. They suggest this might be due to the vehicles being used for shopping trips. There may be a two way link between carshare schemes and local retail: The vehicles may encourage greater shop patronage and thus sales. Conversely a strong local retail economy may increase carsharing popularity.

Carsharing can have benefits for social equality. Litman (2000) suggests that carshare may enable low income households to be able to have some car mobility. This is due to high variable costs but low fixed costs of membership. This may mean that these householders can have the ability to search for jobs and education for example (Litman, 2000). The scheme type may also help to decrease incidences of low income household members driving without insurance.

Another social impact that small, local carsharing schemes can have is that they can facilitate new friendships (Integrated Transport Planning Ltd, 2004). Additional potential benefits of carsharing are positive impacts on road safety (Ecoplan, 2012). These may result from carshare vehicles tending to be more modern, and driven less than typical privately owned vehicles. However, Ecoplan (2012) concede that such benefits have not been quantified.

The carsharing schemes investigated relied on technology of various forms. This can include in-car computer systems that can be used for bookings (Integrated Transport Planning Ltd, 2004, Firnkorn & Muller, 2011). Firnkorn & Muller suggest that eventually touch screens in free-floating carshare vehicles could display local public transport connections and even handle the purchase of tickets for public transport. In addition environmentally friendly driving of the vehicles could be recorded by computer and rewarded. The review now turns to
some of the elements necessary or beneficial for successful operation of a carshare scheme.

A strong theme within the studies reviewed is that carsharing can have a synergistic relationship with measures to improve public transport (Cairns, 2011) and active travel infrastructure and facilities. Carsharing is likely to prosper where public transport and active travel are well provided for (Ter Schure et al., 2012). It can also arguably encourage travel by these modes (Martin & Shaheen, 2011, Firnkorn & Muller, 2011). Other studies suggest that carsharing can lead to new carsharers using public transport less, but active modes more (Martin & Shaheen, 2011a). Martin & Shaheen found that this pattern was not uniform across different carsharing organisations. The overall statistic also masked dissaggregate trends within their findings: They found that lots of new carsharers used public transport more, but even more carsharers used it less.

It is important for carshare and public transport to be well integrated (Firnkorn & Muller, 2011). Opportunities exist to offer carshare members discounts on public transport tickets (Cairns, 2011, Ecoplan, 2012, Litman, 2000). The interaction between carshare and public transport is highlighted by some carshare companies already being operated by public transport companies (Ecoplan, 2012). Bremen, Germany, is a successful example where a ‘Bremer Karte plus Autocard’ enables use of the trams, buses and car-share within the city, at low price (Hurley, 2014) (Multi-modal ticketing is discussed in detail under measure 12). As well as public transport, Litman (2000) suggests other measures that carsharing can be synergistically combined with. These include electric vehicles, dense land use and unbundled parking.

A number of studies highlight the need for marketing if a scheme is to be successful. Some false perceptions may need to be addressed in order to convince people to use the scheme. These include the perception that carshares may be for environmental enthusiasts only (Integrated Transport Planning Ltd, 2004, p.104) and underestimations of the costs of private vehicle ownership costs (Ecoplan, 2012). Some schemes have found carshares can be more successfully marketed in relation to practical and personal, rather than environmental motives (Integrate Transport Planning Ltd, 2004).

It has been noted that a key attraction in carshare membership is financial. Thus to be successful a carshare scheme should carefully consider its pricing in relation to other forms of car rental such as taxi and normal car rental (Cervero & Tsai, 2004, Ecoplan, 2012). Carshare schemes are likely to particularly successful in dense urban areas, where there is parking scarcity (Cairns, 2011, Litman, 2000) and arguably where there may be lower household incomes (Litman, 2000). Schmoller et al. (2014) suggest that socio-demographic data can be used to partly forecast demand. Some of the rural schemes investigated by Integrated Transport Planning Ltd (2004) were not considered economically sustainable, although Cairns (2011) reports that rural carshares can be successful.

18.4.2 Carpooling

The studies of carpooling suggest some factors that might affect its more general implementation. In terms of its patrons, Correia & Viegas (2011, p.81) found that ‘carpooling is still attached with lower income strata and that saving money is still an important reason for participating in it.’ Age and gender may also be significant in take-up. Correia & Viegas found young persons would be more willing to join a carpool. In terms of the organisation instigating the pool, DeGruyter (2006, p.1) suggests that employer based schemes work well when there are lots of employees in the company, when they travel far to work and when a lot of employees use car prior to the intervention. Factors that can make such carpooling
successful include, ‘support from senior management, reimbursement of parking charges for carpoolers, provision of priority parking for carpoolers, efficient management of the carpooling scheme through a dedicated coordinator. Degruyter (2006, p.2) also suggests external conditions that can encourage carpooling. These include ‘presence of high occupancy vehicle (HOV) lanes, lack of parking, absence of convenient alternative modes, increase in petrol price, having the carpooling scheme as part of a wider package of initiatives.’

The number of members that a given carpool scheme can achieve is vital. For instance Macdonald et al. (2010) report the importance of getting corporations involved. This is for the obvious reason that people working at the same location may share trip destination (to work) or origin (from work).

Marketing is also of vital importance in enabling the success of carpooling schemes (DeGruyter, 2006, Macdonald et al. 2010, Chan & Shaheen, 2012). All the cities in Macdonald et al.’s summary considered that achieving public awareness and acceptance of carpool schemes was vital for success. Marketing can be focused at target groups. It can offer strong messages such as the potential for trip makers to save money (Macdonald et al. 2010). Such messages can be conveyed and supported by local media or by car club websites (Macdonald et al., 2010).

The cities reported by Macdonald et al. (2010, p.22) considered that carpooling should be integrated within wider transport strategies, including ‘work travel plan strategies’. It can be integrated along with supporting policies such as free or cheap access to high occupancy toll lanes, cash rewards for opting out of parking spaces and other financial incentives. As part of wider strategies there is the potential for synergistic relationships between carpooling and carsharing and public transport (Chan & Shaheen, 2012).

Strong political interest can support implementation of carpool schemes (Macdonald et al. 2010) This can be motivated by the need to reduce single occupancy car commute use, and policy objectives to reduce congestion and emissions. DeGruyter (2006) in his Australian study identifies local government and transport management associations as suitable bodies for implementing area-wide carpooling. Macdonald et al. (2010) report that there can be resistance and lack of acceptance from some politicians and other stakeholders. These can be resolved through stakeholder meetings. It is desirable that clear delineations of responsibility for aspects of the carpool are drawn amongst the authorities involved (Macdonald et al. 2010).

Macdonald et al. (2010, p.22) suggest that in ‘initial stages’ carpooling schemes may not economically self-sufficient without local authority support. Financial factors such as increases in costs of car ownership and increasing fuel costs can influence uptake of carpooling by trip makers.

Chan & Shaheen (2012) conclude that technology will be important in the future of carpooling. Open source data sharing may provide the wide pools from which users can find matches that are crucial to success and acceptance of the scheme type. Technology can enable easy ride matching for the user. In Stuttgart, technical software issues were felt to be a ‘barrier to transferability’ of the scheme. [Macdonald et al., 2010, p.19]. However, there are now extensive web based platforms that enable carpooling. For instance, Pickuppal had over 156,000 members in 120 countries in 2012 (Chan & Shaheen, 2012).

18.5 Additional benefits
As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- **Access to mobility**: Carshare and carpool schemes can also provide a degree of auto-mobility and accessibility benefits for those on low incomes. This may provide access to the search for and take-up of jobs and education.

- **Land-take**: Carshare vehicles are seen to replace multiple private vehicles, suggesting that schemes could lead to the release of valuable land that otherwise would be needed for parking. This effect is intensified by carshare cars often being smaller than average.

### 18.6 Summary

#### 18.6.1 Carsharing

In conclusion, the studies provide strong evidence that carsharing can have desirable impacts on car traffic related problems. They suggest that carshare can lead to reductions in vehicle kilometres travelled, CO2 emissions, car ownership, incidence of driving alone and numbers of vehicles on the streets. The degree of these reductions, at a societal level, will depend on the popularity of the scheme and the extent of its provision. Conversely the scheme type can also provide a degree of auto mobility and the attendant accessibility benefits for those on low incomes. The free-floating form of carsharing seems to have important advantages for sizeable urban areas, although due to its recent emergence there is still a relatively small body of evidence concerning it.

One caveat about the methodologies of most of the studies is that they tend to rely on the self-reported behaviour of carshare members. This may lead to a bias towards positive reports of the effect of carshare. However some of the studies did not use this method and provide useful triangulation for the approach. These studies also found beneficial behavioural outcomes of carshare membership.

What is also noticeable is that the studies do not highlight many drawbacks or undesirable aspects of the scheme type. One logical caveat regarding the scheme is that it does not in the long term offer the same environmental or public health benefits as walking or cycling. Whilst one carshare vehicle may replace multiple privately owned vehicles, it is still a polluting vehicle. Some carshare trips will have previously been walking and cycling trips (Cervero & Tsai, 2004).

The studies reviewed do suggest that there can be practical issues involved in successfully implementing a carshare scheme, but the large number of successful carshare schemes globally demonstrates that these can be overcome. The review has highlighted that to maximise the success of carshare it is beneficial to price the use of vehicles carefully and to implement the schemes in suitable areas. A particularly strong theme within the studies is the importance of good integration between carshare facilities and public transport. These two forms of mobility can interact synergistically. The importance of good marketing is another operational practicality that has been discussed.

There is no reason to consider that the positive outcomes of carsharing schemes could not, indeed have not, been replicated in other countries and settings than those reviewed, although small rural carshares may struggle for sufficient membership.

Whilst there are some weaknesses in the methodologies reviewed, these do not negate the fact that the studies consistently show carsharing to have positive, rather than negative,
effects at social and individual levels. In addition most of the weaknesses have been themselves caveated, and each methodological weakness applies to only some of the studies reviewed. In combination then, the studies form a consistent picture of strong benefits of carsharing schemes.

18.6.2 Carpooling

The evidence suggests that some vehicle trips, with the attendant costs of CO2 emissions, congestion, parking demand and fuel loss, can be saved through carpool schemes. However there is the possibility of induced trips replacing these and trip makers switching to carpool from public transport. Thus it is hard to conclude the extent of the benefits from the evidence reviewed.

A number of factors acting as facilitators or barriers to carpool schemes have been discussed. The number of potential members is important, as larger pools of members increase the likelihood of a user finding a suitable match for their journey. For this reason marketing and other strategies to raise public awareness of the scheme are important to success, as is engagement with local employers. Uptake of carpool use may be affected by factors external to the scheme, such as fuel prices, car ownership prices, parking availability. Some of these can be managed by local authorities, and can be combined with carpooling, and carsharing as an integrated transport strategy. As with carsharing, technology, particularly web based technology, has become important for the future of carpooling.

The evidence reviewed does not give a clear indication of the benefits to societies and authorities of introducing carpooling interventions, but tends to focus on the benefits for the individual user. More specifically it does not give an indication of economic CBA of carpooling schemes.

The evidence surveyed suggests that there may be good synergistic relations between carpooling and carsharing; both enable car travel while avoiding the least sustainable uses of the mode.

18.7 References for this Review

   http://www.racfoundation.org/assets/rac_foundation/content/downloadables/accessing_cars-cairns-main_report.pdf [Accessed 15/05.2015]


   http://www.transportenvironment.org/newsroom/blog/two-mobility-revolutions-
Measure No.18: New models of car use


Measure No.19: Walking

Improving walking infrastructure and promoting schemes to encourage greater use of this mode of travel.

Cities making changes to the walking environment (and its relationship to other modes of travel) can provide clearer and more acceptable choices for those making short journeys. Interventions that support individuals and groups in choosing to walk as a travel mode may be delivered in support or as freestanding initiatives.

Key messages:

- Evidence suggests that increased walking can flow from improving the walking environment and/or targeting information at individuals.
- Interventions to increase walking are often considered at a community or small scale geographic level, assuming walking journeys are shorter than trips made by other modes.
- Most evidence focuses on the health benefits of walking to individuals. However, there is an expectation in some studies that local economies will benefit from more walking trips.
- Walking interventions may require enhancements to urban design features and infrastructures. Such changes can potentially be expensive and difficult to justify purely from the benefits of additional walking.
- Where cost-benefit analysis (CBA) of improving pedestrian facilities (installing pavements for example) has been undertaken, benefits are drawn from reduced car use and air pollution.
- Businesses place more emphasis on the quality of the walking environment, or public realm. Investment here as opposed to walking itself is seen to provide economic benefits in respect of customers and rental values.

19.1 Context and background

Walking is an element of all journeys, however they are undertaken. Walking is though an option for the whole journey for most people when making short trips. Walking is also a leisure pursuit, with the focus more on aspects such as the environment and health. Consequently cities can pursue initiatives in a number of areas to support walking with different goals in mind. Improving health of the population might be one area of concern, whilst discouraging short journeys by motor vehicles in a city centre to improve air quality might be another. Making a city more attractive to visitors through being seen as a ‘walkable city’ is another potential objective driving action as is reducing traffic around schools to improve road safety. Whatever the goals, walking interventions will broadly split into those that improve the physical environment in which to walk, and those which ‘encourage’ people...
to do it. This measure review will consider both aspects.

Potential Interventions

- ‘Walking bus’ schemes for schools and other destinations for children
- Walking promotions targeting better health, and supporting health care providers
- Walking promotion through challenges or gamification
- Infrastructure changes to facilitate and encourage walking

The review considers ways of encouraging more walking through specific schemes such as children walking to school, walking for health programmes, as well as infrastructure changes, i.e. urban design features. Whilst urban design can facilitate walking it also often presents barriers to walking, as pedestrians have to cross roads, and walk alongside traffic. Thus a context to walking environments is presented below. However, urban design is addressed elsewhere too, in Measure No.4 Access restrictions (e.g. pedestrianisation), and Measure No.23 Inclusive urban design (e.g. shared space). Encouraging individuals to walk to work may also enter into the discussions in Measures No.9 and No.10 (Travel Planning), therefore such schemes have not been included in this review.

19.2 Extent and Sources of Evidence

There are a number of case studies around the urban design of cities that report an impact on increasing walking levels, although the detail in terms of numbers or cost benefit analysis is often not included in the publication. Given that it is argued that without “good” walking infrastructure, and places to walk to at a reasonable distance (e.g. shops, facilities, leisure), then other interventions presented will need this basic infrastructure in place in order for the intervention to have an effect.

There are many publications that claim physical activity, which includes walking, is beneficial to health, but there are only a few studies that present actual evidence of interventions with an impact on walking levels. One of the challenges is separating out evidence from research that considers walking and cycling together where new infrastructure is shared.

The majority of the evidence presented here is UK based, although one paper provides evidence from New Zealand, and a couple from the US, with the research conducted since the start of the twenty first century and mostly published in academic journals.

19.3 What the Evidence Claims

There is some evidence to indicate that levels of walking can increase at an individual and collective level through a number of personal and community interventions, as well as through changes to infrastructure. As indicated above, it can be argued that an infrastructure suitable for walking needs to be in place before undertaking any interventions aimed at behavioural changes. Evidence from Melbourne (Australia), for instance, has indicated that re-designing the urban framework to make the city centre more walkable had a significant effect on the numbers of walking trips in the area. While many reports consider urban design issues to benefit walkers, there are fewer studies that demonstrate the effect of the investment on walking over time. However, issues such as pedestrianisation are dealt with in measure reviews No.4 and No.23, and some of these may have scheme evaluations.

The relationship between physical activity and health has focused health practitioners on
ways of encouraging people to walk for health benefits. Public health interventions in particular have been successful in using walking to encouraging greater activity, but most of these trials have been small scale and short time-frame (i.e. less than a year). Children’s health and activity level is also a driver for measures to increase the number of children walking to school. These studies are focused on the benefits to individuals (and reducing levels of cars near schools) rather than wider economic outcomes of more people walking on the local economy. However, there is some evidence to indicate that increased levels of walking can have a positive effect on the local economy.

The specific interventions discussed below start with those aimed at changing behaviour of individuals and communities, and then move on to the impact of urban design and new infrastructures on levels of walking.

19.3.1 Encouraging Walking for Active Lifestyles

Encouraging walking more generally within the population can benefit people’s health and wellbeing through greater activity, but might not be linked to specific health interventions at the individual level as above. Three interventions are reported here that were aimed to promote walking in the general population and are indicative of studies seeking to test interventions that change behaviour.

The first, ’Doorstep Walks’, provided printed information to the public about a series of leisure walks from specific locations in the small British city Salisbury. These were placed in publically accessed locations (e.g. medical centres, libraries, etc.) for people to pick up and use. The evaluation indicated people who had received the walking route information pack had increased their level of walking.

The second ’Beat the Street’ utilized RFID technology as a way of encouraging and measuring walking within a community. The Beat the Street concept was piloted in Caversham (a suburb of the UK city of Reading) as a feasibility study for the technology, and subsequently extended into Reading. The concept has been developed into walking competition projects in other UK and US cities. Beat the Street Caversham was promoted through schools, doctors’ surgeries, local business and community groups and local media and it had 5,651 people participating, of which 2,627 were schoolchildren. Sixty seven percent of participants reported they had walked more because of the project, but the outcomes in Reading have yet to be reported. The evaluation methodology consisted of analysing data generated by the RFID card swipes from individuals, which logged 255,015 journeys between two swipe points, and an exit survey with a sample of 1,300 adults, along with qualitative feedback from participants. The second phase (Reading) was jointly funded by the Clinical Commissioning Group and local authority transport and public health teams.

A suite of interventions to promote walking within a community was also undertaken in High Point, Seattle (US). This third example is more complex that the other two, as there are multiple interventions associated with the urban regeneration of this location and some of these are discussed under the heading Urban Design below. In terms of encouraging behaviour change to increase walking levels the concept of ‘walking groups’ as an effective social environmental strategy to promote physical activity was utilized. In 2006, the adult community action team identified a 1-mile path around the new central pond as a walking trail. Staff of community-based organizations who were partners were trained as group leaders, including bilingual coordinators with proficiencies in Cambodian and Vietnamese. Five residents also served as walk leaders. Leaders recruited public housing residents (all residents older than 14 years were eligible) through fliers and word of mouth. Leaders made
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Reminder phone calls, checked walkers in, led stretching exercises, and timed the walk. Walkers were encouraged to meet then-current physical activity guidelines (e.g. 30 minutes of moderate to vigorous exercise most days per week) and walking recommendations (10,000 steps per day). The walking groups met 5 times a week during weekday, evening, and weekend sessions. Participants generally walked for 1 hour around the pond although distances varied depending on the capacity of each walker. For example, 1 resident began by walking with an assistive device, later switched to a cane, and, near the end of the intervention, walked on her own. Groups ranged in size from 10 to 30 participants. Walkers received T-shirts, pedometers, and prizes for meeting individual walking goals. Phone call reminders, fliers, and incentives such as raffle tickets helped sustain participation.

The research team used surveys of walking group participants before and after the interventions to evaluate the impact of the improvements to the built and social environments. The evaluation period was March through May 2007. Baseline data were collected prior to implementation of the walking groups, pedestrian advocacy campaign, and informational campaign. Follow up data were collected 3 months after the walking groups and informational campaign, but before all the pedestrian infrastructure improvements were completed. Fifty-eight (97%) of the 60 group participants completed baseline surveys, and 53 (91% follow-up rate) completed exit surveys. Surveys included measures of minutes walked per day, physical activity, general health, and social connectedness. Translators were used where necessary, and participants received an incentive for completing both surveys. The significance of pre–post differences was assessed with the paired t test or the McNemar test via Stata version 10 (Stata Corp, College Station, Texas). The final sample size had a power of 0.8 to detect a difference of 22.6 minutes per day of walking, with a=0.05. The participants increased number of minutes walked per day increased from 64.6 to 108.8, and this was through walking for exercise and errands, but not for walking to work, school, or bus stops. More participants met the recommendation for moderate physical activity after the intervention, and general health improved, with participants reporting fewer days when physical health and mental health were not good. There was an added benefit of increased perception of social connectedness, but the perceptions of environmental factors associated with walking did not change, other than a modest decrease in concern about crime and safety.

A less conclusive study in the US considered the effectiveness of a community based intervention in a rural area, arguing that people in such locations were less likely to have access to everyday pedestrian infrastructures such as pavements (sidewalks) and shopping malls9. Like the studies above, it used targeted material to individual participants as well as card readers to measure the numbers of trips undertaken. Self-reported activity levels increased with the intervention, but the quantitative evaluation indicated there was no statistically significant impact on walking levels.

The evidence of such walking interventions does demonstrate that connecting with the community is important, and therefore the scale may need to be geographically meaningful to gain a sense of local belonging within a community. Targeted materials help direct potential walkers, but there are technological opportunities for walking trips and distances to be measured as indicated by the Beat the Streets initiative. The relationship with the community is important in the next discussion of children walking to school too.

19.3.2 Children Walking to School

The concept of a ‘walking bus’ has been used to encourage more children to walk to school.
Published evidence comes from New Zealand (Christchurch) that examines the Zippy Walking Bus\(^{19}\), but it should be noted the idea is based on a concept developed and used in the UK. The impact of the Zippy Walking bus was evaluated 18 months of start of the intervention. The evidence demonstrated that 19.5 fewer cars came to the school following the setting up of the walking bus, but much of the evidence demonstrates that the community of committed parents and volunteers were critical to the success and continuation of the walking bus. There is an evidence gap around the barriers to using the walking bus by other parents, and what the numbers are as a proportion of the school population. It also notes that this type of project tends to be successful in more middle-class neighbourhoods.

Like the 'Doorstep Walks' and other workplace interventions, 'Travelling Green' is a school based activity that promotes walking by providing printed information\(^{11}\). It was designed to fit into the school curriculum with 'buy in' from the school. The curricular component of the intervention was a curricular resource guide for teachers aimed at 5- to 14-year-olds to support the delivery of school travel projects within the classroom. The Travelling Green pack contained a set of active travel resources designed to be used by children and their families at home to engage them in the project outside the formal curriculum. The evidence is based on 60 participating primary school pupils (aged 9-10 years) from two schools. The research measured how far pupils walked before and after the study, and demonstrated that the mean distance walked increased with the intervention. The researchers claim that the intervention was effective in achieving an increase in the mean distance travelled by active mode and a reduction in the mean distance travelled by inactive mode on school journey.

These examples provide two key approaches to encouraging walking to school. Both require the school to be actively involved, although the organisation of the walking bus can be based within the parent/volunteer community, whereas any links to the school curriculum need close partnership with the school.

### 19.3.3 Urban design

Urban design can engage many different features to promote walking\(^{12}\), and as noted above pedestrianisation etc. are discussed under different measure headings. Urban researchers in Finland argue that reshaping the urban environment around mixed development can have an important impact on the walkability of the city\(^{13}\). The cost benefit analysis of improving pedestrian facilities (installing pavements /sidewalks) has been based on studies in the US, which demonstrate the potential for reductions in car use and air pollution, and other predictions have been made in the UK for wider pavements, greater frequency of pedestrian crossings, dropped kerbs, and seating, arguing a net benefit although the actual evidence is scant\(^{14}\).

The Gold Route in Sheffield (UK) is an example that demonstrates where urban design that has improved the walking environment has generated a positive outcome in terms of increase pedestrian numbers and reduction in vehicles\(^{15}\). Here the local government strongly supported the initiative that redesigned the link between the railway station and the city centre by demolishing a tower block and re-shaping of the station and created new crossing points on the ring road. The new walking route included water features and public art to make is more aesthetically attractive. It also had active support from the local government and other key organisations (e.g. Sheffield Hallam University, heritage charities, etc.) which included financing. Measured outcomes given were more than doubling of pedestrian movements, and a significant reduction in vehicles, although information on how this evidence was generated was not provided.
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The iConnect project examined the impact of new bridges specifically for cyclists and walkers that connected communities, using three locations in the UK\textsuperscript{16}. In April 2010, survey packs were mailed to 22,500 adults randomly selected using the edited electoral register (which covers around 60\% of adults aged 18 years and older) and living within 5 kilometres by road of the core Connect2 projects. The 3,516 individuals returning the pack (16\% response rate) were mailed follow-up surveys in April 2011 and April 2012. After excluding a small number of individuals who had moved or had unreliable physical activity data (change of > 900 minutes/week), the 1-year follow-up study population consisted of 1,796 participants (51\% retention, 8\% of the population originally approached) and the 2-year study population consisted of 1,465 participants (42\% retention, 7\% of the population approached). After 2 years more people living within 1 Km used the facility than after 1 year, with combined walking and cycling increases. The evidence does not pull out the impact solely on walking.

There are many ways in which the urban infrastructure for walking can be improved. These two examples demonstrate the importance of place-based connections (e.g. two communities, transport infrastructure and place of work/retail).

19.3.4 Conclusions drawn from the evidence

Increasing levels of walking is often considered at a community or small scale geographic level. The assumption is that walking journeys usually are shorter distances than by other modes. Communities are engaged as a way of supporting a collective change, and a method of connecting with individuals who can then be targeted with more bespoke information.

There is some evidence that changes can be made to levels of walking either by improving the walking environment and/or targeting information at individuals. However, the evidence is limited in terms of duration beyond short scale interventions, or the infrastructure being in place long enough to measure substantial change. Community based interventions like the walking school bus demonstrate that the community needs to maintain commitment over time for ongoing success.

19.4 Lessons for Successful Deployment of this measure

None of the examples above overtly consider the transferability of the intervention or the upscaling within their intervention. However, the organisation developing the 'Beat the Street' concept has developed it for a number of other case locations which are ongoing, and evidence of the success of these developments has yet to be produced. The High Point example demonstrates how projects aimed at increasing walking levels within particular communities can evolve alongside other regeneration activities, and as such this type of community based activity has the potential to be transferred to other locations. The community nature of this project, and also that of walking buses (to schools), require buy in from community partners who are able to actively participate and drive the initiative within the community. To this end, it requires time and effort to galvanise and motivate people, as well as sustain the activity over time especially where volunteers are involved. The High Point example demonstrates the need to be sensitive to the needs of diverse communities (e.g. ethnically diverse), and tailored facilitation is needed for each community setting. The concept of the walking bus has transferred to other locations (e.g. to New Zealand), but it is not ubiquitous across all communities, and may be affected by social class.

Urban design and infrastructure improvements, such as installing a new bridge, are context dependent in terms generating pedestrian journeys. Conceptually the idea of connecting
communities should be transferrable to other locations, but the design element would need to be sensitive to the local setting. Infrastructure is a durable physical asset, and not reliant on community support as in the other examples, but it is reliant on maintenance to ensure usability over time.

19.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- **Health Benefits**: The main benefits of walking are often seen in terms of improvements in health and fitness. Health benefits might be both physical and mental.
- **Community benefits**: Participation in community-based walking programmes can bring the added benefit of increasing participants' perceptions of social connectedness, and of being part of their community.

19.6 Summary

Many of the examples around encouraging more walking are small scale and the impact measured is often over a short period of time and does not follow up over a longer period. Community based activities that are run for longer periods of time, compared to shorter term trials, need energy from volunteers to maintain the momentum of the activity. Without these key players, the community walking activity could come to an end (e.g. walking buses to school).

Urban design features and infrastructures, therefore, are more durable once they are in place acting as a constant enabler to walking. However, these may benefit the already active, rather than creating active travel as with those interventions focused on encouraging walking amongst individuals and community groups.

19.7 References for this Review

4. Tolley R., (2011) Good for Busine$$$. The benefits of making streets more walking and cycling friendly. Heart Foundation South Australia;


Measure No.20: Cycling

Provision of on-road and off-road infrastructure to facilitate cycle use

Cycling infrastructure interventions aimed at promoting cycling in a city can be developed at all scales, from alteration of a single junction, to entire networks of routes. They may also focus on the necessary infrastructure needed to facilitate more effective routes (such as a new bridge).

Key messages:

- Positive benefit-cost ratios (BCRs) are seen for networks of cycle paths, based on journey time savings and lower health and fuel costs.
- Positive BCRs at the lower end of the scale derive benefits mainly from the value of time; health benefits contribute the additional value at the top of the BCR range.
- Leisure-based networks can also bring benefits in respect of new job creation and additional economic activity.
- Appropriate infrastructure provision for cycle traffic, forming comprehensive networks of routes, is essential to encourage cycling.
- These networks need to be built up from components such as safe junctions and bridges which create suitably direct routes for cycle traffic. There is some lack of clarity, however, as to what specific links, or provision at junctions, would be deemed most suitable by users and potential users.
- There is a perception that it is safer to separate cycle traffic from motor traffic, and that off-road paths are therefore required.

20.1 Context and background

This review is a review of cycling infrastructure and its role in sustainable urban transport. This includes provision along existing road links, and at road junctions. It also includes routes away from motor traffic and specific infrastructure, such as bridges.

Potential interventions

- Integrated networks of bikeways with intersections that facilitate cycling;
- Individual engineering improvements, and
- Good quality bike parking at key destinations and public transport stations.

The scope does not include wider issues about the general layout of general infrastructure within an area, for example relating to land use density and the relative location of land uses. It also does not relate to wider programmes to promote cycling. These matters are dealt with in the following reviews: No.4 access restrictions; No.5 roadspace re-allocation; No.6...
Cycling infrastructure is designed to make cycling for a specific journey quicker, safer, more comfortable and more attractive. It is a necessary but insufficient condition that appropriate infrastructure is provided for cycle traffic. Multiple, reinforcing interventions covering a wide range of activity is required. Pucher and Buehler (2012), in a book which summarises some of the literature we present here, list ten areas of such activity. These activities are listed below in Box 1.

**Box 1: Activities to promote cycling as a mode choice**

- provide a comprehensive package of integrated measures;
- build a network of integrated bikeways with intersections that facilitate cycling;
- provide good bike parking at key destinations and public transportation stations;
- implement bike sharing programmes;
- provide convenient information and promotional events;
- introduce individualized marketing to target specific groups;
- improve cyclist education and expand bike-to-school programmes;
- improve motorist training, licensing and traffic enforcement;
- restrict car use through traffic calming, car free zones and less parking;
- design communities to be compact, mixed use and bikeable.

This review specifically considers issues in connection with points 1, 2 and 3 above. Aspects of the other seven activities can be found across the range of other Measures reviewed for EVIDENCE.

### 20.2 Extent and Sources of Evidence

There has been a much published work in relation to cycling in recent years, with almost one hundred documents selected for initial review here. The characteristics of this source material are summarised below in Box 2.

**Box 2: characteristics of source material for this review**

- This review has drawn on 20 source documents, and has also referenced Handy et al. (2014) in relation to gaps in the knowledge.
- Two of the references are in the nature of reviews of evidence (Pucher et al., 2010 and Yang et al., 2010)
- Implementation of cycling infrastructure is receiving ongoing scrutiny and research
- Evidence is drawn from Australia, Denmark, Germany, The Netherlands, Sweden, UK and USA
- All bar two of the sources are academic, the other two are written by consultants
- The evidence is found in the academic papers, and in one consultant’s report
- Three studies are at the level of the country, six are at the level of an area (for example, town or city level), four are at the level of a route or network of routes, one is concerned with a bridge and another concerned with a bicycle hub.
The evidence ranges in date from 1997 to 2013. The majority of evidence (eleven sources) have been published in 2008 or subsequently.

All of the interventions discussed are currently still implemented.

20.3 What the Evidence Claims

20.3.1 Overview of what the evidence shows

The nature of much of the evidence is at aggregate level. It is concerned with area or city wide effects and hence is related to comprehensive treatments for cycle traffic based on networks for cycle traffic. We discuss first aggregate data analysis and models constructed at the aggregate level which have explanatory variables for infrastructure. We then turn our attention to components of infrastructure. We then consider cost benefit evidence before finally considering wider issues in relation to infrastructure. However, as a pre-amble, we discuss the issue of cycling and safety because the perception of risk is often reported as a reason why people may not cycle.

20.3.2 Cycling and risk

In a disaggregate study and an aggregate study respectively, Ekman (1996) and Jacobsen (2003) show that risk of collisions and injuries with other motor vehicles is reduced where there are greater numbers cycling. Bhatia and Wier (2011) note, however, that accident studies consistently suggest non-linear relationships between volumes of use and collision and injury frequency. The consequence is that great care is needed in when discussing policies in relation to cycling and safety. Promotion of a more benign mode such as cycling, which suffers more at the hands of other traffic, will still result in more collisions and injuries overall, all other things being equal, despite reductions in the rate of collisions relative to measures of use. Bhatia and Wier note that confounding in the evidence base may exist, with safer environments increasing both numbers cycling and safety. In order to understand a little more clearly the direction of causality, Luukkonen and Vaismaa (2015, forthcoming) systematically review evidence which considers cycling levels of use and cycling safety. They find that land use planning, traffic network planning and quality of the bicycle infrastructure are all highly significant positive influence in relation to both safety and level of use. Aldred and Croswell (2015) confirm in a recent study much previous work which shows that fear of injury is a barrier to cycling, and experiencing non-injury incidents (near misses) may contribute to this fear. They note that UK cyclists experience very high rates of non-injury incidents, by comparison with any reported injury rates.

20.3.3 Aggregate data analysis and modelling

Yang et al. (2010) summarise the outcome from a controlled repeat cross-sectional study which examined the effect of improved network connectivity in an area of Delft, The Netherlands. In the control area the proportion of household trips made by bicycle rose from 38% to 39% over a three year period, however, in the intervention area the proportion rose from 40% to 43%.

Nelson and Allen (1997) investigated the relationship between bicycle use and available miles of bicycle pathway per 100,000 population in cities in the USA. They found positive correlation between commuting and the length of bicycle pathway. Other variables they included were as follows: weather, terrain and number of college students.

Dill and Carr (2003) investigated presence of facilities in relation to use of the bicycle in cities
in the USA. They investigated commute cycling in relation to the presence of bike paths or shared use paths (so-called class I facilities) and on-carriageway bicycle lanes (class II facilities) compared with bicycle commuting rates. The extent of cycle lanes was the most significant variable in the model, showing positive correlation with commute cycling. Other variables included were as follows: state spending per capita on cycling and walking, vehicles per household, days of rain, percentage of workers in forestry and farming. They introduced a dichotomous variable to account for New York.

Merom et al. (2003) evaluated a promotional campaign based around a newly constructed Rail Trail in western Sydney, Australia. 450 adult randomly selected respondents completed a pre- and post-intervention telephone survey and were either within 1.5 km of the Trail or bike-owners only 1.5-5 km from the Trail. There was a significant increase in unprompted trail awareness in the after cohort (2.9%, McNemar P <0.05) but post-campaign awareness remained low (34%). Trail usage was higher among bike-owners than pedestrians (8.9% vs 3.3%, P =0.014) and was moderated by proximity to the Trail. Inner cyclists increased mean cycling time by 0.19 hours (SD =1.5) while outer cyclists decreased cycling time (0.24 hours, SD =1.6). Mean daily bike counts in the monitored areas increased significantly after the Trail launch (OR =1.35, P =0.0001, and OR =1.23, P =0.0004). Overall, the researchers considered that the campaign reached and influenced cyclists in the inner area.

Rietveld and Daniel (2004) modelled cycling levels between municipalities in The Netherlands. Factors included in the model were as follows: population, number of addresses per square kilometre, proportion of 15-19 year olds, presence of one or more schools for higher vocational education, share of non-native residents, share of liberal party voters, number of cars per capita, hilliness of the area. Factors specifically relating to policy that they found to be significant included the following: number of times per km a cyclist has to stop, car parking cost in eurocents per hour, number of hindrances (obstructions and narrowings) per kilometre, speed relative to the car. Policy factors not found to be significant were municipal budgets, the number of plans (e.g. policies and strategies) made in relation to cycling, measures for the bicycle network and bicycle parking, incentives given to municipal employees, measure for directness of trip, delay during the trip, average speed, and number of times that the cyclists need to slow down.

Parkin et al. (2008) investigated variability of cycle commuting in English and Welsh wards and found that the proportion of off-road route was relevant and has an elasticity of +0.049 (proportion cycle commuting relative to proportion of route that is off-road). A range of socio-economic and physical factors were also modelled. Hilliness is the most significant variable, with rainfall and temperature also playing a part. The state of repair of the road was also found to be significant.

Goodman et al. (2014) evaluated the effects of providing new high-quality, traffic-free routes for walking and cycling on overall levels of walking, cycling, and physical activity. Interventions were designed to complete missing links in networks and exposure was measured by distance from home to the infrastructure. A cohort of adult residents in three UK municipalities was followed from baseline in 2010 to 2011 (1796 respondents), and after two years (2012, 1465 respondents). After two years it was found that those living nearer the intervention walked or cycled 15.3 additional minutes per week walking and undertook 12.5 additional minutes per week of total physical activity. The researcher found the effects were larger among participants with no car, and conclude that the findings support the potential for walking and cycling infrastructure to promote physical activity.

Panter et al. (2016) studied a cohort of 469 adult commuters as part of a quasi-experimental...
Measure No.20: Cycling

The economic benefits of sustainable urban mobility measures: independent review of evidence

Analysis of the Cambridge busway, which includes parallel cycling and walking routes. The analysis used an exposure measure based on the shortest distance from each participant’s home to the busway. The measure of changed behaviour was the change in weekly time spent in active commuting between 2009 and 2012, measured by validated 7-day recall instrument. In addition, secondary outcomes measured were changes in total weekly time spent walking and cycling and in recreational and overall physical activity. The analysis adjusted for sociodemographic, geographic, health, and workplace confounders and also baseline active commuting; and home or work relocation within a multinomial regression model. It was found that exposure to the busway (and cycle and walking routes) were associated with a significantly greater likelihood of an increase in weekly cycle commuting time (relative ratio of 1.34, with a 95% confidence interval of 1.03 to 1.76) and also with an increase in overall time spent in active commuting among the least active commuters at baseline (relative ratio of 1.76, with a 95% confidence interval of 1.16 to 2.67). The research found no evidence of changes in recreational or overall physical activity.

20.3.4 Analysis of components of networks

The construction of Bryggebroen pedestrian and cycle bridge across the harbour in Copenhagen reduced journey times because adjacent bridges are at a distance of 1km and 3 km respectively COWI (2008). The bridge cost DKK 77 Million and the net present value (NPV) and the internal rate of return (IRR) were DKK 36 million (2008 costs and prices) and IRR 7.7% respectively. Note that the network effects analysis was based on conjecture, not evidence.

The re-construction of the Gyldenløvsgade-Nørre Søgade-Vester Søgade intersection to solve a conflict between right turning cars and cycles reduced injuries by three per year COWI (2008). The cost was DKK9 million, the NPV was DKK 59 million and the IRR was 33%.

The table below draws on a ‘component based’ review by Pucher et al. [2010] of the effect of different types of infrastructure for cycling.

Table 1: Effect of various infrastructure changes on cycling

<table>
<thead>
<tr>
<th>Infrastructure measure</th>
<th>Effect on use</th>
<th>Effect on safety</th>
<th>Effect on perceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle lane on the carriageway</td>
<td>Mixed</td>
<td>No evidence</td>
<td>Little effect</td>
</tr>
<tr>
<td>Cycle tracks adjacent to the carriageway</td>
<td>Positive</td>
<td>Mixed</td>
<td>Rated better than lanes</td>
</tr>
<tr>
<td>Cycle tracks away from the carriageway</td>
<td>Positive</td>
<td>No evidence</td>
<td>Positive</td>
</tr>
<tr>
<td>Coloured cycle lanes</td>
<td>Mixed</td>
<td>Positive</td>
<td>No evidence</td>
</tr>
<tr>
<td>Markings to indicate a lane is shared by cycle traffic and motor traffic</td>
<td>No evidence</td>
<td>No evidence</td>
<td>No evidence</td>
</tr>
<tr>
<td>Two-way cycling on streets that are one way for motor traffic</td>
<td>No evidence</td>
<td>Positive</td>
<td>No evidence</td>
</tr>
</tbody>
</table>
### Measure No.20: Cycling

<table>
<thead>
<tr>
<th>Measure</th>
<th>Evidence</th>
<th>Evidence</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shared bus and bicycle lanes</td>
<td>No evidence</td>
<td>No evidence</td>
<td>No evidence</td>
</tr>
<tr>
<td>Signed bicycle routes</td>
<td>No evidence</td>
<td>No evidence</td>
<td>Positive</td>
</tr>
<tr>
<td>Streets primarily for bicycle traffic</td>
<td>No evidence</td>
<td>No evidence</td>
<td>Positive</td>
</tr>
<tr>
<td>Advanced stop lines at signal controlled junctions (creating a box for cycle traffic to wait in)</td>
<td>No evidence</td>
<td>Little effect</td>
<td>Positive</td>
</tr>
<tr>
<td>Separate stages for cycle traffic at signal controlled junctions</td>
<td>No evidence</td>
<td>Positive</td>
<td>No evidence</td>
</tr>
<tr>
<td>Parking</td>
<td>Positive</td>
<td>N/A</td>
<td>Positive</td>
</tr>
</tbody>
</table>

This rather barren set of evidence at the component level is in contrast to the analysis by Pucher and Buehler (2008) of The Netherlands, Denmark and Germany in which they note that the following all ‘appear’ [their word] to create higher aggregate levels of cycling: separate cycling facilities; extensive cycling rights of way; ample bicycle parking. These are explored in more detail in Box 3 below.

**Box 3. Infrastructure measures relevant to high levels of cycling**

**Extensive systems of separate cycling facilities**
- Well-maintained, fully integrated cycle tracks, cycle lanes and streets primarily for cycle traffic in cities and surrounding regions
- Fully coordinated system of colour-coded directional signs for bicyclists
- Connections creating short-cuts for cycle traffic across what otherwise are dead-ends for motor traffic

**Intersection modifications and priority for cycle traffic at traffic signals**
- Changes to phasing and staging, separate green phases for cycle traffic and layout changes to allow cycle traffic to wait ahead of motor traffic, and which are fed by cycle lanes
- Cyclist short-cuts to make right-hand turns (for right hand rule of the road) before intersections and exemption from red traffic signals at T-intersections, thus increasing cyclist speed and safety
- Coloured surfacing across intersections
- Offset timings between sets of traffic signals set in such a way as to ensure a green wave for cycle traffic
- Flashing lights along routes to signal to cyclists the appropriate speed to cycle at to reach the next intersection at a green light

**Bike parking**
- Large supply of good bicycle parking throughout the city
- Improved lighting and security of bike parking facilities often featuring guards, video-surveillance and priority parking for women
In addition (and considered in other evidence) they note the importance of traffic calming of most residential neighbourhoods and full integration with public transport. There is an almost equally long list of measures that are not related to provision of infrastructure which are also relevant, however, as follows: education and training; promotional events; making driving expensive and inconvenient; restricting car ownership; land-use policies.

### 20.3.5 Cost benefit appraisal of networks

Meletiou et al. (2005) investigated the return on investment of network wide measures in North Carolina (USA). In 10 years since 1993, $6.7 million was invested in 36.5 miles (58.74 km) of on-road facilities such as wide paved shoulders, wide curb lanes, marked bike lanes, and bridge improvements, 18.15 miles (29.21 km) of off-road facilities, such as greenway trails, side paths, and other shared-use paths, to form an extensive bicycle transportation system linking towns and villages in the northern Outer Banks from Corolla south to Nags Head and west to Manteo. $60 million brought to the economy and 1407 jobs supported because of cycling. Return on investment about 9:1.

Wang et al. (2005) investigated the construction of five bike/pedestrian trails for leisure use in Lincoln Nebraska and their continued maintenance. The total cost of construction and maintenance for all five trails per annum (construction costs ammortised over 30 years) is $527,215 (1998 costs and prices). The benefit to cost ratio was found to be 2.94.

Börjesson and Eliasson (2012) considered facilities in Stockholm for cycling, and estimated values of time of cycle users. Bicycle paths are socially profitable at yearly average cycling volumes of a little less than 300 cyclists per day, which in urban contexts is very low.

Gotschi (2011) modelled the benefits of the long term investment in cycling infrastructure by the City of Portland. Benefit-cost ratios based on health care and fuel savings are 3.8, 2.3, and 1.3 for the following scenarios: $100 million renewal (‘basic’), $329 million to put 80% of population within quarter of a mile of a bikeway, and ‘world class’ plan of $773 million. Using a value of statistical lives saved, the benefit-cost ratios are 53, 33, and 20, respectively.

### 20.3.6 Wider measures in relation to cycling

Jones (2012) investigated the construction of an urban traffic-free cycle route. He found that the provision of a traffic free route is insufficient in encouraging a shift from car travel to cycling for everyday practical journeys. The odds of a respondent making a practical journey by bicycle increases if other family members cycle, and if there would be a feeling of regret if the journey was not made by cycle; and when, on balance, there is a belief in personal ability to make a practical journey by cycle (self-efficacy) and/or a perception that this journey is both possible and easy (controllability).

Yang et al. (2010) included in their review a study of the three year Danish National Cycle City project, which aimed to increase cycling in Odense and included promotional campaigns and infrastructural measures. After adjustment for trends in the region, a 3.4 percentage point increase in cycling was observed between 1996-7 and 2002 (increase in proportion of all trips from 22.5% to 24.6%).

Goodman et al. (2013) investigated the construction of a variety of cycling infrastructure and a variety of programmes to promote cycling in eighteen towns and cities in the UK. Investment of £14 to £17 per head of population per annum resulted in increases in the proportion that cycled to work from 5.8% to 6.8%. This represented a significant increase relative to three comparison groups with a percentage point increase for the intervention towns relative to the
matched towns of +0.69% (95% CI 0.60% points, 0.77% points). Other data from a subset of six of
the towns (reviewed by Yang et al., 2010) shows increased were found in the proportions of
residents who reported cycling for at least 30 minutes once per month (+2.78% or +1.89%,
depending on the choice of control areas) or 12 or more times per month (+0.97% or +1.65%).

Rodrigues and Joo (2004) found that the presence of walking and cycling paths and the
population density measured at respondent’s home location were not consistently related to
mode choice. They conclude, however, that natural and built environments in mode choice
studies for urban settings is relevant.

Carse et al. (2013) investigated the factors influencing the use of the bicycle in the bicycle-
friendly city of Cambridge. They developed a multivariate logistic regression model to
examine the socio-demographic, transport and health-related correlates of mode choice for
work, shopping and leisure trips. Commuting distance and free workplace parking were
strongly associated with use of the car for work trips, and car availability and lower levels of
education were associated with car use for leisure, shopping and short-distance commuting
trips. The case of Cambridge shows that more policies could be adopted, particularly a
reduction in free car parking, to increase cycling and reduce the use of the car, especially
over short distances.

Burke (2011) investigated a specific sort of infrastructure investment, a cycle centre. A cycle
centre was constructed in Brisbane with a capacity for 420 members to park, shower and
change and bicycle maintenance facilities are also offered. At this size, the hub is not viable,
but would remove 120,000 motor vehicle kilometres per annum.

20.3.7 Nature of methods employed

The methods employed to analyse infrastructure typically comprise of aggregate multi-
variable regression modelling, typically using a logistic regression model, and also cost
benefit analysis.

The strength of regression modelling is the ability to understand the nature of the impact of
one variable relative to other variables. It can be challenging, however, to collect in an
appropriate and comprehensive format all of the data necessary to undertake such analysis.
Another difficulty which can be revealed in the modelling is related to the fact that many
variables are effectively averaged, because the modelling is using aggregate variables. This
can mask relationships which exist at the level of the individual.

Cost benefit analysis is an established method for estimating the social benefits of public
investment. There are deficiencies in this approach, however, linked with the difficulty of
estimating appropriate values of variables such as time and a ‘life saved’.

The studies presented here have been undertaken with high quality methodologies.

20.3.8 Validity, reliability and significance

The studies presented here are valid and reliable. Some of the studies have resulted in
outcomes which demonstrate findings which are significant, as noted above.

20.3.9 Remaining evidence gaps

Handy et al. (2014) provides a useful summary of a current research needs and challenges in
relation to cycling promotion. Inter alia, they note the lack of knowledge about the relative
importance of such support structures as shops and repair facilities. They point out that,
despite a significant increase in cycle related research, we still know little about individual
factors such as attitudes and preferences in relation to cycling, or factors relating to the
households or larger aggregations such as community or city. The most significant point made is that there remains a dearth of studies directly evaluating the effectiveness of strategies to change travel behaviour.

20.4 Lessons for Successful Deployment of this measure

20.4.1 Transferability
Clearly, every geographical location has unique characteristics, as does the population which lives there. However, the studies included in this review are drawn from a range of countries and localities which allows for a higher level of confidence that the findings are transferable.

20.4.2 Drivers and barriers from a PESTLE analysis
Very few of the studies reference political, economic, social, technological, legal or environmental factors which could create barriers to, or be facilitators of, a wider deployment of suitable infrastructure for cycling. Five of the studies have considered the economic benefits relative to the costs of infrastructure investment, and these all find that the investment is very beneficial. There are likely to be political and social barriers which prevent wider construction of infrastructure for cycle traffic, but these have not been revealed in this review process.

20.4.3 Complementarity
Some of the evidence (for example Nelson and Allen, 1997) appears to suggest that a network of infrastructure for cycle traffic is sufficient. Jones (2012), however, points towards a much wider range of relevant social factors. Pucher and Buehler (2008), while not having specifically modelled the relationship between cycling and specific infrastructure provision, clearly suggest that there is likely to be a range of intervention, including infrastructure, needed to support greater volumes of people cycling. The aggregate models reported here identify the relevance of different specific infrastructure and other interventions. The models are not, however, constructed in such a way as to elicit understanding about what variables are required at certain levels as being necessary but insufficient conditions in relation to other factors.

It is logical that there has to be a sufficient basis in physical reality to allow for the growth in cycling. On this basis, it is clear that infrastructure for cycling in a key component for a successful SUMP.

20.4.4 Resilience and durability
There is no evidence concerning the conditions necessary for on-going success.

20.5 Additional benefits
As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- **Health Benefits**: Evidence of the health benefits of cycling is well documented, through both improved fitness of those who cycle, and reduction in atmospheric pollutants which affect the health of wider population (when cycle journeys substitute for journeys made by motorised transport).
- **Pedestrian environments [ & Walking]**: Cycling infrastructure can also improve the
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environment for pedestrians, thus encouraging walking as a transport mode.

- **Community benefits:** In turn, more cycling and walking as an alternative to car-use offers wider community benefit, improving the 'liveability' of streets and communities, and potentially facilitating greater community cohesion through increased levels of contact between people living there.

### 20.6 Summary

We can be very confident that appropriate infrastructure provision for cycle traffic is a necessary condition to help promote more cycling. The evidence suggests that comprehensive networks of routes for cycle traffic are required. These need to be built up from components such as safe junctions and bridges which create suitably direct routes for cycle traffic. What is less clear is the precise nature of the links in a network, or the types of provision at junctions, that might be deemed suitable by users and potential users. It is clear also, however, that there is a preference in terms of perception that cycle traffic is separated from motor traffic, i.e. separated routes are required.

It would be helpful if future research began to understand in a more detailed way a more precise description of a necessary condition in terms of infrastructure provision. Drawing on Handy et al. (2014) they make the point that we need to know more about attitudes and preferences in relation to cycling.

Success may be defined in terms of the overall proportion of journeys in an area that are undertaken by bicycle. Secondary to that might be the proportion of journeys made for a specific purpose such as commuting. It would be significant for an area to shift cycle use by as much as 10 percentage points in mode share, and this could be achievable over the medium to long term.

### 20.7 References for this Review

Measure No.20: Cycling

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promote cycling: systematic review. BMJ: British Medical Journal. 341 (c5293)
Measure No.21: Bike sharing

Schemes that provide access to cycles in and across a city for short hire periods.

Cities can encourage greater use of cycling to facilitate short journeys by making numbers of cycles readily available on their streets. Schemes may vary in size, and in area covered, and may also extend to electric as well as pedal powered bikes to promote use to non-cyclists.

Key messages:
- The limited evidence available suggests that bike sharing can increase cycling levels when combined with appropriate supporting measures.
- While predominantly enabling a commuting function, bike sharing also allows users to undertake key economic, social and leisure activities.
- Bike sharing can enhance local economies, by connecting people to employment, retail and other places where economic activity takes place. US evidence also suggests additional retail activity near cycle docking stations.
- Bike share users benefit from reduced, and more reliable journey times.
- Bike sharing can connect to, and substitute for public transport for some types of trips and some users, helping to manage public transport demand (benefiting users and transport operators).
- Most schemes are highly dependent on subsidy to operate
- Successful schemes generate revenue that can reduce public funding and subsidy. However the readily available evidence on the financial viability of existing bike sharing systems is limited and predominantly qualitative in nature, partly due perhaps to commercial sensitivities.

21.1 Context and background

Bike sharing schemes (BSSs) have existed for almost 50 years but only in the last decade have they significantly grown in prevalence and popularity to include over 800 cities across the world and a global fleet exceeding 900,000 bicycles.

Potential interventions
- Provision of a pool of bicycles at strategically positioned and fully automated ‘bike sharing stations’, typically distributed in a dense network across an urban area,
- These to be accessible by different types of users (e.g. registered members or occasional/casual users) for short-term rentals allowing point-to-point journeys.

Bike sharing is often named in different ways according to the geographical area of
application, e.g. ‘cycle hire’ in the UK, ‘public bicycle’ in China and ‘bicycle sharing’ in North America. In some instances they are known locally by the name of a scheme commercial sponsor (i.e. ‘Barclays Cycle Hire’ for the original deployment in London) or even political proponent of the scheme (forsaking the sponsor in London, and renaming them as ‘Boris bikes’ after the then incumbent Mayor).

BSSs share a few key features\(^2\text{-}^5\), which are listed in Box 1 below.

**Box 1: Key features of bike share schemes**

a. The bicycles can be checked-in and out through the use of a personal ‘smart card’ using radio-frequency identification (RFID) technology, or a ‘key’;

b. Each bike sharing station, i.e. the station where bikes can be checked in and out of their docking points, can be equipped with terminals, also termed ‘kiosks’, where users can get information on the scheme, view the local and overall station network map, communicate with customer service, and in some cases make the payment for use;

c. Wireless communication technology, e.g. general packet radio service (GPRS), allows real-time monitoring of occupancy rates at each station. If the bicycles are equipped with global positioning system (GPS), their movement through the network can be monitored.

d. BSSs incentivise short-term rental, hence maximise the number of times each bicycle is used, by allowing users to have the first 30 minutes free of charge (within their specific subscription for which they are charged upfront) and then increasing the charges rather substantially after that period. In this sense bike sharing is very different from a bike rental service: the former is about using the shared bikes to make short-term point-to-point journeys, the latter involves the renting, and private use, of a bicycle for a given amount of time. Users are generally required to provide credit card details, which serve both as a deposit, as well as payment for registration and usage fees.

According to the evidence presented in this review but also to the wider body of knowledge about this measure, BSSs are typically introduced as part of sustainable mobility agendas and sometimes within more formalised SUMPs. As such, they are expected to contribute to a number of different objectives, for example\(^2\text{-}^5\):

**Box 2: Wider objectives for BSS**

- To reduce single occupancy car journeys and ease traffic congestion;
- To reduce CO\(_2\) emissions and to improve air quality by reducing other pollutant emissions from motorized traffic;
- To improve public health and increase levels of physical activity;
- To increase cycling levels, and help promote and normalise cycling;
- To improve accessibility and support flexible mobility and inter-modality by acting as a ‘first’ or ‘last mile’ solution, in particular in connection with public transport;
- To improve road safety, in particular for cyclists;
- To enhance the image and liveability of cities and to support local economies and tourism.

**21.2 Extent and Sources of Evidence**

Reflecting the rapid growth of BS in the past 10 years, a number of very different sources of information about bike sharing, across different media, have recently been made available.
These include:

a. **Guidelines and manuals for bike sharing operation**, such as the handbook developed by the EU-funded Obis project; the overview of Spanish BSSs (in Spanish but with a short summary of recommendations in English); and two planning guides to bike share implementation, the first focused on the U.S. experience and context, published by the Federal Highway Administration, U.S. Department of Transportation; the second drawing on the global experience to date, published in 2013 by the Institute for Transportation & Development Policy.

b. **Websites**, comprising both those offering general information on bike sharing and those set up by BSS operators and/or projects, which sometimes include information on this measure as well as scheme-specific data on operational/financial performance and customers’ profile and satisfaction. A well-known example among the former category is The Bike-sharing Blog, which keeps track of all the BSSs across the globe and acts as a point of contact and reference for stakeholders involved in BSSs and, more broadly, anyone interested in this measure. Among the BSS operators that make performance data and/or reports available are: Capital Bikeshare, Washington DC; Nice Ride Minnesota; Barclays Cycle Hire, London.

c. **Reports and academic papers**, including peer-reviewed, exploring one or more aspects and effects of bike sharing and focusing on one specific scheme or a range of schemes where usage data are available. Most of these reports and papers have appeared in the past 5 years, suggesting that this is still an emerging but potentially prolific area of research. It is among this category of resources that the present review of evidence has been conducted, as the most high-quality studies on the impacts of bike sharing have been published as outputs of academic research investigations.

This review focuses in particular on ten high quality studies selected from over fifty items of evidence considered for this task. Several considerations can be made in relation to the availability, scope, significance and quality of the range of existing evidence on this measure.

First, it must be noted that although bike sharing has recently started to attract attention from commentators around the globe, including academic researchers, independent and peer-reviewed in-depth evaluations of existing schemes are not readily available. No single BSS (of a sufficient scale) appears to have been fully and independently evaluated along an extensive range of impact and process dimensions. More frequently, the existing studies look at one particular aspect or a set of characteristics of one or more schemes, with different methodological approaches. As a result, the available evidence is somehow patchy and does not easily lend itself to comparative analysis.

Secondly, the evidence available on bike sharing does not generally offer a clear understanding of the specific objectives that a particular scheme had sought to achieve. This makes it difficult to assess whether, and to what extent, a scheme has been ‘successful.’ This is particularly relevant when interpreting the results of academic studies of specific BSSs, which often reflect the authors’ own research objectives and line of academic inquiry, rather than provide an evaluation of the scheme’s success against its original objectives.

The available evidence is relatively recent and generally refers to established schemes that have been operational for a while. A handful of major schemes in North America (US and

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*The author contributed to an in-depth impact and process evaluation of a small-scale bike sharing pilot scheme in Bath, U.K., co-funded by the CIVITAS Plus Renaissance project, 2009-2012. The evaluation report is to be published by the European Commission.*
Canada) and Europe (UK, Ireland, Spain and France) appear to have attracted the most interest and scrutiny, followed by schemes in China (currently the largest in the world) and Australia.

### 21.3 What the Evidence Claims

#### 21.3.1 Introduction

The selected ten high quality studies include a variety of methodological approaches and objectives. Two are recent reviews of the available evidence to date\(^{10, 11}\). Most involve the collection and analysis of operator data on users and usage characteristics; or the generation of quantitative and qualitative data, through surveys conducted with users, non-users and businesses, via on-street, online or telephone questionnaires. Two are before-after studies\(^{12, 13}\). Models have been used in two studies to determine demand for BSS use\(^{14}\) and health impacts\(^{15}\).

The evidence presented in these studies concerns three main aspects of BSSs. These are described in more detail in Box 3 below.

#### Box 3: Aspects of BSS presented in source material

<p>| | |</p>
<table>
<thead>
<tr>
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<th></th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>The first aspect is reviewing by whom, why and how BSSs are used, as this provides an understanding of how successful the schemes are in attracting customers, and thus generating cycling journeys and revenue. This is also connected to issues around equity of access.</td>
</tr>
<tr>
<td>2.</td>
<td>The second broad aspect is about the direct and indirect impacts associated with BSS implementation and use. These include change in travel attitudes and behaviours, impacts on inter-modality, and environmental, health and economic impacts. The evidence on the first two aspects of BSSs is thematically examined in the following sub-sections.</td>
</tr>
<tr>
<td>3.</td>
<td>Finally, the third aspect concerns issues around implementation and operation of BSSs, which however have attracted academic research scrutiny to a relatively lesser degree. This is discussed in the next section.</td>
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</table>

#### 21.3.2 Users’ socio-economic profile

In terms of users’ socio-economic and demographic characteristics, there is now an established and broadly consistent body of evidence. Overall BSSs seem to attract a particular profile of user: male, white, employed and, compared to the average population in which BSSs are implemented, younger, more affluent, more educated and more likely to be already engaged in cycling independently of bike sharing\(^{11, 15-18}\).

#### 21.3.3 Equity of access

Only two of the available studies specifically focus on equity of access, in particular using Barclays Cycle Hire (BCH) in London, U.K., as a case study. Overall, this evidence\(^{18, 19}\) indicates that residents in less affluent areas can and do use bike sharing systems if these are made available in their local areas, but price increases may have contributed to reducing casual use in poorer areas. Trip rates among registered users were higher among residents in poorer areas after adjusting for the fact that these poorer areas were less likely to be near a BCH docking station\(^{19}\).
Lack of a debit/credit card has been highlighted as a barrier to a more equitable use of BSSs\textsuperscript{18, 20}.

### 21.3.4 Determinants of and barriers to bike sharing use

Evidence on the barriers and determinants of bike sharing use appears to be growing but there are limitations in the range of case studies examined and methodologies used.

According to user surveys conducted in different cities and countries, bike sharing can improve the experience, accessibility and affordability of personal travel, through greater transport choice, reduced journey times and reduced mobility costs. In short, the evidence suggests that “convenience” in its broadest meaning consistently emerges as the key motivating factor for bike sharing use. This has been found by a number of studies looking at BSSs in Europe\textsuperscript{13, 21}, North America\textsuperscript{11, 22}, China\textsuperscript{10} and Australia\textsuperscript{10}.

Barriers to joining and using bike sharing systems have been explored to a lesser extent and predominantly in an Australian context\textsuperscript{10}. These are: mandatory helmet legislation, overnight closure, barriers to instant access, lack of cycle infrastructure and road safety concerns, which are also a major barrier to cycling in general.

In terms of factors that increase the likelihood of bike sharing use, proximity of residence to docking stations appears to be strongly correlated with use, as well as certain socio-economic characteristics and active travel behaviours\textsuperscript{12, 13}.

### 21.3.5 Usage characteristics

In terms of usage rates, reported usage rates vary from 3-8 trips per day per bike, and these have been found to increase significantly in conjunction with disruptions to the public transport systems. Some schemes, such as BCH in London and Capital Bikeshare (CaBi) in the Washington DC area, reported high usage levels, with each bike producing on average 3 trips per day\textsuperscript{17}. Other schemes are comparably less used thus less successful in attracting customers, e.g. in Australia with 0.3 - 0.4 trips per day per bike\textsuperscript{10}.

Concerning the factors influencing usage patterns, a study using real bicycle flow data from BIXI, Montreal, identified the following key variables\textsuperscript{14}: weather conditions, with users more likely to bike-share under good weather conditions; time of day/week: during the weekends the bicycle usage reduced, however Friday and Saturday nights were positively correlated to arrival and departure rates; the provision of cycle infrastructure, with bicycle flows and usage of the BSS increasing with cycle lanes/paths nearby a BIXI station; and the characteristics of the built environment around the stations, with bicycle flows decreasing further away from the core business district. Accessibility indicators appeared to be correlated to bicycle usage for every BIXI station. Restaurants, other commercial enterprises and universities in the vicinity of a station significantly influenced the arrival and departure rates of the BIXI station. Population density and job density around bike sharing stations appeared to influence demand and usage rates at different times of the day/week.

Reallocating capacity by adding a further BIXI station had a stronger impact on bicycle flows compared to increasing one station’s capacity. This means that dense bike sharing station networks may have a beneficial effect on usage levels.

In a study\textsuperscript{19} that combined usage data with members’ residence data, proximity of residence to bike sharing stations significantly increased frequency of use of the London BCH scheme.

Work-related purposes dominate bike sharing use, as the available evidence on journey
Measure No.21: Bike sharing

Purpose suggests\textsuperscript{16, 23}. However, the prevalence of different purposes may be influenced by temporal variables, such as time of the day and day of the week\textsuperscript{20}.

21.3.6 Change in travel attitudes and behaviours

This area of impacts has received comparably more attention and there are now several studies looking at this issue across different BSSs. The ability of bike sharing to attract trips previously made by private vehicles remains a key challenge, with the available evidence exposing relatively low mode substitution rates and suggesting that bike sharing is predominantly used instead of walking and public transport\textsuperscript{10}.

Findings from user surveys suggest that only a minority of journeys transfer from the private car. Among European examples are London BCH (2\% of car trips substituted for)\textsuperscript{17}, Velo\textsuperscript{V}, Lyon (7\%)\textsuperscript{10}, Dublin (19.8\%)\textsuperscript{20} and Bicing, Barcelona (9.6\%)\textsuperscript{23}. Examples outside Europe include BIXI Montreal (2\%)\textsuperscript{25}, CaBi in Washington DC (7\%), Nice Ride Minnesota in the twin cities of Minneapolis-Saint Paul (19.3\%), and Melbourne (19\%) and Brisbane (21\%) in Australia\textsuperscript{10, 17}.

In terms of broader travel behaviour change, bike sharing has been found to influence and change the travel behaviour of users, but with differing results in different contexts and in respect of different transport modes.

With respect to cycling, bike sharing appears to increase the frequency in which a bicycle (personal or shared) is used, thus contributing to promote cycling behaviour and increase overall cycling levels\textsuperscript{11-13, 16, 20-21}. As BSS users don’t generally use helmets or other dedicated cycling clothing, bike sharing can potentially normalise the image of cycling\textsuperscript{18}.

Considering changes in car driving, the available evidence suggests that bike sharing can reduce car use\textsuperscript{11}.

Evidence on behaviour change in walking and use of public transport modes as a result of bike sharing is more mixed and appears to depend upon the particular scheme attributes, transport infrastructure and population characteristic/travel patterns/preferences in the cities implementing the schemes. This is linked to how far bike sharing can support inter-modality, which is discussed the next sub-section.

The reviewed studies offer a number of possible explanations for the different patterns of behaviour change across different BSSs. For example, Fishman et al. (2013)\textsuperscript{10} suggested that BSS users in cities with relatively high car modal share exhibited a higher car mode substitution rate than BSS users in cities with an already low car modal share. However, robust statistical analysis of data from existing schemes is needed to check whether this observation can be supported. Other contextual factors identified as possible reasons for differential patterns of change in relation to public transport use include the quality, level of service and patronage of the available public transport options\textsuperscript{11, 26}.

The main weakness of this body of evidence on travel behaviour change is the lack of reliable quantitative data on the extent, in terms of frequency and magnitude, of the change in overall motorised travel on one hand and active travel on the other. As a result, the available evidence on travel behaviour outcomes cannot currently be used to robustly determine direct and indirect impacts, for example on public health and the environment.

The impact of BSSs on attitudes to cyclists has received very little attention to date thus evidence is limited. The study of Dublinbikes\textsuperscript{20} found that bike sharing can contribute towards raising awareness and acceptance of cyclists, thus contributing to increasing road safety for cyclists. BSS users in Brisbane perceived better behaviour from motorists when riding the...
shared bikes than when cycling with their own bikes\textsuperscript{27}.

21.3.7 Effects on inter-modality

Bike sharing can, at the same time, connect to and substitute for public transport. The exact outcome of this combination is the result of a complex interrelationship among various factors, such as the characteristics of the scheme and the location where it is implemented, including public transport infrastructure attributes and population travel behaviours and preferences.

An analysis of bike sharing usage in Melbourne, for example, revealed that the number of trips was significantly higher for docking stations located in areas with relatively less accessible public transit opportunities, suggesting that the BSS was potentially substituting for public transport rather than connecting to it\textsuperscript{28}. This contrasts with evidence from other cities such as London\textsuperscript{10}, Washington DC and Paris\textsuperscript{11}, where bike sharing usage was significantly higher in correspondence to rail stations (London and Washington DC) and Metro stations (Paris).

In London in particular, Goodman & Cheshire (2014)\textsuperscript{18} found the BCH to be relatively popular with non-Londoners from commuter towns with a cycling culture such as Oxford and Cambridge, so strategic marketing of a BSS in rail-connected commuter towns with an existing cycling culture could potentially increase participation and support bike-rail integration.

21.3.8 Environmental impacts

Many commentators and publications supportive of bike sharing provide estimates of the CO\textsubscript{2} emission savings resulting from bike share use to assess potential environmental impacts. However, the significance of these results is questionable because such estimates are not normally substantiated with robust evidence from usage data and/or user surveys, but rest on the invalid assumption that all bike sharing journeys substitute for car journeys.

One study\textsuperscript{17}, among the ones reviewed, attempted to conduct a more realistic, indirect, assessment of the environmental impacts of bike sharing. Using data from BSSs in London (UK), Melbourne and Brisbane (Australia), Washington DC and Minnesota in the U.S., it found that bike sharing can increase rather than reduce overall motor vehicle usage, when the effect of bike maintenance and re-distribution is accounted for. Re-distribution of bicycles is necessary to correct any imbalance in the number of available bikes and free docking points across the network.

A key limitation of this study relates to the inability to include the contribution of casual users, who might have a different pattern of use and mode substitution rate than those of members.

21.3.9 Health impacts

Health impacts from bike sharing have recently started to attract attention and a few studies are now available, which collectively suggest that bike sharing can have health benefits. However, the different methodological approaches used do not allow for reliable comparative assessments.

Commuting by Valenbisi was found to provide about half the recommended weekly physical activity (150 min) and a small reduction in the students’ Body Mass Index (BMI) was reported. These results suggest that BSSs can have a positive role in the promotion of healthy weight,
potentially preventing 2 kg/academic year of weight gain. Similarly, a survey of CaBi found that of over 3,100 responses, 31.5% reported reduced stress, and about 30% indicated they lost weight due to using Capital Bikeshare.

Positive health benefits from bike sharing were reported by two health impact studies using different modelling techniques, data and assumptions. The most recent, based on actual data from the London BCH, found positive health impacts, but not currently accruing equally to the different social groups using the scheme. The benefits were clearer for men than for women and for older users than for younger users. A limitation of this study is that it only modelled health benefits from short-medium term behaviour change, without accounting for the possibility that cycling at a particular age increases cycling across the life course, or otherwise affects disease incidence at older ages. According to the authors, reliable data on such long term effects are limited and their omission in the model may have underestimated the lifetime health benefits to those who start cycling at young ages.

The other health impact study, using Bicing in Barcelona as a case study, estimated 69.2 deaths averted per million users per year, significantly higher than the results obtained by the London study, which generated estimates of 3.3 to 10.9. This is due to the different schemes and cities under consideration, models used and assumptions made.

### 21.3.10 Economic impacts

Only two studies seeking to quantify the local economic impacts of bike sharing have been identified, thus the evidence on this issue is limited. These examined the economic benefits accruing to both users and businesses and suggested that bike sharing can generate economic benefits and contribute to enhancing local economies. The magnitude of such benefits, and associated level of confidence, is however limited.

Buehler & Hamre (2014) investigated potential economic benefits of CaBi, Washington DC, at the neighbourhood level through a survey of users and businesses proximate to bike sharing stations. Only a minority of surveyed users (23%) reported spending more money because they used CaBi. The business survey showed that while 70% identified a positive impact of BSS on the neighbourhood, only 20% reported a positive direct impact of bike sharing on sales. In addition, 61% would have either a positive or neutral reaction to replacing car parking in front of their business with a bike sharing station but were less favourable towards converting the sidewalk.

The other study, looking at Nice Ride Minnesota, also found positive economic impacts and estimated that BSSs can generate additional economic activity in the proximity of bike stations. An average of US$1.29 per week was reported, which would equate to US$29,000 over the season April to November.

Limitations of both studies include the timing of the surveys in a particular time of the year, which affects the results obtained, and the fact that both the user and business surveys collected estimated spending information based on subjective assessments and perceptions, rather than actual monetary transactions.

As discussed earlier, bike sharing can further benefit users by reducing their travel time and associated costs, which has relevant economic implications. Using actual usage data on bike sharing journeys, including duration and distance, Jensen et al. (2010) found that most journeys on the Lyon scheme were shorter than a trip by car and calculated a 13% reduction in travel time compared to using a car for the same journey. In their study of the health
impacts of the London BCH, Woodcock et al. (2014) estimated a 20% average time saving for trips made using the shared bikes as opposed to the alternative modes used previously. Although these estimates for time saving have not been translated into monetary benefits by the respective studies, a report by Transport for London (2014) provides a calculation of such benefits as part of a broader economic appraisal of the London BCH. This is discussed in the following section.

21.3.11 Evidence gaps

This review has found that the overall evidence on the impacts, and especially on the benefits, of bike sharing is growing but is still limited in terms of the range of case studies available, the methods used, the data collected and/or generated, and the range of characteristics and impacts that have been examined. Further research is needed to allow for systematic comparative analysis of schemes and to increase the level of confidence associated with the results. In addition to the evidence gaps and areas of weakness highlighted earlier, there are further issues that need to be addressed in depth:

1. The perceptions, attitudes and preferences of the social groups that least join and use these schemes, such as those who are able to ride a bicycle but do not cycle, ethnic minorities, disadvantaged social groups, women and older people;
2. The wider impacts of bike sharing on BSS users, in terms of overall mental and physical well-being;
3. The effects of bike sharing on the wider population, in terms of perceptions of the schemes and attitudes to cycling and cyclists, which would improve understanding of whether and to what extent BSSs can act as catalysts for private bike riding and help 'normalise' cycling;
4. The links between bike sharing and travel plans, and the extent to which BSSs systems can support them through strategic location at major workplaces, hospitals and other key destinations.
5. Finally, the impacts of BSSs on urban liveability, city image and tourism.

This review also found a very limited range of robust evidence on the process of setting up and operating BSSs, in particular generated by in-depth process evaluations of the drivers and barriers to implementation, and of the characteristics that support or hinder the continuing 'success' of a scheme. Crucially, evidence on whether schemes are successful according to their original objectives is also lacking. These are all areas that merit further attention and investigation.

21.4 Lessons for Successful Deployment of this measure

21.4.1 Issues around Complementarity and Transferability

Despite the limitations identified by this review, some of the available evidence does contribute to shed light on what factors are at play and in which context in producing specific outcomes from bike sharing. This can be helpful in understanding how particular beneficial impacts, or positive implementation and operation processes, could be replicated in other locations wishing to introduce bike sharing.

The most significant consideration to be drawn from the reviewed evidence is that bike sharing benefits from, and is dependent upon, clear political, policy and public support to sustainable travel and cycling in particular. The development of a positive cycling culture, growing cycling levels and supportive policy measures, such as the provision of quality
cycling infrastructure, have all been identified as important complementary factors that can sustain bike sharing during and after implementation. Bike sharing, in turn, has the potential to reinforce a positive image of cycling, as some of the evidence shows.

The London scheme, for example, was conceived and implemented in the broader context of the Mayor’s Transport Strategy, the Mayor’s ‘Cycling Revolution’ and effectively contributes to deliver the Mayor’s Vision for Cycling in London\(^2\).

Moreover, this and other successful schemes, such as Dublinbikes in Ireland and Bixi in Montreal, were implemented alongside improvements in the cycling infrastructure and in the context of sustained growing cycling trends.

However, achieving success in terms of usage rates does not guarantee that BSSs are also socially inclusive. Bike sharing tends to attract a particular profile of user: male, white, employed and, compared to the average population in which BSSs are implemented, younger, more affluent, more educated and more likely to be already engaged in cycling independently of bike sharing.

If promoters and operators of BSSs wish to achieve equity of access, then schemes need to be made available, attractive, accessible and affordable to a variety of social groups and types of users (registered members and casual users). Furthermore, the evidence on enabling factors to bike sharing operation suggests that effective and ongoing public engagement, including challenging negative perceptions of cycling, may help attract and maintain a diverse range of users.

Making bike sharing more inclusive could also contribute to a more equitable distribution of its positive outcomes, in particular in relation to health benefits and improved experience, accessibility and affordability of personal travel, through greater transport choice, reduced journey times and mobility costs.

Shared bicycles flows have been shown to be dependent on BSS attributes, such as station location and capacity, and positively correlated with a number of variables specific to the area in which a BSS is introduced. These include the availability of cycle infrastructure, mixed land use, spatial accessibility, population and job density. Therefore these factors need to be considered when planning BSSs.

Moreover, whilst commuting appears to be a key purpose for using bike sharing, temporal variables have been shown to affect patterns and purpose of use, so bike sharing can provide access to a variety of activities, including but not limited to employment. This is relevant to understand how bike sharing can contribute to enhancing users’ social inclusion and well-being.

Rather than substituting for car journeys, bike sharing is predominantly used instead of walking and public transport. Overall, cycling behaviour is shown to increase while driving to decrease, albeit for a smaller proportion of users. However, while cycling levels may increase as a result of bike sharing, the potential displacement of physical activity through walking should be borne in mind when supporting the introduction of bike sharing on public health grounds.

Bike sharing can, at the same time, connect to and substitute for public transport for different types of trips and users. The exact outcome of this combination is the result of a complex interrelationship among various factors, such as scheme attributes and the characteristics of the area of implementation, including travel patterns and public transport infrastructure. Therefore it is important to understand how these factors play out in different
contexts, in particular by taking into account the specific regulatory framework underpinning bike sharing and public transport ownership/operation. This in turn may have a significant impact on how bike sharing can be used to help manage public transport demand, and how the outcomes of this interaction benefit users and transport operators.

When the effect of using motorised fleets for bike maintenance and re-distribution is accounted for, bike sharing can increase rather than reduce overall motor vehicle usage and emissions, with associated negative environmental and air quality impacts. Re-balancing the bike network has also been identified as a key operational challenge. Deploying low or zero emission vehicles for this task may help increase the environmental credentials of BSSs. Additionally, by using a system of financial incentives and/or dynamic pricing to users based on real-time assessment of the re-balancing needs of the network, BSSs might become more self-rebalancing and need less external intervention.

Bike sharing can generate economic benefits and contribute to enhancing local economies, by connecting people to employment, retail and other places where economic activity takes place. It is important to develop innovative evaluation tools that are specific to bike sharing and capture their full range of impacts, not just those which are easily quantifiable.

**21.4.2 Issues around barriers and drivers to implementation / operation and resilience / durability**

An important area of ‘success’ emerging from various guides to bike sharing implementation is the ability of BSSs to generate revenue, hence reducing the amount of public funding or other subsidies necessary to run these schemes. Local governments can support bike sharing directly with a subsidy or indirectly by allowing operators to advertise on the bicycles, stations or other public spaces. Overall, the readily available evidence on the financial viability of existing bike sharing systems is limited and predominantly qualitative in nature. This may be due to the commercial sensitivity of such information. Only one quantitative economic appraisal has been identified, which however acknowledges limitations in the assumptions and values used to monetise the costs and benefits of bike sharing.

Interviews with North American scheme operators found that membership fees, usage fees, and sponsorships account for the vast majority of operating income. Additionally, four key factors impacting profitability were identified: the location of bike sharing stations, in particular near tourist attractions and public transport, and in mixed-use areas; the ability to retain registered members, e.g. annual members; providing a range of discounts; and, finally, the ability to find new revenue sources. The interviewed operators also stressed that whilst securing a strong core of annual members was important to success, tailoring the system to encourage occasional/casual use was imperative for a system’s long-term economic viability, especially in lieu of public subsidy.

A recent economic appraisal of the Barclays Cycle Hire by Transport for London (2014) found a Benefit-To-Cost Ratio (BCR) of 0.7:1 based on outturn costs, revenues and benefits realised to date plus forecasts up to 2017/18. The monetised benefits realised to 2013/14 accounted for £55.3m of the expected total of £129.4m to 2017/18 and included: journey time savings of £26m (£61.2m expected overall to 2017/18); health benefits of £22.5m (£70m overall); ambience benefits of £7.4m (£20.6m overall). Ambience benefits include the provision of way-finding at stations, the value of a new bicycle and maintained bicycle, improvements in bicycle and docking point availability and the value of CCTV and lighting at docking stations. The total cost of the scheme to date is £133m, including both capital and operating costs from scheme inception to 2013/14.
In terms of drivers and barriers, only two studies\textsuperscript{11, 16} appear to have systematically collected and analysed the views of BSS operators and stakeholders to understand the challenges and facilitating factors experienced in the implementation and operation of BSSs. However, these reflect only the North American context. Process evaluations of existing schemes are therefore needed to improve knowledge of what works and where in delivering and operating BSSs.

Challenges include bicycle re-distribution, which can be a complex and costly task to organise; addressing negative perceptions of cycling as unsafe and, in certain cultures (e.g. Mexico City), associated with being poor; mandatory helmet legislation; insurance and other legal issues.

Vandalism and theft are both reported to negligible, as are bike sharing accident rates (4.3 accidents per year for schemes with over 1,000 bikes are reported).

Facilitating factors include: establishing partnerships within local government and with community stakeholders; marketing and public outreach prior to and after launch, e.g. by engaging the public through public fora and online-based “suggest-a-station” platforms; locating bike sharing stations through appropriate spatial analysis to support system use; employing mobile station technology that can be easily relocated according to usage patterns; the use of advanced technologies to track bicycles, understand user behaviour, deter bike theft and support system management, for example through pay-as-you-go services; and facilitating membership portability and interoperability.

Similar recommendations are provided by Transport for London (2014)\textsuperscript{23}, in particular around the value of enhanced partnership working with London Boroughs; the adoption of appropriate project management tools to control costs and improve scheme delivery; detailed launch management; accounting for customer feedback; adopting a system software with enhanced asset management, automated job scheduling capabilities and improved billing and customer self-service processes.

Among the challenges experienced in the delivery and evaluation of the Barclays Cycle Hire, Transport for London (2014)\textsuperscript{23} highlights the lack of performance benchmarks specifically for bike sharing at the time of scheme implementation, and the need for improved bike sharing modelling/appraisal techniques and tools.

**21.5 Additional benefits**

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- **Health benefits**: Users can benefit through improved personal health, as well as potentially contributing to air quality improvements if changing from motorized transport.
- **Access to mobility**: BSS offer increased transport choice and convenience, reduced travel times, increased affordability of personal travel and potentially an improved travel experience for users.
- **Mode choice**: Bike sharing can influence and change the travel behaviour of users, but with differing results in different contexts. The ability of bike sharing to attract trips previously made by private vehicles remains a key challenge, with bike sharing predominantly replacing walking and public transport.
- **Cycling culture / road safety**: Bike sharing can contribute towards raising awareness and acceptance of cyclists, contributing to increasing road safety for cyclists.
21.6 Summary

The most significant consideration to be drawn from the all reviewed evidence is that bike sharing benefits from, and is dependent upon, clear and consistent political, policy and public support to sustainable mobility and cycling in particular. The development of a positive cycling culture, growing cycling levels and pro-cycling policy measures, such as the provision of high quality and safe cycle infrastructure, have all been identified as important complementary, and in some cases determining, factors that can sustain bike sharing during and after implementation. In other words, bike sharing needs to be implemented as part of a comprehensive and consistent package of measures making active travel safe, attractive and inclusive. Process evidence also identified partnership working and continuing involvement of stakeholders and local communities as facilitators to bike sharing implementation. Bike sharing, in turn, has the potential to reinforce a positive image of cycling.

Achieving success in terms of usage rates does not guarantee that BSSs are also socially inclusive. An established and broadly consistent body of evidence suggests that bike sharing tends to attract a particular profile of user: male, white, employed and, compared to the average population in which BSSs are implemented, younger, more affluent, more educated and more likely to be already engaged in cycling independently of bike sharing.

Making bike sharing more inclusive could also contribute to a more equitable distribution of its positive outcomes, in particular in relation to health benefits and improved experience, accessibility and affordability of personal travel, through greater transport choice, reduced journey times and mobility costs.

Shared bicycles flows have been shown to be dependent on BSS attributes, such as station location and capacity, and positively correlated with a number of variables specific to the area in which a BSS is introduced. These include the availability of cycle infrastructure, mixed land use, spatial accessibility, population and job density.

Rather than substituting for car journeys, bike sharing is predominantly used instead of walking and public transport. Evidence on broader travel behaviour change as a result of bike sharing is more mixed and varies according to the specific context of implementation and in respect of different transport modes. Overall, cycling behaviour is shown to increase while driving to decrease, albeit for a smaller proportion of users. Bike sharing can, at the same time, connect to and substitute for public transport for different types of trips and users.

The evidence on environmental impacts is very limited. When the effect of using motorised fleets for bike maintenance and re-distribution is accounted for, bike sharing can increase rather than reduce overall motor vehicle usage and emissions, with associated negative environmental and air quality impacts.

Bike sharing can generate economic benefits and contribute to enhancing local economies, by connecting people to employment, retail and other places where economic activity takes place. However the evidence is very limited and the magnitude of benefits appears to be modest.

Rather than being an isolated cycling measure, bike sharing shows the ability to be an effective part of sustainable mobility packages, especially when schemes are designed with a set of measurable objectives in mind, are implemented in partnership with local governments and other local stakeholders, are inclusive in the range of communities involved, employ effective delivery, management, monitoring and evaluation processes, and
are continuously improved by taking into account monitoring data, users’ feedback and changes in the overall transport network characteristics.

21.7 References for this Review

5. Institute for Transportation & Development Policy5 (2013)
Measure No.21: Bike sharing


Measure No.22: Inclusive Urban Design

Enhancements and alterations to the public realm to help to ‘manage’ the presence of motorised traffic

Cities can encourage greater use of more sustainable means of transport (such as walking and cycling), by reducing the impact of motorised transport through changes in the streets themselves.

Key messages:
- These measures can reduce vehicle speeds, fatalities and collisions.
- Traffic calming coupled with public realm improvements in mixed use shopping streets increases pedestrian flows on those streets. There are some indications that this might also benefit retailers in those streets.
- ‘Home zones’ also promote increased pedestrian use of streets, although that finding might vary according to national cultures and specific local contexts. The high cost of some interventions may have limited their wider application to date.
- ‘Shared space’ is likely to work best (i.e. favourable public perceptions and greater pedestrian use of road space) when vehicle flows and speeds are relatively low and pedestrian flows are relatively high.
- The review found insufficient source material to confirm claims made about effects of any of the interventions on economic activity or modal choice.

22.1 Context and background

This is a heterogeneous measure, encompassing schemes where motor traffic is not eliminated but is managed through design.

Potential interventions
- Traffic calming. (Interventions designed to reduce vehicle speeds through physical changes to roads. E.g. speed bumps or carriageway narrowing).
- Shared space
- Home zones

There is some overlap between the three approaches named above, as well as with other measures in the EVIDENCE review, particularly No:4 Access Restrictions, No:6 Environmental Zones, and No:19 Walking.

Whilst traffic calming does have a definition (as is noted), there is no single agreed view on ‘home zones’ or ‘shared space’ – with the definition of the latter being contested in the literature. Broadly speaking, shared space is a design approach which aims to calm traffic and encourage pedestrians to make more use of the carriageway through the removal of
demarcations such as kerbs, barriers, signage and traffic signals. Many shared spaces are flat surfaces, with no distinction between the pavement and carriageway, although the approach does not necessarily imply such a radical solution. Home zones are residential streets which have been designed (new streets) or redesigned (existing streets) with similar aims. The designs of home zones vary, but they tend to use a mixture of shared space techniques (e.g. removing kerbs and creating a flat surface) and traffic calming techniques (e.g. build-outs which narrow the carriageway).

22.2 Extent and Sources of Evidence

Given the wide scope of this measure, the amount of readily-available evidence is rather limited. The nature, source and age of the evidence varies between the different measures. The concepts of home zones (woonerven in Dutch) and shared space both originated in the Netherlands and have been adopted to varying extents in other European countries. Shared space has, in recent years, been promoted through Government guidance in the UK, published in 2011. This has stimulated research interest in shared space in the UK, in recent years. A review (including primary research based on ten case studies) which informed that guidance has provided an important element of the evidence summarised here. Some of the academic studies have been used to critique that review and provide some different perspectives on shared space.

Following practice in the Netherlands, the UK Government also funded a programme of new and retro-fitted home zones between 2000 and 2002. Evaluations of these and other home zones in the UK provided much of the evidence reviewed below. The main sources cited were a review conducted for a UK NGO and an academic study of 7 case studies in the UK.

For both shared space and home zones, a search was also performed in the international literature and Dutch sources for evidence from the Netherlands. This produced relatively little evidence appropriate for this review.

Semi-pedestrianised streets (rues semi-piétonnes) have existed for some time in France. In 2008, the concept of the pedestrian priority zone (zone de rencontre) was introduced in the national highway code. This gives greater legal priority to pedestrian in those zones (including most of the streets previously classified as semi-pedestrianised). These zones are often similar in character to shared spaces in the UK or the Netherlands. Certu, the national transport and planning research institute, has done several evaluations and case studies in France1 and in Belgium and Switzerland2. These are mainly descriptive, however. Very little quantitative evidence was found in the French-language literature.

Traffic calming is an older concept, which has been widely adopted across many countries for several decades and research interest appears to have waned in recent years. This review encompasses an academic meta-study published in 2003 but drawing on international evidence (mainly from Germany, the UK and Australia) from 1972 to 1990. The underlying source documents are not readily available, so the analysis below relies on the findings of the meta-study. Ireland is one country where national traffic calming programmes have begun more recently. Two comprehensive reviews of the road safety impacts of those programmes written by consultants for the Irish government in 2002 and 2008 have also provided useful evidence for this review.

Revised national guidance in the UK in 2008 created a hybrid concept of ‘mixed priority streets’, which combine elements of traffic calming and some shared space to high streets with a mixture of retail and other uses. A road safety and economic evaluation of that
programme, conducted by consultants for the UK Department of Transport, is also reviewed below.

22.3 What the Evidence Claims

22.3.1 Traffic Calming

Quantitative evaluations of traffic calming interventions have almost entirely focussed on road safety impacts. The evidence reviewed suggests that most traffic calming interventions have succeeded in reducing collisions, injuries and/or fatalities. As explained below, the broad conclusions about injuries and fatalities may be considered robust, whereas the findings about collisions are less clear.

One national study calculated that the annual rate of return from the Irish traffic calming programme produced a 46% annualised return on investment, using 'willingness to pay' measures for the value of collisions and fatalities avoided. Various qualitative case studies describe improvements to the urban environment, but these largely reflect the impressions of the person or organisation writing the report. Other potential benefits such as increased rates of walking or cycling, or greater community cohesion, have not been systematically assessed.

International literature was searched by a meta-study looking for controlled before-and-after studies of traffic calming interventions. This identified twelve such studies, reporting on sixteen interventions. Outcome data from the intervention areas were compared to the control areas for three outcome measures. The (statistically significant) reduction in road traffic injuries was 11% greater in the intervention areas. The fall in fatalities was 37% greater, although the authors recommend caution in interpreting that finding, as many of the studies reported no fatalities. The reduction in collisions was 5% greater in the intervention areas, but that small difference was not statistically significant. The meta-study did not report on traffic speeds, but concludes that speed reductions would explain the greater reduction in injuries and fatalities than in collisions.

An Irish study evaluated a national programme of traffic calming implemented on major roads entering and traversing villages and small towns between 1997 and 2002. Here ninety-one schemes were evaluated using four years' pre-intervention and four years' post-intervention data from local authorities. This found a 13% reduction in collisions and a 52% reduction in fatalities, compared to the national trends, which were also downwards. From these reductions, using standard national methods and assumptions the programme was estimated to have generated a 46% annualised return on initial investments. The pattern of reductions was highly variable; collisions fell more than the national average in just 53% of the sites. Different types of intervention achieved more success than others. The most successful interventions included a gateway at the entry to the settlements with side buildouts and a central island. Various types of changes were made on roads within the settlements. Signage and lines on the road made no difference on their own.

The study did not measure differences in speed or volumes of traffic but the fact that fatalities fell by more than collisions suggests (as in the meta-study) that lower speeds reduced the severity and consequences of collisions.

In 2002, the UK Government launched a pilot programme called the 'Mixed Priority Routes Demonstration Project' applied to ten high streets with retail and other uses. This was evaluated and was used to inform new national guidance (Local Transport Note 03/08 Traffic Management and Streetscape). The elements of each individual scheme differed but they
combined general improvements to the public realm with elements of traffic calming such as carriageway narrowing and improved pedestrian crossings using ‘raised tables’ to slow the traffic.

Collisions and casualty rates were compared ex-ante and ex-post. Benefit-to-cost ratios were calculated based on the casualty reductions only. All the thirteen individual cases (ten from the national pilot programme and three implemented by local authorities independently) were directly monitored for one to two years after implementation. Casualty rates were also compared over a three year period.

Overall, the schemes produced a 16% reduction in casualties over and above the national trend, which was also downwards. Using UK Government guidance rates for the value of lives saved and casualties avoided (Highways Economic Note1 2005) this produced a 24% return on investment. Other impacts, including increases (of between 2% and 22%) in the flow of pedestrians in those streets, reductions in vehicle speeds and a small reduction in vehicle flows. These impacts were not included in those calculations.

The 3 local authority schemes were implemented with lower budgets (and fewer physical improvements to the public realm). These were implemented slightly later and the available data was more limited, but the initial analysis suggested that they were generating comparable road safety advantages, so higher rates of return might be possible from lower cost schemes.

A theme in the technical literature suggests one potential disadvantage of physical traffic calming measures, relating to local air quality. Measures that cause vehicles to slow down and re-accelerate increase CO and NOx emissions. Most of this literature is based on hypothetical modelling. For example, a report on an experiment that measured variations in speed and then modelled the effect on emissions projected some significant increases in air pollution from measures such as speed humps. However, an evaluation of a home zone programme, which included traffic calming measures, monitored the air quality in the intervention streets before and after the intervention. The interventions (which also reduced traffic volumes on most of the streets) made no statistically significant difference to air quality. The intervention streets all had low traffic flows - the findings might be different on streets with higher traffic flows. Measures such as average speed cameras, which maintain more constant vehicle speeds, could avoid those potential problems on streets with higher traffic volumes.

Methodologies and Caveats

All of the evidence above was derived from before-and-after studies, which compared intervention areas to national trends (in the UK and Irish studies) or control areas (in the meta-study). This raises two caveats in interpreting the conclusions.

The first of these relates to the statistical phenomenon of ‘regression to the mean’. The Irish study explains that one of the criteria for selecting sites for traffic calming was a high rate of collisions over a 5-year period. Some of the individual scheme evaluations of the UK Mixed Priority Routes programme also suggested that a poor casualty record was a factor influencing the selection of that street for the programme. Although this issue was not discussed in the meta-study, it is likely that similar considerations would have applied in at least some of the cases evaluated.

A ranking of ‘the roads with the highest collision rate’ will be partly influenced by natural variability. Thus, we would expect the roads with the highest collision rate to show an improvement even if no changes were made (just as world record-breakers usually record a
slower time when they next compete – which does not mean their performance is deteriorating). This tendency of those at the extremes to converge over time is known as ‘regression to the mean’. The Irish study acknowledges the problem, but makes no attempt to adjust for it. The meta-study does not mention it. In both cases, the rate of improvement is likely to be overstated because of regression to the mean. A 5-year collision record as used in the Irish programme would reduce (though not eliminate) the natural variation in collisions compared to the alternative of using a shorter time-period.

The second caveat (which also applies to some of the studies of home zones and shared spaces, discussed below) relates to traffic volumes and traffic displacement. Where an untreated alternative route exists, traffic-calming may displace some traffic onto the alternative route. In some residential areas, one objective of a traffic-calming scheme may be to displace traffic away from a residential street (‘rat-running’) onto roads with higher capacities and speeds. Even where displacement is not a deliberate objective, it may occur anyway. Any reduction in collisions on traffic-calmed streets might be partly due to falling traffic volumes – which might also increase collisions on alternative routes. Neither of the reports acknowledges this potential problem or provides any data on traffic volumes. The intervention sites in the Irish study were major roads entering, traversing and leaving small towns or villages so the opportunities for displacement are likely to be limited around most of those sites.

The finding that injuries and/or fatalities improved much more than collisions in both studies is unaffected by these caveats. Thus, the conclusion that traffic-calming significantly reduces injuries and fatalities may be considered robust, although the percentage reductions and the effect on collisions must both be treated with caution. The annualised rate of return in the Irish and UK studies should also be treated with some caution, although it would be reasonable to conclude that the ‘true figures’ would be strongly positive, particularly if benefits other than road safety were included in the calculations.

22.3 2. Home Zones

Home zones are designed to improve the street environment of residential areas. They may incorporate elements of traffic-calming, such as speed humps, chicanes and gateways, and elements of shared space such as flat surfaces with no kerbs. They may also include changes to parking arrangements, street furniture, tree planting and public art. Local residents are sometimes involved in their design. Between 1999 and 2004, the UK Department for Transport funded the conversion of conventional streets to home zones in nine pilot areas – each comprising a small cluster of residential streets. Seven of the pilot areas were evaluated as were newly-built home zones in six British towns / cities.

The evaluation in the pilot areas involved before-and-after interview surveys of local residents and before-and-after measurements of: traffic speeds and volumes, air quality and collisions. The traffic data was measured by automatic counters over three weeks at various locations within each home zone. As far as possible the same locations were used in the ‘before’ and the ‘after’ measurements. Traffic volumes reduced in 6 of the 7 areas, by an average of 24%. In one case (a cul-de-sac) there was no change; at the other extreme, where a through road was closed, traffic levels halved. Average speeds fell in all seven areas, by an average of 24%, and 85th percentile speeds also fell in all seven areas, by an average of 25%. The researchers only had access to preliminary data covering varying periods post-intervention; only one collision was recorded, which suggested some improvement, but the data was insufficient to perform any statistical tests.
There was substantial support for the interventions amongst residents. Across the seven areas 64% were “in favour of the home zone now that it has been installed”. ‘Yes’ answers exceeded ‘nos’ in all areas. The area with the least positive responses was the cul-de-sac where traffic volumes were unchanged. Some of the schemes reduced availability of on-street parking. 34% of respondents thought that parking problems had increased since the home zones were introduced, compared to 20% who thought they had reduced. Car ownership, which increased by 3% between the two surveys, may have partly influenced these perceptions.

The surveys asked about walking and cycling behaviour before and after the interventions. Although most residents thought the streets were now safer to walk or cycle, there was no significant change in the prevalence of walking or cycling. As each intervention only applied to a small area and conditions outside those areas were largely unchanged there would be no reason to expect any significant modal shift.

Post-implementation interviews were also conducted with local authority officers, who emphasised the importance of local community involvement in the schemes, as a factor contributing to their success.

The evaluation of the six newly-built home zones (ex-post only), had a specific focus on the nature of pedestrian and social use of the streets. Using passive on-street observation (or time-lapse photography on one of the six streets), the researchers found that children in particular used the streets intensively for long periods, and that they engaged in a wide variety of play activities across the whole area of the street with relative freedom. Adults were also seen spending time in home zones, but the sense is that this was in response to the children playing there. These observations were more pronounced in streets with home zone treatments (which reduced traffic flows as well as speeds) compared to streets with just speed limit controls or traffic calming.

Methodologies and Caveats

The evaluation of the pilots provides some information on scheme costs, but none of the sources reviewed attempted to calculate economic benefits. The high cost of some home zone treatments has limited their wider application (though no relationship was found between the cost of each scheme and residents’ satisfaction rates). It is worth noting though that no attempt was made to measure traffic flows, nor to interview residents, on streets outside the home zone areas in this study. The interventions would have caused some displacement onto surrounding streets but as traffic flows were relatively low beforehand, the scale of displacement would have been small. The responses to interview surveys in that study would partly reflect social influences amongst neighbours and could also be susceptible to ‘the good subject effect’—where respondents unconsciously reflect what they believe the researchers want to hear. This did not prevent respondents from voicing dissatisfaction (with parking arrangements, for example), however.

22.3.3. Shared Space

Shared space is the most controversial of the sub-measures discussed in this review. It is a heterogeneous concept. Its most radical form is a flat surface across the full width of a street with no demarcations between pedestrians and vehicles. Elsewhere, more limited removal of demarcations such as traffic signals or pedestrian barriers may be described as ‘shared space’. Evidence reviewed below addresses this diversity with a scoring system designed to rank streets from the most shared to the least shared. Given the widespread implementation of the shared space approach across several European countries, the range
and depth of evidence concerning its effectiveness is surprisingly limited. Many claims have been made about the benefits of shared space, several of which are unsupported by evidence. The claims that shared space causes modal shift (towards or away from active travel) have not been evaluated in any of the sources we have reviewed. As most shared space interventions are small in scale, like the home zones, there would be no reason to expect any significant impact on modal choice. No economic evaluations of shared space programmes were found in the literature.

There have been several evaluations of impacts on driver and pedestrian behaviours in shared space streets. The conclusions from these studies are less clear than for the other sub-measures. In some contexts – particularly streets with low traffic flows (like the home zones) – the approach appears to facilitate pedestrian use of carriageway space. In other contexts – particularly where vehicle flows are high – it appears to create environments hostile to pedestrians, particularly those from vulnerable groups, such as blind people, older people and women (more than men).

The depth of the evidence on shared space is limited by methodological concerns. The peer-reviewed academic studies have been limited in scope, whereas the more comprehensive review conducted for the UK Government used methods which leave some of its conclusions open to question. The claim that shared space reduces vehicle speeds (and if so, under what circumstances) remains unproven at present.

The UK Department for Transport commissioned research to inform national guidance on shared space (Local Transport Note 01/11). The resultant study contains an ex-post evaluation of streets in ten UK towns and cities with a range of shared space interventions. On-site observations collected qualitative and categorical information about street design. This was used to score and rank each of the ten streets against a "shared space rating" – those with the fewest demarcations between vehicles and pedestrians (e.g. kerbs, bollards, traffic signals) achieved the highest score. Video cameras were installed at the ten sites, collecting information on pedestrian, driver and cyclist behaviour. Automatic traffic counters were installed at six of the ten sites to capture vehicle speeds and flows.

A regression analysis found that traffic volumes and pedestrian flows predicted over 70% of the variation in the proportion of pedestrians using the carriageway (a key objective of shared space schemes). The propensity of drivers to give way to pedestrians was partly explained by vehicle flows (negative), pedestrian flows (positive) and the extent of demarcations (negative). A further analysis also suggested that these same factors also influenced vehicle speed, although that finding is contestable for the reasons explained below.

A literature review conducted at an earlier stage of the same review for the UK Government concluded that the evidence on casualty impacts of shared space was unclear. Some evaluations (including from the Netherlands) had shown reductions in collisions and/or casualties but one study suggested that at higher traffic volumes shared space resulted in increased casualties.

Further ex-post research was conducted on one of the ten sites used for the DfT research, and findings from this were used to critique some of the conclusions of the earlier work. The site was an inner-urban ring road with high traffic flows subject to a radical shared space solution with a flat surface and no demarcations between traffic and pedestrians. Video evidence showed that pedestrians made little use of the carriageway, apart from crossing the road, mostly using the informal 'courtesy crossings'. Many pedestrians were observed running across the road. Pedestrians gave way to vehicles more than vice versa. 80% of the pedestrians interviewed stated that they "felt safer under the previous scheme".
The informal courtesy crossings were particularly unpopular – pedestrians felt that drivers were less likely to give way than they would on a more formal crossing. Older people and women were more negative about the scheme than younger people and men respectively.

Evaluations of other shared space streets, with lower traffic flows\textsuperscript{15} produced more positive pedestrian evaluations, which is consistent with the finding of the DfT work\textsuperscript{10} about the effect of vehicle flows.

Groups representing blind and partially-sighted people in the UK and the Netherlands have both opposed the spread of shared space schemes. As part of the previously described UK national study\textsuperscript{10} qualitative research was conducted amongst different categories of street user\textsuperscript{12}. People with a range of disabilities preferred “clearly defined areas for vehicles and pedestrians and designated crossing points”. Kerbs were strongly valued by visually-impaired users both as a navigational aid and as a clear demarcation between the pavement and carriageway. Similar opinions were also strongly expressed by mobility-impaired participants, confounding the researchers’ expectations that they would prefer flat surfaces.

**Methodologies and Caveats**

It is argued though\textsuperscript{14} that some of the conclusions drawn by the DfT study\textsuperscript{10} are based on speculative assumptions about the causal mechanisms behind statistical relationships. The ten case study sites, were evaluated ex-post only. The ones with the highest “shared space ratings” tended to have lower traffic speeds. The authors concluded (and the UK Government repeated in Local Transport Note 01/11) that this demonstrates that shared space reduces traffic speeds. They did not consider the alternative explanation that local authorities might have gone further in removing demarcations on streets where vehicle speeds were already relatively low. The shared space rating was the only measure of urban design used in the analysis. In practice, many shared space conversions tend to comprise a package of measures, often including elements of traffic calming e.g. carriageway narrowing. This has led some to suggest that claims that shared space conversions reduce collisions or casualties may sometimes overlook the influence of other associated measures, which may reduce traffic volumes and/or speeds\textsuperscript{16}. This review did not find any methodologically robust evaluations of the effect of shared space conversions on speed, collisions or casualties.

The conclusion that shared space encourages more pedestrian use of street space where traffic volumes are low and pedestrian volumes are high, though not proven, is plausible and supported by the balance of the available evidence. Although there is no specific evidence on this, increased sharing of the carriageway is likely to reduce vehicle speeds where pedestrian volumes are high, relative to the available space – which would be the case in many historic areas or shopping streets.

**22.4 Lessons for Successful Deployment of this measure**

Much of the evidence under all three sub-measures comes from the UK. The conclusions which are affirmed with greatest confidence, below, are likely to apply in most situations in all countries, however. The sources reviewed contain very few references to the process of implementation or the longer-term maintenance and continuation of schemes, so it is not generally possible to comment on how those might differ in other countries. One exception is the commentary in the review of UK pilot home zones\textsuperscript{8} on the benefits of involving local residents in the design of home zones. Although processes would differ between countries, that principle could be applied everywhere (at the possible cost of lengthening
implementation timescales and requiring more staff time).

To what extent home zones promote social interaction, or shared space changes the behaviour of drivers or pedestrians, would clearly depend on the social context of each country as well as characteristics of specific locations. Similarly the economic rate of return calculations for the UK and Irish national programmes would vary if performed in other countries.

Some of the interventions, particularly traffic calming can work as a single intervention on a small or a large scale. Attention should be paid to possible displacement effects, where traffic calming gives drivers an incentive to choose other routes. Home zones and shared space may require an appropriate legal framework to determine liability in the case of collisions or casualties. Depending upon the context in each country, measures to change driver perceptions and behaviour – to make drivers more aware of and ready to give way to – pedestrians and other vulnerable road users, could help to make home zones and shared space more successful.

### 22.5 Additional benefits

As well as the evidence of economic and financial benefits of interventions discussed above, there are a number of additional benefits that are claimed for these policies:

- **Road Safety**: Most traffic calming interventions have succeeded in reducing collisions, injuries and/or fatalities.
- **Community benefits**: Home zones can create a better living environment, particularly for children, depending upon how traffic and parking are handled within them. Residents may also perceive that streets are safer to walk or cycle on.

### 22.6 Summary

The following statements can be made with confidence:

- Traffic calming and home zones reduce vehicle speeds, fatalities and collisions.
- Traffic calming coupled with public realm improvements in mixed use shopping streets increases pedestrian use of those streets

Home zones also promote increased pedestrian use of streets, although that finding might vary according to national cultures and specific local contexts. The evidence around shared space is more ambiguous, but suggests that the approach is likely to work best (i.e. favourable public perceptions and greater pedestrian use of carriageway space) in circumstances where vehicle flows and speeds are relatively low and pedestrian flows are relatively high.

Some of the other claims made for these sub-measures cannot be confirmed or refuted by the available evidence. These relate to the impact of shared space on collisions or casualties and the effect of any of the sub-measures on modal choice or economic activity.

### 22.7 References for this Review

1. CERTU (2009). Mise en conformité des aire piétonnes et zones 30 existantes
2. CERTU (2009). Les zones de rencontre en Suisse et en Belgique


