



What policies are effective at reducing carbon emissions from surface passenger transport?

A review of interventions to encourage behavioural and technological change

March 2009

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A report produced by the Technology and Policy Assessment Function of the UK Energy Research Centre

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March 2009

ISBN 1 903144 0 7 8

Preface

This report was produced by the UK Energy Research Centre's Technology and Policy Assessment (TPA) function.

The TPA was set up to inform decision-making processes and address key controversies in the energy field. It aims to provide authoritative and accessible reports that set very high standards for rigour and transparency. The subject of this report was chosen after extensive consultation with energy sector stakeholders and upon the recommendation of the TPA Advisory Group, which is comprised of independent experts from government, academia and the private sector.

The objective of the TPA, reflected in this report, is not to undertake new research. Rather, it is to provide a thorough review of the current state of knowledge. It also aims to explain its findings in a way that is accessible to non-technical readers and is useful to policymakers.

The TPA uses protocols based upon best practice in evidence-based policy, and UKERC undertook a systematic search for every report and paper related to this report's key question. Experts and stakeholders were invited to comment and contribute through an expert group. A team of expert consultants was commissioned to undertake the review of evidence. Working papers, scoping notes and related materials are all available from the UKERC website, together with more details about the TPA and UKERC.

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About UKERC

The UK Energy Research Centre is the focal point for UK research on sustainable energy. It takes a whole systems approach to energy research, drawing on engineering, economics and the physical, environmental and social sciences.

The Centre's role is to promote cohesion within the overall UK energy research effort. It acts as a bridge between the UK energy research community and the wider world, including business, policymakers and the international energy research community and is the centrepiece of the Research Councils Energy Programme.

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Executive summary

This report from the Technology and Policy Assessment (TPA) function of the UK Energy Research Centre examines the merits of a range of different policies that offer the prospect of CO₂ emissions reduction from road transport. It addresses the following key question:

What policies are effective at reducing carbon emissions from surface passenger transport?

UKERC's advisors indicated that the potential for policies to deliver carbon emissions reduction through encouraging changes to 'behaviour' (changing people's 'travel choices' and reducing car travel) may not be as well understood as policies that target vehicle technologies. The report therefore has the following objectives:

- Review the evidence for CO₂ emission reduction potential and cost-effectiveness across policies that target car technology/choice and those that target wider travel choices
- Identify the key issues and problems associated with each policy type
- Identify whether and where policies are complementary or synergistic
- Identify evidence gaps and highlight future research needs
- Draw conclusions relevant to current UK policy

This report does not undertake new modelling or empirical research; rather it provides a thorough review of the current state of knowledge on the subject, guided by experts and in consultation with a range of stakeholders. The project team undertook a systematic search for every report and paper related to the assessment question. Experts and stakeholders were invited to comment and contribute through an expert group. A team of expert consultants was commissioned to categorise, review and distil the evidence. This tightly specified search revealed over 500 reports and papers on the subject, each of which was categorised and assessed for relevance. The evidence on each policy is reviewed against the following criteria:

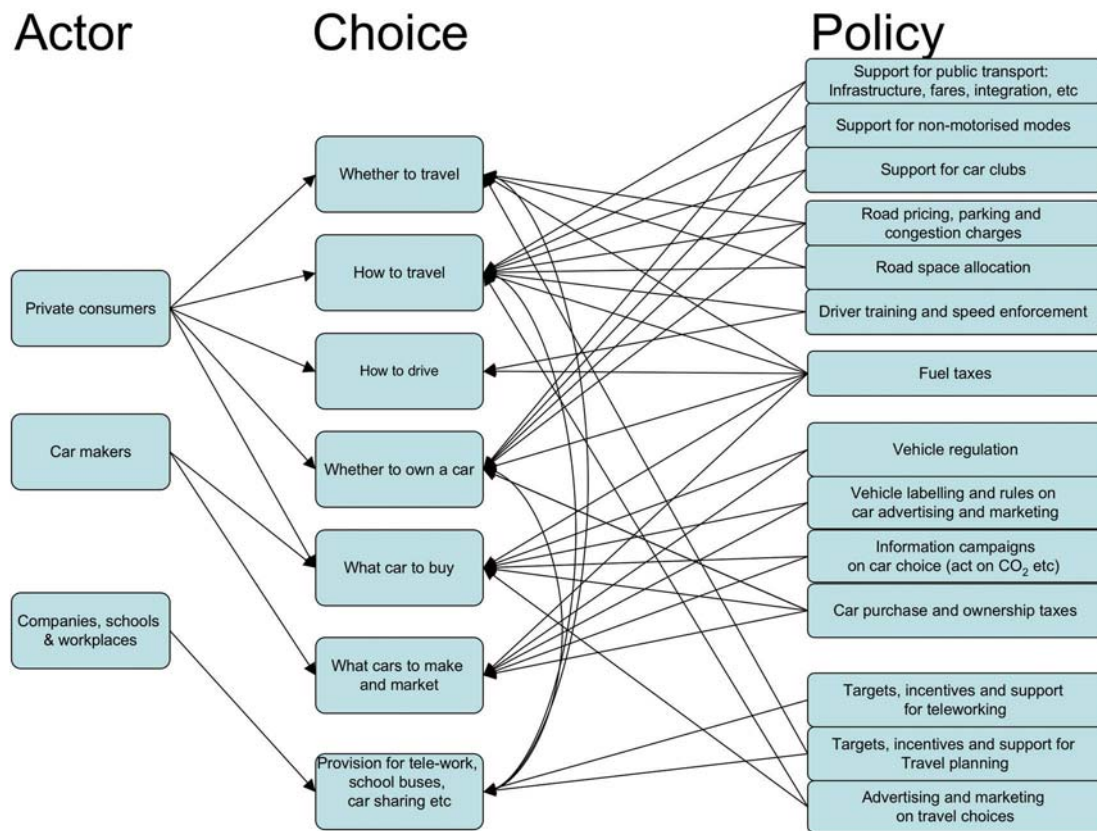
- **Potential emissions saving;** in absolute and percent terms where the evidence permits.
- **Key issues and problems;** including reasons for effectiveness, evidence gaps, obstacles to policy implementation, interactions with other policies and potential rebound effects.
- **Costs;** where possible we provide evidence of costs in £/tonne carbon terms. Where this is not available in the literature we provide a discussion of what evidence does exist.

This report represents one output from this process of review, evaluation and synthesis. The other main output is a set of detailed evidence tables which are published on the UKERC website alongside this report.

Actors, choices and policies: a framework for analysis

Policymaking in the transport arena is complex because so many actors and choices have the potential to reduce emissions. The relationships between actors, choices and policies are illustrated in Figure 1. This framework is used in the report to consider how policies affect a range of choices and the key actors making them.

Figure 1. Actors, choices and policies in the transport arena



The report reviews policies that bear upon two categories of choice: travel choices such as how and how far to travel and vehicle purchase choices. It also discusses fuel taxes and prices, which affect both travel and vehicle choices. Hence the report has a three chapter split between travel choices, vehicle choices and the impact of fuel taxes. These categorisations are also followed in this summary, before we review cross-cutting issues.

Lower carbon travel choices

This part of the report reviews interventions that offer the potential to reduce carbon dioxide emissions by reducing demand for travel, facilitating the use of non-motorised or public transport and using cars more efficiently. In all cases the focus of analysis is on carbon emissions rather than the other advantages and disadvantages particular travel choices and transport policies may offer.

The report focuses on transport policies *per se* rather than the wider set of policies that are important to travel choices, particularly those related to land use. Although planning policies are not discussed in detail in this report, land use planning plays a significant role in reducing (or increasing) demand for travel, affects mode choice and can improve (or undermine) the viability of public transport.

The following main findings emerge:

Reducing demand for travel

Key determinants of travel demand include absolute and relative prices of travel by all modes, land use and choice of destinations, and economic growth. Although land use policies are outside the scope of this study, planning policies can play a significant role in reducing demand for travel. Fuel price increases reduce travel absolutely as well as encouraging mode shifts and more efficient driving. Road pricing may have similar effects. The provision of extra road or public transport capacity can also lead to absolute increases in travel demand. However there are few policies which set out directly to influence the total amount of travel in the system (i.e. to reduce total trips). One set of policies that do are those that seek to promote tele-activity. However, it is difficult to draw firm conclusions about the potential of tele-activity to reduce emissions, or the policies required to accelerate it. Evidence from telework programmes at a company case study or regional level suggests that substantial savings ought to be possible. However there does not appear to have been much macro-level, UK-specific analysis of the potential for tele-activity to reduce emissions. Considerably more work is needed on the potential for tele-activity to influence car dependent lifestyles, on its own or through a package of interventions, and affect energy consumption across the transport as well as commercial and residential building sectors. Particular problems include estimating the 'baseline' trend towards telework and the size of a range of rebound effects. Our review did not reveal data on cost-effectiveness in terms of £/tC but does suggest that costs can be low or even negative due to the low marginal cost of journey avoidance.

Support for non-motorised modes

A significant fraction of journeys can be made by walking or cycling, since this is the experience of several European countries. Increasing the share of cycling in Britain to levels closer to those of our Northern European neighbours could yield emissions savings in the UK of around 2 MtC (7.3Mt CO₂) per year (approximately 6% of total transport emissions by source) if like-for-like mode switching was delivered. The savings could be greater if destination switching was also achieved. Inter-country comparisons suggest that effective policies to make cycling safer and more convenient, for example through segregation and prioritisation, correlate closely with levels of cycling. However there is also evidence that policies that penalise car use (congestion charging in particular) and individualised marketing can assist in the uptake of cycling. Our review did not reveal any systematic attempt to estimate the cost of saving carbon using policies to promote non-motorised modes. This is an important area for future research.

Support for public transport

The evidence on the potential of public transport to reduce emissions presents a complex and somewhat contradictory picture. On average, emissions per passenger km are much lower than those for private cars. There is a strong link between the availability of convenient and affordable public transport and patterns of land use that are conducive to lower reliance on private cars. However, the short to medium term potential for public transport to contribute to emissions reductions is relatively limited. The main reasons are that capacity expansion may need to be large in order to absorb a significant proportion of car journeys, that demand may be induced by new routes and lower fares, and users may be attracted from other low carbon modes as well as from cars. It is important to consider the potential to improve occupancy at underutilised times/routes as well as how to provide new capacity. Similarly, fare reductions, prioritisation and additional services can be combined with measures to restrict car use, helping to ensure mode switching is beneficial in CO₂ terms. Mode switching cannot be divorced from destination switching. Thus, the capacity constraints foreseen in forecasting and modelling exercises may place too much emphasis on the requirement to satisfy current car passenger demand with like-for-like public transport patronage. In all cases there is evidence that changes to journey patterns can, over time, ameliorate congestion impacts from bus prioritisation, and land use effects may multiply the impacts of capacity provision and fare reduction. Our review revealed relatively little attention to costs of investment in public transport in terms of reducing CO₂. We did reveal cost data related to infrastructure provision, which unsurprisingly indicates that new conventional rail, light rail and mass transit infrastructure requires large investments from public bodies and the private sector. Improving utilisation of under-used services can improve cost-effectiveness. More work is needed on cost-effectiveness, and this must take account of both co-benefits and long run and short run effects.

Car clubs

Relative to car ownership, car clubs appear to help reduce total car miles driven, with members who previously owned a car walking, cycling, and using public transport more often, as well as travelling less by car. The research also shows that this reduction of car miles is a direct result of breaking the link between car use and car ownership - exactly the service that clubs provide. More research is needed into the potential rate and scale of growth and how to attract car club membership from a wider section of the population and on cost-effectiveness of carbon saving.

Using vehicles more efficiently

Improving vehicle occupancy offers large potential savings at low cost but the evidence from the US suggests it is difficult to deliver in practice. Potential savings from eco-driving campaigns appear to be significant and costs low: reductions in emissions of 10-15% appear feasible at a cost of below £20/tC. The biggest obstacles to eco-driving are securing driver participation and ensuring that efficient driving habits are sustained over time. This suggests that if the potential benefits of more efficient driving styles are to be

secured, an ongoing programme of training and reinforcement through advertising and other awareness-raising mechanisms is likely to be needed. Speed enforcement and reduction would appear to have potential to reduce emissions from private vehicles in the context of a broader eco-driving campaign. There is some debate over costs. Enforcing speed limits on motorways and trunk roads more rigorously could save around 2-3% of total transport emissions in the short term. The absolute cost and political acceptability of this policy require further investigation.

Individualised marketing and travel planning

The evidence revealed in our review suggests that travel planning can have a measurable and significant impact on travel choices, typically reducing car usage by between 6% and 30% depending upon context. The most common shifts appear to be to non-motorised modes, though use of public transport and improved car occupancy are also significant. There is evidence to suggest that 'sticks', particularly measures such as parking and other charges, help to make travel planning effective. Travel plans are a means by which existing services/options can be utilised more effectively. The options must first exist and/or be improved if travel plans are to have an impact. This highlights the strong complementarities between travel planning and the provision of alternative modes, road space allocation and road/car use charging. Reported costs fall within a wide range for school and workplace travel planning, from below £30 to over £500 per tC. Cost and accounting for co-benefits requires further research.

Road pricing

Individual congestion charging schemes have led to significant reductions in emissions within each zone and the evidence suggests that this is offset only to a limited extent by additional journeys outside the zone. Savings result from both reduced car traffic and more efficient car use, due to reduced congestion. Congestion charging can help promote modal shift and increased vehicle occupancy. The evidence on wider road pricing is based on modelling rather than experience, and suggests a more mixed picture. Analysis suggests that emissions reduction potential is significant and is cost-effective in terms of the economy overall. Several studies estimate large macro-economic benefits, largely resulting from congestion reduction. However, carbon impacts may be rather modest if road pricing is offset by reductions in fuel duty and other car taxes.

Road space provision and reallocation

The evidence examined supports a clear causal relationship between added road capacity and increased traffic volumes. Short-term emissions reductions from lower congestion and higher/smoothier speeds are eroded in the longer term by induced traffic. By contrast, well-designed and well-implemented schemes to reallocate road space away from general traffic may help to improve conditions for pedestrians, cyclists or public transport users, without significantly increasing congestion or other related problems. There is no clear evidence on costs.

Vehicle choices

Policies that target car makers, notably voluntary or compulsory emissions standards, may be able to drive the development and availability of lower carbon vehicles. However the vehicles available are only part of the story, since offerings must be attractive to consumers and/or consumers must be incentivised, encouraged or even obliged to choose lower carbon options. Vehicle purchase is a complex consumer choice in which a wide range of attributes are assessed by consumers. Fuel economy is only one attribute, others such as safety, image and performance play an important role in purchasing decisions. The evidence suggests that there is a tendency for some consumers to display long-term 'myopia' at the point of purchase regarding running costs such as fuel prices, servicing and vehicle circulation taxes.

These choices matter. Emissions per km for the range of cars available today is wide, merely choosing best in class can reduce emissions by at least 50%, sometimes substantially more. The key issues and findings for individual policies are as follows:

Regulations and Standards

The evidence suggests that regulations that set standards for vehicle emissions can and have improved vehicle efficiency and so can reduce emissions. Until recently however, regulation and voluntary agreements have not been pursued with a level of sustained ambition sufficient to deliver large reductions in emissions from the vehicle fleet. A more ambitious target has now been agreed by the EU (95 g/km in 2020), although details of implementation are yet to be defined. There is also some evidence of rebound effects, since on-road efficiency appears not to have improved as much as new car test cycle efficiency. The evidence suggests that to be successful targets need to be mandatory, ambitious, progressive and not amenable to circumvention. Net costs to society and individuals are often low or even negative. Car purchase prices may increase by some vehicle fuel economy measures but these are often offset by lower running costs. There may also be macroeconomic benefits. However, higher capital costs may still deter 'myopic' consumers and some consumer groups may suffer a reduction in utility.

Fiscal measures influence consumers

Targets and standards can be complemented by fiscal measures. Evidence from a range of countries suggests that purchase taxes can have a quantifiable impact on sales of lower emission vehicles, particularly when accompanied by subsidies for the lowest emission cars. Purchase taxes have the most direct impact on sales of more efficient vehicles, and can be used to counteract consumer 'myopia'. Circulation taxes are levied on vehicle ownership and may be graduated by carbon emissions. Evidence from modelling and empirical evaluations indicates that these taxes can have a significant impact on the vehicle mix. Taxes can have welfare impacts and may have particular impact on poorer consumers, particularly those in areas poorly served by public transport and with larger families. These effects may be mitigated through schemes to subsidise the scrapping of old, high emission vehicles.

Information, labelling and car advertising

New car vehicle CO₂ labelling is mandatory in the EU. Views about the effectiveness of labelling differ within the evidence revealed in our review. However the evidence suggests that labelling is an important component of a wider range of policies. Some analysts argue that the relationship between emissions performance and future running costs needs to be explained more clearly to consumers and that this information should be extended to car advertising in a prominent and consistent way. We did not find any quantification of costs in terms of £/tC.

Rebound

Both vehicle purchase/circulation taxes and vehicle emission standards can be undermined to some degree by so called rebound effects, whereby the lower fuel costs associated with more efficient cars encourage drivers to drive more. The rebound effect for more efficient vehicles has been studied and estimated to lie in the range 20 to 40%. Whilst this suggests that absolute reductions in emissions can be delivered regardless of rebounds, fiscal and regulatory measures will be most effective when accompanied by policies which mitigate rebounds.

Fuel prices and taxes

Fuel prices affect the full range of choices relevant to transport emissions: in the short run they affect whether to travel, mode choice, distance travelled, driving behaviour and car occupancy; over a longer time frame they affect car choice and other aspects of travel demand such as home and workplace location.

There is evidence that in principle, and all other factors being equal, fuel price increases lead to fuel demand decreases, albeit in a relatively inelastic way. Hence fuel taxes can reduce emissions, or at least slow emissions growth. Unlike some other policies there is no potential for direct rebound effects to undermine savings.

Response to fuel prices is complex and depends upon availability of alternatives, income, total cost of motoring and a range of other factors. The strong relationship between income and demand for travel suggests that during conditions of economic growth fuel taxes need to be continually increased if they are to constrain demand growth driven by rising incomes. Response to price is generally inelastic, particularly in the short term, with the implication that large increases in prices/tax levels are needed to deliver significant reductions in demand.

There is evidence that short run price elasticity fell in the USA, at least up until the period to 2006, perhaps because consumers became 'locked in' to vehicle use. The most recent evidence suggests that high fuel prices and economic difficulties may be making consumer responses to fuel prices more elastic. Longer run elasticities are generally higher than short run, since consumers can adapt by buying more efficient cars and/or adjusting journey patterns.

Fuel taxes can be cost-effective, offering low cost emission reductions, in part because taxes raise revenue, effectively transferring income from fuel purchasers to other parts of the economy via government. Fuel taxation may have equity impacts and there is strong evidence that consumers resent fuel tax increases. There is also evidence that governments have become sensitive to the political difficulties associated with fuel tax rises. This, combined with the need for tax rises to be large and increase continuously to deliver significant CO₂ reductions, suggests that political acceptability is likely to be an important factor in the potential contribution of fuel taxation to emissions reduction from transport.

Cross-cutting findings

The review also raises some overarching issues:

The importance of policy integration

All of the policies reviewed above have shortcomings as well as advantages. In many cases there are synergies between policies, or opportunities to overcome problems through the implementation of additional policies. For example, improvements to public transport or cycling infrastructure can be augmented by road space reallocation and pricing which discourages car use. Put another way, and viewed from the road pricing/charging perspective, the availability of alternatives improves elasticity of response. Pricing and regulation can also assist in ensuring that new services draw users out of cars rather than from other modes or simply inducing new journeys. Similarly, individualised marketing can improve the utilisation of existing services, increasing occupancy, which improves both carbon efficiency and cost-effectiveness. Finally, provision of packages of policies that offer benefits such as new transport options may help overcome opposition to 'negative' policies such as new charges for road use or parking. Few policies will succeed in isolation, policies work best as packages.

Short-term and long-term impacts

In many cases short-term impacts and long-term effects may differ. For example the potential for public transport to absorb a significant fraction of car journeys in the short term is limited, yet the evidence suggests that locations/regions which do not provide effective public transport, and integrate transport with land use and other policies, become over time far more reliant on private cars. Similarly, the potential share of non-motorised modes (walking and cycling) is affected not just by the safety and attractiveness of routes and paths but also by the distance to key services and workplaces. It appears possible that short run improvements in walking and cycling provisions may also help to 'lock in' longer term patterns of travel behaviour that are inherently lower carbon because key services can be accessed more easily without a car.

Evidence on costs

Evidence on cost-effectiveness in CO₂ terms varies between policies. Whilst clear evidence exists for some policies such as vehicle emission standards and fuel duty it is either limited or non-existent for several policies related to travel choices. Remediating this will be difficult, particularly when it comes to accounting for combined benefits and policy interactions. However it is a key research task if the potential to reduce emissions through interventions that target travel choices are not to be overlooked by policymakers.

The rebound effect takes many forms but can be planned for and mitigated

Rebound effects are not confined to improvements in vehicle efficiency as the reconfiguration of costs and benefits of almost all transport policies can mean that unintended consequences occur. In our review we have highlighted these with respect to a number of policies and can categorise these as follows:

- Potential for policies to 'backfire' through loopholes e.g. CAFE in the US encouraged the SUV market
- Induced travel – increasing capacity on any mode can simply encourage more of its use rather than a substitute for less efficient modes
- Policies may 'leak' – shift purchase or other choices from the target sector to another (e.g. company car tax in the UK)

In all cases well-designed instruments and/or a combination of policies can mitigate rebounds and unintended consequences.

Evidence gaps exist in many areas and more research is needed, particularly on travel choice and behaviour

Whilst transport policies are well studied, transport policies to reduce CO₂ emissions are less than fully understood. There are many gaps in the evidence base and it is difficult to draw unequivocal conclusions about the potential impact of many policy options. The main problem for many of the policies that target *travel choices* is that their potential impact on CO₂ emissions is not as well understood as their role in meeting other policy goals. Indeed, it is possible that whilst policies which are designed to fulfil objectives other than carbon reduction will also reduce carbon, unless designed specifically to reduce carbon they may not.

In particular, the cost-effectiveness of policies designed to save carbon over and above what would have happened anyway, both long run and short run, requires careful and systematic analysis. Aggregated analysis and modelling may obscure important trends and the degree to which transport behaviour is always changing. Whilst this adds to the complexity of interpreting the evidence and formulating policy, it may also increase the potential for policies to harness behaviour and reduce emissions of carbon from the transport sector.

Conclusions

Short run options with clear potential to reduce carbon emissions in the UK include eco-driving and speed enforcement, expanding the use of non-motorised modes and improving vehicle occupancy. Improving the off-peak utilisation of existing public transport in cities and overall utilisation of buses and trains outside the major metropolitan areas may also be possible. Policies to promote these options include travel planning, fuel and road price increases, dedicated infrastructure or prioritisation for non-motorised modes, and training and education campaigns. Whilst policies to promote lower carbon car choices can have an immediate effect on new car sales it takes time for the vehicle fleet to turnover, so short run impacts on transport emissions are modest. Relatively low elasticity of demand for fuel suggests that the impact of fuel tax increases may be limited in the short run. However despite the political problems that surround fuel taxes in particular, prices can play an important role in determining travel and vehicle choices.

Medium term potential exists in reallocating road space to extend bus and light rail provision. Road pricing and fuel tax rises, competitive fares and service improvements, combined with information provision through travel plans are likely to be effective policy packages. It may also be possible to accelerate a shift to a much more efficient vehicle fleet. Circulation and fuel taxes combined with 'scrappage' subsidies may be able to deliver this goal if combined with information and education.

In the long run both travel and car choices can deliver significant emissions reduction: It is possible to provide an integrated approach to delivering new infrastructure for public transport and non-motorised modes, linked to land use planning such that demand for travel is reduced and significant mode and destination shifting is delivered. This is most likely to be achieved if support for mode shift is accompanied by road use and parking charges, fuel tax increases, road space reallocation and travel planning and other information provision campaigns. Relative prices of different modes play an important role in shaping long-term travel choices. It is also possible over time to facilitate a substantial shift to lower carbon cars. Our review suggests that the most effective policies are emissions regulation, purchase taxes and fuel tax, aided by rules on marketing and labelling. Rebound effects need to be addressed.

Overall, this review has revealed a wide diversity of evidence related to both lower carbon travel choices and lower carbon vehicle choices. The review suggests that policies can change behaviour, that behaviour can make a real impact on CO₂ emissions and in several key instances there is evidence that such policies are able to deliver emission reduction at relatively low cost, provided a well-designed package of policies is put in place. For many potentially attractive policies more work is needed to understand costs to consumers and society overall, as well as other factors such as political acceptability.

Glossary

ACEA	European Automobile Manufacturers' Association
ADAC	Allgemeiner Deutscher Automobil-Club
AIT	Alliance Internationale de Tourisme
AT&T	American Telephone and Telegraph, Inc.
bbf	Barrel (of oil)
BFTFII	Bike for the Future II
BT	British Telecommunications Group plc
BTRE	Australian Bureau of Infrastructure, Transport and Regional Economics
CAFE	US Corporate Average Fuel Economy
CBO	US Congressional Budget Office
CCAP	US Center for Clean Air Policy
CCP	UK Climate Change Programme
CEC	Commission of the European Communities
CERA	Cambridge Energy Research Associates, Massachusetts.
CfIT	Commission for Integrated Transport
CO₂	Carbon dioxide
CPRE	Council for the Protection of Rural England
CRA	Charles River Associates Inc.
DEFRA	UK Department for Environment, Food and Rural Affairs
DfT	UK Department for Transport
DoE	US Department of Energy
DoT	US Department of Transportation
DRI	DRI Global Automotive Group
DTI	UK Department of Trade and Industry
EAC	UK Environmental Audit Committee
EC	European Commission
ECMT	European Conference of Ministers of Transport
EEA	European Environment Agency
ESD	Energy for Sustainable Development
EST	Energy Saving Trust
ETSC	European Transport Safety Council
EU	European Union
EU VA	European Union Voluntary Agreement
EVA	Energie Verwertungsagentur (Austrian Energy Agency)

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FDE	Fuel Duty Escalator
FIA	Fédération Internationale de l'Automobile
g CO₂	Grams of carbon dioxide
g/km	Grams per kilometre
GDP	Gross Domestic Product
GHG	Greenhouse gas
GSi	Gear Shift Indicator
HMRC	Her Majesty's Revenue and Customs
HOV	High Occupancy Vehicle
ICARO	Increase of Car Occupancy EU transport research project
IEA	International Energy Agency
IEEP	Institute for European Environmental Policy
ITWP	Integrated Transport White Paper
JAMA	Japan Automobile Manufacturers' Association
KAMA	Korea Automobile Manufacturers' Association
Kmh or kph	Kilometres per hour
km/l	Kilometres per litre
LowCVP	Low Carbon Vehicle Partnership
LUTRAQ	Land Use Transportation and Air Quality
MORI	Market & Opinion Research International
MOSES	Mobility Services for Urban Sustainability project
mpg	Miles per gallon
mph	Miles per hour
MtC	Million tonnes of carbon
Mt CO₂	Million tonnes of carbon dioxide
NAIE	UK National Atmospheric Emissions Inventory
NCTR	US National Center for Transit Research
NICE	UK National Institute for Health and Clinical Excellence
NOx	Nitrogen oxides
NOVEM	Netherlands Agency for Energy and the Environment
NRC	US National Research Council
NTS	UK National Travel Survey
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries

PAYD	Pay-As-You-Drive
ppl	Pence per litre
psi	Pounds per square inch
PTP	Personal Travel Planning (or Plans)
£/tC	Pounds per tonne of carbon
R&D	Research and Development
RAC	Royal Automobile Club
RIVM	Netherlands National Institute for Public Health and the Environment
SACTRA	Standing Advisory Committee on Trunk Road Assessment
SDC	Sustainable Development Commission
SMEs	Small and medium enterprises
SUV	Sports Utility Vehicle
T&E	European Federation for Transport and the Environment
tC	Tonne of carbon
tCe	Tonne of carbon equivalent
TDM	Travel (or Transportation) Demand Management
TfL	Transport for London
TFP	Travel Feedback Programme
TIS	Consultores em Transportes Inovacao e Sistemas, S.A.
TNO	Netherlands Organization for Applied Scientific Research
TPA	UKERC Technology and Policy Assessment
TUD	Delft University of Technology
UKERC	UK Energy Research Centre
VED	Vehicle excise duty
VMT	Vehicle miles travelled
VOC	Volatile organic compound
VROM	Netherlands Ministry of Housing, Spatial Planning and the Environment
VTPI	Victoria Transport Policy Institute
WEC	World Energy Council

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1. Introduction

Transport is responsible for approximately a quarter of the UK's domestic CO₂ emissions and over 90% of these emissions are from road transport, with over 50% from passenger cars. Buses and railways account for approximately 5%, the bulk of the remainder being road freight (DfT 2008c). In the period 2003 to 2025, annual car vehicle kilometres travelled are forecast to grow by 28% (Eddington 2006). Transport is therefore already a very significant contributor to UK CO₂ emissions, and whilst efficiency improvements are expected to reduce emissions per vehicle km travelled, demand is likely to grow considerably in coming years.

In contrast to power generation for example, technology options for decarbonising the road transport sector are currently limited; electric vehicles are emerging in niche markets and other options such as hydrogen vehicles are in the research arena, whilst biofuels present policymakers with a range of challenges. Recent policy analysis in the transport sector has focused on the potential to improve the efficiency of motor vehicles and the timescales for development and challenges facing alternative power systems and fuels (King 2007; Gallagher 2008). Yet it is possible for policies to address not merely vehicle technologies and fuels, but also whether, where and how to travel, including how we drive and choose our vehicles.

This report from the Technology and Policy Assessment (TPA) function of the UK Energy Research Centre seeks to examine the merits of a range of different policies that offer the prospect of CO₂ emissions reduction from road transport. In

particular it considers the role of policies that target the 'behaviour' of individuals, companies and others as well as policies that target the technologies and fuels used in road vehicles. The focus of the report is public and private passenger transport by road and rail. The policy evidence is drawn from initiatives that either directly target carbon emissions from transport or which have other objectives but are likely to have a bearing on transport CO₂ emissions. The report is focused upon UK policy, but draws upon an international evidence base.

1.1 Rationale

All TPA topics are selected by the TPA Advisory Group which is comprised of senior energy experts from government, academia and the private sector. The Group's role is to ensure that the TPA function addresses policy-relevant research questions. The Advisory Group noted a predominance of attention to vehicle efficiency policies in recent analysis of transport policies and CO₂ emissions. UKERC's advisors indicated that the potential for policies to deliver carbon emissions reduction through encouraging changes to 'behaviour' (changing people's 'travel choices' and reducing car travel) may not be as well understood as policies that target vehicle technologies. There is also a sense amongst the transport policymakers consulted by UKERC that the behavioural dimension has been given less attention in CO₂ focused policy analysis than the development of lower carbon cars. The first report of the Committee on Climate Change echoes this concern, noting that

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the potential for mode shift and other behavioural changes to reduce CO₂ requires further research (Committee on Climate Change 2008). Because policymakers may be overlooking important opportunities to reduce CO₂ emissions UKERC decided to undertake this study.

1.2 Key question and objectives

The report provides a review of the effectiveness of policies that target both technology and behaviour, encompassing policies that promote lower carbon vehicles and policies that seek to reduce dependence/usage of private cars. It addresses the following key question:

What policies are effective at reducing carbon emissions from surface passenger transport?

In addressing this overarching question the report seeks to review the potential of a wide range of policies. The policies reviewed include: those that provide public and non-motorised transport infrastructure, that seek to inform travel choices, regulate car technologies, affect vehicle choices and a range of fiscal instruments which affect the prices of fuel, road use, car ownership and public transport.

This report does not undertake new modelling or empirical research; rather it provides a thorough review of the current state of knowledge on the subject, guided by experts and in consultation with a range of stakeholders. It also aims to explain its findings in a way that is

accessible to non-technical readers and is useful to policymakers. A key goal is to explain controversies where they arise. The report has the following objectives:

- Review the evidence for CO₂ emission reduction potential across policies that target car technology/choice and those that target wider travel choices
- Identify the key issues and problems associated with each policy type
- Identify evidence gaps and highlight future research needs
- Identify whether and where policies are complementary or synergistic
- Draw conclusions relevant to current UK policy

The evidence on each policy is reviewed against the following criteria:

- **Potential emissions saving;** in absolute and percent terms where the evidence permits.
- **Key issues and problems;** including reasons for effectiveness, evidence gaps, obstacles to policy implementation, interactions with other policies and potential rebound effects.
- **Costs;** where possible we provide evidence of costs in £/tonne carbon terms. In many cases this is not available in the literature and we provide a discussion of what evidence does exist.

It is important to note that the report does not provide a simplistic rating of 'technology policy vs. behavioural policy'. This is because policies that favour transport modes other than private cars



can also have a strong technological dimension, from traffic management that favours buses to new opportunities for tele-activity. Equally, moves to reduce carbon emissions from cars are affected to a substantial degree by behavioural factors such as consumers' choice of vehicle, driver behaviour and vehicle usage. It is also important to avoid the creation of a 'perceptual dichotomy' that might give rise to the notion that policymakers must trade off or choose between policies to improve the efficiency of cars and policies to reduce car use. We return to these issues in Chapter 2.

1.3 Limitations

The report reviews the effectiveness of a wide range of policies, based upon over 500 documents revealed through a systematic review of the transport policy literature. The review seeks findings relevant to CO₂ emission reduction from policies with a wide range of objectives in addition to those that explicitly target CO₂. Nevertheless the report is relatively narrow in scope. It is not able to provide commentary on:

- Methods for assessing marginal abatement costs for CO₂ emissions
- Wider (non-CO₂) cost benefit analysis for transport investment
- The validity of transport growth projections
- Other transport sectors (marine or air or freight)

The report considers travel and vehicle choices, and the range of policies that bear

upon them. The report discusses the role of regulation and other policies that promote improvement to vehicle technologies. However it does not consider in detail policies that target long run innovations such as the development of hydrogen cars, or policies associated with biofuels or other alternative fuels for cars or public transport including the development of electric vehicles. Developments in fuels and technologies are of immense importance in the transport policy debate; however the area where UKERC advisors perceived an analytical gap pertains primarily to choice and behaviour.

Importantly, a range of policies outside the *transport* arena, particularly planning and land use policies are not discussed in detail in this report, since the goal of this review is specifically to assess transport policies. However as we discuss further in Chapter 3, their importance to demand for travel and transport emissions, particularly in the long term, must not be understated.

1.4 How this report was produced

As part of this project, the project team undertook a systematic search for every report and paper related to the assessment question. This tightly specified search revealed over 500 reports and papers on the subject, each of which was categorised and assessed for relevance (see Chapter 2 and Annex 2 for details on this process). Experts and stakeholders were invited to comment and contribute through an expert group. A project team of expert consultants was commissioned



to categorise, review and distil the evidence (see Annex 1).

Each stage of the process has been documented so that readers and reviewers can identify the origins of our findings.

When the project was initiated a *review protocol* was published on the UKERC website. The approach aims to provide a comprehensive, transparent and replicable assessment of the *balance of evidence*.

Box 1.1: Overview of the TPA approach

The approach the TPA takes to all its work seeks to learn from a range of techniques referred to as *evidence-based policy and practice*, including the practice of *systematic review*. This aspires to provide more convincing evidence for policymakers, avoid duplication of research, encourage higher research standards and identify research gaps. Energy policy gives rise to a number of difficulties for prospective systematic review practitioners and the approach has in any case been criticised for excessive methodological rigidity in some policy areas. UKERC has therefore set up a process that is inspired by the approach described above, but that is not bound to any narrowly defined method or technique.

Assessment activities:

The process carried out for this assessment has the following key components:

- Publication of Scoping Note and Protocol.
- Establishment of a project team with a diversity of expertise.
- Convening an Expert Group with a diversity of opinion and perspective.
- Stakeholder consultation.
- Systematic searching of clearly defined evidence base using keywords.
- Categorisation and assessment of evidence.
- Synthesis, review and drafting.
- Expert feedback on initial drafts.
- Peer review of final draft.

1.5 Report structure

Chapter 2 provides an introduction to some of the complexities inherent in transport policy and explains the approach the report takes to tackling them.

Chapter 3 explores the issues related to

travel choices; whether to travel and how to travel and provides an assessment of the evidence on policies that can shape these choices.

Chapter 4 explores the issues related to vehicle choice and provides a review of the evidence on the policies which may be



brought to bear on both car manufacturers and car purchasers relevant to car choice and vehicle CO₂ emissions.

Chapter 5 discusses fuel prices. Fuel prices affect both travel choices and vehicle purchase choices. Hence fuel prices affect both parts 3 and 4 above and we discuss fuel prices separately.

Chapter 6 provides a discussion of the overarching and emergent implications of the preceding chapters. In particular it provides a review of policy packages that combine benefits or mitigate problems from individual interventions, highlights the areas where more research is needed and seeks to identify the lessons for policy in the short, medium and long-term future.

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2. Why transport is complicated: actors, choices and policies

2.1 Understanding transport choices – an actor/choice framework

The analysis presented in this report is concerned primarily with the relationship between policy and the behaviour of a range of actors in the transport sector. In the context of this report we consider only the actors that policy *bears upon*. Of course policymaker behaviour is in itself a subject for academic and other analysis. Policymakers are themselves actors, but this report is not able to discuss what influences policymaker behaviour or the inter-relationships between different types of policymaker. Carbon emissions in the sector can be affected at a number of points of influence over actors and their choices. Choices include where, how and whether to travel, which services to provide and what vehicles to manufacture. Because transport sector emissions can be affected by this wide range of factors, policymaking in this area is complex. Emissions from passenger transport are affected by travel choices, vehicle usage and driving style. In each case, complexities abound:

- Travel choice is complicated. A range of socio-economic as well as psychological factors affect the choice of whether or not to make a journey in the first place. The choice of destinations and thus travel distances are affected by a related set of factors to do with cost, accessibility and issues outside the transport sector relating to labour and housing markets and land use configuration. Journey time and convenience, as well as costs, service quality, perceptions, social norms and availability, will determine the mode of

travel. Decisions about whether, when and how far to drive are affected by a range of prices related to car use, such as road tolls, parking fees and fuel costs as well as ease of road access to the destination and congestion. All of these factors vary over a range of timescales and are differentiated by type of consumer.

- Vehicle choice is similarly affected by a complex set of vehicle attributes and consumer preferences. The former are a product of decisions made by car manufacturers about car development and design, about the characteristics of individual vehicles and about their model range. In turn, the factors affecting the investment decisions made by manufacturers are diverse and include voluntary or mandatory standards imposed on them. Consumer preferences are a product of lifestyle and income, fashion and social norms, demography, geography and of the costs of fuel, vehicles and vehicle ownership. Different consumers have different preferences. Consumer preferences and vehicle manufacturer choices are inter-related, since manufacturers will seek to both respond to consumer demands and to influence them through marketing and advertising.

Policy impact may be difficult to assess given the multitude of different responses, which can take place over different times and geographical scales. For example, attempts to reduce emissions may be subject to so called 'rebound' effects where potential fuel consumption or carbon emissions savings are 'taken back'. This may happen in a number of ways:

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greater fuel economy due to improved vehicle technology, perhaps as a result of regulatory standards, may lead to an increase in overall mileage travelled because the cost of travel for a given unit of distance has fallen. The potential energy saving is taken back in the form of increased mobility. Similarly, if road tolls reduce total traffic and ease congestion then traffic speeds may increase, to the detriment of overall fuel economy. The potential energy saving has been taken back in decreased journey times. Likewise, engine efficiency gains may be used to power heavier or faster cars rather than reduce fuel consumption. We return to these issues in the chapters that follow.

These effects need to be weighed carefully within a complex picture of policies and responses. A range of policies can be brought to bear upon the decisions being made by consumers and companies. The relationship between each choice, the actor making it and a range of interventions is illustrated in Figure 2.2 below. Similar figures are used to illustrate the relationship between actors, policies and choices in the chapters that follow. In each case the report explores the evidence for the efficacy of the relevant policies with reference to the nature of the actor and choice the policy seeks to influence.

2.2 The evidence on lower carbon transport policy

2.2.1 Categorising interventions and evidence

Interventions in the transport policy arena are frequently divided into two categories:

Those that promote improvements to the emissions performance of private vehicles and those that promote the utilisation of modes of transport other than private cars, often described as 'modal shift' (ECMT 2007). Another way of characterising the policies and policy responses relevant to lower carbon transport is between policies that target 'technology' and policies that seek to influence 'behaviour'. These categorisations might be assumed to be almost synonymous, on the basis that improvements to vehicles are largely driven by 'technology policies' and modal shift and behaviour are one and the same. However, behavioural issues are very relevant to vehicle choice whilst technological developments may be able to precipitate changes to transport mode or reduce the need to travel.

Nevertheless it is useful to be able to differentiate between *reducing emissions from cars* (i.e. making each car more efficient and less polluting) and *reducing the use of cars* (i.e. finding alternatives to car journeys and using cars more efficiently). This is because some transport policy goals, such as urban congestion reduction, can *only* be addressed through reducing (or retiming/displacing) car use. Others, particularly reducing emissions, can be addressed through either policies that reduce the emissions from vehicles in use or those that reduce total vehicle usage (or *both*).

2.2.2 Avoiding dichotomies

It is therefore useful to consider policy focus both in terms of whether they target 'behaviour' and 'technology' and in terms



of whether the focus is on vehicle choice/use or other travel choices, including whether to travel at all. Categorising transport policy choices offers powerful insights. However it is important to avoid presenting policies as either straightforward or dichotomous because doing so risks creating a number of problems:

- A trade-off between policies may be perceived when no trade-off exists
- The 'best' policy may be sought when the key requirement is for a properly designed package of measures
- The 'best may become the enemy of the good' such that effective policies that ought to be implemented are not because of over-reliance on a single policy

- Policy choices may become more susceptible to lobbying by interest groups
- Synergies between policies may be missed and important complementarities overlooked
- Actors perceived as not being central to a particular policy may be overlooked, when in practice there is a need to ensure that all actors are orientated to the same outcomes.

We provide a categorisation that avoids a dichotomous representation by first systematically searching for relevant literature, and then by assigning evidence to various *policy types* (see Box 2.1). This provides a basis for assessment of the amount of attention given to different policies and measures in the literature.

Box 2.1: A Systematic Review of the Literature

The TPA approach to evidence gathering is inspired by the practice of systematic review, and follows a series of clearly defined steps which are described in Annex 2 and briefly reviewed below:

- The first step was to identify the search terms, and the databases and other potential sources of evidence to which those search terms were to be applied. Example search terms include 'CO₂', 'Carbon', 'Vehicle', 'Car', 'Travel Behaviour', 'Technology', 'Regulation'. There are an extremely large number of possible permutations of the full set of terms, so the project team selected combinations to create specific search strings using Boolean terminology, which were then applied to each of the databases and other document sources. Search terms, search strings, databases and document sources can be found in Annex 2.
- The initial search stage returned several thousand 'hits'. The project team sifted this initial set, first by removal of duplicates, and then by reviewing document titles and abstracts to assess the relevance to the research questions.
- The result was an evidence base of over 500 items. The material includes publications in academic journals and national government and EU publications and reviews. Some of the evidence was of measures aimed not at transport CO₂ reduction per se, but nevertheless offered something relevant to our research questions.

continued overleaf



- Records of the evidence were then transferred into a database. This was used to construct 'policy record' documents which draw together all the evidence which relates to a particular type of policy, such as vehicle fuel efficiency standards. These policy records will be published as evidence tables on the TPA web pages alongside the main report. To further inform the project team thinking, a set of 'actor-choice summary' documents were produced which draw together all the evidence which bears upon each of the main combinations of actors and their choices in this arena. These policy records and actor-choice summaries were a key foundation used by the project team during the final report drafting stage.
- Finally, the policy records were assigned to policy groups e.g. 'Using Vehicles More Efficiently', to provide the basis for the analysis discussed in section 2.2.3.

2.2.3 The balance of evidence

Since the report is seeking to provide an evidence-based review it is important to take stock of where the *volume* of evidence lies for policies relevant to reducing transport CO₂ emissions in the round. This can give insights into where policy has been focused to date and the policy areas which have seen the bulk of research activity.

It is important to note that the focus of *policy action* and the focus of *policy analysis* are not necessarily aligned. It is possible that policy options have been extensively analysed yet have been given little attention in policy developments. Conversely, some policies favoured by governments may have as yet received relatively little analytical or empirical evaluation. Understanding why and where this occurs is an important research task in itself. Moreover the number of studies is not a proxy for the usefulness of a policy, since it is perfectly possible that a well-studied policy type is broadly concluded to be of little value. These caveats notwithstanding, the project team analysed where the volume of evidence

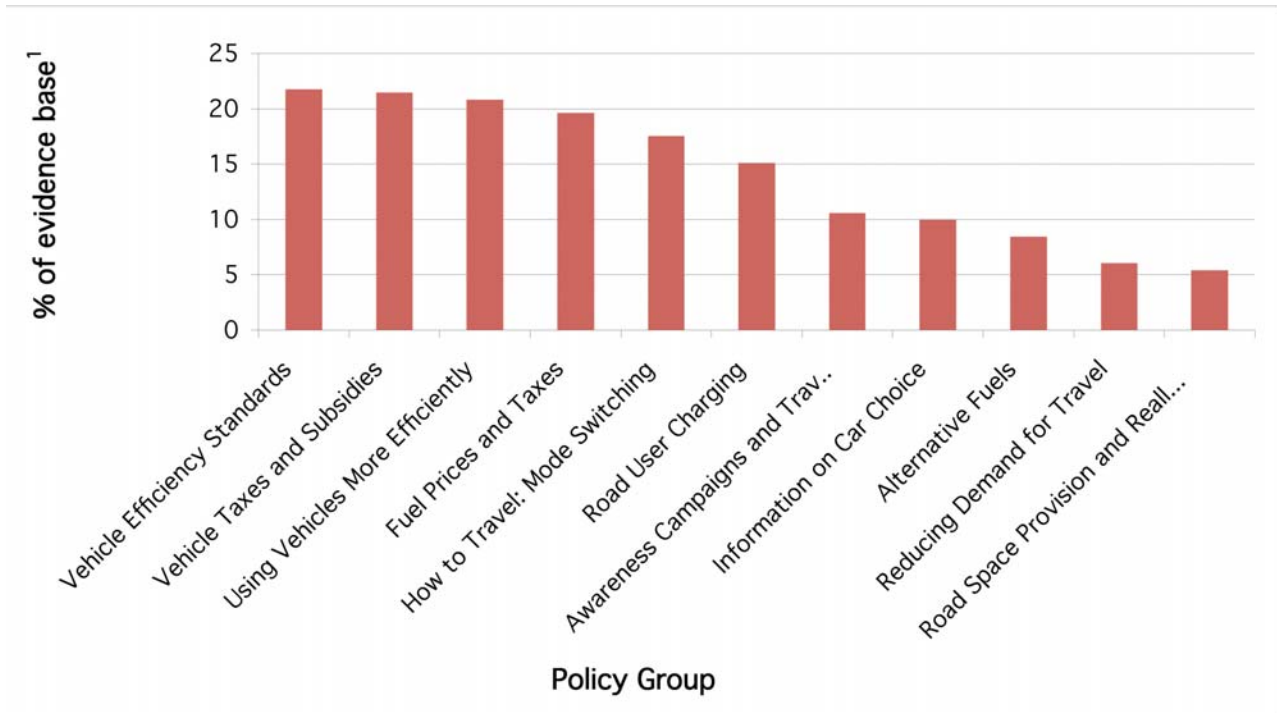
lies and the results of this analysis are show in Figure 2.1 below.

A clear question that arises from these figures is why so much of the analysis we uncovered in our review is concerned with vehicle regulation, vehicle and fuel taxes, mode switch and road pricing? Conversely, why do schemes that target travel choices through travel planning, support for non-motorised modes and a number of other behavioural measures receive relatively less attention? This is particularly surprising given the widespread attention that towns and cities across the developed world, and in many developing countries, have given to schemes related to issues such as walking and cycling, pedestrianisation, bus prioritisation and school and workplace travel plans. Moreover, the team and our expert consultants made specific efforts to seek out evidence in the areas less well represented above.

One reason is that a search for CO₂ related policies may not reveal the full set of policies with other objectives. Whilst the team used a range of alternative search terms and expert solicitation to adjust for this, many schemes did not explicitly target



Figure 2.1: Volume of useful evidence by policy group¹



carbon emissions (air quality, congestion and accidents were more typical objectives) and emissions impacts may not have been quantified or reported. Moreover the evidence from such studies is likely to be difficult to access using a universal review process since such evaluation evidence as has been published may be available only in local authority grey literature, which may not be web-based or may not be revealed through a conventional web search using standard search engines. We return to this issue in the conclusion, since we believe that accessing such evidence is a useful

primary research task for the future. In many cases evaluations with data relevant to CO₂ may not be available at all. In addition, where policies which do not have carbon emissions as their main goal are evaluated it can become difficult to assess the cost-effectiveness or efficacy of the policy in *carbon terms*. For example whilst eco-driving and car CO₂ regulation both target CO₂ *alone*, support for mode switch, car sharing and road pricing serve multiple policy goals. As such policymakers face both challenges and opportunities, which we also return to in the conclusion.

¹A policy group is a set of policy types which share attributes e.g. the 'Using vehicles more efficiently' group includes evidence on policies that relate to eco-driving, vehicle occupancy and high occupancy vehicle lanes. Full details of the grouping of policy types can be found in Annex 2. Figure 2.1 presents each policy group in terms of its percentage of the total documents which contained sufficient information to be used in the construction of the policy records (see Annex 2 for an explanation of the policy records) Many of the source documents contained relevant information on more than one policy type. For this reason the bars on the chart do not represent shares of a whole and do not sum to 100.



Table 2.1: Proportion of modelling vs. ex-post evidence

Category	% of policy type/evidence combinations ²
Modelling/Projections	48%
Ex-post assessment	33%
Unknown/not clear	19%

Some analysts suggest that the evidence from local authority and other schemes offers potentially hundreds of case studies (Goodwin 2008b). ‘Mining’ this data would be a valuable research activity, and we recommend that this is done.

The project team also compared the proportion of their evidence base that presented ex-ante modelling work (i.e. projections about what the effects of a policy *might be*), and ex-post assessment (i.e. measurements about what the effects of a policy *had been*):

These numbers are intended to give only a broad indication about the nature of the evidence base, but nevertheless it is clear that the most common (though not overwhelmingly so) of policy type/evidence combinations reflect modelling work rather than ex-post assessment³.

2.3 This report's approach to policy evaluation

Policymaking in the transport arena is complex because so many actors and choices have the potential to reduce

emissions. This report considers the following actors, choices and policies.

For reasons discussed in more detail in Ch. 3 we focus on policies and choices that are defined relatively narrowly as ‘transport’. However since wider policies and choices, particularly those that relate to land use and location decisions are also very important we include them in the list below. Policymakers and regulators are also important actors and their choices bear upon all of the issues below. However since the report is about policy choices and how policies bear upon *other* actors and *their* choices we do not include policymakers within the list below.

Actors

- Private consumers
- Car makers
- Public transport providers
- Employers, schools and other ‘destinations’ or significant trip generators
- Demand for travel
- Where to live and work

²Because individual evidence documents can cover more than one policy type, the breakdown is based on the relative shares of the total number of policy type/evidence combinations.

³This requires careful categorisation e.g. to distinguish between fuel price elasticity studies using longitudinal data sets (which are ex-post), and modelling work that uses these observed elasticities to forecast what may happen under a particular set of future circumstances.



- Whether to travel
- How far to travel (choice of destination and route)
- When to travel
- How to travel
- Bike/walk
- Public transport
- Car
- Occupancy
- Driving style
- Whether to own a car (or more than one car)
- What sort of car to own
- The range of cars to make/market

It is important to note that these choices interact. For example the decision about whether to own a car will be affected by the accessibility of various desired destinations by other modes and the choice of various destinations will be affected by their accessibility. Transport modellers therefore adopt a somewhat different and more sophisticated configuration which seeks to represent the destination/mode interaction. The list above is not the *only* way to characterise actor-choices. However we do believe it is a simple and intuitively attractive, and for this reason use it to structure the analysis presented in this report.

Relevant policy options include:

Reducing demand for travel, shifting to lower carbon modes and using cars more efficiently:

- Incentives for tele-activity such as teleworking
- Support for cycling and walking facilities
- Support for public transport
- Road space restrictions/rules including priority usage, pedestrianisation and rules on vehicle occupancy
- Incentives for individuals, companies and schools to reduce single occupancy car journeys
- Support for eco-driving and complementary measures such as speed limit enforcement
- Information and communication and planning tools
- Charges for road use and parking of private cars

Encouraging the production and adoption of lower carbon cars:

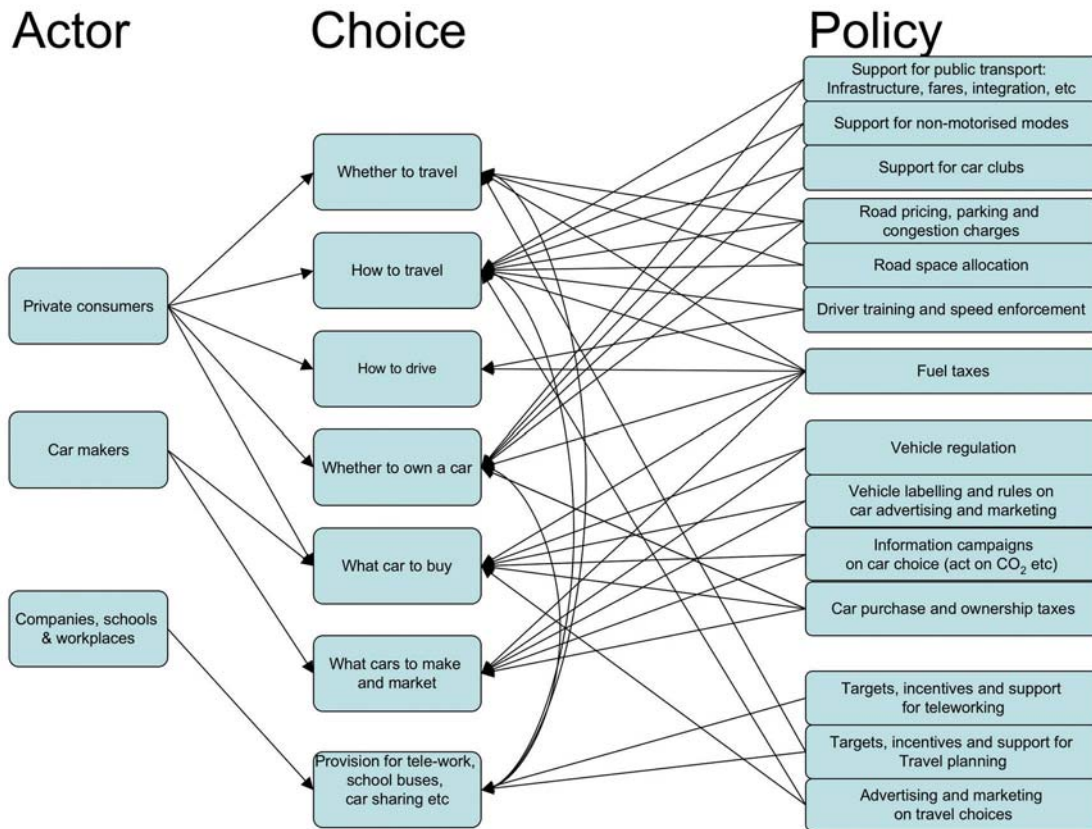
- Vehicle standards and regulations
- Fiscal policies that tax or subsidise vehicle purchase or ownership
- Policies related to vehicle labelling and marketing

Fuel excise duty and other policies that affect fuel prices

The relationships between actors, choices and policies are shown in Figure 2.2.



Figure 2.2: Actors, choices and policies in the transport arena



In each case the report considers the evidence base using the framework/criteria that follows:

- Evidence on potential carbon emissions saving
- From reviews of existing policies or through modelling, where available expressed in terms of total (MtC/CO₂) or percentage reductions available or feasible
- Key issues and problems
- Ambiguities in the evidence, obstacles to development such as capacity to expand or political acceptability, issues related to policy interaction

- Costs
- Where available, £/tC, as well as commentary on total costs and cost-effectiveness

In all cases we present material providing commentary and qualitative evaluation as well as quantification, and draw upon both UK and international evidence. Having reviewed individual choices and related policies we seek out emerging and overarching findings relevant to current policy debates.



3. Lower carbon travel choices: replacing journeys; using lower carbon modes; using cars efficiently

3.1 Introduction and context

This section focuses on those interventions that offer the potential to reduce carbon dioxide emissions by reducing demand for travel, facilitating the use of non-motorised modes or public transport and using cars more efficiently. In all cases the focus of analysis is on carbon emissions rather than the other advantages and disadvantages particular travel choices and transport policies may offer. For example public transport can contribute to policy goals related to congestion, road accident reduction and social inclusion irrespective of its role in reducing emissions of CO₂. However the main focus of this report is CO₂.

3.1.1 The importance of 'non-transport' policies

Travel choices are affected by a range of factors that are outside the immediate scope of this report. For example demographic trends and economic factors affect the location of homes, schools, shops and businesses. These factors in turn affect how far and how often individuals need to travel, and which modes of transport are most attractive to them. Policies play a key role in shaping such developments, for example through land use planning, through tax incentives that can affect business location, local/national authority choices about the location of schools, hospitals and public amenities, and a wide range of other 'non transport' policies. Hence policies outside the transport policy arena are central to transport decisions as are a range of important choices, notably where to live and work, that both affect demand for

travel and are affected by transport availability.

The importance of the long run trends and 'non-transport' choices described above to transport emissions should not be understated. Travel and land use related policies are interrelated (Steadman & Barrett 1991; Brown et al. 1998). The evidence is mixed as to the optimal density and mix of land uses to give the lowest energy demands overall. However, there is evidence to suggest that for locations which have been developed around the car so that journey distances to basic amenities are long, the 'carbon footprint' of the average citizen is much higher than locations where car travel is less necessary (Newman & Kenworthy 1999).

Transport and land use policies interrelate; relative costs, convenience and availability of different modes will over time affect land use choices by individuals and companies, which in turn affect planning decisions. Conversely, policies that seek to minimise travel demand through planning can be undermined if transport services are not appropriate (Goodwin & ECMT 2003). We return to the relationship between planning, land use and transport modes (particularly in the long term) in several places in this chapter and beyond. Nevertheless in what follows we focus primarily on what might be described as 'marginal' or 'short run' travel choices. By this we mean the travel choices that are available to individuals once decisions about land use and the location of home, school, work and shops have been taken.

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3.1.2 Travel choices and policy options

The main choices facing private individuals are as follows:

- Demand for travel
- Where to live and work
- Whether to travel
- How far to travel (choice of destination and route)
- When to travel
- How to travel
- Bike/walk
- Public transport
- Car
- Occupancy
- Driving style

Relevant policy options include:

- Incentives for tele-activity such as teleworking
- Support for cycling and walking facilities
- Support for public transport
- Road space restrictions/rules including priority usage, pedestrianisation and rules on vehicle occupancy
- Incentives for individuals, companies and schools to reduce single occupancy car journeys
- Support for eco-driving and complementary measures such as speed limit enforcement
- Information and communication and planning tools

- Charges for road use and parking of private cars

The relationships between these choices and policies are summarised in Figure 3.1 below. We deal with the effects of fuel prices and taxes on demand for travel and modal choice in Chapter 5.

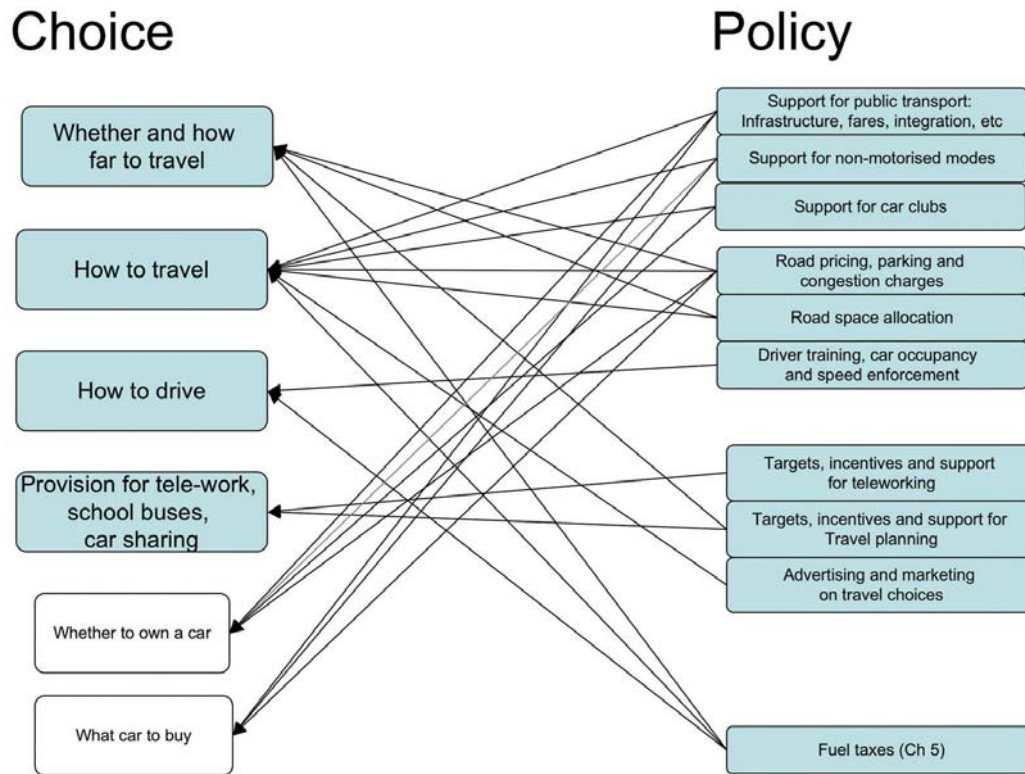
Car ownership

The decision about whether to own a car in the first place is of course relevant to many of the decisions above. Car ownership is affected by fiscal and other policy measures related to car purchase and use as well as the cost and convenience of alternatives to the car. The first of these is evidenced by the strong relationship which exists in the UK and elsewhere between income and car ownership (Dargay & Gately 1999) and the second by the clear correlation between land use density, the provision of public transport and car ownership (Newman & Kenworthy 1999; DfT 2007b). Yet cross-sectional evidence suggests there are substantial differences in car usage which are not related to either car ownership or income, so that countries with high income and car ownership such as Italy and Germany have lower actual car use than other countries with lower car ownership (DfT 1999; CfIT 2000). The UK displays rather a high level of car usage for its level of car ownership. This points to factors other than car ownership determining levels of car use such as spatial structure and the supply of alternative transport forms.

Nevertheless, within the UK, there is a strong relationship between car ownership and use: households with cars travel further and more often by car (DfT



Figure 3.1: Travel choices and policies



2007b). Data from the National Travel Survey (NTS) shows that when a car is acquired, trips by public transport reduce by around 80% for the driver and the non-drivers in the house also reduce their use of buses by more than half. Similarly, the NTS reveals that there is a negative correlation between household car ownership and level of cycling among males with the trip rate for cycling decreasing along with an increase in car ownership. Also, studies of travel behaviour and attitudes to travel point to the importance of habitual use so that car use can become so routine that 'choice' is not an issue as people act automatically without considering alternatives (see (Anable et al. 2006) for a review of this literature). It is also possible that the

desire to get the most value out of what can be a large investment, leads to the near exclusive use of the car, even for trips where other modes are more cost or energy efficient.

Whilst a variety of policies such as the provision of public transport and car taxation may affect levels of car ownership, there are few if any policies targeted directly at the level of car ownership *per se* in Western economies. Here we focus our attention on the marginal cost of car use, through factors such as road pricing. Chapter 4 considers what might be described as the fixed cost of *car use*; factors such as purchase and circulation taxes.

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3.2 Reducing demand for travel

The demand for movement, itself derived from the need to access services, facilities and goods, has been growing steadily in the UK in all decades since the Second World War in line with economic growth (Davis et al. 2007; DfT 2007b). The steady rise in car ownership from the early 1960s has been paralleled by a decline in walking and cycling and the mode share of all other forms of transport. However absolute travel (in terms of distance per person per year) has also grown substantially. Journey distances grew as society became increasingly organised around the car, with people living further from work and school, and travelling further to access other services and leisure facilities (DfT 2007b). In 1965, each person typically travelled around 3,660 miles per year by all modes, and by 2006 this had almost doubled to 7,133 (DfT 2001; DfT 2007b).

Road traffic in the UK is forecast to grow by 21% by 2015 (from a 2003 base) and whilst these projections are sensitive to constraining factors such as higher fuel prices, they are also sensitive to expanding factors such as population and employment growth (DfT 2008c). Non-transport influences such as land use planning and economic growth have an important impact on these trends (DfT 2008c). Notwithstanding this, some commentators argue that the scope for behavioural responses to make a significant contribution to reducing demand growth, hence counteracting these trends, has been consistently overlooked (Goodwin 2008b).

The demand for travel is a product of the number of trips and the distances covered by those trips. Removing from our scope the influence of macro-economic factors which generate travel and land use factors which have a dominant influence on distances leaves only a few policy instruments which impact directly on total travel demand.

Tele-initiatives are a rare example of a mechanism designed *specifically* to lead to a net reduction in the amount of travel in the system. Other policies work less directly by altering the costs and benefits of different modes of travel (e.g. support for public transport, fuel taxes, road pricing, speed limits) or the cost or ability to travel to a destination (e.g. pedestrianisation and car parking). Whilst raising road pricing, fuel taxes and public transport fares may all encourage home working these policies have primary goals other than demand reduction and are therefore discussed in the relevant sections below. Details matter here; for example if commuting requires the purchase of a season ticket then home working may be discouraged. It is not possible to attend to all these interactions in this report. This sub-section focuses on the mechanism to directly suppress the number of trips made or miles travelled – the use of ‘tele’ working or conferencing.

3.2.1 Teleworking, Telecommuting and Teleconferencing

Tele-activity is the use of telecommunications that can replace travel and this report considers telecommuting/ teleworking (targeted at the journey to work) and teleconferencing (which targets travel within the course of



work i.e. business travel). We do not seek to be exhaustive; for example we do not discuss videoconferencing, teleshopping or the role of telecommunication in social activities.

Evidence on potential emissions saving

A total of 21 relevant studies relating to commuting or business travel were revealed through the review process. Many studies present case study evidence from corporate programmes, presenting benefits in the context of reductions in vehicle miles travelled (VMT) and emission reduction by employees to and from work

and to a lesser extent in the course of business. Much of the work has assessed transport impacts in the United States, often centred in California where air quality related programmes encouraged employers to develop home working schemes, see (NCTR (National Center for Transit Research) 2007). A variety of empirical surveys characterising changes in the travel behaviour of telecommuters have been undertaken (Hamer et al. 1991). The consensus seems to be that for the commuters/organisations affected overall vehicle use reduces substantially as a result of telecommuting /working:

Table 3.1: Evidence on potential emissions savings – Teleworking, Telecommuting and Teleconferencing

<p>Vehicle use typically reduces by around 50–70% on telecommuting days (Matthews & Williams 2005) and telecommuting tends to be particularly attractive to longer-distance commuters (Henderson & Mokhtarian 1996;VTPI/TDM 2008).</p>
<p>In the Netherlands, during a year-long study, the total number of trips within a sample group of 30 households reduced by 17% and the distance travelled reduced by 16% due to telecommuting (Hamer et al. 1991).</p>
<p>The results from an AT&T Telework survey of 67,900 teleworkers taking part in a corporate program to promote home working in 2000 also illustrates that the size of potential savings is substantial (NCTR (National Center for Transit Research) 2007). Based on avoided mileage, allowing for some 'errand trips' (a form of rebound where workers make additional short car journeys when working from home) and using US average vehicle economy data the survey found annually (in year 2000):</p> <ul style="list-style-type: none"> • The avoidance of 110 million miles of driving to the office. • A saving of 5.1 million gallons (approx 25 million litres) of fuel • A reduction of 50,000 tons of carbon dioxide emissions.
<p>In the UK, replacing business travel with teleconferencing over the period 2006/2007 has allowed BT to avoid over 860,000 meetings and saved 97,000 tons of CO₂ emissions, net of emissions from electricity enabling the conference call (James & Hopkinson 2006;Anable & Bristow 2007;EEA 2008).</p>

continued overleaf



Teleconferencing also has the potential to replace public transport as illustrated by the BT scheme where 48% of the total trips replaced were public transport journeys. The survey also showed that 36% of the travel miles avoided due to teleconferencing were public transport mileage (BT undated).

There is some evidence on the UK-wide potential. A spreadsheet based modelling study for Defra (Anderson 2003) indicates an increase in teleworking would have the potential to reduce UK carbon emissions from cars by 1.8% per annum in 2010 and by 2.4% in 2050⁴. The same study estimates videoconferencing would have the potential to reduce carbon emissions by 0.8% in 2010 rising to 1.5% in 2050.

Key issues and problems

More work is required to determine how governments might best encourage tele-activity. One possibility is the provision of incentives to businesses such as tax reductions on the cost of equipment for home-based teleworking, or linked to the number of person-days of telecommuting. Another possibility is the provision of funds to develop satellite teleworking centres in remoter locations and to accelerate the installation of fast broadband capacity such as through Scotland's 'Digital Inclusion' strategy. Care must be taken to avoid a potentially large free rider problem, i.e. providing monetary benefits for telecommuting or broadband development that would occur anyway (IEA 2001). Some of the most successful attempts at encouraging telecommuting have occurred through the promotion of employee travel plans discussed in section 3.5.2 below.

The potential for rebounds may be significant. One study by the US Department of Energy found that around half of the travel-related energy savings of telework might be lost to rebound effects (DoE 1993; IEA 2001). Several factors may compromise potential reductions (van

Reisen 1997; Wiegman et al. 2003) (VTPI/TDM 2008); (Shaheen & Lipman 2007); (DoE 1993; IEA 2001); (Wolfram 2005):

- Energy use for home heating and cooling, and to power electronic equipment.
- Whether or not office space and energy use is reduced in proportion to the teleworking activity.
- Additional errand trips that would otherwise have been made during a commute.
- Vehicles not used for commuting may be driven by other household members.
- Increased travel by others on roads vacated by telecommuters.
- Relocation further from work possibly increasing travel distance to other destinations. Research in California showed that within two years, 15% of teleworkers had moved further from work (van Reisen 1997; Wiegman et al. 2003). Hence relocation may be an important long-term rebound.

⁴This is based on telecommuting potentially available to 25% of commuting vkm with 20-40% (increasing from decade to decade) of drivers responding and 24% reduction in miles by each driver who responds.



There is some evidence of explicit targets or programmes for tele-activity. For example, the Netherlands Ministry of Transport has set a country-wide target of reducing peak hour traffic by 5% by 2015 via teleworking (TUD 1997; Marshall & Banister 2000). The US Federal Government and some states and local governments have tried promoting teleworking in recent years using statutes and regulations to encourage telework (Nelson et al. 2007). Some of these promote only teleworking and others promote it as part of a broader set of initiatives to influence single occupancy vehicle travel to work. For instance, in 1999, the National Air Quality and Telecommuting Act established pilot telecommuting programmes in five major US metropolitan areas to offer organizations credits for avoiding nitrogen oxides emitted from vehicles if they let their employees telework or participate in other pollution-reducing initiatives. The credits could be traded with firms that needed emissions reductions for purposes of compliance with the US Clean Air Act. However, (Nelson et al. 2007) conclude that this programme suffered from the difficulties of accurately measuring emissions reductions and in determining whether they are 'surplus, permanent, quantifiable, and enforceable'.

Given the growing importance of e-commerce and other internet-related activity, it is likely that the fraction of the work force suitable for telecommuting will continue increasing (Matthews & Williams 2005)⁵. Their view is that teleworking is happening without the assistance of

directly-related government policy and as it moves more into the mainstream, it is less likely to require special programmes or external support. However, the National Travel Survey measures home-working and shows that there is little sign that the uptake of broadband has resulted in an increase in the number of people working from home. The very latest data (DfT 2008d; DfT 2009) shows that around 3.5% of people always work from home and this number has remained essentially unchanged since the question was first asked in 2002. The number having worked at home at least once in the previous week is rising gradually and stood at around 7% in 2008 (DfT 2009). The proportion who say they haven't worked from home but that it would be possible for them to do so stands at around 10%.

Costs

There is some evidence of cost-effectiveness. It is argued that tele-activity reduces travel costs for private individuals compared with commuter/business travel by privately owned car or long distance public transport commuting. Costs are typically a few hundred pounds for a computer, plus internet service of several pounds per month (VTPI/TDM 2008). Moreover, evidence from business programmes suggests that tele-activity can result in substantial negative costs from avoided travel/subsistence costs and freed up management time (Roitz et al. 2003; Matthews & Williams 2005; EEA 2008). Rebound effects are undoubtedly a factor but even if half the energy savings

⁵Matthews and Williams focuses on teleworking populations and practices in the United States and Japan to assess how energy use associated with transport and building infrastructures might change according to current and future wider adoption of teleworking.



from tele-activity is lost to such off-sets, it could represent a very low cost, or negative cost, way to reduce CO₂ emissions (IEA 2001). Our review has not revealed estimates of costs in terms of £/tC.

Summary

Whilst the evidence on a company case study basis suggests teleworking may have a useful role in reducing demand for travel, considerably more work is needed on the potential for tele-activity to influence car dependent lifestyles and affect energy consumption across the transport as well as commercial and residential building sectors. It is not clear how much tele-activity might increase without intervention and what role there is for policy. It is difficult to draw firm conclusions about the potential of tele-activity to reduce emissions, or the policies required to accelerate tele-activity. The main problem is that there does not appear to have been much macro-level, UK-specific analysis of the potential for tele-activity to reduce emissions. Key questions include:

- The proportion of the working population with jobs appropriate for some degree of teleworking
- Expected trends towards teleworking in the absence of policy
- Size, nature and mitigation of potential rebound effects
- The potential for teleworking to facilitate more pervasive lifestyle change such as the reduction in household car ownership previously dictated by the need for everyday

commuting to work. It may be possible, for example, for some householders to join a car club (see section 3.4.2).

- Potential for video-conferencing, shopping, learning and other travel needs that may be avoided in addition to commuting and business meetings

Additional research addressing all or some of these issues could greatly assist policy analysts in assessing the potential role of tele-activity in reducing emissions. Shortly before this report was finalised, the Department for Transport published a qualitative study on the motivations and travel behaviour of teleworkers (Penfold et al. 2009). Analysis of this nature is likely to provide valuable insights and DfT's analysis appears to correlate with some of the findings related to rebounds cited above, particularly the use of cars for non-work purposes or business trips other than commuting. Nevertheless, our conclusions are that tele-activity appears to offer considerable potential to reduce emissions but that further research is needed to assess the scale of the opportunity on an economy-wide basis.

3.3 How to travel: Mode switching

This section discusses the evidence revealed in our review on the role for non-motorised travel and various forms of public transport in reducing CO₂ emissions. It reviews the potential for emissions reduction and the issues surrounding policies specific to each of these. Section 3.4 discusses more efficient



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uses of cars through increased occupancy, use of car clubs and driving style. Section 3.5 then goes on to review the role of various overarching interventions/programmes which seek to provide information about 'travel choices' and/or to encourage or oblige individuals, schools, employers and others to use cars more efficiently, shift mode or reduce travel demand.

3.3.1 Non-motorised modes: Support for walking and cycling

Walking and cycling are low-emission alternatives to public transport and car use. They are particularly suitable for urban and suburban environments where they can replace the relatively high emissions of short car trips. Although CO₂ emissions from these trips represent a relatively small fraction of the total (DfT 2008c), fuel consumption and emissions per kilometre are significantly higher when the engine is cold and not working at full efficiency (Blaikley et al. 2001).

Evidence on potential emissions savings

A total of 35 relevant studies were revealed through our review. In general it appears that the potential for non-motorised modes, and associated policies, to reduce CO₂ has not been especially well-studied – particularly in terms of the relationship between spending on cycling infrastructure and impact. Also, there is far more information on cycling than walking initiatives. A joint report from the European Conference of Ministers on Transport (ECMT) and the OECD notes that most countries do not include support for cycling and walking within their CO₂ reporting, despite their potential importance as policies to manage demand for motorised transport and hence CO₂ emissions (ECMT 2007).

Nonetheless, there is some evidence that non-motorised modes can contribute significantly to emissions reduction, and that the UK could do more to exploit this potential:

Table 3.2: Evidence on potential emissions savings – Support for walking and cycling

Analysis based upon travel surveys and focus groups suggests that 5-10% of car trips could reasonably be shifted to non-motorized transport in a typical UK urban area (Mackett 2000;VTPI/TDM 2008). Whilst shifting 5% of car trips to bicycling and walking might reduce total vehicle mileage by just 2%, since these are short trips, emissions may decline by 4-8% due to the relatively high emission rates of the vehicle mileage foregone (on short trips vehicle operation is less efficient for a larger fraction of the total journey as the engine is cold) (VTPI/TDM 2008).
Analysis conducted in Portland, Oregon through the Land Use Transportation and Air Quality (LUTRAQ) project suggests that the adoption of pedestrian-oriented design features in residential areas could result in a decline of up to 10% in local VMT per household (Dierkers et al. 2005).
An England-wide mode shift which delivers a 50% increase in mode share for walking and a tenfold increase in mode share for cycling could deliver a saving of nearly 2MtC (7.34 MtCO ₂) per annum (Sustrans 2008).

continued overleaf



Carbon savings from the UK's National Cycle Network in 2003 were assessed by (ESD-Sustrans 2005). Based on approximately 540 million cycling miles, CO₂ savings were estimated to be over 29,000 tonnes. 5,500 tonnes were also saved by pedestrian use of the Network.

Britain has one of the lowest rates of cycling in the EU, with only 2% of all journeys made by bike. The Netherlands has the highest rate in the EU with 27% of journeys cycled (Environmental Audit Committee 2006). Germany and Denmark also have cycling levels ten times higher than in the UK.

In the UK, the National Travel Survey reveals that approximately 25% of all car trips are less than 2 miles/ 3 kilometres and over half (56%) are less than 5 miles, although a proportion of these are part of longer trip-chaining events (DfT 2007b).

Detailed travel behaviour research for the UK Sustainable Travel Demonstration Towns shows that nearly a third of all trips are made by car when only subjective reasons prevent them being made on foot, by bicycle or public transport (Socialdata 2005)

Analysis by (Wardman et al. 2007) indicates that an integrated program of improved cycling conditions, financial incentives and improved trip end facilities could increase British cycling rates from about 6% to more than 20% for commute trips under 7.5 miles, about half of which displace car trips.

The UK Government's advisory group Cycling England set out a proposal called "Bike for the Future II" (BFTFII) to invest £70m a year to 2012. BFTFII proposes a target for Cycling England's specific programmes to raise national cycling levels by 20% (from 2007 levels) by 2012. It is estimated that this will save up to 50 million car journeys a year mainly in congested areas and at peak times and abate 35,000 tonnes of CO₂ per year by 2012 (Cycling England 2008)

In London a combination of measures to enhance cycling, notably road space reallocation, the disincentive to drive created by the congestion charging scheme and associated reduction in car numbers has helped increase cycling levels by 30% since its inception in 2003 (Pucher & Buehler 2008), citing (TfL 2007b; TfL 2007c). Bike parking at train stations and payments for cycling to work can also be effective (Pucher & Buehler 2008); (Wardman et al. 2007).

As noted above, Sustrans have carried out some analysis of potential carbon savings from increasing the share of non-motorised (or 'active') modes (Sustrans 2008). They have been more optimistic than the Cycling England targets, basing their estimates of potential on best practice examples in European cities and

the evidence on the potential for behaviour change highlighted in the UK 'sustainable travel demonstrated towns' cited in Table 3.2 (Socialdata 2005).

None of these calculations allow for the possibility that in addition to mode switching, walking and cycling could also



facilitate *destination switching*. As well as the pure like-for-like replacement of car journeys with non-motorised modes, journey lengths could also be altered by the substitution of longer car journeys with shorter ones by non-mechanised means. Our review found no explicit evidence of the responsiveness of destination choice to changes in cost or travel time. However, much traditional transport modelling is predicated on the assumption that destination patterns and journey length distributions are sensitive to these parameters (Goodwin 2008a). It seems logical to consider the potential impact of total travel reduction by shifting people's travel choices from longer to shorter trips and the multiplier effect of impacts beyond short-term modal shift as people become more confident and experienced with sustainable travel choices. It is possible that if people choose to live, work and play in locations that are accessible by walking or cycling, then over time, this can have a multiplying effect on travel behaviour choices. In such circumstances, some people may prefer not to own a car, but rather hire a car occasionally or join a car club (Section 3.4.2) – particularly if accompanying policy measures make sustainable travel a more attractive option.

Key issues and problems

Whilst one reason for the popularity of cycling in the Netherlands may be the topography of the country there are a variety of policy related reasons why the UK appears less favourable to cycling and walking than many European countries with similar climates:

- A key reason for the higher levels of cycling in the Netherlands, Denmark

and Germany is that cycling is much safer than in the USA and the UK. Cycling is over five times as safe in the Netherlands as in the US and more than three times as safe as in the UK (Pucher & Buehler 2008).

- Other reasons include greater supply of urban motorways and parking; car-free city centres being less common; traffic calming is less widespread; speed limits that are generally higher; and many firms provide incentives to buy and drive cars to work (Goodwin 1999; McClintock 2002; Tolley 2003; Banister 2005; Banister et al. 2007; Pucher & Buehler 2008).
- It is widely believed that commuters are more likely to cycle where cycling levels are already high, all else being equal. This circle of cause and effect may be related to cultural factors which may explain why cycling levels in some areas of Northern Europe are particularly high (Wardman et al. 1997).

Policy effectiveness has been evaluated and a number of measures can encourage people to travel by non-motorised modes:

- Enhancing or extending cycling infrastructure is key to greater cycle use (Dill & Carr 2003); (Pucher & Buehler 2006); (Marshall & Banister 2000). (Wardman et al. 1997) argue that a segregated and continuous cycle path has by far the largest impact though the cause and effect relationship between infrastructure and cycling levels is not necessarily clear-cut. Nevertheless "analysis confirms the hunches of public policy makers that at least some, perhaps



not an inconsequential number, of commuters will be responsive to the bicycling option if only it were made available” (Dill & Carr 2003). For instance, studies have found a positive relationship between the supply of bikeways and the bike share of work trips (Nelson & Allen 1997; Pucher & Buehler 2006). In US cities, a positive relationship was found between the share of bicycle work trips and the extent of bike lanes and paths per 100,000 inhabitants (Dill & Carr 2003; Pucher & Buehler 2006).

- (Wardman et al. 1997) conclude that although investment in facilities such as segregated cycle lanes may lead to increased cycle demand, it would be insufficient to achieve targeted levels of cycle use. This suggests that other traffic management and restraint measures are needed to achieve higher levels of cycling (see below).
- A comprehensive review of evidence by the National Institute for Health and Clinical Excellence (NICE 2006) to identify which transport interventions are effective in increasing non-motorised travel found that ‘the review level evidence is inconclusive on the effectiveness of engineering measures – such as creating or improving cycle routes, constructing bypasses, traffic calming, or combinations of these – in achieving a shift from car use to cycling’.
- The evidence also suggests that alterations to land use need to be integrated with transport policies in order to realise the greatest potential to maximise short journeys undertaken by bicycle (Anable & Bristow 2007).
- (Woodcock et al. 2007) state that a combination of approaches is necessary to ensure that carbon reduction gains from increased cycling are not lost due to substitution by other vehicles on the road. They list the following measures: less car parking, lower speed limits, priority at junctions and improved connectivity and permeability (by opening up road closures to cycle traffic, closing routes to cars; removing one-way systems or allowing contraflow cycling and grid layouts (not cul-de-sacs)).
- (Pucher & Buehler 2008) have also analysed national aggregate data for the Netherlands, Denmark and Germany and contrasted this with the UK and USA. They conclude that it is ‘the coordinated implementation of multi-faceted, mutually reinforcing policies and approaches that best explains the success of the former three countries in promoting cycling. This contrasts to the marginal status given to cycling in the UK and USA.
- Around 50 European cities have automated ‘city-bike’ sharing systems which offer short-term rental of bicycles available at numerous points around a city on time-based tariffs. For example, Barcelona’s Bicing system is planned to cover approximately 70% of the city’s area. Although there is very little evidence on the extent to which the additional cycling journeys generated by these hire schemes originate from car trips, it is clear that they are breaking some of the existing



barriers to cycling in these cities including access to a bicycle, parking and storage and maintenance whilst at the same time enhancing the image of cycling (C40 2008).

As we discuss in Section 3.5, so called 'smarter choices' measures; local, bespoke information and promotion campaigns, also hold the potential to influence short trips (Cairns et al. 2004; Wolfram 2005). However, travel behaviour change is more likely to be sustained over time if associated 'hard' policies (e.g. improving the safety, routing and physical environment for walking and cycling, reallocation of road space away from private cars and road pricing) are also implemented at the same time (Woodcock et al. 2007).

Costs

There is variability across the EU in cycle infrastructure investment, though no evidence was found on the relationship between spend on infrastructure and impact on carbon emissions. Evidence presenting cost in £/tC was not revealed in our review. Currently, the UK Government plans to increase the national cycling budget by 500%. In 2008, Cycling England has a budget of £10m which will increase to £20m upwards to £60m over the period 2009 to 2011 (DfT 2008a). By contrast, the Dutch Central Government, between 1990 and 2006 contributed an average of €60 million per year to various cycling projects (Pucher & Buehler 2008). As with a variety of policies which target modal shift, support for walking and cycling offers multiple benefits including, but not only, carbon emission reduction. Estimating carbon abatement costs in

such circumstances presents some difficulty.

However the recent UK Government investment has been influenced by the prospect of good value for money which cycling projects exhibit. Economic research commissioned by Cycling England showed that a 20% increase in cycling by 2012 would release a total cumulative (not per annum) saving in healthcare costs, damage costs of pollution and costs of congestion worth £500m by 2015. Within this total, the value of the emission savings (local air pollution and climate change) alone is projected to be £71m (SQW 2007).

Summary

There is evidence to suggest that a significant fraction of journeys can be made by walking or cycling, since this is the experience of several other European countries. However the literature reveals a relative lack of attention to non-motorised modes in reporting on CO₂ emission reduction and climate policies.

It is possible to estimate the fraction of trips that could be made by bicycle or on foot, and derive from this an estimate of the contribution these modes could make to emission reduction, assuming that there is mode switch from car to foot or bicycle. Increasing the share of cycling in Britain to levels closer to those of our Northern European neighbours could yield emissions savings in the UK of around 2 MtC (7.34 MtCO₂) per year (approximately 6% of road transport emissions) if pure mode switching was taken into account.

Inter-country comparisons suggest that effective policies to make cycling safer and



more convenient, in particular through segregation and prioritisation, correlate closely with levels of cycling. However there is also evidence that policies that penalise car use (congestion charging in particular) can be effective in promoting the use of non-motorised modes, and individualised marketing can assist in the uptake of cycling. It is important to note the potential for walking and cycling is intimately bound up with wider factors that help to determine journey distances. Increasing the role of cycling is not just a matter of making cycling more attractive and safe, or even of penalising car use; it is also a matter of making more services, shops, schools and jobs within reach of a non-motorised trip.

Our review did not reveal any systematic attempt to estimate the cost of saving carbon using policies to promote non-motorised modes. The relationship between the costs of various factors that increase the attractiveness of cycling and walking and emissions reduction would be a valuable area for future research.

3.3.2 Support for public transport

Public transport plays an important role in transport policies in many countries. ECMT/OECD report a 'large number' of policies related to modal switch from car to less CO₂ intensive modes and suggest that this reflects the many 'co-benefits'

(meeting multiple policy goals at once) such policies can provide (ECMT 2007). The attention many governments appear to devote to public transport in their policy discussion on lower carbon transport might also reflect the fact that public transport offers much lower emissions per passenger distance than private cars (see Table 3.3).

Evidence on potential emissions savings

Our review revealed 42 studies relevant to carbon emissions reductions arising from either fare pricing or from infrastructural/service enhancements to bus, light rail or rail transport. We note that there is a significant lack of ex-post data regarding carbon savings available from public transport measures with most of the evidence comprised of modelling results.

There is some evidence that pricing, service and infrastructural changes to public transport systems can and do result in modal shift and efficiency gains leading to positive effects on emissions levels:

Table 3.3: CO₂ emissions intensities by travel mode, adapted from (DEFRA 2007a)

Travel mode	Rail	Passenger cars Petrol	Passenger cars Diesel	Bus/Coach
gCO ₂ / passenger km	60.2	130.9	124.2	89.1

Note: Table 3.3 makes simplifying assumptions about vehicle load factor for all modes and the fuel mix of rail, see (DEFRA 2007a) for more detail.



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Table 3.4: Evidence on potential emissions savings – Support for public transport

<p>The EC’s Auto-Oil II modelling program for Athens assessed the effect of a policy to reduce public transport fares by 30%. This would cut annual CO₂ emissions for the city’s transportation system by 1%, although the time period required for this saving to materialise is not made explicit. (European Commission 1999;IEA 2001).</p>
<p>According to (IEA 2001) if a national government provides (or increases) transit subsidies in all cities and towns so that fares can be cut by 30%, and the policy affects about half of the country, then annual national emissions of CO₂ would decline by 0.5% by 2010.</p>
<p>Modelling of a free fare public transport system in Stockholm resulted in an estimated 4% reduction in the city’s CO₂ annual emissions by 2030 (Robert & Jonsson 2006).</p>
<p>Modelling of bus signal priority in Helsinki, Finland in 1999 indicates that a 5% reduction in annual fuel consumption is achievable (Lehtonen & Kulmala 2002;Shaheen & Lipman 2007).</p>
<p>Potential immediate fuel savings from road transport across all IEA (International Energy Agency) regions could exceed 4% if selective changes to public transport pricing and to infrastructure/services were immediately introduced (Noland et al. 2006).</p>
<p>Modelling in the US of bus frequency improvements in conjunction with additional service improvement measures resulted in estimated daily VMT savings of between 0.5% and 1%. Potential daily VMT savings from light rail transit is estimated at 2% (Dierkers et al. 2005).</p>
<p>According to (Brand & Preston 2003) light rail systems achieve a sustained modal shift away from car travel. In the UK, between 18% and 25% of light rail users were former car drivers.</p>
<p>A recent major study (ECMT 2007) reported evidence submitted to the UNFCCC on CO₂ emissions savings from public transport investment and initiatives in a number of countries including Austria, Canada, Czech Republic, Finland, Ireland and Slovenia: Whilst all the schemes were forecast to deliver emissions reductions ranging from 0.065 to 3 MtC (0.24 to 11 MtCO₂) per annum, the evidence on costs per unit of CO₂ saved was not clear.</p>

Key issues and problems

What makes the difference in the rate of patronage growth in response to service improvements and fare changes is a complex field in which the evidence is mixed and context dependent. However, a recent study in the UK possibly captures a useful categorisation of the types of measures which appear to make the difference. (White 2008), using published

elasticities on the way people respond to real fare levels, concludes that the growth in public transport patronage in London is much greater than would be expected from the real fares and service level changes alone. Similarly, the fall in patronage on other metropolitan areas of the UK would have been greater if it were all a function of rising car ownership and higher fares/ lower services during the period 1999-2006 covered by the study.



The report attributes the bulk of London's success to factors such as service stability, extensive bus priority, good passenger information, simplified fares and high quality interchange points. Only 5% of the growth can be attributed to the Congestion Charge since 2003. Outside London, the slower than expected decline in patronage is likely to be due to growth in the use of low floor buses, higher quality interchanges and marketing initiatives by operators and Passenger Transport Executives.

Several studies indicate that short-term CO₂ emission savings from public transport are often relatively small. For example, modelled enhancements to the Athens transit system produced a 0.3% reduction in annual city transport CO₂ emissions. Another modelling exercise - undertaken by NOVEM, the Dutch Environment Agency - found that a scenario to improve public transport cut annual CO₂ emissions for the Dutch transportation system by a similarly small percentage, 0.5%, between 1990 and 2010 (Michaelis 1996; IEA 2001). A study of the impacts of transport infrastructure investment in 13 European cities showed transport CO₂ emissions reductions at most in the range 2-5% (Transec 2003; Annema 2005), whilst (Dierkers et al. 2005) and (Noland et al. 2006) report passenger car fuel savings and/or VMT reductions of between 1-2% from public transport infrastructure or service improvements.

Indeed, whilst noting that well targeted support for public transport has an important role to play, ECMT/OECD suggests that the prominence given to modal shift policies is at odds with its

potential to reduce emissions (ECMT 2007). The principal limitations of public transport are as follows and we explore each issue in more detail below:

- Capacity for expansion and occupancy
- Induced demand for travel
- Non-beneficial mode shift
- Price responses and cross-elasticity of demand
- Extra congestion affecting car users

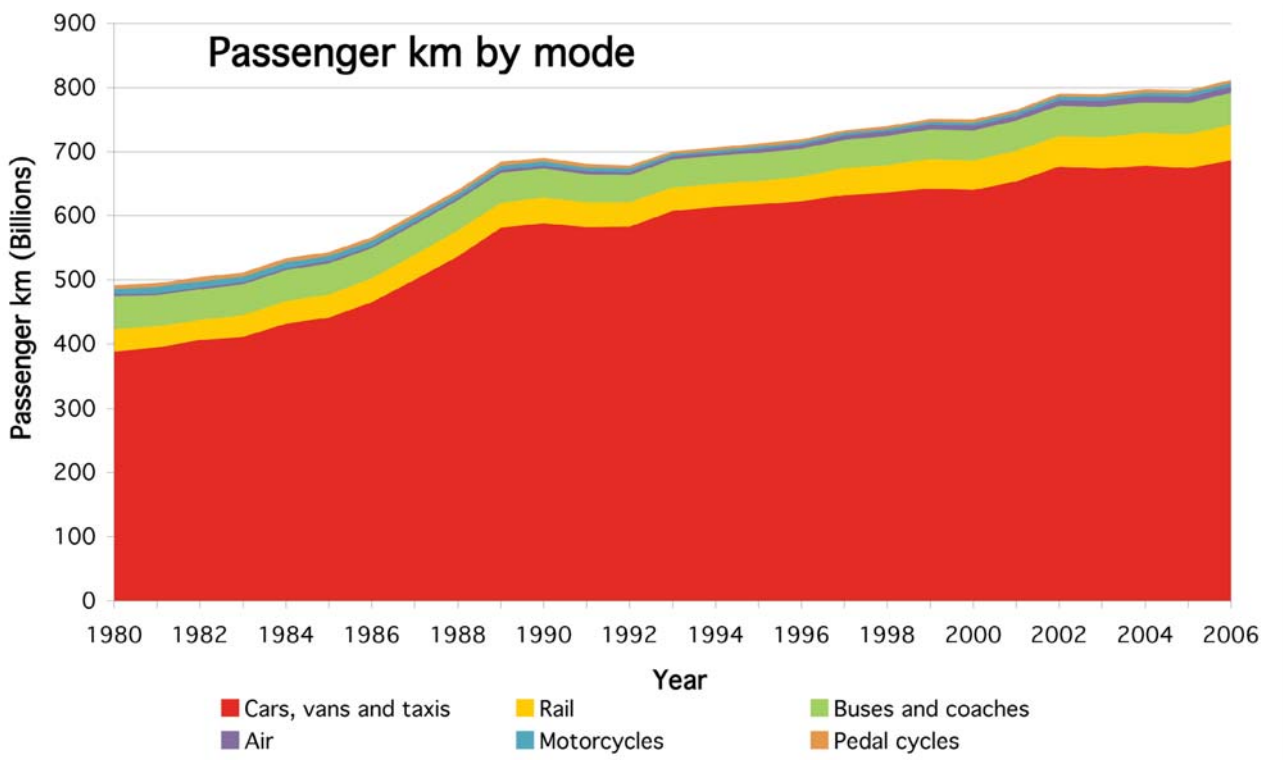
Capacity for public transport to expand

Even a small rise in public transport market share represents a large increase in the transport activity for public transport modes. This is because public transport modes have much smaller shares of total passenger mileage than that of private cars (see Figure 3.2 below). Even a relatively small change in share represents a large increase in the transport activity for these modes. Neglecting for a moment the role for reducing overall demand for travel via home-working or destination switching, this illustrates the scale of expansion in public transport (and other modes) needed if the use of private cars is to be substantially reduced. The scope for the public transport network to expand sufficiently to make a substantial contribution to emission reduction has therefore been questioned by some analysts (Stopher 2004).

The picture regarding potential for expansion is complex and differentiated by time of day according to occupancy. Busy routes and urban commuter systems may be unable to absorb a substantial fraction



Figure 3.2: Passenger kilometres travelled by mode in the UK (Source: (DfT 2007c))⁶



of car journeys without major expansion. This may be both expensive and practically difficult. On the other hand off-peak, rural and suburban routes may offer plenty of spare capacity. Under such conditions both the scope for expansion and the potential for emissions improvements per passenger may be large. It is also important to disaggregate the potential for expansion between public transport modes. For example, bus capacity is often easier and less expensive to expand than rail capacity, unless existing rail infrastructure is underutilised.

Public transport load factor is also of central importance in determining whether fuel usage per passenger-kilometre is

higher with private or public transport (BTRE 2002). Whilst the average emissions from trains reported in Table 3.3 is much less than that of cars per passenger kilometre, it is often only during peak hour that trains are at capacity. In both trains and buses, during times of under-capacity individual vehicles may produce higher emissions per passenger kilometre than cars (BTRE 2002). Thus, improvements which encourage greater use of rail or bus capacity at off-peak times will improve the overall efficiency of these modes as well as reducing emissions from road transport if a mode switch has occurred (DfT 2008c). The potential for emissions savings is largest if car drivers can be persuaded to switch modes and

⁶Journeys by vans and taxis are reported in national statistics along with those of private cars and hence are not disaggregated in this figure. As a guide, vans accounted for approximately 13% of total road km travelled in 2006.

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spare capacity is filled with little extra energy consumption, since marginal public transport emissions can increase very little whilst car journeys are removed (Van Essen et al. 2003; Annema 2005). Price reductions may help with this, although the limited cross-elasticity and potential for non-beneficial mode switch discussed below suggest that fare reduction in isolation is likely to be of limited value.

Long run effects are important. Increasing car dependence and increasing dispersion of jobs and residences, produces a pattern of demand that is very difficult for public transport to serve (Stopher 2004). Long run and short run effects may differ markedly for public transport, since there is evidence to suggest that over time location patterns and transport options interact. These effects are determined by both service availability and convenience, and relative prices of public and private transport. For this reason we return to long run effects in the sub-section below.

Induced demand, non-beneficial modal shift and cross-elasticity of demand

If enhanced and expanded infrastructure becomes available then additional journeys may take place. One way of expressing this is in terms of time and cost 'budgets' for travel. Unless people's travel time or cost budgets are used up entirely then they may not 'bank' these 'savings' but instead may travel more (Wolfram 2005). The evidence on 'constant travel time budgets' comes from country-wide travel data which shows that daily travel times, averaged across the population, have remained more or less constant over many years at about an hour a day. This finding is consistent across countries with

a wide range of GDP per capita (Metz 2002). This finding is important as it implies that the development of faster travel modes, including public transport, will lead to longer travel distances. However, data on this phenomenon only appears robust at the aggregate level and there is some dispute that this is true at the individual level and over the trade-offs that individuals make between time, cost and other journey attributes (Mohktarian & Chen 2004; Van Wee et al. 2006). We found limited evidence of induced demand, but two studies do provide evidence of it resulting from new capacity/services:

- In the US, studies from the 1970s show that many new rail passengers were making an additional trip because of additional capacity (13% for Philadelphia's Lindenwold line, 11% for San Francisco's BART line, and 16% for Chicago's Dan Ryan line); and many others formerly used buses (respectively 36%, 54% and 72% for the three lines). A combination of induced demand and non carbon beneficial mode shift (from bus to rail) resulted in a net energy increase per passenger-mile of travel when compared with the modal energy previously used (CBO 1977; Pikarsky 1981).
- A 1996 survey of a park and ride in Bristol found the scheme has been moderately successful in encouraging a switch from car to public transport, but some trip generation had also taken place. The percentage of users who would not otherwise have travelled was over 2% on Thursdays, and over 8% on Saturdays (Marshall & Banister 2000).



- Also in relation to bus-based Park and Ride, an important study in several UK market towns demonstrated a clear pattern that approximately 65% of the users were indeed people who would have otherwise driven by car all the way into the town centre, but 35% were people who would have otherwise travelled by bus all the way from their home to the centre (Parkhurst 2000). The extra car mileage from the latter group outweighed the reduced car mileage from the former group, thus leading to an increase in car distance travelled and putting pressure on the out of town services as demand was reduced. Policy discussion has since centred on the need to locate Park and Ride sites far enough away from town centres so as to make the journey worthwhile and to prioritising bus corridors both in to town and outside the inner urban areas.

Similarly, public transport fare reduction can promote modal shift from car use but may also encourage a shift from low carbon modes such as walking and cycling. As a result, many studies conclude that impacts on CO₂ are modest. ECMT describe a low level of 'cross modal elasticity', meaning that responses to prices in terms of modal shift from car to public transport are low (ECMT 2007) (also see bullet below). It is even possible that more fuel may be used carrying additional bus passengers who previously walked, or who were car passengers, than is saved by the number of car drivers attracted to use the bus (BTRE 2002).

- A 10% decrease in public transport fares can, in the long run increase

public transport patronage between 5 – 9% (or more in some markets), but only 10 – 50% of this increase is likely to be drawn from car use (ECMT 2007). Most of the rest is drawn from pedestrians and cyclists switching to public transport.

- Analysis of the impact of free public transport for Adelaide, Australia, suggests zero fares would probably result in a 30% increase in patronage, but only around half of the additional riders are likely to come from cars and even less would have been drivers. Hence, it was estimated that car trips would decline by less than 2% (Phillipson & Willis 1990; BTRE 2002). This also illustrates the difficulties in shifting from modes which account for a very high share of total travel to modes with a lower share of the total, which were discussed in the previous section.
- Modelling of the transport system of Stockholm suggests that free public transport had a relatively modest impact on private vehicle mileage and associated CO₂ emissions. Making public transport free of charge implied a 4% reduction of annual CO₂ emissions from private vehicles. The reason is that the policy mainly caused a shift from walking and cycling to public transport (Robert & Jonsson 2006).
- Modelling of a 50% reduction in bus and train fares in 2010 in Sydney suggests this could reduce annual transport CO₂ emissions 0.42% by 2015 from the Sydney metropolitan area (Hensher 2008).



- A similar relationship appears to hold for most IEA cities, if fares are cut by 30% then reductions in city transport annual CO₂ emissions of between zero and 1% appear reasonable through to 2010, perhaps reaching 2% by 2020 after taking into account longer-term impacts on traffic and land use. (IEA 2001).
- Modelling suggests that a halving of UK public transport fares in 1996 would lead to a reduction in annual CO₂ emissions from car usage of 1.4% in 2010 (Acutt & Dogson 1996).

Nevertheless it is important that the long run relationship between the total costs of different modes is examined carefully when considering the growth of each. For example over a two decade period in the UK public transport costs have risen dramatically relative to the cost of motoring. Between 1985–1986 (when bus deregulation outside London and Northern Ireland was introduced) and 2000–2001, local bus fares rose by 36% in real terms whereas motoring costs rose by just 2% (CfIT 2003; Begg & Gray 2004). Over the same period car passenger kilometres grew by 41%, and public transport passenger km grew by 12% (all of which was accounted for by the growth in rail travel) (DfT 2007c).

It is therefore important that the long run effects of price differentials are assessed with reference to patterns of travel and demand growth by mode. A significant price differential may contribute over time to the dominance of a particular mode and 'lock in' to patterns of land use and lifestyle choice that suit that mode (Banister 2005). Although the evidence

suggests that better or cheaper public transport may often have a relatively modest short run potential to reduce net CO₂ emissions, the longer term impacts on land use and travel patterns may be more profound. Public transport services may facilitate less car dependent lifestyles. In 2007, 43% of households in London had no car compared with 10% in rural areas (DfT, 2007). Whilst the reasons for this are varied, there is a clear relationship between the availability of public transport, accessibility of jobs and services, and the need to own a car.

The relationship between good public transport provision and longer term lifestyle changes was investigated by (Hass-Klau et al. 2007) who used census data to explore changes over time in car ownership in public transport corridors in 17 areas in five countries (Germany, UK, France, US and Canada). The study concluded that in the majority of cases car ownership is lower and grows less in areas close to public transport, even when socio-demographic factors are controlled for. The average case showed a relative reduction of car ownership of about 37 cars per 1000 population, or about 9% less car ownership in these areas. The strongest car reducing effect was seen around underground stations followed by light rail or tram.

Therefore it is possible that some studies examining the potential of public transport to reduce emissions, such as those cited above, have taken a rather narrow and short-term view of the potential carbon savings from this area of policy. In the case of public transport, for instance, it is not just a matter of increasing patronage levels in the short term, drawing



passengers making similar journeys from cars, but also of shaping long run travel/location patterns such that individuals are less dependent upon private cars. Similar long run interrelations hold for infrastructure and road space priority (see below).

Increased emissions due to car congestion

The introduction of urban bus lanes can show some improvements in overall travel time for buses, but sometimes at the cost of delays for general road traffic sharing the same corridor (Brand & Preston 2003). Hence, increased car traffic congestion due to lanes lost to buses can have a negative emissions effect, at least in the short run.

- The EC's Auto-Oil II modelling program for Athens described above assessed the effect of measures to improve public transport, primarily by increasing average bus speeds by 15%. The measures included adding new bus lanes and giving buses priority at intersections. As a result, CO₂ emissions from the city's transportation system declined, but by only a net 0.3%, mainly because of a projected increase in overall traffic congestion due to loss of lanes for private vehicles (IEA 2001). However as we discuss below, there is also evidence to suggest that road space reallocation can reduce overall traffic volumes, as drivers opt to make alternative travel arrangements (see Section 3.7).

As with fares and new infrastructure, long

run changes can be different from short run impacts. The models described above do not capture all of the impacts of transit improvements, and exclude potential long-term effects on land use. A strategy that gave public transport priority might therefore yield much greater-than estimated reductions in CO₂ emissions in the long term. Some studies have estimated a long-run land-use multiplier of five to ten times the amount of the short-run reductions. This effect may be especially strong when transit improvements or expansion are planned in conjunction with land-use decisions and other policies that promote transit use (IEA 2001).

Costs

Our review revealed relatively little attention to costs of investment in public transport in terms of reducing CO₂. We did reveal cost data related to infrastructure provision, which unsurprisingly indicates that new conventional rail, light rail and mass transit infrastructure requires large investments from public bodies and the private sector. Improving utilisation of under-used services can improve cost-effectiveness. We did not find evidence linking the costs associated with subsidies for fare reduction and emission reduction. As noted in the discussion of costs in the section on walking and cycling, support for public transport brings multiple benefits additional to carbon emission reduction. We therefore conclude that more work is needed on cost-effectiveness, and this must take account of both co-benefits and long run and short run effects.



Summary

The evidence on the potential of public transport to reduce emissions presents a complex and somewhat contradictory picture. Policy support for public transport is provided by a large number of countries and its role in climate policies is recorded by many countries. Emissions per passenger km travelled by bus or rail are generally lower than those for private cars. Moreover, there is evidence to suggest that there is a strong link between the availability of convenient and affordable public transport and patterns of land use that are conducive to lower reliance on private cars, hence lower long-term emissions.

However, there are significant reasons to believe that the short to medium term potential for public transport to contribute to emissions reductions is relatively limited. Carbon savings from fare reduction and the provision of new capacity appear modest. The main reasons are that capacity expansion may need to be large in order to absorb a significant fraction of car journeys, that demand may be induced by new routes or lower fares, or that users may be attracted from other low carbon modes as well as from cars.

All of these observations require careful qualification, and are often context specific. It is important to consider the potential to improve occupancy at underutilised times/routes as well as how to provide new capacity. Similarly, fare reductions, prioritisation and additional services can be combined with measures to restrict car use, helping to ensure mode

switching is beneficial. Changes to journey patterns can ameliorate congestion impacts from bus prioritisation and land use effects may multiply the impacts of capacity provision and fare reduction.

More work is needed on cost-effectiveness of public transport in carbon reduction terms, taking into account the long term-short term differences discussed above.

3.4 Using vehicles more efficiently

This section discusses three key means by which the use of cars may be made more efficient; by increasing the occupancy of (number of people in) vehicles, by encouraging a different model of shared car ownership through car clubs and by encouraging drivers to use techniques that are more efficient, including through the use of speed enforcement. Policies to promote these measures exist and have been evaluated in the literature.

3.4.1 Vehicle Occupancy

Total car use is reduced by greater car occupancy whenever passengers who would otherwise be car users themselves car share instead. Such ridesharing or car pooling/sharing can result in emissions savings and has the potential to be low cost if a vacant seat is utilised by someone who would otherwise have driven separately for a journey that cannot be avoided or made by another mode. Because occupancy rates are low in many countries, considerable potential to reduce car use exists in principle. For example, the 2002-2006 average car occupancy in



the UK was 1.1 persons per car for commuting journeys and 1.6 overall (DfT 2008c). Since the vast majority of cars have four or five seats there is potential to improve occupancy by at least 100%. If this could be realised, it would (other factors being equal) yield a dramatic reduction in car use. Our review revealed 32 relevant studies and the evidence attends to two main policy types; schemes to promote car sharing at the company level and road space allocation based on vehicle occupancy. We also discuss the role of travel planning in promoting car sharing in Section 3.5.

Evidence on potential emissions saving

Carsharing schemes

Many reviews focus on experience in the US, particularly California, where air pollution-related legislation since the late 1980's has required larger employers to develop and implement a trip reduction program. Hence, many of the findings are presented in terms of reductions for

companies or regions. In the UK there are also many active schemes, and a number of companies who offer car sharing systems and support. Typical participants are individual businesses, business parks, and local authorities using car sharing as a component of their involvement in school and company travel plans (Cairns et al. 2004).

Whilst the evidence suggests that there is potential to reduce vehicle usage and hence emissions, there is little data regarding VMT reductions (especially in the UK) and we found no specific data on estimated or projected CO₂ emissions savings.

High Occupancy Vehicle Lanes

High Occupancy Vehicle (HOV) lanes directly target vehicle occupancy through restricting road-space for single occupancy vehicles and prioritising HOVs. There is some evidence on the effectiveness of HOV lanes.

Table 3.5: Evidence on potential emissions savings

<p>Carsharing schemes</p> <p>(Bonsall 2002), cited by (Cairns et al. 2004) reviewed the literature for the Department of Transport, Local Government and the Regions, and the Motorists Forum and concluded at the time that there was relatively little that was useful. Nevertheless, the review's overall conclusion was that car sharing could make a useful contribution towards reduction in traffic levels and that the potential existed for an increase in the number of car sharing schemes.</p>
<p>A European assessment concluded that the future potential of car sharing was for an increase in car occupancy of 13% for home to work journeys. However, the report did caution that one-fifth of this potential could be a non-beneficial shift from public transport (ICARO 1999; Cairns et al. 2004).</p>

continued overleaf



Specialist car share company, Liftshare estimated in 2004 that its activities were saving about 18 million miles of car travel in the UK per year (Cairns et al. 2004).

(Cairns 2000; Cairns et al. 2002b) reviewed multiple employer-led schemes and found that for organisations where overall levels of car sharing had been measured, on average, an additional 3% of staff had been encouraged to start car sharing. Whilst a small absolute number, this is a 23% increase over previous levels. Moreover, the 3% figure was considered to be a very conservative measure of the potential for achievable change.

In the US, rideshare programs can typically reduce up to 8.3% of commute VMT, up to 3.6% of total regional VMT, and up to 1.8% of regional vehicle trips (Apogee 1994; TDM Resource Center 1996; VTPI/TDM 2008).

Regulation XV – Los Angeles’s air pollution control requiring employers to develop and implement a trip reduction program to achieve specified ride-sharing goals delivered some reduction in commuting journeys. In the first year, 1988, the proportion of workers driving to work alone decreased from 75.7% to 70.9%. The largest shift in mode was toward car-pooling (car sharing). The carpool mode share increased from 13.8% to 18.4%, accounting for nearly all of the decrease in driving alone. These modal shifts resulted in a reduction of auto trips from 84 per 100 employees to 80 trips per 100 employees (Giuliano et al. 1993). Impacts in terms of CO₂ emissions, vehicle miles or fuel savings were not provided for this study however, the focus being on changes in vehicle ridership levels.

HOV lanes

(Comsis Corporation 1993; Turnbull et al. 2006; VTPI/TDM 2008) suggest that in the US, HOV facilities can reduce vehicle trips on a particular roadway by 4-30% and that HOV facilities can reduce peak-period vehicle trips on individual facilities by 2-10%, and up to 30% on very congested highways if HOV lanes are separated from general-purpose lanes by a barrier (Ewing 1986).

One study estimates that HOV lanes can reduce up to 1.4% of VMT and up to 0.6% of vehicle trips in a US region (Apogee 1994; VTPI/TDM 2008). (Lindqvist & Tegner 1998) estimated the impact on the city of Stockholm’s transport CO₂ emissions from introducing HOVs where cars with 3+ persons are permitted to use the bus lanes. The forecast result was a 3 kiloton reduction of CO₂ emissions, or approximately a 0.3% per annum saving on the city’s 1995 emissions level of 1,100 kilotons.

Key issues and problems

Car sharing schemes

Because rideshare passengers tend to have relatively long commutes, mileage reductions can be large. For example, if

ridesharing reduces 5% of commute trips it may reduce 10% of vehicle miles because the trips reduced are twice as long as average (VTPI/TDM 2008). However, there are barriers to widespread ridesharing. The most important factor is



the origin and destination – two people cannot car-pool if they live and work in different places. Another factor is time – both the journey’s length and deadlines for arrival and departure (ECMT 2007). Commuters may also prefer to travel alone (Redmond & Mokhtarian 2001;Nasser 2002;Stopher 2004).

(Recker & Parimi 1999) argue that ride-sharing options lead only to minor shifts in the distribution of emission reduction – in the sample cited (Portland, Oregon), 15% of households had feasible alternative travel patterns involving carpooling but most of these households showed little or no improvements in emissions.

Indeed, one potentially negative effect of car sharing could be greater use by other household members of cars that had been left at home due to car-sharing for journeys to work (Dix & Carpenter 1983). However, whilst this is clearly a potential risk, earlier work by (Vincent & Wood 1979) seems to suggest that the scale of effect is relatively small (both these sources are cited by (Cairns et al. 2004). More significantly, (Bonsall 2002) cited by (Cairns et al. 2004) draws attention to a problematic finding that up to half the number of future car-sharers might be abstracted from public transport, although in an earlier study (Bonsall & Kirby 1979), it was suggested that this may be beneficial if public transport was over capacity at peak times.

HOVs

HOV lanes generally are found to be more effective when commutes are to locations which allow access on foot to other activities (Noland et al. 2006). Some of the literature is sceptical about HOV effectiveness, and various shortcomings

have been identified. (Fielding & Klein 1993;IEA 2001) summarise as follows:

- Many HOV lanes are under-utilized, even though nearby roadways are congested. This may reflect decisions to ride alone in congested traffic rather than carpool in free-flowing traffic.
- Some car-poolers would travel together even without a HOV lane. For example, 43% of car poolers are members of the same household.
- Finally, HOV lanes can be expensive to construct, especially if they require new highway capacity to be built. See also the discussion of induced demand in Section 3.7.
- Secondary effects could offset the benefits of HOV: these include increased travel by vehicles picking up other passengers to become HOV, and increased travel by non-HOV traffic, for example, by taking alternative routes that may be longer or involve more stop-and-go driving.

Some of the problems with HOVs may be inherent to their design (Dahlgren 1998):

- The success of an HOV lane in motivating people to car sharing and/or buses depends on maintaining a travel time differential between HOV and general purpose lanes. If delay is eliminated when the HOV lane is constructed, there will be no incentive to shift to an HOV.
- If the proportion of HOVs is greater than the proportion of capacity that will be devoted to HOVs after the HOV lane is added, the HOV lane will be as congested as the general purpose lanes and will offer no travel time advantage.



- Travel time has been found to have a weak effect on mode choice.

It is also important to note that HOV lanes that operate only during peak hours can have a useful impact on congestion but will necessarily have a more limited impact on carbon emissions, given that they have no effect outside of their operating period.

Costs

Whilst there is evidence on the cost savings that can be achieved through car-sharing (BTRE 2002;VTPI/TDM 2008), we found very little evidence that was presented in terms of costs per unit of CO₂ saved. It is important to note that many of the programmes investigated in the US were implemented to relieve local air pollution and many were implemented to target congestion. As with mode shift this makes assessing carbon costs/benefits problematic. One study that did carry out a cost-effectiveness analysis of possible traffic measures to reduce transport CO₂ emissions in the city of Stockholm found that measures whose costs mainly consist of administrative surveillance yield the highest cost-efficiency of carbon abatement (Lindqvist & Tegner 1998). Ridesharing incentives from HOV lanes is one such measure that was found to be highly cost-efficient with a cost (in 1998) of 0.1 Swedish Krona per kg of CO₂ saved (equivalent to less than £8/tonne of CO₂ at 1998 exchange rates). Lindqvist's analysis assumed that it was existing bus lanes that were made available to higher occupancy cars (three persons or more) as opposed to creating any new high occupancy infrastructural capacity.

Summary

Our review revealed some evidence of the potential for car sharing to reduce emissions and given the low occupancy rate of private cars in the UK and most other developed countries in principle the potential to reduce emissions significantly is obvious. A doubling of occupancy is theoretically possible, other factors being equal this would lead to a corresponding reduction in car journeys. In practice however the literature reveals many obstacles to persuading people to car share, suggesting that whilst HOV lanes and corporate car sharing schemes have had moderate success in the US there may be limits on their wider application. More research is needed to quantify the potential emissions impacts and costs of a range of policies to increase car occupancy in UK conditions.

3.4.2 Car Clubs

Car clubs are commercial or not-for-profit schemes that are essentially short-term car hire schemes. Members generally pay an annual membership fee which enables them to hire cars for short periods of time and at short notice. Cars are generally distributed around cities, can be booked electronically or over the phone and accessed by 'smart card' technology which facilitates all inclusive pay-as-you go charges. This concept is generally known as 'car sharing' elsewhere in Europe and in the USA (hence not to be confused with car sharing as described in section 3.4.1 above). In the UK, the commercial car club sector is expanding at a rate of 100%+ per year: there are now more than 51,000



car club members within the UK, the majority of these (71%) are based in London⁷. At least 200,000 members are expected by 2012.

Evidence on potential emissions saving

An assessment of the impact of car clubs on carbon reduction requires data to understand the travel patterns of members before and after joining a club. For some (non-car owners), membership of a car club increases access to and use

of a car. Others may give up their privately owned car and join a club instead. Thus the debate has been to try and understand the net impact. Our review revealed 11 relevant studies. As there has been over a decade of experience of car clubs elsewhere in Europe and recent growth in the UK, there is now some evidence to show that average carbons savings per member could be significant:

Table 3.6: Evidence on potential emissions savings – Car Clubs

<p>The European funded Mobility Services for Urban Sustainability (MOSES) project assessed car clubs in a number of European cities and concluded that Car-Club schemes can reduce car use and change mobility patterns towards a larger use of environmentally friendly modes of transport. The MOSES report 2005 showed car mileage reductions of 28% (Belgium) and 45% (Bremen) after joining car clubs (Ryden & Morin 2005).</p>
<p>Research in Switzerland suggested that those who gave up their car as a result of joining a car club reduced their amount of car travel by around 6700km (approximately 72%) a year (Mulheiu & Reinhardt 1999).</p>
<p>A Canadian car club organisation, Communauto, announced a 13,000 ton reduction in CO₂ emissions as a result of their 11,000 car club users in Quebec. They calculate that on average each club member reduces car distance travelled by 2,900 kilometres per year. With a potential market of 139,000 households in the province the annual CO₂ reductions could be 168,000 tons per year (Shaheen & Lipman 2007).</p>
<p>In a survey of Austrian car club members, a strong impact on total mileage travelled was observable. Individuals within households who had previously had access to a car reduced their car mileage by 62%, whereas those who had previously not owned a car increased their car mileage by 118%. In absolute per person terms the increase of the latter group is only one sixth of the reduction of the former group. The aggregated net effect depends on the relative group size of the no-car-households - in this experiment it was a reduction of 53% and grossing this up to Austrian-wide car club membership (of which 52.5% did not own a car prior to membership) a net effect of a reduction of car mileage of at least 46.8% was derived (Steininger et al. 1996).</p>

continued overleaf

⁷Quarterly UK Car Club Data available from Carplus www.carplus.org.uk



(Steininger et al. 1996) also note that car club vehicle use results in an average of 1.9 passengers per trip, which is 36% above the national average.

In the UK, the annual survey of members of accredited car club organisations revealed that when people join a club, the changes they make to mileage driven and car ownership results in a saving of 0.7t CO₂ per member per year (Carplus 2008). This is based on sample data that shows that:

- 44.7% of member households get rid of a car or defer purchase
- car club cars emit only 63% as much CO₂ as the cars that they replace
- One car club car takes at least 5 -11 private cars off the road.

The UK survey data also showed that members:

- reduce their mileage by 53% after joining
- use cars for a third of the number of trips of non-members (22.8% journeys vs. 65.4%)
- walk and cycle almost twice as much as non-members (45.4% journeys vs. 25.8%)
- use public transport (especially rail) three times more than non-members (31.8% journeys vs. 8.7%)

Transport for London commissioned research on car clubs found, on average, car club members reported that they had reduced the number of days per year that they drove a car from 64 to 41, implying a potential reduction in car use in the order of 36%. Before joining, 55% of the sample owned or had access to a car in their household, compared with 26% afterwards, and the average number of cars per car club member fell from 0.77 to 0.35. 19% of the sample explicitly reported selling a car as a result of joining the club, with longer-term members more likely to have done so (Synovate 2007).

By scaling up car club membership to 118,000 (from the 28,000 members in 2007) and assuming car club members drove the national average before membership and reduced their car use by 50% afterwards, making assumptions about average mileage, a UKERC report (Ledbury 2007) estimated that 0.02 MtC (0.07 MtCO₂) could be saved each year as a result of scaling up car clubs to this level. If car clubs were to reach participation of 15% of the population (9m people), this could produce annual savings of almost 8MtC (29 MtCO₂) per annum.

Key issues and problems

Despite seemingly large amounts of evidence, there are still issues to be resolved about the type of people who are currently attracted to car clubs in the UK and elsewhere. It is usually assumed that

the difference between the travel choices of club members and non-members is due to the club facilitating a voluntary change in travel behaviour. But it could be that the people that join clubs are the types that already have non-standard travel



behaviours. For example, the results from the Carplus survey (Carplus 2008) show that people who join car clubs already travel just 31.6% of the national average car miles per person per year before joining, i.e. their behaviour is already different. This leads to the question of whether the club has played a part in promoting a shift in travel behaviour, or whether it simply allows users to continue with their pre-existing suite of travel choices, modified by inclusion of a club.

There are also questions about the extent to which car clubs can and should be supported through government policy. In the UK, the majority of car clubs are operated commercially, without subsidy of any form. However, these operators are concentrating resources on relatively affluent areas in London and other major cities. An alternative model may be for national policy support for a network to provide initial funding for other areas, including smaller towns, and to make links with public transport operators. In the late-1980s and early-1990s, many car club efforts were initiated in Europe and initially supported by government grants.

Much of the evidence on car clubs comprises relatively descriptive accounts of the growth and scale of operations. One study, however, concluded that car club programs are more likely to succeed when they provide a dense network and variety of vehicles, serve a diverse mix of users, create joint-marketing partnerships, design a flexible yet simple rate system, and provide for easy emergency access to taxis and long-term car rentals. They are more likely to thrive when: environmental

consciousness is high; driving disincentives such as high parking costs and traffic congestion are pervasive; car ownership costs are high; and alternative modes of transportation are easily accessible (Shaheen, 2002).

The King Review notes that the typical car club vehicle is already significantly more efficient than the average car registered in the UK (King 2007). It is possible that car clubs could be test beds for new car technologies in the future, for example urban users may be able to adopt electric cars if car club parking is co-located with recharging posts.

Costs

We found no direct analysis of cost effectiveness of car clubs in terms of carbon emissions reduction. However, one study concluded that a national network of car clubs which placed 8,000 vehicles in rural and urban areas across the UK over four years and provided the support network and operational infrastructure, would cost £12 million of Government seedcorn funding at a cost-benefit ratio of 1:10 (Carplus 2007). This calculation was based on the evidence of behaviour change noted above and follows standard UK 'webtag' guidance on appraisal. To the extent that car clubs favour both the procurement of more efficient cars and improved utilisation rates for those cars, it would seem that they may offer a cost-effective means of saving carbon.

Summary

Evidence in the UK and mainland Europe clearly shows that, once established, car



clubs reduce total car miles driven, with members walking, cycling, and using public transport more often, as well as travelling less. The research also shows that this reduction of car miles is a direct result of breaking the link between car use and car ownership - exactly the service that clubs provide. The debate is over the potential rate and scale of growth and how to attract car club membership. It is also possible for car clubs to provide more efficient offerings and perhaps electric and other low emission vehicles as these emerge into the vehicle market.

3.4.3 Eco-driving

Eco-driving reduces fuel consumption through more efficient driving style, reducing speeds, proper engine maintenance, maintaining optimal tyre pressure, and reducing unnecessary loads. Policy measures can include information campaigns and encouraging or requiring driver training⁸.

Evidence on potential emissions saving

Our review revealed 21 relevant studies. There is evidence that suggests there is potential for cost-effective CO₂ saving:

Table 3.7: Evidence on potential emissions savings – Eco-driving

In the UK, eco-driving could immediately reduce emissions and fuel consumption from cars by 8% (DEFRA 2007c;King 2008). Some studies indicate that, over time, and particularly with proper training, drivers could achieve efficiency savings of as much as 10-15%, which may be further improved through technologies like gear shift indicators, econometers and cruise control (Kageson 2003;EST 2005;Smokers et al. 2006;Anable & Bristow 2007;King 2008).

In the EU-15, if eco-driving is included in the lessons for new drivers, then a total reduction of 1.8 Mtonne per year could be achieved in 2012, increasing to 5.5 Mtonne per year in 2020 (Smokers et al. 2006).

In 2004, a widespread mass media campaign targeted at private car drivers in the Netherlands (population 6m) aimed to stimulate eco-friendly driver behaviour (Eco-Drive 2005;Anable & Bristow 2007). This programme has been estimated to have saved around 0.6 MtC (2.2 MtCO₂) per year.

Vehicle maintenance taught in eco-driving courses, especially maintaining correct tyre pressure, can make a significant difference to fuel economy. Citing survey data from (IEA 2003), (Noland et al. 2006) estimates that the average light duty vehicle tyre is under-inflated by 3 psi, and a 1-3% increase in fuel consumption for every psi below the optimal tyre pressure.

⁸Recent examples include the current UK Government 'Act on CO₂' campaign, and the inclusion of an 'Eco-safe driving' element into the UK driving test.



Key issues and problems

There is a general lack of ex-post evidence on the longevity of the effects of eco-driving programmes with estimates in our evidence base ranging from 2 years to 40 years. The other problems identified in the literature include:

- Difficulty in monitoring the long run effects of eco-driving.
- Eco-driving policy does not provide a high level of reliability in the range of CO₂ reductions to be delivered (CEC 2007b), (Smokers et al. 2006).
- Drivers who already have a driving license are difficult to reach.
- Campaigns and interventions need to be repeated on a regular basis to make sure that the effect does not fade out (Harmsen et al. 2003).
- The ways in which the change in driving style can be brought about vary in effectiveness and cost. Training programmes linked into driver licensing training can be very cheap – an additional cost of less than €1 per driver – and effective (Smokers et al. 2006). Separate eco-driving courses are estimated to cost between €50 and €100 per person per course for a half-day session.
- Eco-driving information campaigns are less effective than training programmes suggests (Smokers et al. 2006), reaching only 1.5% of drivers in an example cited in the Netherlands.

Costs

Notwithstanding problems related to longevity and reach, eco-driving appears to offer cost-effective savings:

- In the Netherlands, where eco-driving has formed part of the driving test since 2001, about 1.5% of existing drivers had been reached by training programmes by 2004. Together with an information campaign, the cost is estimated to be around £13 per tonne of carbon saved (Eco-Drive 2005; Anable & Bristow 2007).
- Also in the Netherlands, a recent estimate by (Harmsen et al. 2007) put the cost at around £22 per avoided tC (£6 per avoided tCO₂) based on eco-driving programme costs of about £1.4 million annually (including subsidised training programmes and communication campaigns).

Eco-driving is thus a very cost-effective means of reducing CO₂ emissions of passenger cars. For oil prices ranging from 25 €/bbl upwards the cost of carbon saving is negative for all combinations of fuel cost, eco-driving course cost, Gear Shift Indicator (GSI) cost, and duration of effect modelled (Smokers et al. 2006).

Summary

The evidence related to eco-driving is very clearly linked to CO₂ emissions and quantifies both potential savings and cost-effectiveness. Potential savings appear to be significant and costs low, with the biggest obstacles being securing driver participation and ensuring that efficient driving habits are sustained over time. This suggests that if the potential benefits of more efficient driving styles are to be secured, an ongoing



programme of training, and reinforcement through advertising and other awareness raising mechanisms is likely to be needed. Additional research into the effectiveness, cost and acceptability of such measures is needed to determine whether such a campaign (akin perhaps to road safety, seat belt wearing, drink driving) would be desirable.

3.4.4 Speed enforcement

Adhering to speed limits and particularly avoiding high speeds is one of the most important ingredients of eco-driving. Here we deal with speeds on higher speed roads (motorways and trunk roads) as vehicle efficiency rapidly deteriorates at speeds above 50-60 mph (80-100 kph). Depending on the vehicle driven, running the car at constant speed at 80 mph (130 kph) instead of 70 mph (110 kph) increases fuel consumption by 15 to 20 percent (NAEI 2007). In the UK, motorways and trunk roads account for less than 4% of Britain's total road length, yet account for around a third of car (and taxi) vehicles miles travelled (DfT 2007b). The speed limit on these roads is 70mph for cars. However, 54% of these vehicles travel in excess of this limit at any one time, 18% of these above 80mph (DfT 2007a). The policy option is therefore to better enforce the existing speed limit on these roads, or even to lower the speed limit which would reduce average speeds to nearer the fuel-efficient optimum.

Ensuring compliance through better enforcement can be augmented through in-car instrumentation whose adoption may be accelerated through regulation. Intelligent Speed Adaptation (ISA) is one such device which uses information and communications technology to provide

speed limit information on a vehicle's dashboard. This information, linked to digital maps and GPS receivers, can either be advisory or be linked to the vehicle's engine management system to provide an intervening ISA. This in turn may or may not be able to be overridden by the driver. Recent studies have shown that the potential for emissions savings on trunk roads is significant (see table 3.8 below), but that speeding drivers are the least likely to use ISA systems at these speeds if they are advisory or able to be overridden (Jamson 2006). Therefore, unless manufacturers begin to voluntarily fit systems that cannot be overridden, legislation at a European level would be required. Alternatively, substantial scheme rebates and discounts coupled with strict speed enforcement regimes may be required to incentivise their introduction (Carsten et al. 2008).

Evidence on potential emissions saving

The evidence in the literature on the effect of speed enforcement is the product of three main sources of data: (i) test cycle data on fuel consumption of vehicles at different speeds and driving cycles (ii) modelled estimates of traffic based on test cycle data and, (iii) some examples around the world of where speed limits have been lowered and the changes in actual fuel consumption measured. Estimates of the potential CO₂ reduction that could result from reducing the speed limit vary according to the assumptions made about the speed limit, the scale of enforcement and compliance and the emissions factors used to calculate the savings. However, all the evidence points to quick (i.e. effective in the short term) and relatively substantial potential savings:



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Table 3.8: Evidence on potential emissions savings – Speed enforcement

<p>Estimates of carbon savings specific to enforcing the existing 70mph limit on UK motorways and trunk roads based on modelling forecast traffic demands and vehicle fleet into the future range from 1 MtC (3.7 MtCO₂) a year in 2010 (LowCVP 2006b) to 0.6 MtC (2.2 Mt CO₂) a year in 2010 (DEFRA 2007b). This represents a 2-3% reduction in total transport emissions.</p>
<p>A new 60mph limit could nearly double the reduction compared to enforcing existing 70mph limits. Estimates specific to enforcing the existing 60mph limit on UK motorways and trunk roads range from 2MtC (7.3Mt CO₂) per year in 2010 (LowCVP 2006b) to 0.9 MtC (3.3Mt CO₂) in 2010 (DEFRA 2007b). This represents a 3-6% reduction in total transport emissions. Both these models assume 100% compliance with the speed limit.</p>
<p>The use of variable speed limits can reduce breakdown of traffic flow. Smoother traffic flow is likely to reduce individual vehicle emissions for a given average speed, as shown by the M42 pilot scheme (DfT 2008b).</p>
<p>In the Netherlands, analysis of a hypothetical reduction of speed on Dutch highways from 100 kph (62mph) to 80kph (50mph) based on uncongested driving behaviour, concluded that CO₂ from petrol and diesel cars emitted on highways could be reduced by 21% and 26% respectively (TNO 2006). (Harmsen et al. 2003) quote the Dutch government experience "it has been estimated that a general speed limit of 100 km/h for all highways (from 120km/h) could - if accompanied by sufficient enforcement - lead to 1 Mt CO₂ reduction – or 3% of total national transport emissions".</p>
<p>France enforced strict speed limits on main motorways in 2004. Its environment ministry in its 'Plan Climate' (2004) concluded that the potential impact of full compliance with speed limits has been worked out at 2.1 Mt CO₂ for private cars (plus a further 0.4 million tonnes for heavy goods vehicles and 0.5 million tonnes for light utility vehicles) amounting to a total of 3 million tonnes of CO₂ per annum. This is equivalent to a 2% reduction in transport sector CO₂ emissions (ETSC 2008).</p>
<p>Other countries in the EU have considered or announced an intention to use speed enforcement or reduction as a tool to reduce carbon emissions. A recent announcement by Spain's energy minister revealed an intention to lower the speed limit on the country's motorways in order to reduce fuel consumption (Keeley 2008). The speed limit will be cut on dual carriageways outside major cities by 20%. The German Ministry for the Environment calculated that a 120 and 100 km/h speed limit on German motorways would reduce CO₂ emissions from cars on motorways by 10% and 20% respectively (ETSC 2008).</p>
<p>In the USA a 55 mph national speed limit was in place for 21 years from 1974 following energy shortages caused by the OPEC oil shocks. The IEA estimate that the US could save 2.4% of total oil consumption if the 55 mph limit was re-imposed. The equivalent figure for Europe was 2.1% (IEA 2005).</p>

continued overleaf



Simulation modelling of tailpipe emissions based on real-world trial data of vehicles fitted with ISA systems found that the CO₂ emissions of traffic on 70mph roads in the UK would be reduced by 3-4% with a voluntary (overrideable) system and around 6% with a mandatory system (Carsten et al. 2008).

Key issues and problems

It is possible that speed enforcement impacts on more than one choice. For instance, as well as the obvious change to driver behaviour, the calculations cited above do not take account of the reductions in car *mileage* that might result from lower speeds and longer journey times. For instance, there is the possibility of modal switch as the longer the car journey, the more time-competitive other modes may become. Although it follows that eco-driving and lowering speeds could reduce the cost per car mile travelled, thus leading to more distance travelled, this effect is likely to be suppressed by the effect of lower speeds on journey times. Thus this initiative might suppress any rebound effect. However, these latter effects are not explicit in the evidence. Speed control also impacts on safety and journey time reliability due to smoother traffic flows during congested periods. When motorways become congested, reducing the speed limit to 60mph or 50mph reduces rather than increases journey times. There has been some evidence of this from the UK 'controlled motorway' trials where speeds are reduced below the normal speed limit at congested times (Harbord et al. 2006).

(Harmsen et al. 2003) speculate that an EU-wide speed limit of e.g. 120 km/h could lead to a different car design for the European market (especially engine size, power output and transmission lay-out)

resulting in a more efficient passenger car and a substantially larger CO₂ reduction. Given the physical laws governing the relationship between speed, wind resistance and power, there is little dispute over the principal that reduced speeds lead to carbon reductions. There is some debate over the degree to which new vehicle technology will mean that newer cars will be more efficient at higher speeds thus reducing the impact of speed policy (see (Anable & Bristow 2007) for a discussion).

Speed enforcement may run into problems with political acceptability. Whilst it could be seen as a more equitable carbon reduction policy than many fiscal instruments or other prices/restrictions which save equivalent amounts of carbon (LowCVP 2006b), it is possible that rigorous enforcement of speed limits will be unpopular. The evidence on public attitudes to speed control is very large and is outside the scope of this review. However, political acceptability has been noted by several authors. For example the (Environmental Audit Committee 2006) note that: "A proposal to reduce to 60mph or rigorously enforce the existing motorway speed limit ...had been discussed within Government for inclusion within CCP 2006, but had been withdrawn following concerns as to the costs in manpower and finances of policing it. We asked the Secretary of State whether this policy could not be delivered more cheaply by fixing speed cameras on motorway



bridges. His reply suggested to us that, ultimately, the overriding reason why this policy was not included in CCP 2006 was a fear of popular antagonism.”

Costs

The evidence on the costs of enforcement to achieve compliance with a new speed regime is mixed. The UK calculations (and some of the other examples) assume 100% compliance with the new speed limits (i.e. zero revenue from speeding fines). On this basis, enforcement of 70mph limit is estimated by (DEFRA 2007b) to cost £410/tCe saved. However, (Anable & Bristow 2007) argue this estimate is based on relatively old speed camera technology and may be grossly exaggerated as a result. The DfT are due to update these estimates using costs for new time-over-distance cameras which may reduce the number of cameras required and the transmission and maintenance costs. As well as the cost of the technology, there are at least two other issues that could be taken into account when assessing costs of this policy. Firstly, increased speed enforcement has been shown to be cost-effective if safety benefits are taken into account and time gain from exceeding the speed limits is disregarded (IEA 2001; Harmsen et al. 2003). Also, enforcement of speed limits can be financially self-supporting or even revenue generating (IEA 2001; Harmsen et al. 2003; Anable & Bristow 2007). For instance, analysis in the Netherlands found revenues from speed controls on highways of 10km/h lower than current are 10 times the costs, even excluding safety gains (Harmsen et al. 2003).

Summary

Speed enforcement and even reduction would appear to have great potential to reduce emissions from private vehicles in the context of a broader eco-driving campaign. The evidence would suggest that enforcing existing speed limits on motorways and trunk roads more rigorously could save around 2-3% of total transport emissions. What is more, these savings are possible in the short term. The absolute cost of this policy and its political acceptability require further investigation.

3.5 Awareness campaigns and travel planning

Awareness campaigns and marketing initiatives can improve public understanding of the environmental impact of cars and inform a variety of actor-choices including the potential for walking, cycling and public transport, eco-driving and even which cars to buy. Campaigns may be mounted at a national level or by local authorities to target the general population. More tailored campaigns can be applied at the personal or household levels. Individualised marketing, often known as personal travel planning or travel feedback programmes, provide targeted individuals at home, work and schools with personalised information on alternative travel modes. The campaigns seek to incentivise and encourage individuals to adopt the various carbon reduction options discussed in the previous sections of this chapter, from walking to eco-driving.



Table 3.9: Evidence on potential emissions savings – Individualised marketing

In the UK, DEFRA analysed the potential for extending the combined 'Smarter Choices'⁹ programme and found that a 'low' scenario (which assumes a continuation of current funding on a national scale) could lead to a 1.4% reduction in annual UK traffic by 2010, and a 1.8% reduction by 2020. The 'high' scenario involves much wider implementation of present good practice and could mean a 4.2% reduction in traffic by 2010 and a 5.3% reduction by 2020.

On personal travel plans, (Cairns et al. 2004) concluded from their case studies and the literature review that they can lead to a 7–15% reduction in car driver trips amongst the targeted populations in large urban areas. In smaller urban and rural areas, the reduction in car driver trips is 2 – 6%.

Under the 'Smarter Choices' programme, the UK Government has allocated £10m over 3 years to showcase packages of smarter measures in three Sustainable Travel Towns. Results of household travels surveys show that individualised marketing (combined with other improvements in the town such as cycle promotion) has resulted in increases in walking of up to 14%, cycling of up to 60%, public transport of up to 11% and a corresponding reduction in trips as a car driver of up to 5%¹⁰.

An evaluation of 12 in-depth case studies in the UK and 10 smaller case studies concluded that personalised travel planning reduced car driver trips by 11% and distance travelled by car by 12% amongst the target population. In terms of mode share, this represents a decrease in car driver trips of 4 percentage points, with walking the main beneficiary, having, on average, a reported increase of 3 percentage points (Parker et al. 2007).

In Australia a proposed community travel plan between 2008 and 2012 will target 180,000 households, and is forecast to save 1.2 Mt CO₂ per annum by 2010 (ECMT 2007).

In four Japanese cities during the period 2000 to 2002, studies on travel feedback programmes (TFPs) have indicated potential transport CO₂ savings of between 15 and 35% compared to baseline (Fujii & Taniguchi 2006). Overall, TFPs had a 19% mean average effectiveness in reducing CO₂ emissions arising from changed travel behaviour though there is no information on whether these are net CO₂ reductions (i.e. taking into account the increase in public transport use). Importantly, TFPs appear to be able to change travel behaviour over the longer term. (Fujii & Taniguchi 2006) cite three studies whose results suggest longevity of impact of more than one year.

⁹'Smarter choices' combine individualised marketing with the travel planning discussed below (see 3.5.2), car sharing schemes, public transport marketing and awareness campaigns. We have included their impacts in this section for illustrative purposes and it is important to note that these are a combined product of marketing and planning.

¹⁰This data has been drawn from various survey reports from the three Sustainable Travel Towns which can all be accessed from the DfT website <http://www.dft.gov.uk/pgr/sustainable/demonstrationtowns/sustainabletraveldemonstrati5772>



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A trial of individualised marketing, aimed at increasing both public transport patronage and cycling, began in the municipality of South Perth, Western Australia in 1997 (James 1998; Taylor & Ampt 2003). The evaluation survey suggested a 10% reduction in car driver trips and a 14% reduction in VMT had been achieved. Public transport trips increased by 21%, cycling by 91%, walking by 16% and car passenger trips by 9% (indicating increased ride-sharing). In 2000 a major project for travel behaviour change was then implemented. In this project all 15,300 households resident in the area were invited to participate in a Travelsmart program. (John 2001; Taylor & Ampt 2003) reports a 25% increase in public transport patronage and a 16% increase in walking trips resulting from this study.

In 2002, the Department for Transport funded a series of 14 pilot projects on personalised travel planning, which aimed to assess the effectiveness of the techniques in a range of different contexts. All seven residential pilots saw a modal shift away from car use, with estimated reductions in car use over a year ranging between 0.05 million and 6.2 million car kilometres (DfT 2005).

3.5.1 Individualised marketing/personal travel planning

Evidence on emissions savings

Our review revealed 19 relevant studies on personal travel planning and individualised marketing campaigns. There is considerable consistency in their conclusions regarding the potential to reduce carbon emissions.

Key issues and problems

There has been considerable debate about the validity of results emerging from individualised marketing or personalised travel planning techniques (Ker 2003; Stopher 2005; Bonsall 2007; Moser & Bamberg 2008). Concerns include monitoring being carried out by the same people who have undertaken the activity; the sample sizes being used, the evaluation of results against the counterfactual and the possibilities of

unrepresentative reporting of different types of household. Nevertheless, it would appear that, in the UK at least, individualised marketing has been subject to rigorous evaluation of impacts. Various UK studies have been independently audited in order to understand the extent to which behaviour changes only apply to the households who agreed to receive the information as opposed to the wider neighbourhood and whether control groups were used to understand background changes (Bonsall 2007). At the time of writing, UK DfT is funding a study to evaluate the results from the three Sustainable Travel Towns mentioned above and corroborate evidence from other indicators of traffic levels.

The effectiveness of the initiatives is due to numerous factors which include the existence of high quality alternatives to the car and seem to be most successful when they are implemented alongside



public transport service and cycling and walking improvements. Evaluation of the UK pilot studies concluded that the success appeared to be largely due to 'well-chosen target populations, sizeable intervention groups, and well-orchestrated individualised marketing and personal travel planning' (DfT 2005). In addition, research has concluded that any behavioural effects could be quickly eroded if the newly released road capacity is not reallocated away from the car or priced in order to lock-in the benefits (Cairns et al. 2004).

Costs

Given the differences between case studies in terms of sample sizes and the intensity of activity (i.e. the degree of feedback given to participants), it is difficult to conclude on the costs. Our review did not reveal costs per tonne of carbon saved. However the 2004 Smarter Choices report (Cairns et al. 2004) collected data on two small campaigns in Gloucester and Bristol which had cost £20 or £60 per head, translating into 3.3 or 3.4 pence per km saved. They also calculated the projected cost of larger scale schemes planned for London and Nottingham; £10-£14 per head or 0.7-1.2 pence per km saved. These economies of scale are corroborated by a later study evaluating a larger number of UK schemes (Parker et al. 2007) which concluded that larger-scale UK PTP projects demonstrated a value for money estimate (in the first year) of between £0.02 and £0.13 per vehicle km.

Summary

Given the number of travel behaviours which PTP targets (e.g. mode choice, car occupancy, total travel demand) and the fact that it never takes place in a vacuum, it can be difficult to measure the impacts and then isolate the effects of personalised travel planning or marketing alone. Nevertheless, there is consistent evidence to suggest that at the individual or household level, behaviour is indeed malleable when bespoke information about travel choices is offered. The evidence reviewed for this study found remarkably consistent reported effects in very different parts of the world with approximate car usage reductions of around 5-10%, greater reductions in VMT and significant increases in alternative modes. Further work is needed to identify the relationships between provision of alternatives to the car, penalties and restriction on car use and personal travel planning. Work is also needed to determine cost per tonne carbon saved.

3.5.2 Travel Plans

In addition to generalised awareness raising and travel planning targeted at households, government policy can also encourage or require the establishment of formalised travel plans at destinations i.e. in schools and workplaces. Studies tend to report results in terms of reduced car use and rarely identify what proportion is due to increased walking, cycling, and ride-sharing as opposed to greater use of public transport.

Workplace travel plans are packages of measures put forward by businesses to



encourage and enable staff and customers to commute and travel more sustainably. Government policy involvement can include tax exemptions tied to employer-provided public transport passes – as well as more obvious general interventions such as infrastructural changes and the pricing of roads and zonal access. Local authorities can also choose to promote travel planning, particularly by enforcing it through the planning system. In 1997, the first national UK guidance on workplace travel plans was published. In 2004, the Department for Transport reissued their guidance on what was expected from local authorities in their 'local transport plans' (DfT 2004b). This also gave increased emphasis to workplace travel planning, and various local authorities have subsequently significantly expanded their work in this area. Examination of US research on workplace travel plans by (Potter et al. 2006) concluded that direct financial incentives or subsidies are a key element of successful programs to reduce single-car occupancy travel to work. Overall, the more targeted tax concessions were estimated to be more cost-effective than other policy options to effect modal shift, such as investment in light rail systems.

Workplace travel plans tend to influence

mode choice and vehicle occupancy (through car sharing) and have less of an impact on total travel demand unless teleworking and teleconferencing are part of the strategy. They can also affect timing of travel by encouraging flexible working hours. This can have an emissions impact by avoiding car use during peak hour congestion periods.

In February 2007, in conjunction with Transport 2000, the UK Department for Transport launched their new 'National Business Travel Network', a forum intended to encourage more employers to get involved in travel plan work. There is also considerable interest in exploring the potential for further tax reforms that would benefit businesses directly, in order to encourage greater take-up of travel plans by employers.

School travel plans operate in a similar way but tend to be more often coupled with targeted initiatives such as bicycle training, 'walking school buses' or broader road safety measures. In the UK, the DfT and Department for Schools and Education have set a target that all schools must have a travel plan by 2010.

Within each of the sub-sections that follow, we discuss the evidence under the categories of schools and workplaces.

Table 3.10: Evidence on potential emissions savings – School Travel Plans

(Cairns et al. 2004) surveyed evidence from both the UK and Europe regarding the effect of school travel plans on car use and found that the results varied widely. A few schools showed no change at all but most schools showed a reduction in car use ranging from 6% to over 50%. They concluded that after 10 years of intensive implementation, school travel plans could reduce car mileage on the journey to school in urban areas of the UK by 4% in a low intensity and 20% in a high intensity scenario.

continued overleaf



Information from the Department for Transport's 1999-2003 'Making School Travel Plans Work' project suggests a similarly mixed picture. However, the results show that when UK local authorities do engage with schools a high proportion (somewhere between 60 and 90%) can be expected to achieve positive modal shift, and there are more than a hundred schools around the country where this has occurred. The implied overall reduction in traffic that might occur across all engaged schools is likely to be in the order of 8-15% (Cairns et al. 2004).

Evidence of potential emissions saving

Schools

There were 7 relevant studies found that dealt with school travel planning. The 'school run' accounts for a relatively small proportion of all car traffic on the road, but, in urban areas, it is a significant contributor to peak hour congestion. In Britain, over the ten year period from 1995/97 to 2006, cars taking children to school in urban areas have increased as a proportion of car trips in the morning peak period from 10% to 12%. However, this proportion peaked at 15% in 2004 and has fallen slightly since then (DfT 2008e). There is evidence that travel plans can reduce the use of cars for school transport:

Workplace

There were 15 relevant studies found that dealt with workplace travel planning, and this literature highlighted the significant changes in commuter habits that can be achieved in a wide variety of contexts using a broad array of incentives, small-scale infrastructural changes (such as providing cycle parking) and information provision. There is good evidence of effectiveness.

Key issues and problems

Schools

Whilst the UK has been slow to introduce widespread practical work with schools, there has been relatively rapid progress in the last few years. Evidence from UK case

Table 3.11: Evidence on potential emissions savings – Workplace Travel Plans

Based on case studies in UK local authority areas, data from British Telecom, and on evaluations of travel planning in the US and Netherlands, individual workplace travel plans typically reduce commuter car driving (trips) by between 10% and 30% (Schreffler & Organisational Coaching 1996; Cairns et al. 2002b; Cairns et al. 2004). The greatest switch is to the non-motorised modes i.e. walking and cycling.

(Cairns et al. 2004) conclude that after 10 years of intensive implementation, based on 30-50% of employees being covered, workplace travel plans could reduce car mileage undertaken on the journey to work in urban areas of the UK by 5% in a low intensity and 9% in a high intensity scenario. The equivalent figures in rural areas are 2 or 4%. The high scenario translates into 0.31 MtC (1.1Mt CO₂) per annum (Anable et al. forthcoming).



studies suggests that in the next ten years a significant proportion of schools in all areas (somewhere between 30% and 95%) will have developed effective travel plans (Cairns et al. 2004). However, there is a danger that the emphasis has been on putting a travel plan in place rather than achieving mode shift.

Improvements to public transport rather than non-motorised modes offer the greatest potential to reduce car escort mileage rather than car trips. This is because most car mileage for this journey purpose is on trips too long to be walked or cycled (Cairns et al. 2004). However, much of the mode shift – i.e. the proportion of trips that has taken place due to school travel plans – has been to walking, cycling and car sharing. In addition to public transport availability and safe walking and cycling links, (Cairns et al. 2004) suggests that the other main issues likely to influence the success of school travel planning are:

- Willingness of schools to engage with the process
- Funding
- Use of the planning system
- Presence or absence of traffic restraint/calming measures
- Parental preference
- Advertising & Marketing

Workplace

The literature also provides some assessment of 'what works' in work place travel planning:

Examination of US research on workplace travel plans by (Potter et al. 2006) concludes that direct financial incentives or subsidies are a key element of successful programs to reduce single-car occupancy travel to work. The most effective plans have an element of parking restriction – permits, charges or reductions (Cairns et al. 2004; Wolfram 2005; Dierkers et al. 2005). Organisations that have addressed parking in some way have achieved more than double the reduction in car use of those that have not, and have car driver levels that have been, on average, 25% lower. There is little hard evidence of whether flexitime and a compressed working week result in net benefits to VMT and carbon emissions (BTRE 2002); (VTPI/TDM 2008). However, it is also suggested such options may encourage extra day car trips, single occupancy vehicle driving over rideshare, and more dispersed land use (Ho & Stewart 1992; Giuliano 1995; VTPI/TDM 2008).

One of the greatest barriers is the limit on the uptake of employers and employees. Typically, intensive effort to engage employers in local authority areas in the UK have resulted in around 30% of employees targeted in urban areas, whilst county authorities have managed to engage with organisations representing about 10% of the workforce. Larger employees are easier to engage than SMEs (Cairns et al. 2004).

Costs

Schools

Costs can include the capital costs of 'safe



routes' infrastructure such as pedestrian crossings, traffic calming and cycle lanes and the administrative costs of travel planning and monitoring. (Cairns et al. 2004) estimates infrastructure costs ranging from £30,000 to £75,000 per school, and from £32 to £243 per pupil. On the basis of their estimated potential for traffic savings cited above (0.04 MtC or 0.15 Mt CO₂ after 10 years of intensive application), school travel plans would cost between £405 - £2865 t/C (£110 - £732 CO₂), the range being due to the different costs found in the original case studies (Anable et al. forthcoming).

Workplace

Cost-effectiveness has been studied and there is evidence that the cost per tonne of carbon varies widely depending on cost and effectiveness of the measures deployed:

- (Cairns et al. 2002b) examined case study evidence and suggest an average gross cost of £47 per full time employee for UK employers implementing travel plans, although these costs vary widely between employers.
- Another study in the UK found the typical cost to the local authority of promoting workplace travel plans to be on average £2-£4 per affected employee per year and concluded that differences in cost per kilometre probably relate to a range of factors, including whether the area is easy or difficult territory for travel planning; congestion levels (and hence willingness of employers to become

involved); the proportion of the workforce based in larger, more-easily targeted organisations; and how far advanced travel planning work is, with costs appearing higher in both early and later stages (Cairns et al 2004). Using this information in conjunction with the findings on travel plan impact in car use, (Anable et al. forthcoming) calculate that workplace travel plans will cost £29 - £579 per tonne carbon saved. As with School Travel Plans, this range reflects the different assumptions made in the original study with respect to potential effectiveness plus the case study results which highlighted the varying costs of implementing travel plans. These results indicated that it is more cost-effective to target larger companies with in-depth advice and implementation support than to deliver more superficial advice to smaller companies.

- Whilst there are local authority costs, the majority of travel planning costs are borne by the employer, but these can be compensated for by parking charges, extra land gained from reduced parking, and even improved staff health and morale. The latter point is, however, only anecdotal in the literature. Costs may also be reduced if business travel is affected, though the evidence concentrates on impacts on commuting.

Summary

The evidence revealed in our review suggests that travel planning can have a measurable and significant impact on



travel choices, typically reducing car usage by between 6% and 30% depending upon context. The most common shifts appear to be to non-motorised modes, though use of public transport and improved occupancy are also significant. Programmes that target workplaces appear to be more significant than schools in carbon terms, though it is possible that there are synergies that exist between the two given the number of parents who drop their children to school on the way to work (Jones & Bradshaw 2000; McDonald 2008). There is evidence to suggest that 'sticks', particularly measures such as parking and other charges, help to make travel planning effective. As with personal travel planning, it is also important to note that travel plans are a means by which existing services/options can be utilised more effectively. The options must first exist and/or be improved if travel plans are to have an impact. This highlights the strong complementarities between travel planning and the provision of alternative modes, road space allocation and road/car use charging discussed elsewhere in this section.

3.6 Road user charges

In this section we examine the potential for carbon emissions reductions from instruments and policies that charge consumers directly for their road use. Such initiatives may be based on actual distance travelled, the time of day trips are made, and the type of roads used. Both local 'cordon charging' schemes (e.g. urban congestion charging in London and as proposed for Manchester, Edinburgh and elsewhere) and national schemes are discussed. It is important to note that the impact of road pricing on overall traffic and hence carbon is dependent (amongst other things) on the scale of implementation. Our review revealed 30 relevant studies.

From the evidence gathered, it is clear that the concept of the road user charge has considerable support in some quarters (although not necessarily because of any potential CO₂ savings). For example the Eddington Review remarks that "Introducing markets (pricing) where none exist can have a very powerful and positive economic effect in any sector. The

Table 3.12: Evidence on potential emissions savings – Road user charges (national level)

The UK's Commission for Integrated Transport (CfIT) estimated that national road charging could reduce overall traffic levels by 5%, with an associated reduction in CO ₂ (CfIT 2002).
Modelling by (Kollamthodi 2005) of a UK national road-pricing scheme in 2015 projects a 3% reduction across all roads in annual vehicle kilometres travelled by all vehicles, including a 6% reduction on urban roads.
In the Netherlands, the effects of road pricing policy have been estimated by the RIVM National Institute for Public Health and the Environment. It could decrease car use between 10-13 %. Emissions of CO ₂ from road transport would be reduced by 2.3 Mt, a decrease of more than 10 % (Wiegman et al. 2003).



Table 3.13: Evidence on potential emissions savings – Road user charges (local level)

On a local level, if governments adopt an incentive for all major metropolitan areas to implement cordon-pricing systems, they could reduce fuel consumption and emissions of CO₂ for light-duty vehicles 3%-6% nationwide by 2010 (IEA 2002).

In the two most cited examples in western cities (London and Stockholm), carbon savings from congestion charging have been in the order of 14-16% against background levels within the charging zone in the first year of implementation. In London, a 15% reduction in traffic volume changes resulted in an 8% reduction in transport emissions, speed changes reduced emissions 7.3% and the remainder were delivered through vehicle stock changes (0.7%) Around 50%-60% of the London traffic reduction was attributed to transfers to public transport, 20%-30% to journeys avoiding the zone, and the remainder to car-sharing, reduced number of journeys, more travelling outside the time of operation, and increased use of motorbikes and cycles. After the first year, any reductions in emissions arise from any changes in the vehicle fleet rather than further traffic effects.(TfL 2006a).

Since TfL was formed in 2000, there has been a modal shift of 5% from car usage to public transport, walking and cycling, saving around 500,000 car journeys per day and an estimated 210,000 tonnes of CO₂ emissions per year (TfL 2006b).

transport sector is no exception, and in particular the potential for benefits from a well-designed, large-scale road pricing scheme is unrivalled by any other intervention” (Eddington 2006). That report goes on to suggest that a UK national road pricing scheme could reduce congestion by some 50% below what it otherwise would be in 2025 and reduce the economic case for additional strategic road infrastructure by some 80%. Benefits could total £28 billion a year in 2025, including £15 billion worth of GDP benefits.

Evidence on potential emissions saving

This is a particularly well studied area albeit reliant upon modelled results. Several studies have assessed the potential to reduce CO₂, although caution must be exercised in comparing them due to the different pricing regimes and timescales involved:

Key issues and problems

Despite the apparent advantages of road pricing for emissions, some authors urge caution about emissions benefits, suggesting that optimising road use could actually increase the volume of traffic overall, and with it emissions of CO₂ (Environmental Audit Committee 2006). This is particularly likely to occur if road charges are offset by reductions in fuel duty. Even if travel demand and traffic volumes do not increase, the potential to increase traffic speed by reducing congestion may also increase emissions. An improvement in travel time may lead to an increase in emissions without any change in travel demand (Yin & Lawphongpanich 2006), citing (Nagurney 2000). A number of studies have attempted to quantify these effects:

- Modelling work for the Eddington review of UK transport policy (Eddington 2006)



suggests national pricing would lead to a reduction in annual CO₂ traffic emissions of 7% by 2025 (from 2003). This forecast, however, assumes a 1.3% increase in vehicle efficiency annually as a result of existing agreements between motor manufacturers. Sensitivity analysis reveals that halving this improvement rate leads to emissions from transport 11.3% *higher* than the 2025 baseline (Anable & Bristow 2007).

- Modelling described in (Anable & Bristow 2007), citing (Graham & Glaister 2004) based on revenue neutrality suggests that such schemes lead to increased traffic CO₂ emissions of 7% and 5% respectively, whereas a revenue-raising charge is estimated to reduce emissions by 8.2%.
- (Grayling 2005) presents results from the DfT's National Transport Model that imply a slight fall in both traffic levels and related CO₂ emissions, 2% and 1% respectively, from a revenue neutral implementation.

This evidence describes a rather confusing picture, but it does appear that revenue raising schemes are likely to deliver CO₂ reductions. The evidence for revenue neutral schemes is mixed but it appears that, given the potential redistribution of traffic to lower charged routes, the likely carbon increases from higher speeds and falls in motoring costs on less congested roads, such schemes will deliver either no or only marginal CO₂ reductions unless reinforced by other trends such as changes to the CO₂ intensity of the vehicle fleet.

Partial implementation of road pricing (congestion charges and toll roads) can

lead to rebound effect and unintended consequences:

- If tolls result in traffic being diverted to secondary roads, congestion on these roads could increase. Emissions would simply be diverted elsewhere and might actually increase with any increased distances (BTRE 2002).
- Whilst evidence on urban zones suggests that road-user charging can realise emissions savings, this is dependent on traffic not diverting around the zone and travelling further to alternative destinations (Beevers & Carslaw 2005; TfL 2006a; TfL 2007a; TfL 2007b).
- Road pricing can involve a reduced pressure on tolled roads either because some drivers choose alternative routes not subject to pricing, or because some drivers reduce total travel demand or switch to alternative modes. In each case the consequence may be a higher speed potential for those on the tolled roads. This can result in increased emissions, especially if the total demand for transport is not reduced, or has even increased as a result of the improved accessibility through the tolled roads (Harmsen et al. 2003). Increasing traffic speeds may also worsen safety and access problems for pedestrians and cyclists.

It is possible that road user charging schemes will, by their very nature, encourage behavioural changes not yet assumed in the modelling. By highlighting the cost per journey, possibly through a highly visible in-car metering, this measure may encourage a rethink of



habitual patterns and reinforce the link between behaviour, travel costs and potentially also carbon emissions (Anable & Bristow 2007). Research participants in the DfT's 2004 'Feasibility Study of Road Pricing in the UK' agreed that the current system of paying for road use does not encourage drivers to think about their car use and that a potential system of paying at the point of use was more likely to encourage people to think about the journeys they make (DfT 2004a).

Road charging in general has been subject to considerable public and political debate. There is evidence that charging is viewed with scepticism by a considerable fraction of the public. Recent referendums on congestion charges in Edinburgh and Manchester in the UK demonstrated public opposition. In addition, a significant body of attitude research on public acceptability of road pricing in all its guises leads to consistent conclusions. A recent review of this evidence synthesized it as follows: 'Research suggests that some people consider that they are already paying enough for their car use. Increases in costs is a concern for certain groups, particularly those on low incomes. The public has a strong attachment to their cars. Any policy intervention that is perceived to interfere with how people use their cars is likely to generate a knee-jerk response, high levels of opposition and, in the case of road pricing, a belief that revenue generation is the overall aim. There does seem to be a consensus that congestion needs to be solved, but the public needs to be convinced that it can be solved.' (Lyons et al. 2008)

Vehicle fuel economy

One of the criticisms of road pricing and VMT taxes is that such policies will not motivate improved vehicle fuel economy (efficiency gains used to reduce fuel consumption rather than improve performance). Unless a policy is specifically CO₂ linked, there is an absence of a direct incentives for consumers to buy cars with higher fuel economy ratings because the tax depends only on mileage (U.S. Government Accountability Office 2007). The same criticism can also be applied with regard to eco-driving – good driving style is not rewarded in a road pricing system; mileage is key. A CO₂ linked scheme would address this concern. Our review revealed limited evidence on the subject, but some studies quantify the potential:

- One modelled system in the Netherlands involved differentiation according to indicators of environmental pressure (by vehicle weight and fuel type) which suggested significant CO₂ reductions would be possible. Two alternative calculations pointed to reductions of 9-10% and 4-5% respectively. The bulk of this comes from cars, mainly through reductions of trip lengths (10%) and number of trips (4%). The range of outcomes depends on assumptions over the sensitivity to potential reductions in vehicle purchase costs (resulting from the tax burden shifting between vehicle purchase and vehicle use) (Harmsen et al. 2003).
- Modelling conducted by the Open University and others suggests that using a CO₂ banded car distance



charge of 3.3–10.4 pence per km, would reduce total surface passenger transport CO₂ emissions by up to 6% as compared to a base scenario (Potter et al. 2004;LowCVP 2006b).

Importance of complementary policies

Analysis suggests that the greatest impacts of pricing car use occur within markets where reasonable alternatives exist (Soberman & Miller 1999). The London Congestion Charging evidence shows that prior investment in public transport has been a key to its success (Annema 2005).

Costs

Estimating the costs of road use charging in terms of a cost per tonne of carbon saved is not straightforward. Our review did not reveal any estimates presented in terms of £/tC. One reason is that road user charging brings multiple benefits, congestion reduction being a foremost consideration. Indeed, as we note in the introduction to this section, Eddington (2006) suggests that economic benefits could sum to around £28 billion. Set up costs may be significant; several authors suggest they would run to many tens of billions of pounds (BTRE 2002;Anable & Bristow 2007). However road user charging is a revenue raising instrument, so set up and admin costs may be recovered through the charge. Costs to drivers may impact significantly on emissions yet are redistributive rather than absolute. This means that costs per tonne of carbon have the potential to be negative, since charging both reduces road use (hence emissions) and (by reducing congestion) improves vehicle efficiency, *and* creates revenues which can

be spent elsewhere in the economy, including direct hypothecation to enhancing lower carbon transport. Additional research is needed to develop a systematic methodology to account for the carbon emission benefits of road user charging, and the costs thereof.

Summary

The evidence on road user charging demonstrates that individual congestion charging schemes have led to significant reductions in emissions within each zone and suggests that this is offset only to a limited extent by additional journeys outside the zone. Savings result from both reduced car traffic and more efficient car use, due to reduced congestion. Congestion charging can help promote modal shift and increased vehicle occupancy. The evidence on wider road pricing is based on modelling rather than experience, and suggests a more mixed picture. Analysis suggests that emissions reduction is substantial if charging is *additional* to existing fiscal instruments but may be rather modest if road pricing is offset by reductions in fuel duty. Modelling also suggests emissions savings will be greater if charges are differentiated according to the emission profiles of the vehicles, thus promoting savings by altering car purchasing behaviour as well as use. The behavioural responses assumed in the modelling may also underestimate the effects that highly visible marginal cost pricing has on drivers. The cost-effectiveness of road user charging in solely emissions reduction terms are not clearly articulated in the literature revealed in our review and this appears to be an area where additional research is merited.



3.7 Road space provision and reallocation

In this section we examine the potential effect on carbon emissions from the provision of *additional* road space, and the reallocation of *existing* road space. As discussed elsewhere, traffic growth is a product of a wide range of interacting factors, including economic growth, demographic changes and land use. This section focuses specifically on that fraction of road traffic that is *induced* by new road capacity, or *reduced* when capacity is reallocated. Our review revealed 19 relevant studies, but we note that much of the literature on this subject is unrelated to discussion about carbon reduction and may not have been revealed in our review. We found that the majority of the evidence examined was framed in terms of traffic volume and congestion levels rather than the impact on carbon emissions.

Road Provision

Table 3.14: Evidence on potential emissions savings – Road Space Provision

In the UK, a seminal study by the Standing Advisory Committee on Trunk Road Assessment (SACTRA 1994) identified the phenomena it called 'induced' traffic. By analysing the traffic flow on improved roads and comparing them against forecasts, it concluded "An average road improvement, for which traffic growth due to all other factors is forecast correctly, will see an additional [i.e. induced] 10% of base traffic in the short term and 20% in the long term." In responding to SACTRA the Government accepted that the capacity of the road network influences traffic growth (DfT 1994).

The Council for the Protection of Rural England investigated three large trunk road schemes in the UK and a further ten smaller schemes. As with the SACTRA report, the authors concluded "Careful scrutiny of the traffic flow data suggests that traffic growth after the scheme opened has been significantly higher than growth on other nearby road corridors or national traffic growth." The increase was in the range of 10-35% within one or two years of opening (CPRE 2006; Goodwin 2006).

A number of studies have analysed the relationship between adding roadway capacity and

Evidence on potential emissions saving

Capacity and reallocation are directly related since road space reallocation is effectively a form of negative road provision as far as the car driver is concerned. From the mid-1990s a shift in UK Government policy on road building recognised that building roads was not always a solution to congestion, as creating new capacity could generate traffic additional to that anticipated in response to economic growth and other factors. However, the opposite proposition, namely that reducing road space could reduce traffic, was not as widely accepted. Consequently, numerous proposals for pedestrianisation or bus priority schemes (which may have carbon savings potential) were rejected, due to fears of the problems that they could create on surrounding streets (Cairns et al. 2002a).



changes in travel. Studies such as (Fulton et al. 2000) and (Lem & Noland 2000) cited in (IEA 2001) suggest that elasticity for travel increases as a function of increases in lane-kilometres of capacity of the order of 0.3-0.5 in the short run and as high as 0.9 in the long term. The latter figure suggests that most of the congestion reductions gained by capacity expansion (with possible concomitant carbon savings) may eventually be lost to increases in traffic.

According to (Litman 2001) traffic congestion tends to maintain equilibrium. If road capacity increases, the number of peak-period trips also increases until congestion again limits further traffic growth. The additional travel is "generated traffic" which consists of diverted traffic (trips shifted in time, route and destination), and induced travel (shifts from other modes, longer trips and new trips).

Research indicates that generated traffic often fills a significant portion of capacity added to congested urban roads. (Cervero 2003a;Cervero 2003b) estimated that 80% of additional roadway capacity is filled with additional peak-period travel, about half of which (39%) can be considered the direct result of the added capacity (cited by (Litman 2008a). Similarly, (Hansen 1995) estimated that with respect to California state highways, 60-90% of increased road capacity is filled by new traffic within five years. Total vehicle travel increased 1% for every 2-3% increase in highway lane miles (cited by (Litman 2001).

Modelling results from the European Commission Auto-oil non-technical measures study found that a 0.5% increase in private vehicle travel would offset the fuel savings from a 1.5% rise in average vehicle speeds, which in city traffic helps reduce fuel use. The results show that increasing road capacity by 5% to improve traffic flows has broadly no net fuel savings (European Commission 1999;IEA 2001). However, the effect on emissions depends on the scale of the new capacity provision. Modelling by NOVEM, the Dutch Environment Agency, found that a blanket policy of "provide roads to meet demand" would raise transport emissions of CO₂ by a net 9% between 1990 and 2010, compared to a no-new-roads policy (Michaelis 1996;IEA 2001).

This is not to say that initial CO₂ benefits to capacity expansion do not exist since emissions may be reduced when the same volume of traffic flows more smoothly. For example, between winter 2003 and winter 2006, individual fuel consumption and CO₂ emissions were reduced by 4% by the M42 pilot hard shoulder running scheme (hard shoulder running is a form of capacity expansion that uses the existing 'break-down lane' (hard-shoulder) in peak periods). However, results of modelling by (Stathopoulos & Noland 2003)

also confirm that traffic-flow improvements and capacity expansion projects are unlikely to provide lasting emission reduction benefits. In the long-run, total emissions are likely to be higher after traffic-flow improvement. Further analysis by the same authors suggests that in the absence of traffic flow improvements the long-term suppression of traffic would be enough to off-set any increases in emissions from congested traffic flow (Stathopoulos & Noland 2003). As noted above, faster roads may also discourage cycling and walking.



Road space reallocation

There is evidence to suggest that the phenomenon of generated traffic may work in reverse in that when urban

roadway capacity is reduced a significant portion of previous vehicle traffic may be removed from the road network altogether.

Table 3.15: Evidence on potential emissions savings – Road space reallocation

(Cairns et al. 1998) examined over 70 case studies of roadspace reallocation from 11 countries and the collation of opinions from more than 200 transport professionals worldwide. Key findings were as follows:

- When road space is reallocated, traffic problems are usually far less serious than predicted.
- Overall traffic levels can reduce by significant amounts.
- Traffic reduction is partly explained by recognising that people react to a change in road conditions in much more complex ways than has traditionally been assumed in traffic models.

Follow-up analysis by (Cairns et al. 2002a) of twelve new case studies supports the conclusion of their earlier research (Cairns et al. 1998) that taking away road space from general traffic can cause overall traffic levels to reduce. The data analysed by (Cairns et al. 2002a) suggest that the scale of reduction can be quite substantial. In half the case studies analysed, over 11% of the vehicles that were previously using the road or the area where road space for general traffic was reduced, could not be found in the surrounding area afterwards.

Key issues and problems

Road space reallocation

A recurrent issue of road reallocation is whether displaced traffic will simply divert to neighbouring streets. However, the findings of (Cairns et al. 2002a) suggest that such problems are, in reality, rarely as bad as predicted and that, with careful planning and appropriate implementation, reallocating road space to lower emission modes of transport can result in a variety of complementary benefits. (Cairns et al. 2002a) found that two different patterns of experience emerge:

- In some cases, over time, traffic appears to creep back to its original

level, or higher because the 'deterrent' provided is not sufficient to result in long-term changes in travel behaviour or overcome demand growth driven by income or other factors. There may be a real reduction in capacity on a treated road or area, but this is offset by adequate spare capacity on alternative routes or at other times of the day.

- However in situations where there is not adequate additional capacity on other routes or at other times, in addition to re-routing or re-timing trips, a wide range of other responses were reported in surveys. These included people changing their mode



of travel, choosing to visit alternative destinations, changing the frequency of their journey, consolidating trips for different purposes, more efficient trip-making, car-sharing, or no longer making journeys (e.g. by working from home occasionally).

Longer-term responses included changes in job location, changes in household location and changes in developers' choice of location for new development (Cairns et al. 2002a).

Costs

Given that it is generally not the aim of road building programs to reduce carbon emissions it is perhaps not surprising that no evidence was found for associated carbon abatement costs. Neither was any direct evidence on carbon abatement costs uncovered for road reallocation projects. Nevertheless, some commentators do highlight the danger of omitting the dis-benefits of even small volumes of induced traffic from economic calculations (SACTRA 1994; Litman 2001). They also point to the unambiguous net environmental costs resulting from adding road capacity (SACTRA 1999).

Summary

The evidence examined supports the idea of a clear causal relationship between added road capacity and increased traffic volumes. Short-term emissions reductions from lower congestion and higher/smoothed speeds are eroded in the longer term by induced traffic and traffic growth generated by economic growth and other factors. By contrast, well-designed and well-implemented schemes to

reallocate road space away from general traffic may help to improve conditions for pedestrians, cyclists or public transport users, without significantly increasing congestion or other related problems. Road space reallocation can also help to lock in the benefits from other demand management policies and smarter choice measures.

3.8 Conclusions

This chapter reviews a wide range of policies that bear upon individual travel choices. The research revealed a variety of evidence types. Some of the evidence is empirical: for example reviews of company or community programmes and ex-post analysis of the impact of major policy developments. However a substantial fraction of the overall evidence is comprised of modelling studies and analytical work. In some areas there has been relatively little attention to the potential to reduce CO₂ emissions, in others there is evidence at a company or community level, but little evidence of national potential. Whilst many interventions appear in principle to offer a low cost means to reduce emissions our review revealed a relative absence of attention to costs, at least in terms of costs per unit of CO₂ saved.

Nevertheless the review reveals an interesting array of evidence, which provides insights into the strengths and weaknesses of a range of policies. We review the headline findings for each category of policy below. However the review also points up some overarching issues:



The importance of policy integration

All of the policies reviewed above have shortcomings as well as advantages. In many cases there are synergies between policies, or opportunities to overcome problems through the implementation of additional policies. For example, improvements to public transport or cycling infrastructure can be augmented by road space reallocation and pricing which discourages car use. Put another way, and viewed from the road pricing/charging perspective, the availability of alternatives improves elasticity of response. As we discuss in Chapter 5, similar issues affect responsiveness to fuel prices. Pricing and regulation can also assist in ensuring that new services draw users out of cars rather than from other modes or simply inducing new journeys. Similarly, individualised marketing can improve the utilisation of existing services, increasing occupancy, which improves both carbon efficiency and cost-effectiveness. Finally, provision of packages of policies that offer benefits such as new transport options may help overcome opposition to 'negative' policies such as new charges for road use or parking. Few policies will succeed in isolation, policies work best as packages.

Short-term and long-term impacts

In many cases short-term impacts and long-term effects may differ. For example the potential for public transport to absorb a significant fraction of car journeys in the short term is limited, yet the evidence suggests that locations/regions which do not provide effective public transport, and integrate transport with land use and other policies, become over time far more

reliant on private cars. Similarly, the potential share of non-motorised modes (walking and cycling) is affected not just by the safety and attractiveness of routes and paths but also by the distance to key services and workplaces. It appears possible that short run improvements in walking and cycling provisions may also help to 'lock in' longer term patterns of travel behaviour that are inherently lower carbon because key services can be accessed more easily without a car. We return to these intriguing interrelationships in Chapter 6.

The importance of additional analysis

Our review reveals that in almost every policy category reviewed above there are important gaps in the available evidence. These span the full range of issues this review seeks to uncover: potential to save emissions, problems/limitations, and costs. They include:

- Assessment of the long run potential for tele-activity to reduce emissions, both in terms of 'baseline' (business as usual) trends and the potential for policy enhancement
- Assessment of the long run potential for walking and cycling to reduce emissions; particularly in terms of the cost and potential benefit of investment in dedicated cycling infrastructure
- Quantification of the long run relationships between public transport provision and patterns of travel behaviour and location decisions
- Analysis of the cost-effectiveness of road user charging in terms of emission reduction



- Analysis of the factors that determine the public acceptability of road use charges
- Evaluation of the potential expansion of car clubs and better characterisation of the profile of current car club members
- Additional research into the effectiveness (particularly over the longer term), cost and acceptability of options to reinforce eco-driving training amongst existing drivers
- Assessment of the absolute cost and public acceptability of improved speed limit enforcement

In almost all cases evidence on cost-effectiveness in CO₂ terms is either limited or non-existent. Remediating this will be difficult, particularly when it comes to accounting for combined benefits and policy interactions. However it is a key research task if the potential to reduce emissions through interventions that target travel choices are not to be overlooked by policymakers.

Findings from individual policy categories are as follows:

Reducing demand for travel

Demand for travel is impacted by costs of fuel, public transport, road use and vehicles. There are few policies which set out directly to influence the total amount of travel in the system. Therefore this section reviews the direct effects of only policies to promote tele-activity. However, it is difficult to draw firm conclusions about the potential of tele-activity to reduce

emissions, or the policies required to accelerate it. The main problem is that there does not appear to have been much macro-level, UK-specific analysis of the potential for tele-activity to reduce emissions, on its own or through a package of interventions. Whilst the evidence on a company case study basis suggests teleworking may have a useful role in reducing demand for travel, considerably more work is needed on the potential for tele-activity to influence car dependent lifestyles and affect energy consumption across the transport as well as commercial and residential building sectors. It is not clear how much tele-activity might increase without intervention and what role there is for policy.

Support for non-motorised modes

A significant fraction of journeys can be made by walking or cycling, since this is the experience of several European countries. Increasing the share of cycling in Britain to levels closer to those of our Northern European neighbours could yield emissions savings in the UK of around 2 MtC (7.3Mt CO₂) per year (approximately 6% of total transport emissions by source) if like-for-like mode switching was taken into account. The savings could be greater if destination switching was also assumed. Inter-country comparisons suggest that effective policies to make cycling safer and more convenient, in particular through segregation and prioritisation, correlate closely with levels of cycling. However there is also evidence that policies that penalise car use (congestion charging in particular) can be effective in promoting the use of non-motorised modes, and



individualised marketing can assist in the uptake of cycling. Our review did not reveal any systematic attempt to estimate the cost of saving carbon using policies to promote non-motorised modes. Increasing the role of cycling is not just a matter of making cycling more attractive and safe, or even of penalising car use; it is also a matter of making more services, shops, schools and jobs within reach of a non-motorised trip.

Support for public transport

The evidence on the potential of public transport to reduce emissions presents a complex and somewhat contradictory picture. On average, emissions per passenger km are much lower than those for private cars. There is a strong link between the availability of convenient and affordable public transport and patterns of land use that are conducive to lower reliance on private cars. However, the short to medium term potential for public transport to contribute to emissions reductions is relatively limited. The main reasons are that capacity expansion may need to be large in order to absorb a significant proportion of car journeys, that demand may be induced by new routes and lower fares, and that users may be attracted from other low carbon modes as well as from cars. It is important to consider the potential to improve occupancy at underutilised times/routes as well as how to provide new capacity. Similarly, fare reductions, prioritisation and additional services can be combined with measures to restrict car use, helping to ensure mode switching is beneficial in CO₂ terms. Mode switching cannot be divorced from destination switching. Thus, the capacity constraints foreseen in

forecasting and modelling exercises may place too much emphasis on the requirement to satisfy current car passenger demand with like-for like public transport patronage. In all cases there is evidence that changes to journey patterns can build up over time to ameliorate congestion impacts from bus prioritisation, and land use effects may multiply the impacts of capacity provision and fare reduction.

Car clubs

Relative to car ownership, car clubs appear to help reduce total car miles driven, with members who previously owned a car walking, cycling, and using public transport more often, as well as travelling less by car. The research also shows that this reduction of car miles is a direct result of breaking the link between car use and car ownership - exactly the service that clubs provide. More research is needed into the potential rate and scale of growth and how to attract car club membership from a wider section of the population and on cost-effectiveness of carbon saving.

Using vehicles more efficiently

Improving vehicle occupancy offers large potential savings at low cost but the evidence from the US suggests it is difficult to deliver in practice. Potential savings from eco-driving campaigns appear to be significant and costs low, with the biggest obstacles being securing driver participation and ensuring that efficient driving habits are sustained over time. This suggests that if the potential benefits of more efficient driving styles are to be secured, an ongoing programme of training and reinforcement through



advertising and other awareness raising mechanisms is likely to be needed. Speed enforcement and reduction would appear to have great potential to reduce emissions from private vehicles in the context of a broader eco-driving campaign. Enforcing speed limits on motorways and trunk roads could save around 2-3% of total transport emissions. What is more, these savings are possible in the short term. The absolute cost of this policy and the political acceptability require some further investigation.

Individualised marketing and travel planning

It can be difficult to measure the impacts and then isolate the effects of personalised travel planning or marketing alone. Nevertheless, there is consistent evidence to suggest that personal and organisational travel planning can have an impact on travel choices. Approximate car usage reductions are around 5-10% for personal travel planning and between 6% and 30% for organisation (school, workplace) level, depending upon context. The most common shifts appear to be to non-motorised modes, though use of public transport and improved occupancy are also significant. There is evidence to suggest that 'sticks', particularly measures such as parking and other charges, help to make travel planning effective. With all forms of travel planning, it is important to note that travel plans are a means by which existing services/options can be utilised more effectively. The options must first exist and/or be improved if travel plans are to have an impact. This highlights the strong complementarities between travel planning and the provision

of alternative modes, road space allocation and road/car use charging.

Road pricing

Individual congestion charging schemes have led to significant reductions in emissions within each zone and these are offset only to a limited extent by additional journeys outside the zone. Savings result from both reduced car traffic and more efficient car use, due to reduced congestion. Congestion charging can help promote modal shift and increased vehicle occupancy. The evidence on wider road pricing is based on modelling rather than experience, and suggests a more mixed picture. Analysis suggests that emissions reduction potential is significant and is cost-effective in terms of the economy overall (because charges reallocate revenues). However, carbon impacts may be rather modest if road pricing is offset by reductions in fuel duty and other car taxes.

Road space provision and reallocation

The evidence examined supports a clear causal relationship between added road capacity and increased traffic volumes. Short-term emissions reductions from lower congestion and higher/smooth speeds are eroded in the longer term by induced traffic additional to ongoing traffic growth. By contrast, well-designed and well-implemented schemes to reallocate road space away from general traffic may reduce traffic and help to improve conditions for pedestrians, cyclists or public transport users, without significantly increasing congestion or other related problems.

What policies are effective at reducing carbon emissions from surface passenger transport?
A review of interventions to encourage behavioural and technological change





4. Lower carbon vehicles: technology development and consumer choice

4.1 Introduction

This chapter addresses car technology development and purchase choices; it considers policies which seek to affect the behaviour of two actors, car makers and car buyers. Technology potential is very large, since zero carbon emission options for vehicle propulsion could become available, but the timescales are long (King 2007). This report does not consider R&D or wider innovation policies. In the shorter term, efficiency gain is the main option for reducing the level of emissions each vehicle produces. Policies that target car makers, notably voluntary or compulsory emissions standards (see Section 4.2), may be able to drive the development and availability of lower carbon vehicles. However, the vehicles available are only part of the story, since offerings must be attractive to consumers and/or consumers must be incentivised, encouraged or even obliged to choose lower carbon options.

Vehicle purchase is a complex consumer choice in which a wide range of attributes are weighed up, largely subjectively. Fuel economy is only one attribute, others such as safety, image and performance play an important role in purchasing decisions. Whilst lower carbon vehicles are also lower fuel cost vehicles since efficiency yields emission reduction, car purchase is not usually an entirely 'rational' economic decision where capital and operating costs are optimised against utility.

To the extent that consumers do evaluate the cost-effectiveness of their purchase a number of factors militate against adequate attention to fuel savings. For

example, depreciation remains the main running cost for most new cars and so factors such as brand choice are key, though fuel economy can play a large role in resale value (Veitch & Underdown 2007). A core issue is the tendency for consumers at the point of purchase to display long-term 'myopia' regarding running costs such as fuel prices, servicing and vehicle circulation taxes (Koopman 1995; COWI 2002a; Lane 2007).

Thus the availability of fuel efficient vehicles does not guarantee their purchase and hence does not necessarily guarantee the decline in CO₂ emissions one might expect from the vehicle fleet as a whole (Michaelis & Zerle 2006).

In this section we consider the principal policies which bear directly on the range of vehicles that manufacturers make and the vehicles chosen by consumers. The main levers of policy and primary actor choices are shown in Figure 4.1. The figure also shows (in greyscale) policies discussed in Chapter 3 that have a potentially significant, if less direct bearing on vehicle choice.

Car purchase choices matter: the emissions per km for the range of cars available today is wide – from under 100g/km up to over 500 (see Figure 4.2). Purchasers may choose a vehicle based on occasional needs, such as the family holiday, rather than their main need, which may be for a small, economical car for urban use. Nevertheless simply by choosing a more efficient vehicle within a particular class of car consumers are able to reduce emissions per km by typically 50% or more (see Figure 4.2), and substantially more for some classes

What policies are effective at reducing carbon emissions from surface passenger transport?
A review of interventions to encourage behavioural and technological change



What policies are effective at reducing carbon emissions from surface passenger transport?
 A review of interventions to encourage behavioural and technological change

(though vehicles within classes may not be particularly comparable). Recent analysis suggests that the efficiency of the best available models will continue to improve (King 2007), hence there is an ongoing

role for consumer choice in improving overall fleet efficiency even as technological improvements enhance the potential for emissions reduction.

Figure 4.1: Car choices and policies

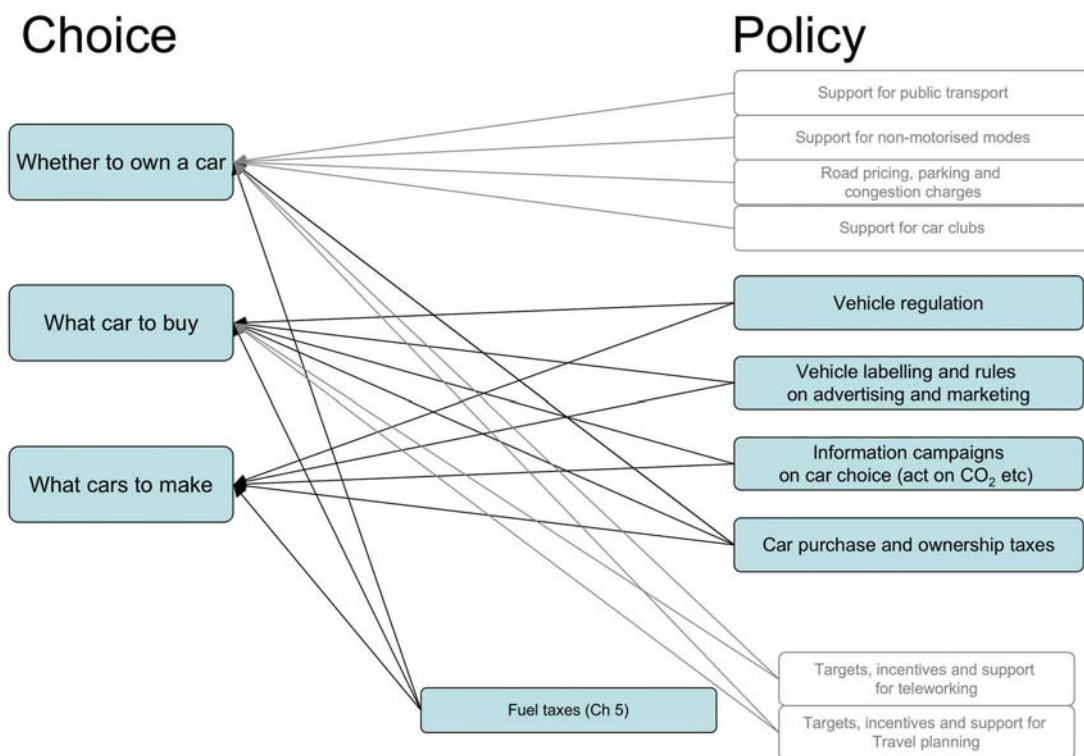
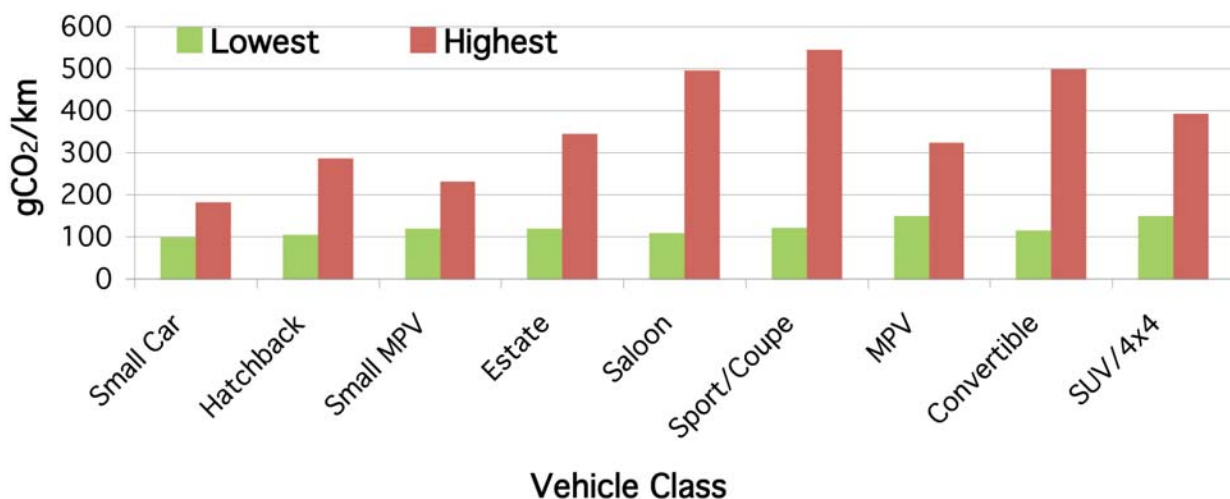


Figure 4.2: CO₂ emissions by vehicle class (King 2007)





The remainder of this section discusses the evidence our review revealed on the following policy types:

Regulatory and voluntary standards for efficiency/emissions

Purchase taxes and subsidies

Circulation taxes and subsidies

Information, labelling and car advertising

4.2 Vehicle efficiency standards

Vehicle efficiency standards require car manufacturers to ensure that their vehicles meet a defined standard level of fuel consumption or CO₂ emissions. Such standards include voluntary or legal instruments, applied at national or international level. Unlike the mechanisms discussed in Chapter 3 the principal actor that standards bear upon is the car makers, although their efficacy is also affected by the car purchase preferences of consumers, as we explore in more detail below (Section 4.3). Standards may involve some mechanism for sharing the burden of compliance between companies, for example a company specialising in large cars may share compliance with a company that offers a smaller, more efficient range.

Evidence on potential emission savings

Whilst reducing CO₂ emissions has only become the focus of policy research relatively recently, there is a substantial body of international evidence on the efficacy of fuel consumption standards, which are a strong proxy for CO₂ emissions. Our review revealed 40

relevant studies. An important source of analytical literature on this topic is the long-running US Corporate Average Fuel Economy (CAFE) standard which has been extensively analysed.

Broadly, the evidence suggests that vehicle efficiency standards can and do work in terms of improving, over time, average new car and overall vehicle fleet efficiency. However, the outcome of any individual standard is influenced by a range of potential factors, some related to the specific design of the standard and some linked to wider issues such as how the uptake of more efficient vehicles is encouraged, or how such vehicles are actually used once purchased. For example, in the period 1996 - 2007 the EU Voluntary Agreement improved average passenger car fleet fuel economy as measured in the standard European drive test cycles by around 10% (SMMT 2008). Total CO₂ emissions from cars fell in the same period by around 4% (DfT 2008d). However, there has not been any measurable improvement in on-road fuel economy as measured by consumers participating in the national travel survey (DfT 2008d).

Our review revealed evidence drawn from experience with analysis of three main sources: the US CAFE standard, the EU Voluntary Agreement (VA) and proposed mandatory standard, and Japan's 'Top Runner' scheme. We consider the evidence on each, before discussing generic issues and problems with standards and agreements.

US Corporate Average Fuel Efficiency standard

The US CAFE standard was enacted in 1975 in response to the 1973 oil crisis, and requires automobile manufacturers to



meet sales-weighted average fuel-economy standards for the passenger car and light-duty truck (including minivan, pickup, and SUV) fleets sold in the US.

The EU Voluntary Agreements and proposed regulation

The EU voluntary agreements on passenger car CO₂ emissions, known as the Voluntary Agreement (VA) were secured during the late 1990s between the EC and passenger car manufacturing associations in Europe (ACEA), Japan (JAMA) and Korea (KAMA) to reduce vehicle tailpipe CO₂ emissions to a sales-weighted average of 140g/km by 2008/9 (a cut of around 25% on 1990 levels).

We report below the results of the existing EU VA. However the voluntary agreements are in the process of being superseded by a regulatory target. The legislation, which includes fines for non-compliance, sets a vehicle tailpipe target of 130g/km for the EU new car vehicle fleet by 2012. Additional measures are intended to bring the effective level down to 120g/km. The legislation also establishes a more ambitious target of 95g/km in 2020. This

was agreed in December 2008 and at the time of writing (March 2009) implementation and enforcement details are not available.

The 2012 target is a sales-weighted average, and applies to each manufacturer. A limit value curve is used to define the vehicle-specific target, depending on the vehicle mass. There is a voluntary pooling mechanism to facilitate burden sharing between manufacturers and an exception for low-volume and specialist vehicles (CEC 2007c). In principle the sales-weighted average approach ought to translate into both what is available to consumers and (crucially) what consumers actually buy, because manufacturers are incentivised to both *make* and encourage the *purchase* of lower carbon cars.

The Japanese 'Top Runner' scheme

The Japanese 'Top Runner' scheme for vehicle fuel efficiency ratchets up efficiency targets within a vehicle class by using the current year's 'best in class' vehicle emissions as the next year's target for 'average' new vehicles.

Table 4.1: Evidence on potential emissions savings from the US CAFE standard, EU VA and Japanese Top Runner schemes

CAFE

The evidence from this mandatory standard is that it was effective in the first decade or so of its operation, with fleet average fuel economy of passenger cars rising from approximately 15 miles per gallon (mpg) in 1975 to approximately 28 mpg by 1989 (National Research Council 2002) and (Gallagher et al. 2007). Both test cycle and on-road fuel efficiency (for vehicles covered) improved (Schipper 2007).

Some argue that it has little impact in recent years (Gallagher et al. 2007). The reasons for this include:

- the standard for passenger vehicles has not risen since 1985



- it did not apply to light trucks (SUVs) until 2006
- the ability of manufacturers to gain CAFE credits for alternative fuel vehicles whose in-service CO₂ savings may be minimal (U.S.DoT et al. 2002);
- penalties for non-compliance are relatively low (U.S.Government Accountability Office 2007).

EU VA

Interim targets have been largely met, in part due to dieselisation (DfT 2006). The agreement appears initially to have delivered significant CO₂ reductions for new cars sold in the EU but the evidence suggests that these year-on-year improvements subsequently tapered off: EU 15 average new car fleet CO₂ emissions dropped from 185g/km to 165g/km by 2001 but have declined only marginally since then (CEC 2007b). Moreover on-road efficiency has improved only marginally (DfT 2008d).

Top Runner

Japanese sales-weighted average new car CO₂ emissions fell by approximately 18% between 1995 and 2005 (Schipper 2007). The scheme is primarily voluntary but has achieved a greater level of compliance than the EU VA.

Key issues and problems

A number of factors can influence the effectiveness of standards. Some of these reflect the design of the standards themselves whereas others are a function of the wider commercial and regulatory environment and can only be mitigated through complementary policies:

Design of standards:

- Continuous improvement: Standards need to be devised so that they continue to drive improvements over the life of the policy. There is a clear contrast here between the US CAFE target which has remained flat since 1990 and the Japanese Top Runner scheme which has an in-built ratchet that encourages continuous improvement (see Table 4.1).
- Penalties and rewards: To be effective, the cost of non-compliance to

manufacturers needs to be sufficiently high that there is a strong financial incentive to achieve compliance rather than accept the penalty (U.S.Government Accountability Office 2007). Conversely, there should be some mechanism to reward those manufacturers who are able to exceed the standard, either through direct payments or by allowing trading with those manufacturers who are unable to comply (see below).

- Loopholes: Experience suggests that standards must be applied to all manufacturers and all vehicles where improvement is desired, with the exception of allowing trading between over and under-compliers. Care must be also taken to ensure that manufacturers are not allowed to achieve compliance through technologies which may not deliver any benefits in practice e.g. the CAFE



credits for multifuel vehicles (National Research Council 2002; US DoT et al. 2002).

Wider factors:

- **Consumer time preferences:** If consumers won't buy the more efficient offerings then policy will disappoint. Buyers of new cars typically consider fuel costs over a three year horizon, reducing the value of vehicle efficiency in their evaluations. As a result, the additional cost associated with more efficient technology cannot fully be passed on to consumers (ECMT 2006). It is hard for consumers to make a full evaluation of operating costs at the time of purchase since there is rarely perfect knowledge of duty cycles, annual distances etc (ECMT 2006).
- **Other vehicle attributes:** In recent years a large number of additional features have become available in vehicles, contributing to weight gain and rising electrical demands (Anable & Bristow 2007; T&E 2007). The impact of optional features such as air conditioning on fuel efficiency is often not captured by the standard test cycles used. Manufacturers have used some of the improvement in powertrain efficiency to compensate for weight gain and additional loads such as air conditioning. Potential CO₂ emissions savings from cars sold in the UK have been reduced by up to 50% as a result of weight increases (Ricardo 2005; Anable & Bristow 2007). Some of these factors may partially explain the disparity between test cycle and on-road efficiency described in Table 4.1.
- **Vehicle use:** Even if consumers purchase lower CO₂ vehicles, they may use them in a way which does not deliver CO₂ reductions. See Box 4.1 for discussion of this 'rebound effect'. Again this may explain the relative absence of improvement in on-road efficiency relative to test cycle performance.
- **Driving style** is also extremely important, since more efficient techniques can offer considerable emission reduction in all types of vehicle (see the discussion of eco-driving in Section 3.4.3).
- (Buchan 2007) casts some doubt on the basic effectiveness of vehicle efficiency standards by arguing that increasing the rate of manufacture, in order to replace existing cars with more efficient models, could increase carbon emissions since 15-20% of the total carbon emitted during a car's lifetime is from its manufacture.
- **Policy conflicts:** There is the potential for a degree of conflict between the requirements for reduced CO₂ emissions and other pollutants because some of the technical options to reduce CO₂ such as lean burn may make the achievement of other emission control requirements more challenging (National Research Council 2002). Better fuel economy may reduce per km emission rates of some pollutants, such as VOCs, but not others, such as NO_x and particulates. Vehicle safety regulations have significantly increased and this has, in



many cases, led to an increase in vehicle weight. There are differing views on the necessity of weight gain to increase safety but vehicle makers often cite safety as a key reason for not attaining CO₂ reductions (Anable & Bristow 2007). Test cycles by which CO₂ emissions are measured can influence the type of technologies that are used. For example, (Plotkin 2001) notes that Japan is in a more favourable position than Europe and the US to obtain strong increases in fuel economy from available drivetrain technology (because of differences in the testing cycle and other emission standards) whilst Europe and the US have higher potential to exploit load reduction technologies such as improved aero design (which plays a bigger role in overall efficiency at higher speeds).

- Technical potential: (ECMT 2007) suggests that a step-wise evolution in technology is “likely to be the only approach compatible with the business-model and corporate philosophies of the car industry”; (Kampman et al. 2006) expects innovation to be gradual until the marginal abatement cost becomes too high and then a step will occur. Faced with continued pressure to improve, it is suggested that these step-changes of new technological solutions are likely to appear, and then repeat the same cycle of falling costs (as the new technology matures) followed by rising marginal abatement costs in the longer term.
- Vehicle class inertia: technically it may be possible to achieve significant GHG

savings by encouraging consumer to purchase smaller vehicles in the short to medium term (in the longer term the difference in fuel efficiency between classes is likely to be less significant, see the best-in-class fuel efficiencies shown in Fig 4.2). However, consumers exhibit strong preferences for a particular class of vehicle and are likely to have a very inelastic response to policies that encourage them to shift. For example, in a modeling study (Greene et al. 2005) found that only 5% of the improvement in fuel efficiency that occurred as a result of a feebate scheme was due to changes in the vehicle mix. Even when the price elasticities of vehicle choice were doubled, the effect still only increased to 16%.

- Safety penalty: Some manufacturers have suggested that reducing vehicle mass and size to minimise fuel consumption could be detrimental to vehicle crash performance. Analysis of this suggests that if a uniform downsizing across all vehicles took place, there would be a slight reduction in the total number of casualties in car accidents. However, if a non-uniform downsizing occurs, further research would be needed to assess the effect on accident casualties.(TRL 1999)

Costs

These schemes can impose costs – on governments through reduced fuel tax revenue, on manufacturers through increased R&D cost and on consumers through increased purchase price.



However they also have the potential to reduce vehicle running costs, since fuel use will decrease.

(Ricardo 2005) explored the cost of technology improvements deployed in an effort to meet the European voluntary agreement range, and these are shown in table 4.2 below. The costs are those faced by the vehicle manufacturer – they are not necessarily the additional cost to the consumer, and they do not take into account the reduced fuel cost to the consumer.

Also in relation to the EU VA, (ten Brink et al. 2005) found that the net costs to society and to the consumer for reaching the 140 g/km target in 2008/2009 would be negative; there are benefits to society and net cost savings to the consumer (because of the fuel savings benefits). Similarly, (Barker & Rubin 2007) also see positive macroeconomic effects, with small increases in GDP and employment and small reductions in general inflation, alongside significant reductions in final

energy demand and CO₂ emissions. The negative marginal abatement costs to society are estimated by (ten Brink et al. 2005) to lie between minus 44 and minus 10 Euros per tonne of carbon saved depending on the discount rate used. The marginal reduction costs to the consumer are estimated at between minus 39 and minus 21 Euros per g/km saved. However, to achieve the more stringent 120g/km target in 2012, the marginal abatement costs to society are estimated to increase to between approximately 140 and 180 Euros/tonne saved. The net societal costs per car to meet the 120g/km target are of the order of 1-2% of the cost of a car (ten Brink et al. 2005). Another study (Stans & Bos 2007) used April 2007 fuel costs in a 120g/km vehicle, to calculate a lifetime vehicle fuel cost saving of €2171 (compared to the 140g/km baseline) making the net cost of ownership approximately neutral. This may not make it attractive to consumers however, who tend to heavily discount future savings. We discuss this further in the next section.

Table 4.2: Costs of reducing car CO₂ emissions

Car type	CO ₂ reduction achieved between 1995 and 2004	Cost of CO ₂ reduction to vehicle manufacture (£ / vehicle)
Diesel cars		
Small car	18.3%	567
Medium car	9.2%	319
Large car	8.3%	288
Gasoline cars		
Small car	3.5%	140
Medium car	4.7%	207
Large car	4.5%	198



It is also important to note that a range of market and non-market factors complicate evaluations of cost-effectiveness. For example some consumers exhibit strong preferences for fast, large or luxurious cars, and cars which have 'off-road' capabilities. These attributes typically add many thousands (or tens of thousands) of pounds to vehicle prices. If policies require such customers to forego these pleasures they may suffer a loss of utility, unless preferences change. However, in societal welfare terms there may be benefits if smaller and slower cars result in fewer pedestrian deaths or injuries. These may be monetised, for example through healthcare cost reductions. Hence the cost estimates above must be considered as approximations, based upon simplifications, as they cannot fully account for preferences for certain attributes and do not seek to monetise all social costs.

Summary

There is clear evidence that vehicle efficiency standards can result in improved fleet fuel economy, provided they are mandatory, ambitious, progressive (targets must extend as initial objectives are met), and cannot be circumvented. Whilst none of the standards adopted so far have been perfect, none have been entirely ineffectual. Although the direct costs associated with these standards are not trivial, these do need to be considered in the round with the wider economic benefits of the resultant more efficient, lower CO₂ vehicle fleet. Several studies suggest that the net social and lifetime costs may be negative. However, higher capital costs may have a more profound impact on consumer choices because consumers tend to discount long-term

costs. If many consumers won't buy the more efficient offerings that result from fuel economy standards, then the policy may not deliver. For this reason standards should reflect actual vehicle sales, and may be complemented by fiscal measures that make lower carbon options more attractive. This is the subject of the next section.

4.3 Vehicle taxes and subsidies

4.3.1 Introduction: the rationale for fiscal policies

Car buyers can only make choices from amongst the purchase options actually made available to them. However unless *all* vehicles are low/zero emission the *availability* of lower carbon vehicles is a necessary but not sufficient condition for the *purchase* of such vehicles. Not only must vehicle manufacturers comply with the standards but car buyers must make more emissions-aware purchases. Several types of policy can affect consumer vehicle choices, these include fuel prices and CO₂ linked road user charges discussed in chapter 5 and section 3.6, and information provision discussed in Section 4.4. This section considers three of the fiscal instruments that bear directly upon vehicle ownership: vehicle purchase taxes/subsidies, company car tax, and vehicle circulation taxes. Company car tax is covered in the circulation tax section as it is effectively a special form of such taxes.

The rationale for policies that target



vehicle choice is derived, in part, from the purchasing 'myopia' described in sections 4.1 and 4.2. To recap, consumers often do not fully evaluate or value long-term savings at the time of purchase. This pattern of behaviour is often described as high 'personal discount rates', and there is considerable evidence that car purchasers (indeed most private consumer purchase decisions) exhibit a strong preference for short-term savings over long-term cost-effectiveness (ten Brink et al. 2005; Lane 2005; IEEP 2006).

Hence, even though any increased purchase cost associated with more fuel efficient cars may be offset by reduced fuel costs, making lower carbon vehicles cost-effective investments (see Section 4.2), consumers may prioritise short term cost savings.

A preference for short-term savings is not 'irrational' per se. There is rarely perfect knowledge of duty cycles, annual distances, real world performance and so on. There may be insufficient information about the savings available (Greene 1997). Therefore consumers may quite sensibly apply high discount rates to future fuel savings (ECMT 2006), as well as placing value on other vehicle attributes such as safety, image, equipment, comfort, performance, reliability and space (Lane 2005). Moreover, buyers of new cars typically consider fuel costs over a three year horizon which substantially reduces the value in their evaluations of vehicle efficiency that 'pays back' over a longer timeframe (ECMT 2006). Any long

run savings from energy efficiency must be factored into this complicated equation.

The result is two-fold. First, many car buyers may be less motivated to purchase 'best in class' for fuel efficiency or to change class to improve efficiency. Second, it is harder for manufacturers to fully pass on to consumers any additional cost associated with more efficient technology.

4.3.2 Purchase taxes and subsidies

One policy applicable at the point of purchase is a purchase tax linked to fuel economy or CO₂ emissions per kilometre. A variation of this is the 'feebate'¹¹ system which involves providing consumers with a subsidy for purchasing the best performing vehicles and taxing the worst performing vehicles. These feebates can be funded by the taxes and the system as a whole may be revenue-neutral, positive, or negative.

Although the UK does not have a vehicle purchase tax scheme as such, the changes to the Vehicle Excise Duty (VED) that will take effect from 2010 introduce what amounts to a purchase tax element in the first year VED rates. Under these VED changes, confirmed in modified form in the 2008 pre-budget report (HM Treasury 2008), cars with CO₂ ratings of 166g/km and above will be subject to an increased first-year only VED rate, with the additional duty being between £70 and £515, depending on the vehicle CO₂ rating.

¹¹Now often referred to as bonus/malus schemes e.g. the current scheme used in France.



Table 4.3: Evidence on potential emissions savings – Purchase taxes (ex-post assessments)

In Denmark, a fuel efficiency based purchase tax was in place (without feebates) during the period 1998 – 2002. During that period, a fuel efficiency increase of 4.1 km/l for diesel vehicles and 0.6 km/l for gasoline vehicles was observed (ADAC 2005;Smokers et al. 2006).

In the Netherlands, a 2002 taxation scheme including feebates saved approximately 0.6-1 million tonnes CO₂ per year according to (Harmsen et al. 2003). This was the equivalent of 2-3% of total transport sector GHG emissions. The scheme offered consumers incentives to purchase cars in the two most energy-efficient categories. In one year the market share of category A cars increased from 0.3% to 3.2%, while that of category B cars rose from 9.5% to 16.1%. The withdrawal of the incentive after 1 year resulted in a drop in market share, but their share still remained higher than the pre-incentive year (VROM 2003;Smokers et al. 2006). Such a tax policy based on fuel consumption would result in a 4% fuel consumption efficiency gain across the Dutch car fleet as a whole by 2010. (Van den Brink & Van Wee 2001;Anable & Bristow 2007).

Evidence on potential emission savings

Our review revealed 25 relevant studies of purchase taxes and feebates. There is evidence from modelling studies and overseas experience of the impact of purchase taxes on consumer purchasing decisions. We present the evidence from each category of analysis in tables 4.3, 4.4 and 4.5.

Ex-ante estimates of potential emissions savings

Various modelling studies have estimated the impact that different vehicle purchase tax or feebate configurations could have on total emissions or per vehicle emissions:

Table 4.4: Evidence on potential emissions savings – Purchase taxes (ex-ante estimates)

A US national feebate of \$1,825 per gallon per 100 miles was estimated to reduce average new vehicle fuel consumption by 16% by 2010 and by 28% by 2020 (CEC 2002;Langer 2005).

(Lane 2007;McManus 2007) state that a California feebate gradient of £11/gCO₂/km was estimated in a modelling study to reduce gCO₂/km by 27% (this was an average projected reduction in California fleet-wide emissions across four different regulatory and fiscal scenarios for the period 2009 – 2016 compared to a 2002 baseline)

(Greene et al. 2005) modelled feebate results in the US for a single year approximately 10-15 years into the future and estimated that a \$1,000/0.01 gallon per mile feebate would overcome the market failure of consumers not taking account of lifetime fuel efficiency benefits. The effect of this feebate would be to raise light-duty vehicle MPG to 32 – an approximately 24% improvement. They also concluded that 95% of fuel savings would be secured through improved technology on existing vehicles and only 5% from changes in purchasing behaviour resulting in a different mix of models.

continued overleaf



Modelling by (COWI A/S 2002) for nine EU member states concludes that the purchase tax differentiation required to achieve a 1 percentage point reduction in new vehicle CO₂ emissions is €35-48/g CO₂ for gasoline cars and €13-67/gCO₂ for diesel cars.

In the Netherlands, (Van den Brink & Van Wee 2001) postulated that the original car purchase tax policy based on fuel consumption would result in a 4% fuel consumption efficiency gain across the Dutch car fleet as a whole by 2010 (from (Anable & Bristow 2007)).

The evidence does suggest that purchase taxes and subsidies can have a significant impact on the efficiency of the vehicle fleet, and therefore emissions – subject to any rebound effects as discussed in Box 4.1. Our review did not reveal any evidence on the efficacy of the UK’s differential first-year VED. However, whilst the principle of differential first-year VED rates was broadly welcomed by the Environmental Audit Committee (EAC), concern was expressed that the charge may not be immediately visible to buyers because car dealers may include it in the total vehicle cost, which may reduce its potential to influence purchasing

decisions. The EAC recommended that additional research be carried out to understand the effects of the first-year VED rates on purchasing decisions and CO₂ emissions (Environmental Audit Committee 2008).

In addition to the assessment of the effects of purchase taxes designed specifically to reduce CO₂ emissions, there are also some potentially useful insights to be gained from reviewing the experience from other taxes that act in some way as a proxy for emissions, such as taxation linked to engine size, weight or rated power. (Anable & Bristow 2007) summarise the following:

Table 4.5: Evidence on potential emissions savings – proxy taxes

European countries with purchase tax regimes favouring smaller cars tend to have more fuel efficient national fleets compared to countries without the tax regime in place (Wallis 2005).

Countries where new car sales tax is linked to vehicle size or performance (crude proxies for efficiency), show on-road efficiencies¹² that are better than the UK (e.g. in Italy, Denmark and the Netherlands by 25%, 15%, 11% respectively). In the period 1970 to the mid 1990s fuel economy in the UK improved by 5%, with the Netherlands registering a 15% improvement and Italy a 20% improvement (Potter et al. 2005).

Vehicle purchase tax in Denmark has contributed to reducing the number of privately owned vehicles throughout the fleet as a whole, the average car size, and reduced the emissions of greenhouse gases, including carbon, associated with car usage (Jacobsen et al. 2003).

¹²Average on-road car fuel economy measures actual fuel usage per vehicle km, based on data for total vehicle kilometres per year and fuel consumed per year. As such, some authors argue it is a more accurate measure of vehicle efficiency than new car fuel economy based upon a test cycle (Potter et al. 2005).



Key issues and problems

Several attributes of purchase incentives are noted in the literature:

- Purchase taxes are applied upfront and are highly visible at the time of purchase choice. Unlike circulation taxes (see below, Sect 4.3.3), they are not liable to discounting by vehicle purchasers (Anable & Bristow 2007).
- Not only can such taxes encourage purchases of lower CO₂ vehicles but they may also result in reduced car ownership. For example, in EU member states (Smokers et al. 2006) cites an elasticity of -0.144 for response to vehicle purchase taxes (i.e. a 10% increase in vehicle purchase taxes would lead to 1.44% decrease in car ownership). Car ownership is linked to mode choice (see Section 3.3) and there is evidence that consumers who choose not to own a car make fewer journeys overall and greater use of lower carbon modes. However there may also be welfare and equity impacts, discussed below.
- There is some evidence to suggest that feebates can create stronger incentives for consumers to purchase more fuel efficient cars (or producers to introduce more efficient technology) than a purchase tax alone (COWI A/S 2002). In a modelling study using California's model year 2002 new vehicle fleet as a basis for comparison, (Johnson 2006) found that a feebate can increase the marginal incentive to reduce emissions by a factor of 10 relative to a simple purchase tax.

Nevertheless, some commentators have highlighted problems:

- Purchase taxes may slow down renewal of the car fleet and therefore delay new technology entering the market (Kageson 2003), although this problem may be at least partially overcome with a feebate scheme. Purchase taxes may also be complemented by scrappage schemes that provide subsidies for consumers to scrap older, high CO₂ vehicles.
- (DRI 1995;Kageson 2003) also suggest that vehicle purchase taxes would be more effective if linked to fuel efficiency or gCO₂/km in a non-linear fashion because for more expensive models the tax paid will form a progressively smaller proportion of the total purchase price of the vehicle (since the price of cars does not increase linearly with fuel consumption).
- The effectiveness of purchase taxes and subsidies depends in part on market expectations of their stability and longevity. Frequent changes to the vehicle tax system may erode the credibility of government policy, undermining the confidence and decision-making of both car purchasers and manufacturers, and potentially resulting in a weaker impact of tax changes (Harmsen et al. 2003).
- The EU has expressed a preference for circulation taxes (see section 4.3.3) over purchase taxes/feebates, due to the latter's effects on competition in the intra-EU car market (according to (LowCVP 2006a;Anable & Bristow



2007). Some commentators believe that the European Union policy context is not conducive to introduction of new registration taxes. Although a proposal from the Commission for a Council Directive (COM(2005)261) which would have phased out registration taxes (and force Member States to link circulation taxes to CO₂ emissions) has not been accepted by the Council, it is still an indication that the European Commission perceives registration taxes to be an instrument which "impedes the proper functioning of the Internal Market". (Smokers et al. 2006; Anable & Bristow 2007). Notwithstanding this, the UK House of Commons Environmental Audit Committee appears supportive of purchase taxes, and in particular feebates: "we further recommend that the Treasury examine the merits of some kind of "feebate" system, similar to the "bonus/malus" scheme in France, in which levies on high emission cars are accompanied by subsidies on low emission cars" (House of Commons Environmental Audit Committee 2008).

- Purchase taxes and feebates may create a large disparity between the cost faced by larger/heavier vehicles and smaller/lighter vehicles (since weight is correlated to fuel efficiency). Some consumers place a premium on these characteristics, since larger and heavier cars are generally considerably more expensive than smaller cars. (Harmsen et al. 2003) suggest that if vehicle purchase taxes result in some people not being able to afford a car, they will suffer a welfare loss. Vehicle downsizing can also

result in a welfare loss (Smokers et al. 2006) – particularly for families with children and rural families because of their tendency to prefer larger, and therefore less fuel efficient, cars. In sum, if feebates are perceived as penalising those consumers who must (or wish to) buy large vehicles these factors may limit the feebate's political viability.

- However, (Greene 2007) notes that most of the effect of vehicle purchase taxes is achieved through fuel efficiency, not vehicle downsizing. Similarly, (Johnson 2007) argues that the primary market response to a fuel efficiency-based feebate is likely to be efficiency improvements within vehicle class, and only a small fraction (e.g., 5–10%) of the emissions reduction would come from consumers choosing smaller vehicles. The data from the King Review (2008) presented in Figure 4.2 bears this out; best emissions performance is similar across classes of vehicle. It is also possible that feebates could be constructed to focus the regulatory incentive more exclusively on technology e.g. emissions per vehicle tonne (Johnson 2006).
- Experience with feebates in Ontario, Canada highlights the need to ensure the scheme is visible to consumers, has strong differentiation and covers all vehicle classes (Langer 2005).

Costs

Our review did not reveal evidence on the cost-effectiveness of purchase taxes. Consumers will clearly face higher prices for higher emission vehicles. Under a



revenue neutral feebate scheme the cost to consumers of lower emission vehicles would fall. Purchase taxes may be revenue raising or revenue neutral (e.g. if associated with feebates). As with all taxes the potential for redistributive effects elsewhere in the economy will improve the overall cost-effectiveness of a revenue raising scheme in terms of £tC. Vehicle manufacturers may face additional costs if the development and production of lower emission vehicles is encouraged through the scheme. These may be passed through to consumers, see the discussion of net costs in section 4.2.

Summary

The evidence suggests that a well designed vehicle purchase tax or feebate could have a significant impact on transport sector CO₂ emissions provided that vehicle efficiency improvements are not undermined to a substantial extent by rebound effects. By acting on the point of

sale purchase incentives overcome consumer 'myopia' about future running and ownership costs. Purchase tax schemes can provide a continuing incentive to increase fuel economy as new technologies are developed. Purchase taxes have a modest effect on overall car ownership which may be beneficial in emissions terms. However this may also slow down vehicle fleet renewal. Feebate or 'bonus/malus' schemes could neutralise impacts on fleet turnover. There may be welfare impacts from purchase taxes, particularly if they result in larger cars being most heavily penalised. Schemes can be structured to focus on best in class rather than vehicle downsizing, which may be almost as effective in terms of their impact on vehicle CO₂ emissions. Feebates or 'bonus/malus' schemes can create stronger incentives for consumers to purchase more fuel efficient cars than purchase taxes alone.

Box 4.1: The rebound effect

Both regulatory and fiscal measures have the potential to increase vehicle efficiency. However, more efficient vehicles are cheaper to operate, since each journey made requires less fuel. As a result more efficient cars may be used to make more, or longer, journeys.

Several studies have examined the evidence for this so called 'rebound effect' where fuel efficiency improvements are 'taken back' in the form of increased mileage, or a preference for higher performing vehicles. See (Sorrell 2007) for a comprehensive discussion of the rebound effect and the related literature).

In practice it is hard to separate the effects of fuel efficiency, fuel cost variation, wealth changes and other factors so the evidence is mixed regarding the existence and size of a rebound effect.

An effect of the order of 0.2 - 0.4% rebound for every 1% increase in efficiency is supported by several studies (Sorrell 2007).



4.3.3 Vehicle Circulation Tax

Circulation taxes are charges levied on vehicles that are in use on public roads. They take the form of a recurring fee or licence purchase obligation, the administrative details of which differ by country. Circulation taxes can aim to reduce CO₂ emissions per kilometre by linking the level of taxes directly or indirectly to emissions (indirect links include: fuel efficiency, engine size, power to weight ratio).

In the UK circulation tax is referred to as vehicle excise duty (VED), and since 2001 it has been linked to CO₂ emission bands, with the best performing cars attracting zero tax and a graduated scale penalising increasing emissions. In 2008, the graduation scale was revised to increase the tax differential between bands. This also involved the introduction of more finely graduated bands from 2009-10, bringing the total number of bands to 13 (House of Commons Environmental Audit Committee 2008). As noted in 4.3.2 the differential VED rules also incorporate a form of purchase tax, in that first year VED is differentiated more substantively by emission performance.

Another UK variant of circulation tax is the level of income equivalent that employees are taxed for the benefit of a company car,

so called company car tax. We treat this as a circulation tax because it is a recurring tax on 'ownership' of the vehicle, paid for as long as the employee benefits from a company car. In the UK since 1999, tax on company car drivers has been linked to the car's value and fuel/engine type, ranging from 15% - 35% of the car's list price, graduated according to the level of the car's CO₂ emissions (g/km). The effect of these reforms on the use and type of cars within the UK company car fleet is covered in the evidence section below.

Evidence on potential emissions saving

Our review revealed 37 relevant studies related to VED differentiation and/or company car tax rules.

VED

Much of the evidence deals with the projected impacts of further differentiation between circulation tax CO₂ bands, and the magnitude of the differentiation that may be required to precipitate significant changes in vehicle purchasing decisions.

UK company car tax

There is evidence to suggest that the 1999 company car tax reforms described above have had a considerable effect on the use and type of cars within the UK company car fleet:

Table 4.6: Evidence on potential emissions savings

VED

In the 2007 budget, (HM Treasury 2007a) estimated that vehicle excise duty would help to deliver a 0.1-0.17 MtC (0.37-0.62 Mt CO₂) annual reduction by 2020. In evidence given to the Environmental Audit Committee's 10th Report, the Treasury indicated that the recent VED reforms are projected to save 0.16MtCO₂ per year by 2020, with a cumulative saving of 1.3MtCO₂ by that date.¹³

¹³Whilst noting that the Treasury projections did not model the impacts on second-hand cars, the Environmental Audit Committee expressed disappointment at the relatively small scale of these projected savings, contrasting them unfavourably with the savings that the EU Voluntary Agreement (see section 4.2) is projected to deliver. However, the Treasury response to this criticism maintains that some of the savings from the VA should be attributed to the VED reforms since the VED, by reinforcing the VA, makes the VA more likely to succeed (House of Commons Environmental Audit Committee 2008). We return to policy complementarities below.



In an earlier modelling study, (COWI A/S 2002) estimated that increased differentiation in UK vehicle excise duty could reduce fleet average emissions from new passenger cars by 4.8% (by 2008 from a 2005 baseline). Changes to both vehicle circulation and vehicle purchases taxes in other European countries were estimated to reduce emissions from new passenger cars between 3.3 and 8.5% over 3 years (also by 2008 from a 2005 baseline). The study concluded that correctly designed vehicle purchase and circulation taxes could reduce the emissions of new passenger cars in the EU by about 5% on average. These estimates are based on an approach which had three key restrictions: (1) no downsizing of vehicles (2) no increase in the proportion of diesel vehicles in the fleet and (3) no net change in tax revenue.

(SDC 2005) estimated that a £300 differential between each VED band would save 0.07 – 0.85 MtC (0.26-3.12 Mt CO₂) per year in 2010 and 0.15 – 1.51 MtC (0.55-5.54 Mt CO₂) per year in 2015 (the wide ranges are the results of the differing assumptions used in the SDC scenarios).

Company car tax

In the first year of the new system, the number of business miles was reduced by over 300 million miles per year and the average CO₂ emissions of new company cars decreased from 196 g/km in 1999 to 182 g/km (IR 2004;Potter et al. 2006).

The long-term carbon savings attributed to the company car tax reform are estimated to be between 0.4 and 0.9MtC/year (HMRC 2006b). The policy achieved its objectives of reducing GHG emissions from company cars by reducing average company car CO₂ emissions and by reducing the number of company cars registered. This effect, however, may be a significant source of leakage because whilst the number of company cars registered dropped from 1.6million in 2001 to 1.2million by 2005 (HMRC 2006a) there has been a 1.4% rise in the total number of vehicles registered since the reform (Anable & Bristow 2007). Furthermore, HMRC's review (HMRC 2006b) suggests that if drivers no longer have company cars, on average, they will choose private cars with CO₂ emissions figures that are around 5g/km higher.

Key issues and problems

A number of generic issues and problems have been identified by a range of authors:

Tax level/Extent of graduation required

Critics of the use of the UK VED system to encourage CO₂ reductions have argued that the difference in tax rates between bands is too small (even taking into account the most recent revisions) to provide an incentive to buy a less polluting

car. The (House of Commons Environmental Audit Committee 2008) for example, has suggested that "There is perhaps a danger that the proposed changes are large enough to be noticed, but not large enough to change behaviour or to reinforce the message that tackling climate change is an urgent imperative."

Several studies have estimated the differentiation which would be required between taxation bands to promote a stronger change in purchasing behaviour:



- Consumer research conducted for the Department for Transport (MORI 2003) concluded that if differentiation between VED bands was £50, a third of people would change bands; if £150, over half would change; and if £300 then 72% would change.
- The RAC Foundation suggested that, based on an attitude study, a £1,100 differential between bands would be required before private car drivers would consider switching to an alternatively fuelled or smaller engine car (RAC 2004).
- In their modelling study, (COWI A/S 2002) calculated the tax differentiation required to achieve a 1 percentage point reduction (between 2005-08) in CO₂ emissions per vehicle (i.e. measured in grams per kilometre) for the UK. Their modelling indicated that a differentiation of €1.60 per gCO₂ for gasoline vehicles and €1.20 per gCO₂ for diesel vehicles would be required. The study also concluded that linking vehicle circulation taxes directly to CO₂ emissions (i.e. to grams CO₂ / km) would lead to greater reductions in CO₂ emissions than using proxies such as engine size.
- Econometric modelling for the DfT showed that the response to both purchase price and costs such as VED varies according to both the car segment and household characteristics. In particular, the research found that, following a change in the purchase price or costs of motoring, there is likely to be a greater response in the middle CO₂ bands (121-165g/km) than in the

upper bands and that there is a greater propensity for consumers to switch between similar models of cars in order to reduce costs, than to change between market segments (Cambridge Econometrics 2008).

It has also been suggested that the UK VED scheme might be more effective if the tax paid was not based on wide bands of g CO₂/km (e.g. 120 – 145 g CO₂/km), but was specific to the actual gCO₂/km of a vehicle (e.g. VED could be £1/gCO₂/km, so the tax for a car with an efficiency of 140 gCO₂/km would be £140, and £145 for a 145 gCO₂/km car). (Anable & Bristow 2007) cite two studies which suggest this marginal differentiation would be more effective: (Ekins & Dresner 2004; Buchan 2007). The (COWI A/S 2002) study and others including (Smokers et al. 2006) also concluded that strong differentiation is essential, and (Buchan 2007) suggests that this would at least help to get people to buy the best in class. Recent qualitative research supports this (Anable et al. 2008).

Welfare issues and impact of ownership costs

Like purchase taxes vehicle circulation taxes have the potential to lead to a loss of welfare. This may particularly affect rural families and families with children because of their preference for larger (and therefore potentially less fuel efficient) cars. In this context, welfare loss is defined in terms of car purchasers being forced to buy other cars than those they would have preferred in the absence of tax (Koopman 1995; COWI 2002b; Smokers et al. 2006). As with purchase taxes it is important to note that where tax targets



emissions (not size, weight or seats) any welfare loss could be mitigated through the purchase of best in class emissions. One important difference between purchase and circulation tax impact on welfare however is that the latter has the potential to affect older cars, hence poorer families buying second hand.

In addition to the direct costs of having to pay more tax, (Veitch & Underdown 2007) finds that increases in vehicle excise duty effectively reduce a vehicle's resale value, therefore increasing depreciation costs to the consumer. An increase in VED equivalent to 1% of the purchase price would increase car ownership costs by 12%. However it is also possible for VED differentiation to increase the value (slow depreciation) for cars in the lower tax categories.

One option to mitigate the negative effects of VED changes on poorer households with large and inefficient second hand cars is a scrappage scheme, where owners of older, high CO₂ vehicles are paid to scrap those vehicles. If the payment is sufficiently high then it could facilitate the purchase of a lower CO₂ second-hand car. This solution received some support from the (House of Commons Environmental Audit Committee 2008).

A circulation tax may also have an influence on CO₂ emissions through decreasing demand for private cars e.g. (TIS 2002; Smokers et al. 2006) suggest an elasticity value for circulation taxes of -0.121 in relation to car ownership in EU member states, indicating the modest negative effect of taxation on the decision to own a car.

Tax Revenues

Vehicle circulation taxes are, by definition, revenue-raising. However, in the long term, a second order effect of using vehicle circulation taxes to reduce CO₂ emission per kilometre (and therefore to improve fuel efficiency) is a reduction in tax revenue from fuel excise tax (Smokers et al. 2006). The impacts of any rebound effects resulting from a more efficient vehicle fleet also require consideration (see Box 4.1 above).

There are suggestions from some quarters that the effectiveness of, and public support for, CO₂-linked VED charges could be improved if they were hypothecated to spending on other low CO₂ transport initiatives, or if any changes to VED charges were revenue neutral (House of Commons Environmental Audit Committee 2008).

Residual Values

Over half of all new cars sold in the UK are to businesses where buying decisions are mainly made on the basis of cost of ownership or leasing cost over three years. The largest cost is depreciation and by using this to calculate the residual value at the end of a lease period, research undertaken by the Energy Saving Trust showed that introducing a VED level of £600 on 225 g/km car has a significant negative impact on the residual value of a vehicle (EST 2007). The EST claim this disproves the argument that raising VED would have little impact on purchase decisions because it is a low proportion of the purchase price of a vehicle. EST argue therefore that even a reasonably modest rise to £500 per annum in the top band could have significant impact on choices in the company car market.



Costs

Our review did not reveal any discussion of the costs, in isolation, of circulation taxes. Indeed much of the literature is concerned with the effectiveness of additional differentiation of circulation taxes rather than cost-effectiveness per se. The policy package containing the manufacturers' Voluntary Agreements, VED increases and company car tax is claimed to cost £365 per tCe (DEFRA 2006b; Buchan 2007). However it is not clear how this figure disaggregates and what proportion is attributable to circulation taxes. It is also notable that this relatively high cost is inconsistent with the literature on regulation reviewed in Section 4.2, which reveals low net costs or even small net benefits for society and car owners.

Summary

Broadly, the evidence suggests that vehicle circulation taxes can reduce CO₂ emissions by encouraging the purchase of lower CO₂ new cars and influencing the second-hand car market. They can, however, have equity and welfare impacts, potentially impacting negatively on poorer and larger households who may need a larger car. Scrappage grants may assist poorer households get rid of old inefficient cars and replace them with a newer model in a lower tax bracket. The economic modelling work and related research cited above suggests that the magnitude of incentive provided by a vehicle circulation taxes is one of the most important factors in determining the success or failure of this type of policy. The recent changes to the UK VED charges appear to be a response; showing a clear move to significantly greater differentiation and

more finely graduated banding. Some critics, notably the Environmental Audit Committee argue that far greater differentiation will be needed for the tax to have real impacts.

4.4 Information on car choice

Information provision about fuel efficiency is subject to regulation. This applies to both information in car showrooms and the 'small print' attached to car advertisements in print and other media. However there is relatively little regulatory attention to the 'messages' that car makers put across in their advertising. This section considers both labelling and advertising codes/standards. Our review revealed 27 relevant studies.

Evidence on potential emission savings

Labelling schemes

Emissions labelling is mandatory for new cars sold in the UK. EU Directive 1999/94/EC requires that EU consumers are given information on fuel consumption and carbon dioxide emissions (litres per 100 km and gCO₂ per km) in three different formats: the label, a guide and posters. The UK label, introduced in 2005, is colour-coded in accordance with the Vehicle Excise Duty bandings and information is provided on the CO₂ emissions per kilometre, annual VED charge, fuel consumption and average fuel costs for a certain number of miles and fuel price. Our review revealed somewhat contradictory findings about the effectiveness of labelling.



Table 4.7: Evidence on potential emissions savings – labelling

Some analysts suggests vehicle labelling has a role to play in increasing awareness, but this is only happening slowly, and has not yet contributed significantly to emissions reductions (Smokers et al. 2006).
Others argue that in Sweden and the UK, where CO ₂ labelling schemes and fuel consumption information have been in operation for 20 years, the experience is not promising given the fact that the power rating of new cars has increased faster in these countries than in any other Member states (Kageson 2003).
Five EU Member States (Austria, Denmark, France, the Netherlands and Spain) have assessed the effectiveness of the EU label Directive 1999/94 in terms of reducing CO ₂ emissions and concluded that while CO ₂ emissions have declined since the label was introduced, it was not possible to separate out the effect of the label from reductions in emissions resulting from technical improvements by car manufacturers and fiscal measures (ADAC 2005).
(Boardman et al. 2000) used social survey data which attempted to elicit consumer response to information about similar sized and priced vehicles and estimated the effect of a comparative label design would be to reduce UK fuel consumption from new passenger cars by 2.7%. An earlier survey by EVA had suggested this was closer to 4-5% (EVA 1999). When that label is accompanied by other instruments and strategies, it could be even more effective (Raimund & Fickl 1999; Boardman et al. 2000).

In order to assess the potential for car labelling, the relevant research base can be broadened to include those studies which have examined car purchasing behaviour and the extent to which information on fuel consumption and CO₂ emissions may lead to a shift in car

purchasing behaviour. We have already pointed to some of this research in section 4.3.2 in relation to consumer ‘myopia’ about future running and ownership costs. This myopia has a direct impact on the extent to which any information about these costs will be influential.

Table 4.8: Evidence on potential emissions savings – labelling and car purchasing behaviour

Research (by MORI for the DfT) shows that nearly four in five car buyers do not look at the vehicle's emission rating before purchase (Commission for Integrated Transport 2005). This is backed up by recent research by (Anable et al. 2008) who discovered that only 3 out of 28 interviewees knew the CO ₂ emissions of their new vehicle within 10% accuracy, and 3 knew the correct VED band of their car. Similarly, (EST 2008) found that nearly three-quarters of UK drivers (74%) did not know how much carbon dioxide their car emits.



In a US study, (Noblet et al. 2006) concluded that information may influence choice between vehicles but does not influence class choice.

According to surveys by (EVA 1999; Boardman et al. 2000), 70 – 80 percent of respondents said they would change their car purchase if a point of sale label indicated that the car they were interested in was “very inefficient” compared to other cars of the same size.

Advertising and marketing codes and standards

Marketing of cars by vehicle manufacturers is an important driver of consumer attitudes to various vehicle attributes (Wright & Egan 2000). Whilst some recent advertising campaigns have focused on CO₂ emissions the evidence is mainly concerned with an historic trend for car makers to focus their advertising on attributes other than efficiency, particularly on performance. This may have a detrimental effect on CO₂ emissions, if it encourages consumers to purchase larger, higher performing, heavier or otherwise less efficient offerings.

We did not find any quantitative evidence on the CO₂ impacts of advertising or marketing codes or standards. However, there is evidence to suggest that marketing activity in the car market has, at least until recently, been markedly skewed towards the most polluting vehicles:

- A survey by (FoE 2007) found that 55% of car adverts in national newspapers (over a 2 week period) were for cars in the most polluting VED bands E to G (>165gCO₂/km), representing 37% of registrations in the UK. A more recent survey by the LowCVP found, however, that

advertising expenditure on cars in VED bands A, B and C are on an upward trend (Murray 2008).

- Manufacturers’ marketing strategies are “often at odds with, and overshadowing, the message that the CO₂ label is projecting” (Smokers et al. 2006). Indeed it may be that “In addition to consumer information, the way in which cars are marketed may also need to be adapted, so as to focus less on the dynamic performances of vehicles” (CEC 2007b).
- Others have recommended that car adverts must carry bold and visible warnings about the contribution of driving to climate change making the parallel with smoking where “Research has shown that the larger a health warning is the more impact it has on persuading a smoker to give up: labels that occupy 30% or more of each of the largest sides on the cigarette pack have been found to be strongly linked with structured decisions to quit or to cut down their smoking” (Retallack et al. 2007).

Key issues and problems

Labelling

Labelling can help overcome information barriers/failures related to running costs but may not of itself be sufficient to overcome



time preferences that lead consumers to discount future costs, or an over-riding preference for vehicle attributes other than fuel efficiency. (Plotkin 1999) argues that without a market change that boosts the value of fuel savings to the consumer, information programs of this type are likely to have little material benefit. (Anable et al. 2008) and (EST 2008) suggest that to maximise effectiveness, any label needs to be 'dynamic' to reflect changing fuel price and concentrate on running costs that mean something to buyers (for example range on a tank of fuel costing a given amount) – and it should have comparative best in class information. The same analysts point out that new car labelling does not apply to second hand cars and these make up 75% of cars sold.

It is important that the relationship between labels and future running costs is explained to purchasers. For example the EAC argues that the Treasury should have taken greater care to explain that the new VED bands would apply to all vehicles registered on or after March 1st 2001. "If the point of green taxes is to change behaviour, they need to be properly publicised, so that people are fully aware of what they are being encouraged to do" (House of Commons Environmental Audit Committee 2008).

Generally, the effectiveness of various types of energy labels may be influenced by how information is presented to the consumer, level of market support, and the credibility of the labelling program sponsor (Wiel & McMahon 2003).

Advertising and marketing codes and standards

Some analysts suggest that policy could pay more attention to the manufacturers'

messages on car advertising. In fact, the EU Labelling Directive does put some structures in place "This (CO₂ and fuel consumption) information should, as a minimum, be easy to read and no less prominent than the main part of the information provided in the promotional literature". Existing UK regulation requires that information on CO₂ emissions and fuel economy is given equal prominence to other information on vehicle specification, performance or price in advertisements. However, surveys have revealed that this information is often very difficult to find on any advertising media, if it is there at all (Dings 2008). In addition, until recently, the regulation did not extend to some of the more popular 'graphical' media such as the internet, bill boards and cinema advertising (King 2008;Dings 2008). Some progress has been made recently – in June 2008 the Department for Transport changed its guidance on car advertising following a review of its recommendations on CO₂ emissions in promotional information. Car adverts on billboards and in magazines must now have CO₂ emissions prominently displayed (LowCVP 2008).

The King Review recommended that vehicle advertising regulation should be strengthened so that fuel consumption and CO₂ emissions information is presented more prominently and consistently in advertisements across all media (King 2008). It also recommends that, as with the car label, provision of comparative information would be beneficial. The European Parliament has also backed stronger regulation of vehicle advertising, supporting a proposal that 20 per cent of advertising space should be devoted to information on CO₂ emissions



(CEC 2007a) and there are opportunities for changes as the EU CO₂ labelling directive is up for review.

An example has been set in Norway where a code of conduct, introduced for car advertisements, was put in place from October 2007. The guidelines distributed to carmakers said "we ask that...phrases such as 'environmentally friendly', 'green', 'clean', 'environmental car', 'neutral' or similar descriptions not to be used while marketing cars" (Reuters 2007). Manufacturers would risk fines if they failed to drop the words from the car adverts.

Some commentators go as far as suggesting an outright ban on advertising. Nevertheless, the Low CVP believe that there is a risk that overly strict regulation will suppress the use of environmental performance as a selling point or channel activity into unregulated media (Murray 2008). A compromise may be the banning of ads for cars that emit more than 50% over the fleet average (Dings 2008).

Costs

Labelling schemes impose compliance costs on manufacturers. They may also encourage manufacturers to develop more efficient vehicles, hence incurring RD&D costs and possibly leading to higher vehicle purchase prices. Various member states have reported costs associated with compliance to the EU directive pertaining specifically to vehicle labels. The Netherlands reports €400,000 of material costs associated with the label and posters, plus €2 million of personnel costs. The UK reported €36,000 per manufacturer (ADAC 2005). Smokers et al. (2006) indicates that any costs

incurred by the manufacturers, importers and dealerships are likely to be passed on to the consumer but may be balanced by cost savings from fuel efficiency gains as, if effective, they offer the potential of reduced lifetime costs of ownership (see the discussion of costs in the section on vehicle regulations). We did not find any quantification of costs in terms of £/tC.

Summary

Surveys of consumer responses to hypothetical questions about how they would be influenced by labelling of vehicles with fuel efficiency or CO₂ information suggest large GHG savings could result from these initiatives. However, there is no ex-post evidence to support these findings – in fact some evidence suggests that few consumers even look at this information explicitly during their purchase decision (although it may be considered implicitly if running costs are taken into account). In addition, it would appear that consumers' strong preference for other vehicle attributes over fuel efficiency and their tendency to discount future costs mean that, even when they do look at this information it does not influence their purchase decisions. In order to achieve CO₂ reductions from cars it seems that not only do products need to be clearly labelled; they also need to be marketed effectively. Greater regulation of advertising by vehicle manufacturers, which often reinforces consumer preferences for vehicle characteristics other than fuel efficiency, may be a potential mechanism for enhancing consumers' receptiveness to information about fuel efficiency and CO₂ emissions.



4.5 Conclusions

The evidence reviewed in this chapter comprises ex-ante evidence of regulation and voluntary agreement on vehicle emissions or efficiency from the US, EU and Japan, evidence on purchase taxes from a range of countries and evidence on circulation taxes from the UK. Our review also revealed a body of modelling evidence from various countries, particularly with regard to the role of both purchase and circulation taxes. The policies described and discussed in this section are complements rather than alternatives. Nevertheless the key issues and findings for individual policies are as follows:

Standards work

The evidence suggests that regulation and standards can and have improved vehicle efficiency and so, neglecting rebound effects (see below), reduce emissions. Regulation and voluntary agreement have yet to be pursued with a level of ambition sufficient to deliver large reductions in emissions from the vehicle fleet. However, the evidence indicates that targets can be successful in improving overall vehicle fleet efficiency. Targets need to be mandatory, ambitious, progressive and not amenable to circumvention. Net costs to society and individuals are low or even negative. There may also be macroeconomic benefits. However, higher capital costs may still deter 'myopic' consumers.

Fiscal measures influence consumers

Targets and standards can be complemented by fiscal measures.

Evidence from a range of countries suggests that purchase taxes can have a quantifiable impact on sales of lower emission vehicles, particularly when accompanied by subsidies (or 'feebates') for the lowest emission cars. Purchase taxes have the most direct impact on sales of more efficient vehicles, and can be used to counteract consumer 'myopia'. Purchase taxes are subject to a range of difficulties, and at present the EU opposes them on competition related grounds. Circulation taxes are levied on vehicle ownership and our review revealed considerable attention to the UK's CO₂ linked VED and company car tax policies. Evidence from modelling and empirical evaluations indicates that these taxes can have a significant impact on the vehicle mix. Like purchase taxes they can have welfare impacts and because they apply to older cars may have particular impact on poorer consumers, particularly those in areas poorly served by public transport and with larger families. These effects may be mitigated through schemes to subsidise the scrapping of old, high emission vehicles, provided these are designed such that they can benefit poorer car owners.

Information, labelling and car advertising

New car vehicle CO₂ labelling is mandatory in the EU. It is difficult to conclude that labels provide tangible direct contributions to reductions in average CO₂ emissions of new cars. Views about the effectiveness of labelling differ within the evidence revealed in our review. However the evidence suggests that labelling is an important component of a wider range of policies. Some analysts argue that the relationship between emissions



performance and future running costs needs to be explained more clearly to consumers and that this information should be extended to car advertising in a prominent and consistent way.

Rebound

Both fiscal policies and regulation can be undermined to some degree by so called rebound effects, whereby the lower fuel

costs associated with more efficient cars encourage drivers to drive more. The rebound effect for more efficient vehicles has been studied and estimated to lie in the range 20 to 40 %. Whilst this suggests that absolute reductions in emissions can be delivered regardless of rebounds, fiscal and regulatory measures will be most effective when accompanied by policies which mitigate rebounds.



5. Vehicle fuels: prices and taxes

5.1 Introduction

This section considers the relationships between fuel prices and CO₂ emissions from the surface passenger transport sector. Fuel prices affect the full range of choices relevant to transport emissions: in the short run they affect whether to travel, mode choice, distance travelled, driving behaviour and car occupancy; over a longer time frame they affect car choice and other aspects of travel demand such as home and workplace location.

Fuel prices vary as a result of movements in the global oil markets or policy mechanisms such as fuel or carbon taxes which bear directly on fuel prices. The effect is the same (to change the price the consumer pays per unit of fuel) and the literature discusses both. The remainder of this section considers fuel prices *per se* - whether market-driven or taxation-driven. However our principal policy conclusions relate to the role and effectiveness of taxes or other policies that affect fuel prices.

The evidence on the relationship between fuel prices and carbon emissions utilises a range of approaches and data sources including:

- The application of dynamic models to longitudinal data, using econometric methods to split out all the factors determining demand (prices, income and socio-economic and demographic factors) and establish behaviour response to price increases, so called price elasticity of demand (defined below Sect 5.2).
- The use of price elasticity of demand to model the potential effect of fiscal

changes and fuel price increases on travel behaviour, fuel consumption and carbon emissions.

- Data examining actual traffic growth / CO₂ figures compared to expected growth in a given country after a fuel tax increase was implemented.
- Comparisons of car ownership and use between countries with different rates of fuel tax.

In what follows we examine first the evidence on price elasticity, then consider the evidence from other sources, such as inter-country comparisons. We then discuss key issues and problems associated with fuel tax increases drawing on both categories of evidence. This is followed by a sub-section that examines the evidence on the cost-effectiveness of fuel taxes as a tool for lowering CO₂ emissions.

5.2 Price elasticity of demand

The responsiveness of demand to changes in price is measured by the term 'price elasticity of demand'. In numerical terms, this elasticity is the percentage change in quantity demanded divided by the percentage change in price. If demand is not very responsive to a change in price it is described as being relatively inelastic, and the formula would result in a value between zero and minus one (the closer to zero the more inelastic demand would be). Some products exhibit *elastic* response to price changes, where a change in price can generate a proportionately larger change in quantity demanded. As we explain below, the evidence suggests that

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demand response to fuel price changes is relatively *inelastic*. In economic theory inelastic demand response to price is typical for products with few alternatives, and/or where consumers suffer serious loss of utility if the product is foregone. The extent to which this is true of road fuels determines the elasticities found in different locations and time periods. Moreover, because demand reduces a relatively small amount in response to price increases, products with inelastic demand are also a good source of purchase tax revenue. This again is true of road fuels, which are heavily taxed in many countries.

Evidence on potential emission savings

Our review revealed 62 relevant studies. One source (Goodwin et al. 2004), cites 69 studies published since the previous round of literature reviews in 1992.

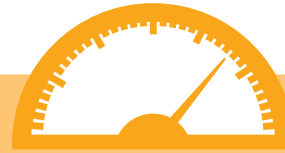
Fuel prices bear upon on a variety of different points of leverage of travel behaviour and these influences differ over time. In the short run, fuel price increases can cause reductions in vehicle mileage by encouraging a reduction in unnecessary trips and influencing modal choice and car occupancy (Ayres 1998;Potter et al. 2006). Short run effects may also include more efficient driving styles. In the longer run, drivers have an economic incentive to drive more fuel efficient vehicles, retire old, less efficient vehicles and potentially to make less car-dependent home and work location choices. Habits, imperfect information and uncertainty about whether price increases will be sustained all contribute to a 'lag' between fuel price increases and economic response. They may also contribute to the degree of short and long run elasticity.

Table 5.1: Evidence on potential emissions savings from the literature on price elasticities

Several reviews suggest that short run elasticity of demand for road fuel is around -0.25 to -0.3 (Goodwin et al. 2004;Graham & Glaister 2004). If the price of fuel were to increase by 10% and be sustained at that level, this would result in a 2.5% to 3.0% decrease in fuel used within a year, split approximately into two thirds more efficient driving and one third less distance traveled (Kahn Ribeiro et al. 2007). (Buchan 2007) states that evidence in the UK points to this split being approximately equal between more efficient driving and less distance travelled in the short term).

There is some evidence from the USA that demand may be becoming much more inelastic in that recent studies suggest that the short run price elasticity of demand for gasoline fell from -0.21/-0.34 in the 1975-1980 time period, to -0.034/-0.077 in the 2001- 2006 time period (Hughes et al. 2006). The authors of that report hypothesise a number of reasons for this dramatic change, including the impact of suburban development on the share of journeys that are non-discretionary and the reduced scope for shift to non-motorised transport modes. As a result, people in the USA have become so dependent on their vehicles that they have little choice but to adapt to higher prices.

(Small & Van Dender 2007) found that short run price elasticities in the USA dropped to about -0.11 in the late 1990s.



This is tempered by US evidence from the period since 2006, when elasticities appear to be increasing, reflecting both much higher absolute prices and income/wider economic effects. In 2007 and 2008, per capita fuel consumption and vehicle travel declined, suggesting that fuel prices are high enough to significantly affect consumer behaviour (CERA 2006; Williams-Derry 2008; Litman 2008b). According to Litman, (Komanoff 2008) estimates that the short-run U.S. fuel price elasticity reached a low of -0.04 in 2004, but this increased to -0.08 in 2005, -0.12 in 2006 and -0.16 in 2007. This probably reflects a number of factors, particularly the growing share of total household budgets devoted to fuel.

Other indicators also suggest that high fuel prices (and economic problems) are affecting demand for travel. In the first half of 2008 vehicle miles travelled declined 2.8% relative to 2007 (DoT 2008). In addition, there has been substantial declines in the sale of fuel inefficient vehicles such as SUVs and light trucks, and reduced demand for housing in automobile-dependent locations, indicating that consumers are taking fuel costs into account when making long-term decisions (Cortright 2008).

(Goodwin et al. 2004) suggest that long run elasticity is around -0.6 to -0.7. Over a period of about 5 years a 10% price increase translates into a reduction of approximately 6% in the volume of fuel used, comprised of the volume of traffic falling by about 3% and the efficiency in the use of fuel rising to around 4%. This translates into a 3% reduction in the mileage per car and an 11% increase in fuel efficiency per car. In addition, the total amount of vehicle ownership can be affected – by less than 1% in the short term, but building up to around 2.5% reduction in the longer term.

Table 5.2 below summarises fuel price elasticities drawn from the evidence base.

Table 5.2: Fuel Price elasticities

Category	Short-term elasticity (mean) (within 1 year)	Long-term elasticity (mean) (5 years)
Fuel consumption (total)	-0.3 ¹ -0.25 ²	-0.7 ¹ -0.64 ² - 0.3 / -0.4 ³
Fuel consumption (per vehicle)	-0.08 ²	-1.1 ²
Traffic volume (total vehicle km)	-0.15 ¹ -0.10 ²	-0.3 ¹ -0.29 ² -0.2 ³
Vehicle fuel efficiency	-0.15 ²	-0.40 ²
Vehicle ownership	-0.08 ²	-0.25 ²

¹(Graham & Glaister 2004)

²(Goodwin et al. 2004)

³(Jansson & Wall 1994; Michaelis & Davidson 1996; Johansson & Schipper 1997; Kageson 2003)



Overall, the literature on elasticities suggests that there is a difference between short run and long run effects after allowing for other effects such as income – long run elasticity being about twice as great as short run. That notwithstanding, the evidence is clear that fuel consumption and hence emissions do respond to fuel prices, albeit relatively inelastically particularly in the short run. How inelastic the demand response is varies according to the data set, time period and absolute level of price.

The implications for the level of taxation required to deliver long-term CO₂ reductions can be illustrated through example: To achieve a target of reducing total fuel demand from the surface passenger transport sector by 25% with price elasticity of fuel demand at -0.6 (the long run figure from (Goodwin et al. 2004) would require a price rise of 41.7%. This neglects any potential for income effects

to undermine reductions over time (see below), and since tax is just one component of the total price, implies even larger percentages increases in tax. If as some of the evidence described above suggests fuel demand is becoming more inelastic, even greater prices rises/tax levels would be required to achieve the same objective. Using, for example, an elasticity value of -0.3 from table 5.2 above suggests that achieving a 25% reduction in fuel demand would need a price rise of 83.3%.

5.3 Wider evidence: historical trends and inter-country comparison

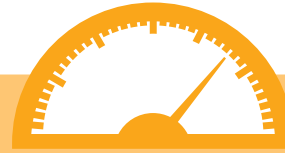
Historical and inter-country evidence on the impacts of fuel taxation policy provides a similar picture to the evidence from the price elasticity literature:

Table 5.3: Evidence on potential emissions savings – historical experience with fuel tax policies

In the UK, the effects of the Fuel Duty Escalator (FDE) are still felt in terms of emissions which are estimated to have been 1.9 MtC (7 Mt CO₂) higher in total by 2010 if the policy had never existed (DEFRA 2006a; Anable & Bristow 2007). This compares to 2.3 MtC (8.4 Mt CO₂) in total by 2010 for the Voluntary Agreement package (including car labelling, VED and company car tax) using the same methodology.

(Potter et al. 2006) notes that rises in traffic levels in Britain over the decade to 2000 had been relatively low, despite levels of economic growth that had previously stimulated significant traffic growth. (Buchan 2007) suggests that what happened during this period is consistent with the elasticities quoted above: the short-term impact of fuel duty between 1994 and 1999 was for every 10% increase in cost, a 3% decrease in fuel used.

In particular, the FDE apparently contributed to a significant slowing of traffic growth over about two years, despite strong economic growth during this period. "Between January 1998 and July



2000, a combination of rising oil prices and fuel tax meant that the fuel price index rose by 23% above inflation. Assuming a traffic elasticity of -0.3 , this would be expected to reduce traffic by about 7% over the two and a half years, or an average of 2.8 per cent per year. This is of the same order as the growth that would be expected as a result of economic growth. So, the evidence on traffic is consistent with the view that the government did, indeed, manage almost to halt traffic growth over a period of 2 years or so. This was not achieved by any complicated transport policy, but by the simple policy of increasing fuel tax, supported by increasing world crude oil prices". (Glaister 2002).

Fuel taxes are about 8 times higher in the UK than in the USA, resulting in fuel prices that are about three times higher. UK vehicles are about twice as fuel-efficient; mileage travelled is about 20% lower and vehicle ownership is lower as well (Kahn Ribeiro et al. 2007). It is important to note other factors such as congestion and availability of roads, cultural norms, land use and urban planning and income levels also play into this equation.

The 2007 budget announced an increase in the fuel duty rate of 2 pence per litre (ppl) from October 2007, and increases in the next two years of 2ppl (the 2ppl was subsequently postponed until December 2008) and 1.84 ppl respectively. Relative to baseline models of future transport demand these increases are expected to secure carbon savings of 0.16 MtC (0.59 Mt CO₂) per year by 2010-11 in a scenario of falling crude oil prices (Anable & Bristow 2007; HM Treasury 2007b; HM Treasury 2008).

Key issues and problems

This section draws upon evidence from a number of sources, including reviews of elasticities and inter-country comparison. Several commentators emphasise the benefits of fuel taxes, for example: "Carbon and fuel taxes are the ideal measures for addressing CO₂ emissions. They send clear signals and distort the economy less than any other approach" (ECMT 2006). There is evidence that fuel taxes are a cost-effective way to reduce emissions, but this is largely because taxes facilitate a transfer of funds from the purchasers of fossil fuels to the wider economy. This has equity and political implications which we discuss in more detail below.

The relationship between price changes and demand response is complicated by a number of factors and the impact of fuel tax increases on vehicle usage and ownership is also affected by:

- Income elasticity: Disposable income affects demand for fuel even more strongly than price, referred to as income elasticity. There is evidence that increasing incomes far outweighed fuel tax increases in Britain in the 1990s (see below).
- Total cost of motoring: the barrel price of oil, costs of car purchase and ownership and any road user charges may be as important as the fuel duty. There is evidence that the total costs of motoring in Britain fell in real terms



and relative to public transport even whilst fuel prices were being increased by taxation (see below).

- Cost of substitutes, such as alternative modes, referred to as cross-elasticity of demand.
- Whether and how much road capacity is increased or decreased.

We explore these factors in more detail below, together with the implications for equity and a discussion of the impact of concerns over public acceptability of fuel taxes as a policy tool.

Income effects

Rising incomes can over-ride demand reductions caused by fuel price rises. Conversely, if incomes are not growing in real terms (or are falling) then the effect of price rises will be greater. In practice, the price elasticity of demand tends to be significantly less than income elasticities of demand (ECMT 2006). The implication is that fuel prices/taxes would need to rise more quickly than incomes if they are to have an overall reducing effect on fuel demand:

- (ECMT 2006) "For transport, the main reason why a carbon (fuel) tax would have limited effects is that price elasticities tend to be substantially smaller than the income elasticities of demand. From (Goodwin et al. 2004) we conclude that the price-elasticity of total transport demand can be 0.6 in the long run and the income-elasticity of demand is a factor 1.5-3 higher. This implies that price of fuels must rise faster than incomes to curb CO₂ transport emissions if the price

mechanism is used as the principal policy tool. One reason for the low price elasticity is that environmentally motivated tax increases are largely invisible within the overall movement in fuel prices caused by volatility in international oil markets".

- Others also conclude that income elasticity may be greater than one e.g. (Glaister 2002) suggests that in the long run a 10% increase in income may increase fuel demand by 12%.

Some commentators suggest that to maximise the long-term effect of fuel taxes on carbon emissions they should be adjusted upwards on a regular basis, both to counter the income effects described above and the tendency of consumers to become accustomed to higher fuel prices/taxes and to revert to previous demand levels (ECMT 2007; World Energy Council 2007).

- (Metschies 2005; Litman 2008c) assert that one of the most appropriate emission reduction strategies is to gradually and predictably increase fuel taxes. At a minimum, they suggest that fuel taxes should increase to reflect all public expenditures on roadways and traffic services.
- (ECMT 2007) "This type of policy (fuel duty) is particularly effective if it adjusts excise duties annually, as was the case in the UK, in order to keep the cost of transport in line with increases in real incomes".
- The (World Energy Council 2007) notes the UK and German experience and concludes the taxation of fuel should follow an escalator approach



with periodical growth rates in order to influence car use behaviour in the longer term. Otherwise, they suggest, consumers tend to get used to the higher prices and the short-term effects of a rise in taxes are undermined.

Total cost of car use

The effectiveness of fuel taxes as a policy lever will be limited if the total cost of motoring is falling, especially if it is falling relative to the alternatives (Ekins & Dresner 2004). In addition, the effect of fuel taxes on the choice of vehicle may be limited because these decisions are more affected by upfront rather than recurring costs (Jansen & Denis 1999; Lane 2007).

- (Glaister 2002) explains how despite the focus of the public on the cost of fuel as a result of the fuel duty escalator, the cost of motoring (including purchase, maintenance, petrol and oil, and tax and insurance) between 1987 and 2001 remained relatively stable – at or below its 1980 level in real terms, even though the real cost of fuel in 2003 was 12% higher than in 1980 (Ekins & Dresner 2004). This was partly a result of a reduction in vehicle purchase price.

Availability, convenience and cost of alternatives

Mode choice is a complex area (see Chapter 3). The influence of fuel price/taxes will depend in part upon the availability, convenience and cost of the alternatives (Soberman & Miller 1999). The cross-elasticities of demand between transport modes will have a major bearing on the extent to which switching between

modes occurs in response to fuel prices rises.

These factors do not operate in isolation; rather they combine to influence patterns of travel behaviour and car choice. One study links the three factors, income, availability and relative cost:

- “In contrast to overall motoring costs (which remained largely constant), public transport fares have risen in real terms over the last 20 years. In 2001, bus and coach fares were 31 per cent higher and rail fares 37 per cent higher than in 1980. Over the same period, average disposable income has gone up more than 80 per cent in real terms. Transport has therefore become more affordable, with a greater improvement in the affordability of car use than that of public transport.” (Ekins & Dresner 2004)

Road space creation and reallocation

For reasons discussed in more detail in Section 3.7, the relationship between fuel prices and vehicle distance travelled is moderated by availability of road space, congestion and prioritisation of road space for non-car uses. The evidence suggests that road space creation can induce demand irrespective of fuel prices whilst road space reallocation away from private cars can have the reverse effect.

Public acceptability

Despite its advantages, there is widespread feeling that governments are now very wary of simply charging higher rates for existing transport tax measures and that public acceptability is an important concern:



- “The experience of the UK fuel duty escalator, introduced in 1993 and frozen in 2000, and opposition to increases in Germany’s eco-tax demonstrates the political difficulties involved with policies that operate through fuel taxes. Public acceptability is unlikely to cease to be a constraint on the use of fuel carbon taxes for the foreseeable future.” (ECMT 2007)
- (Begg & Gray 2004) describe the huge impact of the political unacceptability of the Fuel Duty Escalator in the UK. The resulting fuel protests led to the loss of the Government’s 20-point lead in the opinion polls in 1 month. The policy was then abandoned in the 2000 Budget (after the fuel protests) and duty was subsequently frozen in money terms (i.e. reduced in real terms) in the budgets of 2001 and 2002 and increased in line with inflation in 2003. They remark that by 2004, allowing for inflation, there had been a cut of around 6 ppl in petrol and diesel fuel duty rates, and the Government abandoned its only lever for managing traffic levels.
- (Potter et al. 2006) believes “that transport taxation in the UK, particularly upon fuel, is an increasingly controversial subject”. He claims the UK alone reduced annual automobile and truck taxation by nearly £2 billion following the autumn 2000 fuel protests.
- This controversy has been captured in (CEC 2007b) which explains why use of fuel duty was not considered further in the European Commission’s review of mechanisms to achieve vehicle CO₂ targets “Concerns about its effectiveness and political acceptability have led to excluding the option of relying exclusively on excise duties on transport fuels as a policy option. The equity considerations raised by the tax rates that would be needed to have a significant impact on vehicle fuel efficiency limit the political acceptability of this option, especially in a context where oil prices have significantly increased in the past years.”
- Some argue that the protests could at least be in part put down to a lack of communication of the policy goal by the Government. For example, (Begg & Gray 2004): “...this may be related to public perception of the policy goal...the Government was perhaps mistaken in allowing the escalator to be perceived as a purely fiscal policy. If it had been more aggressive in justifying the policy on environmental grounds (vis-a-vis raising revenue for public expenditure) then direct action, and the abandonment of the policy, may have been avoided.”
- However, others are not convinced that the environmental message will win over the public. (Potter et al. 2006): “There is a widespread perception that the motorist is simply a convenient source of revenue and that the environmental justification of taxation is little more than a matter of presentation.”

Welfare impacts

Costs are discussed below. However a key issue is that impacts may be unevenly



distributed amongst consumers. Fuel tax is described as a blunt instrument by (AIT & FIA 2001), unable to distinguish between rural and urban areas, rich and poor, areas of high and low traffic density and environmental problem areas. (Ekins & Dresner 2004) point out that fuel taxes are not regressive in the aggregate because in the UK poorer households are less likely to have a car, although petrol taxes are regressive *among* motorists (Blow & Crawford 1997).

Costs

We found considerable evidence on the cost-effectiveness of fuel taxation. The revenue raising nature of this policy is the reason a variety of commentators conclude that the cost-effectiveness of this instrument is high compared to other instruments. This is also due to the lack of rebound effect associated with its introduction and the fact that it is relatively cheap to administer. (Harmsen et al. 2003; ECMT 2006; U.S. Government Accountability Office 2007; Anable & Bristow 2007)

- In the UK, (DEFRA 2006b) estimate the cost-effectiveness of the fuel duty escalator (FDE), to yield a net *benefit* (including air quality benefits) of £250 per tonne of carbon (£68 per tonne of CO₂), compared to, say, a net *cost* of £105-220 t/C (£29-60 t/CO₂) for a Voluntary Agreement with car manufacturers reaching 135g/km by 2020), cited by (Anable & Bristow 2007). Indeed, Defra calculate fuel duty to be one of the most cost-effective instruments across all sectors included in its Climate Change Programme.

- Similarly, in the US, the CAFE system was found to cost 4.5 times more than a gasoline tax (CRA 1991; Koopman 1995). Likewise, (U.S. Government Accountability Office 2007)) reviewed the evidence and claimed: "Furthermore, this literature and all of the economists with whom we spoke stated that a tax on gasoline or carbon would be cost-effective, whereas increasing CAFE standards would not be as cost-effective. For example, (CBO 2003) estimated that increasing the gasoline tax to achieve a 10 percent reduction in fuel consumption would cost far less than an increase in CAFE standards".

Fuel taxation imposes a direct cost on businesses and consumers however:

- Some authors directly compare the burden on consumers from fuel tax versus fuel economy standards. (Koopman 1995) concludes that for CO₂ savings of 10%, a CAFE scheme has 20% higher welfare than a CO₂ tax, and this would widen further for more ambitious CO₂ targets. On the other hand, unlike CAFE, fuel tax does not increase the cost of new cars to consumers. In addition, fuel taxes have a relatively greater welfare benefit as a result of revenue redistribution. Overall, Koopman concludes that CO₂/ fuel tax is actually likely to lead to the smallest welfare loss *per tonne of carbon abated* because of the absence of a rebound effect.
- (Jansen & Denis 1999) also point to welfare benefits that can occur from reduced congestion and increased



travel speeds, and suggest that the environmental benefits of reducing emissions, as well as reductions in noise and accidents would reduce welfare costs even further.

Summary

Evidence from the literature on fuel price elasticity indicates that fuel prices rises can reduce demand, hence CO₂ emissions. The long run relationship is believed at present to be of the order of -0.6 , meaning that *all other factors being equal*, a 10% increase in fuel prices would result in a 6% decrease in fuel consumption relative to an otherwise identical future state where prices did not rise. However recent experience suggests that elasticities have been much lower than this, at least in the short run in the US. Moreover, other factors such as rising real incomes and reductions in other costs of car ownership can rapidly overhaul fuel price increases, with the result that in the absence of large, sustained and (assuming conditions of economic growth) constantly increasing fuel taxes, carbon emissions are not reduced in absolute terms.

5.4 Conclusions

There is clear evidence that in principle, and all other factors being equal, fuel price increases lead directly to fuel demand decreases, albeit in a relatively inelastic way. Hence fuel taxes can reduce emissions, or at least slow emissions growth. Unlike some other policies there is little potential for rebound effects to undermine savings and a policy along the lines of Britain's fuel duty escalator is

administratively straightforward given that mechanisms to tax fuel already exist. However, response to fuel prices is complex and depends upon availability of alternatives, income, total cost of motoring and a range of other factors. The strong relationship between income and demand for travel suggests that during conditions of economic growth fuel taxes need to be continually increased if they are to constrain demand growth driven by rising incomes. Response to price is generally inelastic, with the implication that large increases in prices/tax levels are needed to deliver significant reductions in demand.

There is evidence that short run price elasticity fell in the USA, at least up until the period to 2006, perhaps because consumers have become 'locked in' to vehicle use. The most recent evidence suggests that high fuel prices and economic difficulties may be making consumer responses to fuel prices more elastic. Longer run elasticities are generally higher than short run, since consumers can adapt by buying more efficient cars and/or adjusting journey patterns.

Fuel taxes are cost-effective, offering low cost emission reductions; however this is because taxes raise revenue, effectively transferring income from fuel purchasers to other parts of the economy via government. As a result, fuel taxation may have equity impacts and there is strong evidence that consumers resent fuel tax increases. There is also evidence that governments have become sensitive to the political difficulties associated with fuel tax rises. This, combined with the need for tax rises to be large and increase



continuously to deliver significant CO₂ reductions, suggests that political acceptability is likely to be an important

factor in any realistic analysis of the potential contribution of fuel taxation to emissions reduction from transport.

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6. Key Findings and Lessons for Policy

6.1 Introduction: the evidence base

This report provides a review of the evidence about policies that seek to promote lower carbon travel choices and the production and purchase of lower carbon vehicles. The policy landscape is broad, since it encompasses a wide range of policies related to travel choices as well as fuel taxes and measures affecting car ownership. In this final chapter we provide an overview of the main policy issues that emerge from our review. We review each of the main categories of choice discussed in chapters 3, 4 and 5 before discussing overarching conclusions and lessons for policy.

Our review revealed a wide diversity of evidence sources and evidence types, which indicates that the attention given to different policies varies considerably. Some options are better understood, more widely tested and have easier to quantify impacts than others. Some policies that serve multiple policy goals are well proven with regard to non-carbon transport policy issues (congestion, accidents, etc) yet have not been analysed adequately in terms of carbon impact and cost-effectiveness. In many cases further work is needed to assess how effective measures might be, and to fill gaps in policy research.

In general it is particularly difficult, indeed inappropriate, to attempt to pick 'winners' between policy types. In part this is a result of evidence that varies in focus, quality and quantity, but more important it is because it makes little sense to consider policies in isolation. For example,

improvements to public transport or cycling infrastructure can be augmented by road space reallocation and pricing which discourages car use. Conversely, responsiveness to road, parking or fuel price signals can be enhanced if attractive and convenient alternatives to the car are readily accessible. Pricing and regulation can also assist in ensuring that new public transport services draw users out of cars rather than from other modes or simply inducing new journeys. Similarly, individualised marketing can improve the utilisation of existing services, increasing occupancy, which improves both carbon efficiency and cost-effectiveness. Few policies will succeed in isolation – policies work best as packages.

Moreover, policies that seek to affect travel choices interrelate strongly with 'non-transport' policies, such as land use planning, particularly in the long term since availability of public transport correlates strongly with location choices. In many cases policies have different impacts for the long and short term, and are context specific, since what works in one set of circumstances may not in another.

In sections 6.2 to 6.5 we review each of the main choices that affect carbon emissions from transport. In each case we consider the main actors, their choices, and the policies that affect choice. In so doing we synthesise material from across the chapters above, combining insights where appropriate. Section 6.6 reviews overarching conclusions and lessons for policy.

Sections 6.2 and 6.3 tackle the closely interrelated issues of travel choice in

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terms of demand for travel *per se* and choice of mode. Mode choice and destination choice are not independent of one another, since consumers will choose a destination (for example a shopping centre or work location) in part as a result of its accessibility by various modes. However we discuss total demand and modal choice separately because whilst a variety of policies bear upon *both* forms of travel choice a more specific set of policies can affect mode shift (including a shift to shorter non-motorised journeys). Our review also suggests that it is important to avoid a simplistic representation of lower carbon transport decision making as being *only* about car technology and mode shift, since this neglects a whole raft of measures that affect demand for travel. Sections 6.4 and 6.5 make a similar distinction between car use and car choice. Again there are important interrelationships. We deal with these topics separately because we believe that there are distinct policies which can be brought to bear in each area.

6.2 Reducing demand for travel

Key determinants of travel demand include absolute and relative prices of travel by all modes, land use and choice of destinations and economic growth. Fuel price increases reduce travel absolutely as well as encouraging mode shifts and more efficient driving. Road pricing may have similar effects. The provision of extra road or public transport capacity can also lead to absolute increases in travel demand. Car clubs may be able to reduce car ownership

and hence the use of the car for previous car owners, particularly for short journeys. These factors are also relevant to mode choice, which we discuss in 6.3 below. The only policy that seeks solely to reduce travel is support for tele-activity. The evidence suggests that teleworking can directly reduce demand for travel but there is little evidence of its long-term, economy wide potential to reduce emissions.

Actors

Individual travel choices constitute a significant potential to reduce emissions. The principal actors are private individuals since they make the majority of relevant choices, though schools, workplaces and other 'destinations' can also play a role.

Choices

The main choices facing private individuals are whether to own a car, whether to travel, how often to travel and how far to travel. It is important to note that distance travelled in terms of the destinations and routes chosen is a key choice, alongside whether to travel. Organisations and businesses may be able to provide opportunities to work from home and other teleworking incentives, as well as restricting parking (which can affect both how and whether to travel) and factoring travel choices into location decisions (which affects journey length and may also affect decisions about both home working and how to get to work). The choice to join a car club may affect the utilisation of cars, particularly for short journeys.

Policies

Several of the most important determinants of overall travel demand lie



outside the immediate scope of this report; planning priorities and urban design being key policy examples. Travel demand is also affected extremely strongly by economic development and cultural factors. Apart from the promotion of car clubs to change the ways in which cars are owned, there are no policies which explicitly target car ownership levels. Demand for car travel is affected by fuel prices, particularly in the long term, as high prices lead people to seek locations, workplaces and other travel destinations that require less car travel. Lower costs of motoring have the opposite effects. There is also an important relationship between modal choice and total travel demand, since for services to be accessible by non-motorised modes they must be located within a relatively short distance of dwellings. Hence support for non-motorised modes may encourage closer location of services and workplaces, encouraging shorter journeys and

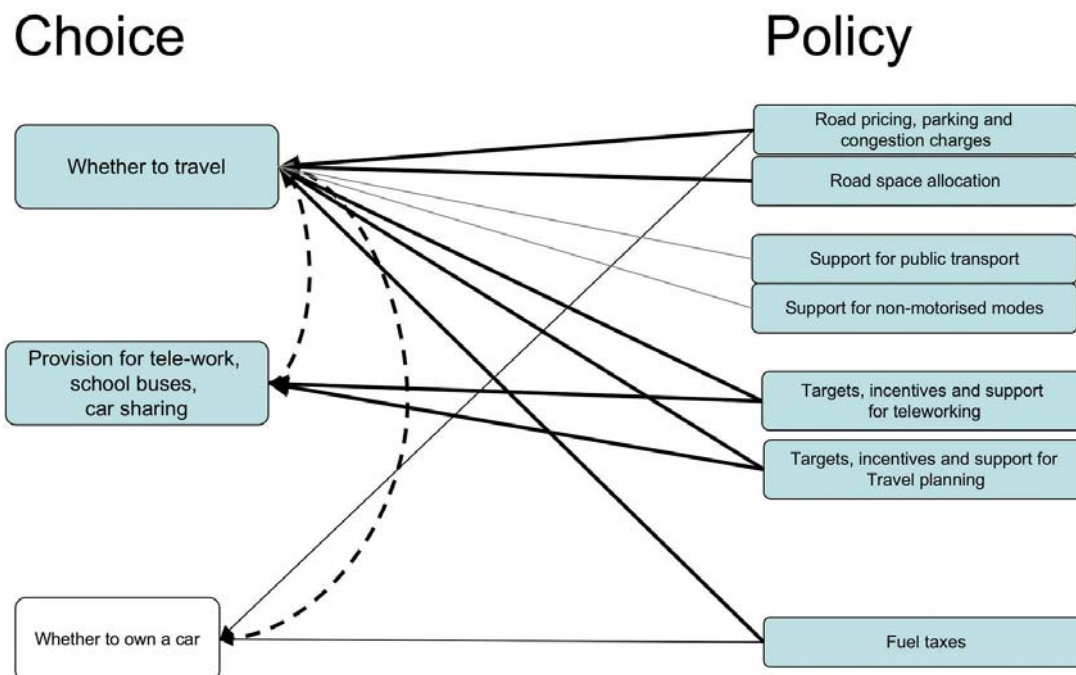
decreasing overall demand for travel as well as the use of lower emission modes. The main options for *directly* reducing demand for travel are teleworking initiatives. Choices and policies are illustrated in Figure 6.1, with primary linkages shown bold and secondary effects greyscale. Feedbacks between choices are shown hatched.

The evidence

Telework schemes have been promoted by policymakers in several countries, notably the US, where much of the evaluation evidence originates. Unfortunately whilst the literature is replete with examples of travel and fuel savings from telework programmes at a company or regional level there appears to have been much less attention to the long run potential for tele-activity in the economy overall. We found only one piece of analysis of UK potential. Teleworking offers low cost fuel

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Figure 6.1: Whether (and how far) to travel: choices and policies





and emission savings since it generally reduces individuals' expenditures at low marginal cost (home-working is often cheaper than travelling to the office). Since telework offers time and cost savings it may also be subject to rebound effects; as people avoid the journey to work they may make additional journeys from home. Further work is needed to assess the extent to which tele-activity might be expected to expand autonomously, what the emissions impacts (allowing for rebounds) might be, and how policy might expand its role.

The evidence suggests that road/parking/congestion charging and fuel price increases *will* affect demand for travel. Quantification is context specific, but some journeys will be avoided, trips may be combined or cars shared, closer destinations selected. These effects are in addition to shifting to other modes, driving more efficiently and choosing different vehicles. The impact of road pricing of various forms will be affected to a large extent by whether the charge is additional to existing taxes or offsets a reduction in fuel taxes. In the latter case the effect may be to retime and reorganise car journeys rather than reduce them overall. There is evidence to suggest that where car clubs are provided they can lead to reductions in car use.

6.3 Mode switch

Both non-motorised modes and public transport have a potential role in reducing emissions. There is evidence that the emission reduction potential for walking and cycling has been overlooked in many

countries and could be expanded considerably in the UK. Costs and emissions impacts have not been thoroughly quantified. The short-term potential for mode shifting from cars to public transport is restricted by capacity constraints and low cross-elasticities, though road pricing and road space reallocation can help as can factors such as the safety and convenience of non-motorised modes. In the long run both access to services by non-motorised means and integrated public transport are central to less car intensive and low emission transport patterns. Many of these factors interrelate strongly with those discussed in 6.2 above. This section seeks to review those policies which bear most directly on mode choice.

Actors

Individual travel choices have a considerable bearing on mode share. The primary actors (apart from policymakers) are private individuals. Private sector providers of public transport services, schools, workplaces and other organisations can also play a role.

Choices

The central choice of interest in this area of policy is private individuals' decisions about *how to travel*. Workplaces, schools and other organisations may be able to provide opportunities to co-ordinate car sharing, bus to work schemes, as well as restricting parking and factoring travel choices into location decisions. Private sector providers of public transport options make important choices about routes and fares, particularly where routes are not regulated.



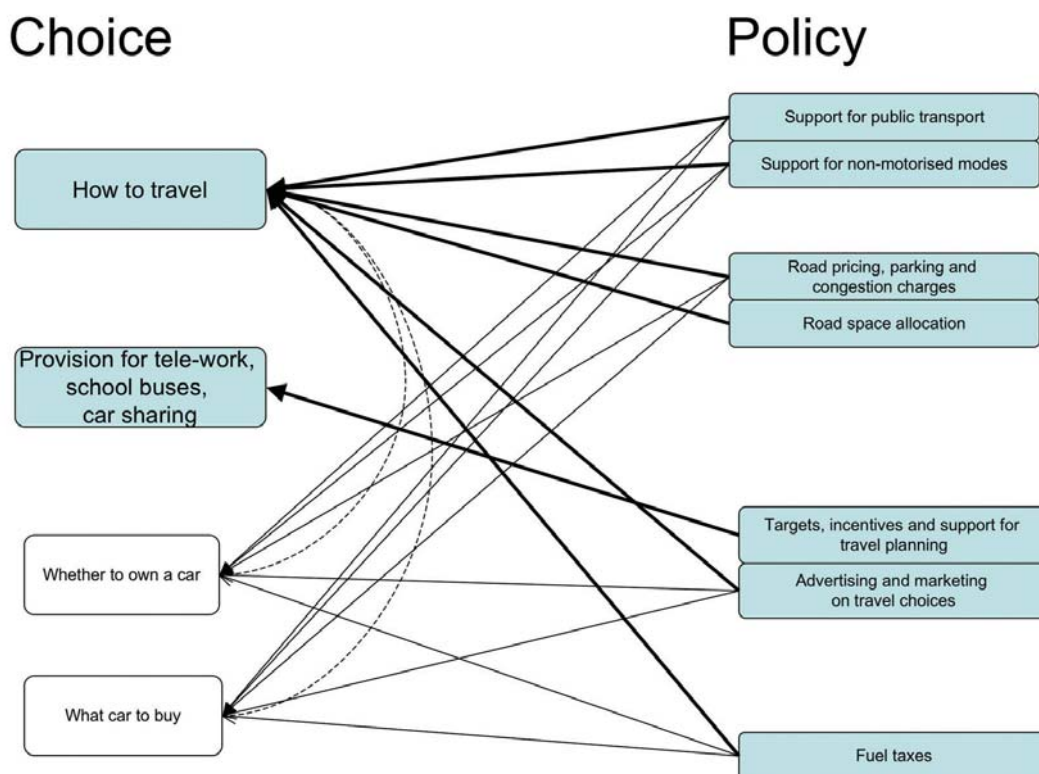
Policies

Direct support for public transport can take the form of subsidies for infrastructure expansion and upkeep and for running/rolling stock, fare subsidy and regulation, road space prioritisation and land use policies that integrate with public transport provision. Support for non-motorised modes takes the form of infrastructure, road space allocation and integration into land-use planning. Policies such as individualised travel plans can have a significant impact on mode choices as can road use charges and fuel taxes. All of these interventions can be augmented by fiscal policies which reconfigure the price signals in favour of alternatives to the car. The relationships between policies and choices are illustrated in Figure 6.2.

The evidence

Whilst many countries report public transport policies in relation to CO₂ emission objectives, few do so for non-motorised transport. Despite this, our review revealed considerable potential for policies to support walking and cycling to reduce emissions, particularly if in the long run it helps to encourage and lock-in journey patterns that favour shorter trips. Several studies suggest that the potential for non-motorised modes to contribute to emissions reduction has been neglected by policymakers in many countries. In the UK in particular, expansion of walking and cycling appears feasible, not least because levels of such 'active' travel options are much lower than in other European countries. Better infrastructure, in order to

Figure 6.2: How to travel: choices and policies





improve safety and amenity, appears to be of great importance to encouraging cycling in particular. 'Stick' measures such as congestion charging can also play a significant role in encouraging a switch to these modes. However there is a paucity of evidence on the cost of cycling infrastructure and little evidence of cost-effectiveness in terms of how such expenditure affects carbon emissions. Future research on these aspects could provide a considerable improvement to understanding the importance of non-motorised travel.

Direct support for public transport, whether through fares subsidy or capacity expansion, can reduce emissions as public transport is considerably less carbon and energy intensive than private motoring. Evidence from several countries reports the emission savings such schemes can yield. However the literature also provides considerable evidence of the limitations of public transport in emissions terms. This is because of factors such as the scale of expansion that would be required to absorb a sizeable fraction of car journeys and the potential for non-beneficial mode switch (bus to train, walking to bus, etc). The short run limitations need to be set against the long run relationship between the availability of good quality public transport, at a total cost that is competitive with motoring, and lower carbon patterns of land use and journeys.

Increased utilisation of both non-motorised modes and public transport can be greatly enhanced by a range of 'soft' policies such as individualised travel planning. 'Hard' measures that restrict car access or road space, charging for road use and parking, and fuel prices are also

very important. These policies can be linked, for example if feedback from travel planning informs public transport provision. As we discuss in section 6.2, the evidence suggests that the impact of road pricing of various forms on both overall demand for travel and modal switch will be affected by whether the charge is revenue raising (additional to existing fuel taxes) or revenue neutral (substituted for existing fuel taxes). In the latter case the main effect of road pricing may be to retime and reorganise car journeys rather than reduce them overall thus having a neutral or even negative effect on CO₂. Finally, there is evidence to suggest that car clubs can assist/encourage individuals in making less car dependent travel choices.

6.4 Using vehicles more efficiently

Car occupancy and driver behaviour can have a significant impact on emissions given the decision to travel and to use a car. There is strong evidence that more efficient driving styles (so called eco-driving) can reduce a typical driver's emissions by around 15%. The principal issue for policy is how to secure and sustain such benefits through training, education and reinforcement, including through speed limits. Average vehicle occupancy in the UK is around 1.6, and lower for commuter journeys. Improving occupancy through car sharing between former drivers could therefore deliver substantial reductions in emissions provided it did not give rise to commensurate additional or longer journeys. The evidence on the effectiveness



of car sharing schemes and high occupancy lanes is inconclusive, indicating that additional attention to this area is required before clear conclusions can be drawn for policy.

Actors

The primary actors are individual drivers and prospective passengers. Schools, workplaces and other organisations can also play a role.

Choices

The central choices of interest are those of individual drivers about how to drive and whether to share their journeys, and if so with whom. Schools and workplaces can also help by providing information and incentives for car sharing. Where they exist, the choice to become a car club member is another option.

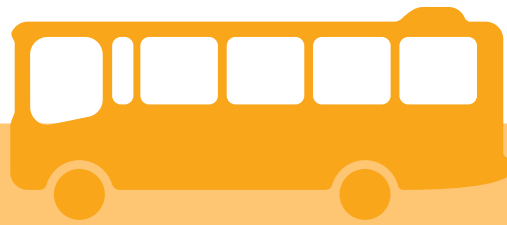
Policies

Policies that oblige companies to assist with and incentivise car sharing, individualised marketing and information campaigns, and road space allocation and charging to favour higher occupancy vehicles can all encourage higher car occupancy. Fuel prices, road user and parking charges are also incentives for car sharing. Road pricing will encourage car sharing but time of day/congestion linked charges may also lead to retiming of journeys. Eco-driving can be directly promoted through the driving test, voluntary or compulsory training, speed enforcement and education and awareness campaigns. Fuel prices also affect driver behaviour. In the UK car clubs have developed through commercial operators, but more rapid development in less commercially attractive locations

could be supported through policy. The relationships between policies and choices are illustrated in Figure 6.3.

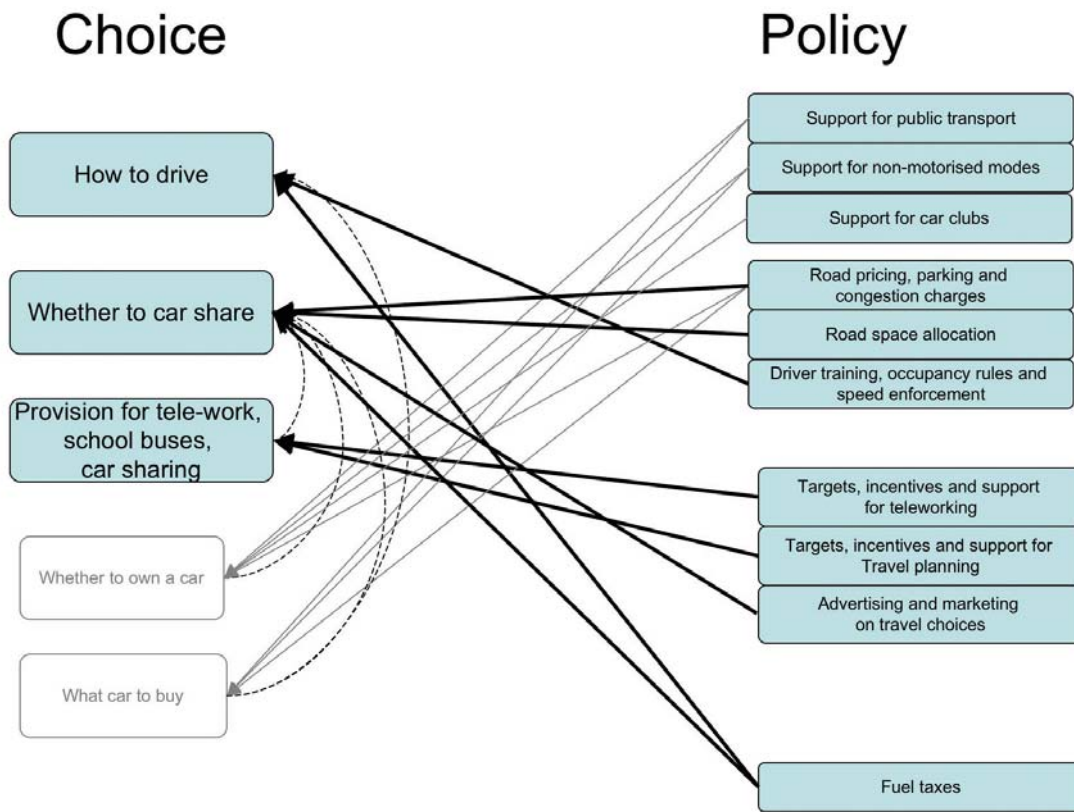
The evidence

The evidence on car sharing campaigns indicates that company level incentives instigated in the US in response to state legislation met with a limited response. The literature provides a variety of reasons for why people may either prefer not to car share or find it difficult to do so. Penalties in the form of parking and other charges increase the uptake of car sharing schemes. Whilst UK occupancy levels are low, suggesting a theoretical potential to double occupancy and therefore reduce car use by as much as 50%, there is little UK evidence on which to derive an estimate of practical potential or of policy efficacy. US evidence on high occupancy lanes is also rather mixed, and several authors devote attention to the conceptual and practical limitations on such measures. By contrast the evidence on eco-driving suggests that there is a significant potential to reduce emissions, by perhaps 15% per driver. The principal issue for policy is how to secure and sustain such benefits through training, education and reinforcement. The main problem being that it is not clear that the benefit of eco-driving campaigns sustain over time. The evidence for the potential for speed enforcement to secure savings from eco-driving are based on the physical relationship between speed and energy use and the assumption that effective enforcement will lead to high levels of compliance. The cost of this enforcement is less certain. Fuel and road user charges also have an important impact on driver behaviour and occupancy.



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Figure 6.3: Car usage: choices and policies



6.5 Lower carbon vehicle choices

Regulation is effective in driving the production and marketing of lower carbon vehicles, the evidence suggests that it can reduce the carbon intensity of the vehicle fleet provided standards are mandatory, ambitious, progressive and not subject to circumvention or leakage. It also suggests that regulation can deliver carbon reduction at low net costs to society and car users. Smaller and lighter vehicles need not be more expensive, but even when lower carbon cars have higher capital costs these can be offset by lower running costs. However consumers may continue to prioritise capital cost savings. Partly for this reason, regulation is not sufficient alone and fiscal measures are

needed to incentivise lower carbon car choices. Purchase taxes have been proven to be effective in several countries and can help overcome the partial 'myopia' exhibited by some consumers over running costs. Circulation taxes can also play a role and the UK company car tax rules have had a demonstrable impact on that segment of the market. Despite running cost 'myopia', fuel prices also significantly affect vehicle choice; around half of the long run response to price increases is a product of more efficient vehicles entering the market. Fiscal measures can have equity and welfare impacts, and measures that target vehicle efficiency can give rise to rebound effects. Active promotion of lower carbon choices through mandatory labelling and marketing rules have a potentially



important but as yet relatively poorly quantified effect.

Actors

Two actors are involved, private consumers and car manufacturers.

Choices

Private consumer choice of vehicle type and model are key to the efficiency of the vehicle fleet. Since car travel is more carbon intensive than public transport, for any particular marginal travel choice the choice *not to drive* is in almost every case going to yield a lower carbon outcome, irrespective of how efficient the car¹⁴. Notwithstanding this, car choice can have a profound impact on emissions since the range of emissions per vehicle km is extremely wide and for this reason vehicle

choice is an important factor in reducing transport CO₂ emissions. Choices for car manufacturers include investment decisions related to new models, R&D and marketing.

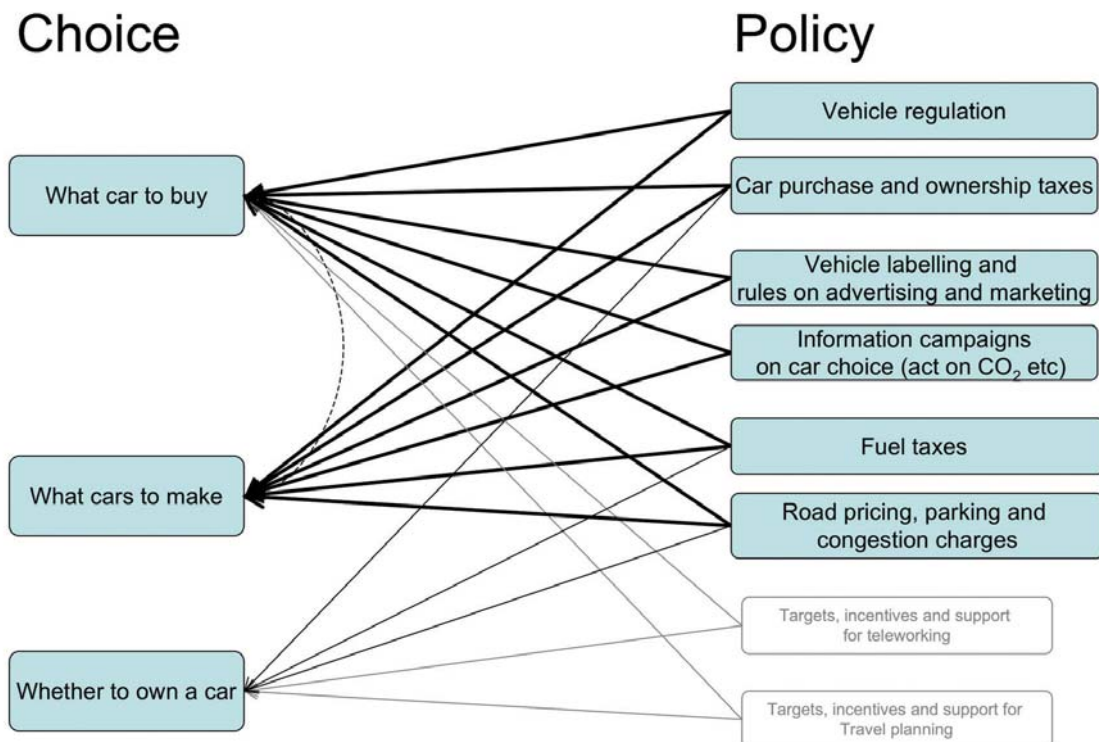
Policies

Four main categories of policy affect car choice: regulation (efficiency/CO₂ standards); fiscal policies that target car purchase and ownership; information and marketing rules; and fuel taxes. The relationships between policies and choices are shown in Figure 6.4.

The evidence

The evidence suggests that regulation and standards can and have improved vehicle efficiency and so, neglecting rebound effects, reduce emissions. In some cases

Figure 6.4: Car choice: choices and policies



¹⁴Neglecting the long run potential for electric cars run on decarbonised electricity



on-road efficiency gains have not emerged, despite an improvement in test cycle performance, suggesting that a range of rebounds counteract improved performance. Until recently, regulation and voluntary agreement have not been pursued with a level of sustained ambition sufficient to deliver large reductions in emissions from the vehicle fleet. However, a more ambitious target has now been agreed by the EU (95 g/km in 2020), although details of implementation and enforcement are yet to be defined. Standards are most effective if they are mandatory, ambitious, progressive and not amenable to circumvention. Whilst standards can deliver emissions reductions at low net costs to consumers and society at large they may give rise to higher capital costs. Targets and standards can be complemented by fiscal measures. There are four categories:

- *Purchase taxes* can have a quantifiable impact on sales of lower emission vehicles, particularly when accompanied by subsidies (or 'feebates') for the lowest emission cars. Purchase taxes have the most direct impact on sales of more efficient vehicles, and can help overcome 'myopia' exhibited by some consumers about long run running costs. Purchase taxes are subject to a range of difficulties, and at present the EU opposes them on competition related grounds.
- *Circulation taxes* are levied on vehicle ownership and our review revealed considerable attention to the UK's CO₂ linked VED and company car tax policies. Evidence from modelling and empirical evaluations indicates that

these taxes can have a significant impact on the vehicle mix, providing the delineation between different CO₂ bands is sufficiently large to affect choice. Because circulation taxes are paid on older cars as well as new cars they may have a particular impact on poorer consumers, particularly those in areas poorly served by public transport and with larger families. The evidence is inconclusive on the effect that recent reforms of VED in the UK have had on car purchase habits, and indeed qualitative evidence seems to suggest that many people have not been influenced by this policy because of the relatively low cost penalty between bands. However, company car tax is more finely graded and here there is good evidence that it has influenced vehicle choice.

- *Road user and congestion charges* of various forms can be graduated by vehicle, hence targeting the types of cars driven.
- *Fuel taxes* do influence vehicle choice, particularly in the longer term. There is clear inter-country evidence of a correlation between average levels of fuel taxation, hence price, and average vehicle efficiency. Car purchases are complex and purchase prices may affect decisions more than running costs. However this does not mean that fuel costs are entirely ignored by all consumers. Indeed, long run price elasticity of demand for road fuel is of the order of 0.6 (a 100% rise in prices leads to a 60% fall in fuel demand) and around half this effect is attributed to changes to vehicle efficiency. Overall,



notwithstanding the 'myopia' referred to above, high fuel prices lead some people to buy more efficient cars.

The impact of labelling of cars has not got a strong empirical support base. Also it cannot of itself shift consumer preferences or overcome 'myopia'. There are strong complementarities between labelling and regulation and taxation, since in the absence of information it is impossible for consumers to make choices to benefit the environment or their personal finances. However, information on the label has so far failed to enable consumers to put CO₂ and fuel information in context of their own travel patterns and compare impacts between vehicles. Marketing by car makers may focus on attributes other than efficiency and this can act against the direction of other CO₂ policies as well as affect consumer preferences. Therefore regulation and agreement over marketing may be important in orienting purchasers toward lower carbon options.

Both fiscal policies and regulations that target cars but not car usage can be undermined to some degree by so called rebound effects, whereby the lower fuel costs associated with more efficient cars encourage drivers to drive more. Whilst

the evidence is generally that absolute reductions in emissions can be delivered regardless of rebounds, fiscal and regulatory measures will be most effective when accompanied by policies such as fuel taxes which mitigate rebounds. Car clubs may also be able to help to promote the development of use of electric vehicles and on-street recharging facilities.

The policies described and discussed in this section are complements rather than alternatives. The evidence suggests that policies need to be implemented as a package to have best effect. This is recognised to some degree in policy. For example the UK Treasury argues that the VED rules exist to help facilitate the delivery of the EU voluntary agreement. However, it is not clear that policies are yet fully aligned. For example, rebound effects are not catered for as vehicle efficiency improvements are not matched by equivalent fiscal levers to at least stabilise the cost of motoring.

The evidence and issues are summarised in tables 6.1 and 6.2 below and reproduced in annex 3. We go on to discuss the implications for policy in section 6.6.



Table 6.1: Lower carbon travel choices: replacing journeys; using lower carbon modes; using cars efficiently

Policy/measure	Potential CO ₂ impact	Evidence for cost – effectiveness	Key issues & problems
Support for teleworking, telecommuting, teleconferencing	UK aggregate potential unclear: Much evidence is company and/or US specific.	No specific data on £/tC saved but likely to be highly cost-effective.	Possible rebound effects may be substantial (e.g. home location shifting and induced trips). Baseline trends to tele-work unclear. Role for policy unclear. More research needed on UK potential, policy needs and baseline.
Support for non-motorised modes (walking/cycling)	Substantial: E.g. 2MtC per year (6% of UK transport emissions) if UK reached levels common in other northern EU countries.	No specific data on £/tC saved; possibly highly cost-effective.	Safety, routing and prioritisation are key. Road reallocation and dedicated routes improve perceived safety. Evidence from London that improved provision combined with penalties for car use can have great impact. Destination shifting may be induced and will raise long run potential. More research needed on abatement cost.
Public transport: pricing, service & infrastructure	Marginal/modest in short/medium term. More substantial in longer term.	Little data on £/tC saved. Likely to be context specific since new infrastructure may be high cost but improving utilisation of existing transport can be cost-saving.	Short vs long-term CO ₂ reduction potential. Short-term issues – limit to capacity to expand sufficiently to absorb significant share of car trips, induced demand, non-beneficial mode shift. Long term affordability and quality of PT has strong link to mode share and land use patterns.
Vehicle occupancy: car share schemes & HOV lanes	Mixed evidence from the US: no aggregated UK CO ₂ data.	Little data on £/tC saved but likely to be medium to highly cost-effective if existing road space reallocated.	Common origin & destination required. Driver preferences. Under-utilisation of HOV lanes. Congestion of HOV lanes. Cost if HOV lane is constructed. Possible rebound effects. More research needed on emissions savings and abatement cost.
Car clubs	Unclear: Could be substantial, depending on scale of UK driver engagement and impact on car use patterns.	No specific data on £/tC saved but likely to be medium/highly cost-effective.	More research needed on characteristics of car club users and potential role for government policy to promote car clubs. Incentives for car club cars can be linked to low emissions; may create early adoption of low emission vehicles and facilitate adoption of electric cars/charging facilities.



Eco-driving & speed enforcement	<p>Substantial: 10-15% reductions in UK car emissions from eco-driving; 2-3% savings in total UK transport emissions from motorway speed limit enforcement.</p>	<p>Highly cost-effective for training & campaigns: less than £20/tC saved. Mixed evidence on cost of speed enforcement.</p>	<p>Potential for swift results from both eco-driving and speed limits/enforcement. More research needed on securing longevity of eco-driving training. Safety benefits from speed constraint. Political acceptability of speed limit enforcement may be a barrier.</p>
Travel plans: personal, schools, & workplace	<p>Modest/substantial: 5-10% reductions in UK car usage from PTPs; good evidence of impact from schools/workplace plans (6-30% reduction).</p>	<p>No specific data on £/tC saved. Unclear cost-effectiveness for PTPs; variable for schools/workplaces (below £30 to over £500 per tC).</p>	<p>Some concerns re PTP evidence quality. Provision of alternative modes crucial. Safety issues for school plans. Effective marketing needed. Hard policies - parking restrictions, penalties & subsidies are key. Limited level of workplace plan uptake. Large companies easier target than SMEs. More research needed on emissions savings and abatement cost.</p>
Road pricing & congestion charging	<p>Modest/substantial but only if net revenue raising: E.g. possible 7% annual saving in traffic CO₂ by 2025.</p>	<p>No specific data on £/tC saved but likely to be highly cost-effective as revenue raising.</p>	<p>Possible leakage & rebound effects. Revenue raising vs revenue neutrality. Charges should be CO₂-differentiated. Public transport and other alternatives are key. Political acceptability appears limited. Road pricing data based on modelling.</p>
Road space provision & reallocation	<p>Road space provision may increase long run emissions. Modest to substantial benefit for reallocation away from private cars.</p>	<p>Negative cost-effectiveness for road provision (expenditure induces traffic); no data on £/tC for reallocation.</p>	<p>Road capacity can ease congestion and reduce emissions from highly congested roads but induced traffic effects can increase long-run emissions. Potential for induced traffic well established and accepted by government. Possible leakage if traffic diverts from reallocation area. Effective reallocation planning is key. Much of evidence is unrelated to CO₂.</p>

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Table 6.2: Lower carbon vehicles: technology development and consumer choice & vehicle fuels: prices and taxes

Policy/measure	Potential CO ₂ impact	Evidence for cost – effectiveness	Key issues & problems
Vehicle efficiency standards	Could be substantial: E.g. possible g/km savings in excess of 50% through 'best in class' alone. US evidence suggests CAFE doubled on road efficiency up to 1990, but neglects SUV market. Mixed results from measures in EU/Japan.	Can be highly cost-effective: individual (-39 to -21 Euros per g/km saved) & societal (-44 to -10 Euros per tC saved). May increase purchase price.	Effective design essential: continuous improvement; adequate penalties; no loopholes. Consumers tend to discount lower running costs and additional measures (fiscal support, labelling) may be essential to induce purchase, particularly if purchase price increases. Rebound effects and driving style must not be overlooked. Costs for manufacturers, possible loss of fuel tax revenue.
Fiscal measures: Purchase tax and subsidies	Moderate to substantial: E.g. Dutch 'feebate' scheme produced savings of 2-3% of total transport emissions. International experience suggests clear impact on car fleet.	No specific data on £/tC saved but likely high cost-effectiveness.	Key policy to counter-act consumer discounting of long run costs. Policy stability & longevity are important. EU competition rules militate against purchase taxes. Possible rebounds from more efficient cars.
Fiscal measures: Circulation & company car taxes	Evidence not clear: Company car tax successful for that section of car market, but some 'leakage'. VED evidence not disaggregated from other policies and much analysis focused on band differentials.	No specific data on £/tC.	Consumer myopia may undermine effectiveness of circulation tax for some purchasers. Differentials may need to be large to impact purchase choices. Welfare/equity concerns for owners of old and inefficient cars. Scrappage subsidies may mitigate. Possible rebound effects. Possible reduction in fuel tax revenue.
Information on car choice Advertising standards & regulations	Marginal to modest: possible reduction of between 2.7% and 5% in new car fuel consumption. Contradictory evidence on effectiveness. Potentially important complements to taxes and standards.	No specific data on £/tC saved. Expected to be highly cost-effective.	Importance of information prominence/clarity and link to 'real world' cost savings. Comparative best in class information important. Consumer preference for vehicle attributes that increase emissions can be reinforced by manufacturer advertising. Possible rebound effects from increasing fleet fuel efficiency.



Fuel tax/price	Marginal to modest short-term: probable short run price elasticity of fuel demand -0.25 to -0.3 Modest to substantial long-term: probable long run price elasticity -0.6 to -0.7	Highly cost-effective for macro-economy. FDE estimated to yield net benefit of £250 per tC. But direct cost to businesses and consumers.	Clear linkage to vehicle fleet efficiency. Could counteract rebound effects associated with more efficient cars. Income effects can outweigh tax effects and continuous increases may be needed to manage demand. Welfare/equity impacts may be negative. Political acceptability appears low. Total cost of motoring and availability of alternative travel/destination patterns affect price response.
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6.6 Summary and lessons for policy

This report has revealed both a wealth of policy options and huge policy potential and some fundamental inadequacies in our ability to quantify, compare, or in some cases even meaningfully discuss relative roles in reducing CO₂ emissions.

Policymakers are faced with a complex set of issues related to the long and short run potential of a range of policy options, reflecting the complex choices open to individuals in the transport arena. It is clear that policies work best as *packages*; for example, provision of better or cheaper public transport, improved cycling facilities and opportunities to reduce travel can be augmented by travel planning/information, road pricing, fuel taxes and road space reallocation. Similarly, car choices can be affected by a range of fiscal measures and market information as well as through regulation. Whilst there is some evidence that policies are indeed implemented in an integrated fashion there is also evidence that this has failed to occur in many instances. For example,

rebound effects are not catered for as smarter choices are still implemented without locking in mechanisms, and vehicle efficiency improvements are not matched by equivalent fiscal levers to at least stabilise the cost of motoring. Moreover, whilst outside the direct scope of this report, it is also possible that land use and other 'non-transport' policies are continuing to create demand for travel and/or to favour car dependent long-term choices.

Our review reveals the following key findings:

There is untapped potential for carbon reduction from altering consumer behaviour. *In addition to purchasing fewer and more efficient cars in the first place, consumers can be persuaded to make fewer trips, change destinations, switch mode and use cars more efficiently:*

- Non-motorised modes can make a significant contribution, particularly in the medium term as travellers not only substitute like-for-like trips, but also change travel patterns. However, more work is needed on costs and

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effectiveness of the main measures to directly promote their use.

- Public transport is important, as well as other alternatives to private cars, though these are not the whole solution, particularly in the short term as private cars account for a much larger fraction of passenger distance travelled. In the long run public transport availability, and cost relative to motoring, has a profound effect on location and travel choices, suggesting that the long-term potential for emissions reduction is much larger than short-term analysis suggests.
- 'Smart' measures such as travel planning offer a cost-effective means to realise the potential of 'hard' measures such as improved public transport. Conversely, expanding road and parking capacity may undermine their effectiveness.
- Penalties in the form of parking and road space priority facilitate mode switch and complement 'smart' measures such as information provision.
- Road user charges can reduce congestion but may not reduce carbon, unless accompanied by other measures.
- Growth in car ownership correlates with growing car usage. There is evidence to suggest that where car clubs are provided they can lead to reductions in car use. They may also be able to help promote the use of electric vehicles and emergence of charging facilities.
- Efficient driving styles are a quick and

cost-effective route to carbon savings from car use. However, the long-term benefits of eco-driving training are uncertain, since more efficient driver behaviour may not sustain over time. Further research needs to focus on the need for and value of ongoing programmes along the lines of road safety and drink driving campaigns as well as in-vehicle technology to help consumers achieve efficient driving practices. Behaviour change would be effectively and consistently achieved by comprehensive speed limit enforcement on trunk routes and motorways.

Lower carbon vehicles are a result of consumer choice and investment by car makers. *Regulation works if properly designed and implemented. Fiscal measures to influence consumer choices are also important:*

- There is clear potential for well designed emissions standards to reduce average fleet emissions, particularly over the medium to long term.
- Vehicle efficiency standards need to be mandatory, ambitious and without loopholes.
- Vehicle efficiency standards can make vehicles available, but policy is also needed to influence vehicle choice by consumers.
- Taxes and rebates at point of sale offer the benefit of overcoming consumer 'myopia' related to longer term running costs. Circulation taxes also influence car choice, and have an impact on second hand car choices, though their effectiveness is dependent on the degree of



delineation and cost difference between bands. They can have welfare impacts, in particular in that they may impact negatively on poorer, larger households in locations with few alternatives to the car.

- Labelling and measures to encourage supportive marketing of lower carbon cars can augment fiscal policies, but their direct effects will always be difficult to determine. It would appear that information needs to be placed in the context of consumer travel choices and provide comparative data in order to be most effective.
- More efficient cars may be subject to rebound effects as people take advantage of the lower costs of motoring. This can be tempered by a balanced approach to fiscal levers which ensures that the cost of motoring is not reduced, particularly in relation to alternative modes.

Fuel prices, and fuel taxes, are an important determinant of vehicle choice and use but should not be relied upon in isolation:

- Short run response is fairly inelastic, particularly where there are few alternatives to car use.
- Longer run elasticities are higher as people adjust travel patterns, locations and car choices. In all cases other policies such as provision of public transport, land use planning and effective measures to promote the development and marketing of lower carbon cars are key to the elasticity of response.
- Fuel taxes can be used to mitigate

rebounds from improving vehicle efficiency.

- There is evidence of public opposition to fuel price increases in several countries and hence fuel taxes may be particularly sensitive politically.

The rebound effect takes many forms but can be planned for and mitigated.

- The 'classic' rebound example, well documented in the literature, is where more efficient cars reduce the cost of travel and increase car use. But rebound effects are not confined to improvements in vehicle efficiency as the reconfiguration of costs and benefits of almost all transport policies can mean that unintended consequences occur. In our review we have highlighted these with respect to a number of policies and can categorise these as follows:
- Potential for policies to 'backfire' through loopholes e.g. CAFE in the US encouraged the SUV market.
- Induced travel – increasing capacity on any mode can simply encourage more of its use rather than a substitute for less efficient modes.
- Policies may 'leak' – shift purchase or other choices from the target sector to another e.g. company car tax in the UK led to a reduction in company car sales whilst sales of privately owned cars increased.
- Policies which seek to address non-carbon goals may create perverse incentives from a carbon saving perspective. For example, congestion charging combined with fuel duty reduction has the potential to decrease



the cost of motoring on uncongested roads and increase their use.

In all cases well designed instruments and/or a combination of policies can mitigate rebounds and unintended consequences. An important implication is that carbon needs to be factored into policies which have other goals to both maximise combined benefits and guard against rebounds or unintended consequences.

Evidence gaps exist in many areas and more research is needed, particularly on travel choice and behaviour.

- Whilst transport policies are well studied, transport policies to reduce CO₂ emissions are less than fully understood. There are many gaps in the evidence base and it is difficult to draw unequivocal conclusions about the potential impact of many policy options. The main problem for many of the policies that target travel choices is that their potential impact on CO₂ emissions is not as well understood as their role in meeting other policy goals. Indeed, it is possible that whilst policies which are designed to fulfil objectives other than carbon reduction will also reduce carbon, unless designed specifically to reduce carbon they may not.
- In particular, cost-effectiveness of policies designed to save carbon over and above what would have happened anyway, both long run and short run, requires careful and systematic analysis. Aggregated analysis and modelling may obscure important trends and the degree to which transport behaviour is always changing. Whilst this adds to the

complexity of interpreting the evidence and formulating policy, it may also increase the potential for policies to harness behaviour and reduce emissions of carbon from the transport sector.

Importance of policy packages

- Policymaking for low carbon transport needs to be approached in a holistic fashion. Packages work best since policies can have unwanted side effects which other policies can mitigate. As already discussed it is possible for policies with non-carbon goals to have a perverse effect on carbon emissions. Moreover, many policies complement each other and it is possible to promote 'virtuous circles' where policies mutually reinforce one another over time. For this reason it is important for policy to promote long run trends and development through a succession of shorter term choices as well as through major infrastructure development or radical technological changes.

Our review suggests the following overarching conclusions about policy effectiveness:

Short run options with clear potential to reduce carbon emissions in the UK include eco-driving and speed enforcement, expanding the use of non-motorised modes and improving vehicle occupancy. Improving the off-peak utilisation of existing public transport in cities and overall utilisation of buses and trains outside the major metropolitan areas may also be possible. Policies to promote these options include travel planning, fuel and road price increases, dedicated infrastructure or prioritisation for non-



motorised modes, and training and education campaigns. Whilst policies to promote lower carbon car choices can have an immediate effect on new car sales it takes ten to fifteen years for the vehicle fleet to turnover, so short run impacts on transport emissions are modest. Relatively low elasticity of demand for fuel suggests that the impact of fuel tax increases may be limited in the short run. However despite the political problems that surround fuel taxes in particular, prices can play an important role in determining travel and vehicle choices.

Medium term potential exists in reallocating road space to extend bus and light rail provision. Road pricing and fuel tax rises, competitive fares and service improvements, combined with information provision through travel plans are likely to be effective policy packages. It may also be possible to accelerate a shift to a much more efficient vehicle fleet. Circulation and fuel taxes combined with 'scrappage' subsidies may be able to deliver this goal if combined with information and education.

In the long run both travel and car choices can deliver significant emissions reduction: It is possible to provide an integrated approach to delivering new infrastructure for public transport and non-motorised modes, linked to land use planning such that demand for travel is reduced and significant mode and destination shifting is delivered. This is most likely to be achieved if support for mode shift is accompanied by road use and parking charges, fuel tax increases, road space reallocation and travel planning and other information provision campaigns. Relative prices of different

modes play an important role in shaping long-term travel choices. It is also possible over time to facilitate a substantial shift to lower carbon cars. Our review suggests that the most effective policies are emissions regulation, purchase taxes and fuel tax, aided by rules on marketing and labelling. Rebound effects need to be addressed. Circulation taxes can be effective, but it is important that they are designed in such a way as to directly influence new car purchases and/or are combined with 'scrappage' subsidies or other schemes to remove old and less efficient vehicles from use. Car clubs may be able to help to promote the development of use of electric vehicles and on-street charging facilities.

Overall, this review has revealed a wide diversity of evidence related to both lower carbon travel choices and lower carbon vehicle choices and use. The review suggests that policies can change behaviour, that behaviour can make a real impact on CO₂ emissions and in several key instances there is evidence that such policies are able to deliver emissions reductions at relatively low cost, provided a well designed package of policies is put in place. For many potentially attractive policies more work is needed to understand costs to consumers and society overall, as well as other factors such as political and social acceptability. Nevertheless, there are policies with the potential to reduce emissions in the short term, particularly those which influence travel choices. In the long run a range of policies related to both provision for mode shifting and the development and adoption of lower carbon cars could bring about a substantial decarbonisation of the passenger transport sector.

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Annex 1: Project team, expert group and contributors

Project Team

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Expert Group

The expert group was chosen for its combination of transport industry, academic and policy expertise. It met twice during the early stages of the project, providing input to the initial framing of the issues. Individual members of the group made additional contributions in the form of comment and advice.

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What policies are effective at reducing carbon emissions from surface passenger transport?
A review of interventions to encourage behavioural and technological change

Annex 2: The evidence gathering and analysis process

Introduction

Chapters 1 and 2 of the main report describe the overall approach that the TPA team adopted, involving question definition, forming a team of experts, gathering evidence, consultation, analysing and synthesising the evidence, and peer review – ultimately leading to the production of the report and supporting documentation. This annex provides a more detailed description of the process which the TPA team followed during the evidence gathering and analysis stages of the project.

Evidence Gathering

The TPA approach to evidence gathering is inspired by the practice of systematic review. Whilst this evidence-based approach is not bound to any narrowly defined method or techniques, the goal is to achieve high standards of rigour and transparency. To that end the research process for this report followed a series of clearly defined steps which are described below.

The first step was to identify the search terms, and also the databases and other potential sources of evidence to which those search terms were to be applied. The databases and other research sources are shown in Table A2.1.

The search terms in Table A2.2 below provided the basis for the creation of specific search strings. A decision was taken at the scoping stage of the project not to include the issue of land use in considering the overall question. Land use was therefore not included in the basic search terms and is not addressed in any depth in this report.

The search strings were described using Boolean terminology, but with “+” operators explicitly stated. There are an extremely large number of possible permutations of these terms, so for practical purposes the project team selected those combinations which provided the appropriate coverage.

The challenge was to keep the number of search strings to a manageable level without losing relevant papers from the review process. Where possible, therefore, search terms were kept very general. *Travel Demand Management and biofuels*, for example, were searched without any other restrictive terms, since it was anticipated that any papers that mention these terms could be relevant, regardless of the context. Terms such as *car*, *travel* and *technology*, however, were used only in conjunction with terms such as *climate* or *emissions*.

Where practicable, for example in the case of an academic database such as Elsevier Science Direct or ISI Web of Knowledge, the database or potential evidence source was searched for all the proposed Boolean combinations. However, not all the databases or evidence sources provide the degree of search sophistication provided by dedicated search engines such as Google. In some cases therefore, the evidence search was adapted to fit

Table A2.1: Research Sources

DATABASES / SEARCH ENGINES
Elsevier 'Science Direct'
ISI 'Web of Knowledge'
CSA Illumina (Natural Sciences, Social Sciences, Technology)
Compendex
Google and Google Scholar
DfT Research Database (via Google site search)
Annual Reviews
ETDE (Energy Technology Data Exchange)
TRIS (Transportation Research Information Services)
University of Nottingham Online Planning Resources (now in Resource for Urban Design Information, RUDI)
Online TDM Encyclopaedia produced by Victoria Transport Policy Institute (VTPI)
Consultant academic experts' research recommendations
ACADEMIC GROUP WORKING PAPER SERIES
Transportation Research Board
Centre for Transport Policy, Robert Gordon University
University Transport Studies Group
Centre for Transport Studies, Imperial College London
Transportation Research Group, University of Cambridge
Transportation Research Group, University of Southampton
Centre for Transport and Society, University of the West of England
Centre for Transport Studies, University College London
Institute for Transport Studies, University of Leeds
GOVERNMENTAL ORGANISATIONS
DfT, DfCLG, Treasury, HMRC, NAO, CfIT documents & publications (via Google site search)
Carbon Trust
Energy Savings Trust
Low Carbon Vehicle Partnership
International Energy Agency

Table A2.2: Basic Search Terms

1. CLIMATE CHANGE	2 TRAVEL MODE	3 TRANSPORT (behaviour)	4 TRANSPORT (technology/fuel)	5 POLICY
"Global warming" Carbon Emissions Greenhouse Environment Climate CO ₂ Efficiency	Vehicle Car Bus Lorry Rail Train Rail Tram Cycling Bicycle Walking "Public transport" "Alternative " modes	Travel Journey "Travel behaviour Transport Transportation Traffic Congestion "Mode/modal choice/shift" Use Journeys Purchasing Choice "Travel reduction" Commuting Driving "Eco-driving" "Driver behaviour"	Engine Hybrid "Technology Design Efficiency "Low emissions vehicle" Biofuel Biodiesel Ethanol CNG LPG "Flex fuel" Hydrogen Fuel Cells Electric Battery	Policy Strategy Regulation Incentives Subsidy Fiscal Taxation "Soft factors" "Smarter choices" "Travel demand management (TDM)" "Mobility management" "Congestion charging" "Road pricing" "Fuel price" "Awareness campaigns" "Eco labelling" Cost "Policy Appraisal"

a more restricted range of terms and term combinations. For example, the Transportation Research Board was searched using simply the terms "carbon", "CO2", and "climate".

For transparency the actual search terms used for each evidence source were documented. An example list of search term combinations – the one applied to Elsevier Science Direct - is shown in Table A2.3 below.

Table A2.3: Example search string list

Behavioural and Technological Policy Search

(CO2 OR carbon OR climate OR greenhouse OR emissions OR efficiency) AND Travel AND Behaviour AND Technology
(CO2 OR carbon OR climate OR greenhouse OR emissions OR efficiency) AND Transport AND Behaviour AND Technology
(CO2 OR carbon OR climate OR greenhouse OR emissions OR efficiency) AND Driving AND Behaviour AND Technology
(CO2 OR carbon OR climate OR greenhouse OR emissions OR efficiency) AND (Car OR Bus OR Train OR Rail OR Tram) AND (behaviour OR "vehicle choice") AND (technology OR design)
("Vehicle choice" OR "vehicle purchase" OR "car choice" OR "car purchase" OR "Alternative modes") AND (technology OR design)

Behavioural Policy Search

"vehicle use" AND (Policy OR Strategy OR Fiscal OR Tax OR Regulation OR Incentives OR Subsidy)
"driver behaviour" AND (Policy OR Strategy OR Fiscal OR Tax OR Regulation OR Incentives OR Subsidy)
"modal shift" AND (Policy OR Strategy OR Fiscal OR Tax OR Regulation OR Incentives OR Subsidy)
"Modal shift" AND (CO2 OR carbon OR climate OR greenhouse OR emissions)
(Driving OR commuting) AND (policy OR strategy) AND (CO2 OR carbon OR climate OR greenhouse OR emissions OR efficiency)
Commuting AND (policy OR strategy)
("travel reduction" OR "driver behaviour") AND (policy OR strategy)
(Congestion OR traffic) AND (policy OR strategy) AND (CO2 OR carbon OR climate OR greenhouse OR emissions OR efficiency)

Technological Policy Search

(Policy OR Strategy OR Fiscal OR Tax OR Regulation OR Incentives OR Subsidy) AND
AND "vehicle technology" AND (CO2 OR carbon OR climate OR greenhouse OR emissions OR efficiency)
AND "vehicle efficiency"
AND "Low emissions vehicle"
AND Biofuel
AND Biodiesel
AND Ethanol
AND ("Compressed Natural Gas" OR CNG)
AND ("Liquid Petroleum Gas OR LPG)
AND "Flex fuel"
AND "Hydrogen car" OR "hydrogen vehicle" OR "hydrogen for transport"
AND "Fuel Cells"
AND ("Electric Car" OR "electric vehicle")
AND "Battery powered car" OR "battery powered vehicle"

Transport Policy Effectiveness Search

(CO2 OR carbon OR climate OR greenhouse OR emissions OR efficiency) AND (Transport OR Travel OR Vehicle) AND ("Policy Appraisal" OR "Policy Assessment")

Transport Policy Cost Search

("Modal shift" OR "vehicle choice" OR "driver behaviour") AND cost
(CO2 OR carbon OR climate OR greenhouse OR emissions OR environmental OR efficiency) AND (Transport OR Travel OR Vehicle) AND (policy OR strategy) AND cost

Specific Policies

"Travel Demand Management"
"Mobility Management" AND (transport OR travel OR car OR bus OR train OR vehicle)
"Congestion charging" OR "Congestion Pricing"
"Road Pricing"
(Travel OR Transport OR Driving) AND "Awareness campaigns" AND (CO2 OR carbon OR climate OR "global warming")
(Travel OR Transport OR Driving OR car OR vehicle) AND eco AND (labeling OR labelling)
("fuel efficiency" OR "fuel economy" OR "energy efficiency" OR CO2 OR "low carbon" AND (transport OR travel OR car OR bus OR train OR vehicle) AND (policy OR policies OR initiative))

The appropriate search terms were applied to each of the potential evidence sources, and the results were exported to a reference database. As anticipated, this stage returned several thousand 'hits', which the project team then refined down to those pieces of evidence which were judged to be relevant. First, the team removed any duplicates arising from overlapping databases and search strings. Inspection of the titles was used to remove any obviously non-relevant papers and the abstracts were then used to make a subjective assessment of the relevance of the remaining papers. Where there was ambiguity regarding relevance, the systematic review team considered this on a case by case basis.

The result was an initial evidence base of approximately 400 items. During the analysis phase additional evidence that came to light or was recommended by our team of experts was also added. The final evidence base therefore consists of over 500 items. The material includes publications in academic journals (sometimes very specific e.g. Greene 1999 'Why CAFÉ worked', with others taking a broader view) and UK and other national government and EU publications and reviews e.g. ECMT 2007 'Cutting Transport CO₂ Emissions - What Progress?' It is worth noting that much of the evidence is not aimed at assessing transport CO₂ reduction policies per se, but nevertheless has something relevant to our research question. The Greene 1999 paper cited above falls into this category, along with less obvious ones such as Noland 2006 'Travel demand policies for saving oil during a supply emergency'.

Categorisation of the evidence

A broad categorisation process was undertaken, classifying the focus of each evidence piece as 'technological', 'behavioural', 'both', or 'neither'. In addition, to allow the project team to focus on material which most closely matched the research requirements, documents were also allocated a 'relevance rating' where:

- A rating of 1 indicates that the paper dealt very clearly with one or more aspects of the research questions.
- A rating of 2 indicates that although the paper is relevant, its findings are presented in a way which could preclude direct comparison with other results.
- A rating of 3 indicates limited relevance and/or clarity.
- A rating of 4 denotes papers that are duplicative or, on closer inspection, were deemed not relevant.

Where necessary the reasons for the rating were noted in the database.

The team carried out a further categorisation process based on policy type (the policy record level listed in Table A2.4 below and described in the Policy Record section). To facilitate this, the evidence base was exported into an Access database. This allowed for the categorisation of any evidence which covered more than one policy type so that such

evidence could be flagged in the database as addressing all of the policy types to which it pertains.

The evidence was also categorised by 'policy group' (e.g. 'Vehicle efficiency standards', 'Using vehicles more efficiently' – see Table A2.4 below for the full list) where each group consists of sets of policy types with shared attributes. For example, the 'Using vehicles more efficiently' group includes evidence on policies that relate to 'eco-driving', vehicle occupancy and high occupancy vehicle lanes. The database was structured so as to avoid double counting evidence which, for example, addressed more than one policy type within the same policy group.

Table A2.4: Transport evidence categorisations

Category level	Category description	Specific Category	Example for CAFE standards
1	Policy Group	<ul style="list-style-type: none"> - Vehicle Efficiency Standards - Vehicle Taxes and Subsidies - Fuel Prices and Taxes - Road User Charging - Using Vehicles More Efficiently - Alternative Fuels - How to Travel: Mode Switching - Information on Car Choice - Awareness Campaigns and Travel Planning - Reducing Demand for Travel - Road Space Provision and Reallocation 	Vehicle Efficiency Standards
2	Policy Record (type)	<ul style="list-style-type: none"> - Awareness and marketing - Bus and fuel choice - Bus infrastructure - Bus pricing - Car clubs - Commuting travel - Company car tax - Congestion charging - Cycling 	Vehicle Fuel Economy Standards

		<ul style="list-style-type: none"> - Eco-driving including in-car information systems - Flexible trip generation - Fuel CO₂ policies - Fuel taxes - Individualised marketing - Information on car choice - Light rail infrastructure - Low emission zones - Parking - Rail infrastructure - Rail pricing - Refuelling infrastructure - Road planning and investment - Road pricing - Road traffic management - Teleworking and teleconferencing - Travel planning (residential or community) - Travel planning (schools) - Travel planning (workplace) - Vehicle air quality emissions standards - Vehicle capital grants - Vehicle circulation taxes - Vehicle fuel economy standards - Vehicle occupancy - Vehicle procurement - Vehicle purchase taxes - Walking 	
3	Individual Policy	N/A	Corporate Average Fuel Economy (CAFE)

As shown by Figure 2.1 in the main report this categorisation process gave the team a view as to where the *volume* of evidence lies. This can give insights into where policy has been focused to date and the policy areas which have seen the bulk of research activity.

Policy Records

The first step of the detailed analysis was to assess what the evidence base had to say about each type of policy. The policies relevant to emission reduction from transport are diverse, encompassing fiscal interventions related to both fuels and vehicles, regulations and standards, support for public and non-motorised transport, information provision and more. Moreover, they seek to influence decisions made by a variety of actors in a range of contexts and scales; from investment decisions of global car manufacturers to the day to day travel choices of private individuals.

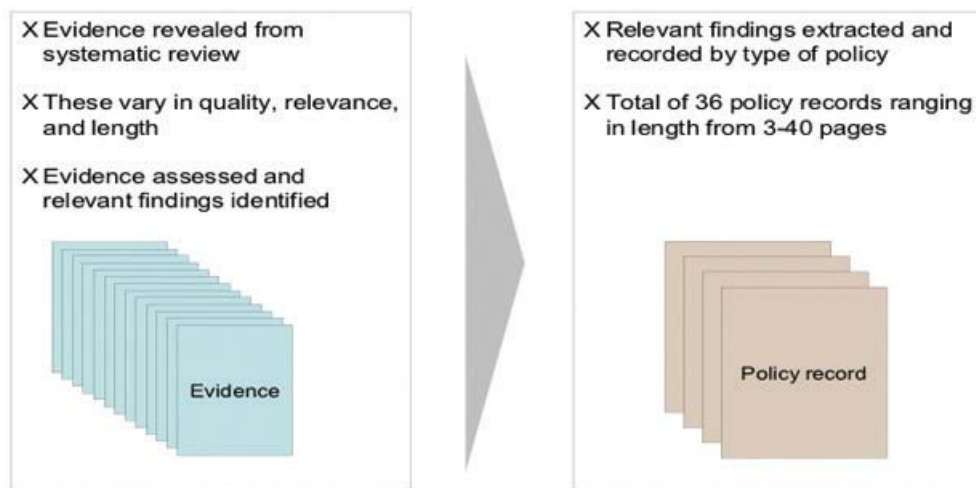
In order to provide a coherent structure and a route through the complexity that surrounds transport choices, and to assess the effectiveness of policies on CO₂ emissions - both separately and in terms of their aggregate impact - the project team considered 36 policy types and the evidence for each one was collated into one 'policy record' document per policy type. Examples of policy type include: vehicle circulation taxes; vehicle fuel economy standards; and workplace travel plans. The complete list of policy records is shown in Table A2.4 above.

Whilst some of the evidence focused solely on one type of policy, other pieces of evidence addressed several types within the same paper. Hence, each piece of evidence was analysed in terms of its relevance to one or more policy type. Information was then extracted and placed in the appropriate policy records. Throughout this process, the evidence's specific relevance to CO₂ emissions was kept clearly in mind.

In order to facilitate the management of large amounts of data, further categorisation took place within each policy record. Evidence was organised in each record under the following headings:

- Cost of policy measure and revenue if applicable
- Cost to businesses and/or the consumer
- Carbon savings
- Reasons for success or failure of policy
- Suitability of policy to the UK
- Other CO₂ impacts
- Other benefits
- Unintended consequences

Figure A2.1: Policy Record process



Once the project team had reviewed all the evidence and captured the relevant data, each policy record was distilled and concentrated, drawing out principal findings and arguments. If appropriate at this stage, the project team added supplementary comment and critique.

The distilled policy records were the key resource for the project team during the analysis stage. They constituted the primary material supporting the findings of this report. Because the project team feel that the records provide invaluable material and links to the wider evidence base, it was felt appropriate to make the material available as a research resource to a wider audience. To this end, the distilled policy records have now been converted (and in some cases, merged) into 'evidence tables' to provide a more accessible way of presenting the information. The evidence tables are listed below and are available on the UKERC TPA website at www.ukerc.ac.uk.

List of evidence tables

- Awareness and marketing
- Bus technology and fuel choice
- Car clubs
- Commuting travel
- Company car tax
- Congestion charging

Eco-driving
Flexible trip generation
Fuel CO₂ policies and refuelling infrastructure
Fuel taxes
Information on car choice
Low emission zones
Parking
Public transport infrastructure
Public transport pricing
Road planning and investment
Road pricing
Road traffic management
Teleworking and teleconferencing
Travel planning (residential and community)
Travel planning (schools)
Travel planning (workplace)
Vehicle air quality emission standards
Vehicle capital grants
Vehicle circulation taxes
Vehicle fuel economy standards
Vehicle occupancy
Vehicle procurement
Vehicle purchase taxes
Walking and cycling

The tables contain a summarised description of the policy measure(s) followed by the evidence itself presented in tabular form. Each piece of evidence has been assigned a separate row and tabulated using four columns:

- Year of publication, arranged chronologically, beginning with the most recent year
- Name of author, including where applicable additional cited authors (and year); and a reference ID number.
- Type of evidence:
 - Evidence containing quantitative information is denoted by the letter 'Q'
 - Qualitative evidence is denoted by the letter 'C' for 'commentary'
- The evidence itself

Any charts, figures and tables referenced in the evidence are not reproduced in the evidence tables but can be found in the original publication or evidence material. Where no relevant evidence was found for a particular sub-heading, this has been noted.

The Actor-Choice Framework

Given the complex nature of the subject matter, it was also deemed beneficial to create an additional, complimentary lens through which to assess the core elements influencing CO₂ emissions and policy effectiveness in the personal transport sector. This so-called 'actor-choice framework' enabled the report to both respect and dissect the inherent complexity of the subject matter and, in particular, it helped to avoid a simplistic opposition of 'technology' versus 'behaviour' or of vehicle choice & usage versus modal shift. Instead, looking through the additional lens of the actor-choice framework helped to identify opportunities for policy integration and cumulative benefit, and assist in the analysis of policy implications.

In operation, the framework distinguished the primary constituents that together make up the passenger road transport sector, namely actors, choices, and policy or entity influences. Through it the team considered the complex interactions of:

- The different actors (consumers, companies and others) relevant to CO₂ emissions within the surface passenger transport sector.
- The choices those actors face, and the circumstances under which these choices are facilitated or constrained.
- The policies that bear upon, and can influence, the choices each actor makes.

An example: Consumer car purchase choice

An example of the above interaction is car purchase, where the consumer is an 'actor' faced with a range of choice considerations regarding the purchase of a vehicle (e.g. capital costs and running costs). Different policy measures, such as purchase tax or vehicle excise duty, may have a bearing on those considerations and hence on the consequent choice of vehicle.

Additionally, in this and some other actor-choice interactions, another actor type is also an influence. In the case of car choice, manufacturers seek to influence the attitude of consumers, often via advertising and marketing campaigns.

Figures A2.2 and A2.3 below illustrate how at an overall level consumers are faced with several fundamental choices in their travel decision-making including whether to travel, how far to travel, how to travel; and, if a car user, what type of car (and fuel) to drive. In turn, these choices may be influenced by one or more different types of policy measures.

Figure A2.2: Consumer travel choices – Whether (and how far) to travel

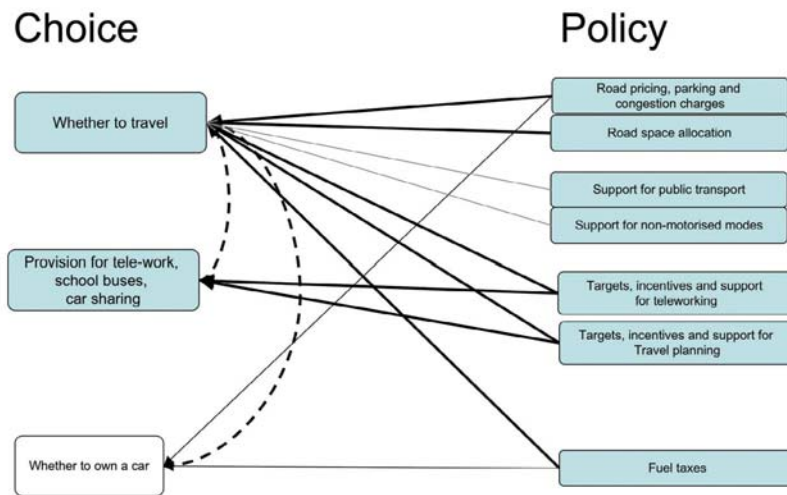
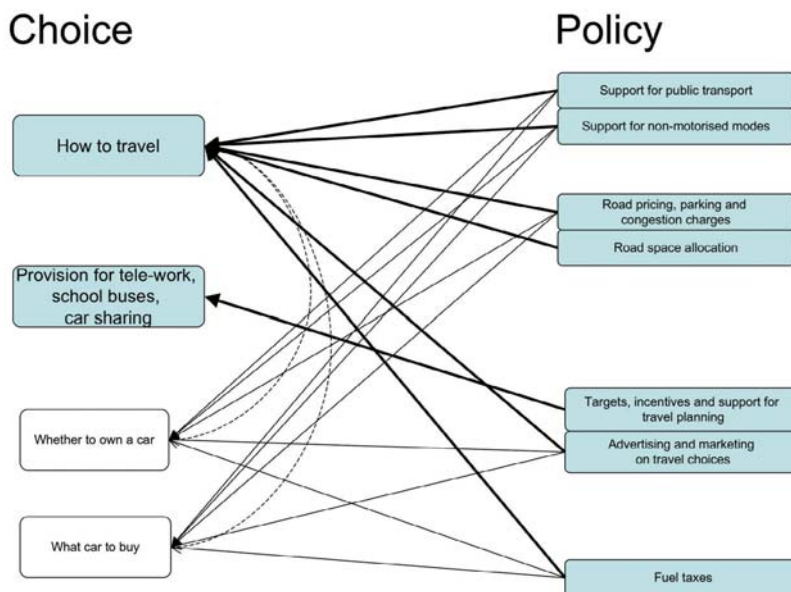
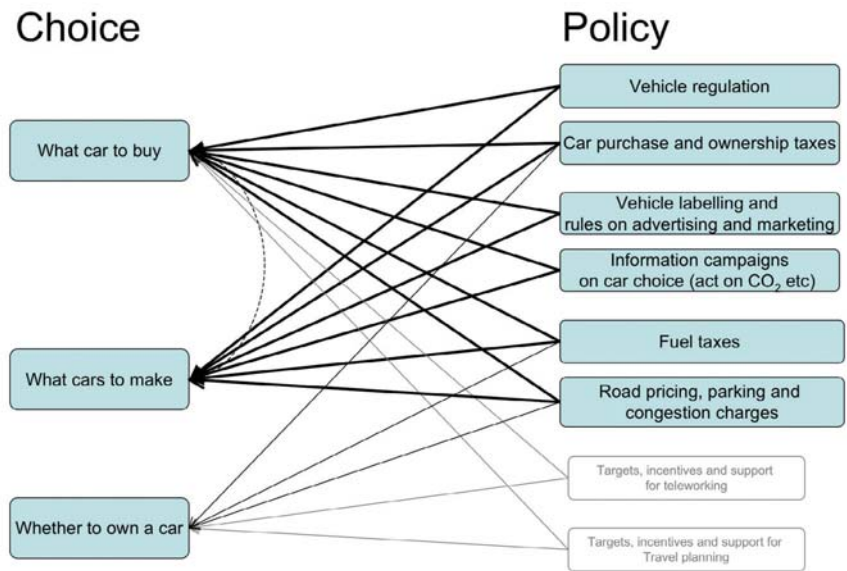


Figure A2.3: Consumer travel choices –How to travel



To illustrate the level of complexity that can surround just one of the choices faced by an actor, and how other actors and policies can all bear upon those choices, the complete actor choice-map for vehicle choice is shown in Figure A2.4.

Figure A2.4: Vehicle purchase actor-choice map



What policies are effective at reducing carbon emissions from surface passenger transport?
A review of interventions to encourage behavioural and technological change

What policies are effective at reducing carbon emissions from surface passenger transport?
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Annex 3: Summary tables on impact, cost effectiveness

This annex reproduces, for ease of reference, the main summary tables on this report's findings by policy type from Chapter 6 (conclusions). It is important to note that policies work best as packages and that the individual measures reviewed below work best and can complement and reinforce each other when combined effectively.

Lower carbon travel choices: replacing journeys; using lower carbon modes; using cars efficiently

Policy/measure	Potential CO ₂ impact	Evidence for cost – effectiveness	Key issues & problems
Support for teleworking, telecommuting, teleconferencing	UK aggregate potential unclear: Much evidence is company and/or US specific	No specific data on £/tC saved but likely to be highly cost-effective.	Possible rebound effects may be substantial (e.g. home location shifting and induced trips). Baseline trends to tele-work unclear Role for policy unclear. More research needed on UK potential, policy needs and baseline.
Support for non-motorised modes (walking/cycling)	Substantial: E.g. 2MtC per year (6% of UK transport emissions) if UK reached levels common in other northern EU countries.	No specific data on £/tC saved; possibly highly cost-effective.	Safety, routing and prioritisation are key. Road reallocation and dedicated routes improve perceived safety. Evidence from London that improved provision combined with penalties for car use can have great impact. Destination shifting may be induced and will raise long run potential. More research needed on abatement cost.
Public transport: pricing, service & infrastructure	Marginal/modest in short/medium term. More substantial in longer term.	Little data on £/tC saved. Likely to be context specific since new infrastructure may be high cost but improving utilisation of existing transport can be cost-saving.	Short vs long-term CO ₂ reduction potential. Short-term issues – limit to capacity to expand sufficiently to absorb significant share of car trips, induced demand, non-beneficial mode shift. Long term affordability and quality of PT has strong link to mode share and land use patterns.
Vehicle occupancy: car share schemes & HOV lanes	Mixed evidence from the US: no aggregated UK CO ₂ data.	Little data on £/tC saved but likely to be medium to highly cost-effective if existing road space reallocated.	Common origin & destination required. Driver preferences. Under-utilisation of HOV lanes. Congestion of HOV lanes. Cost if HOV lane is constructed. Possible rebound effects. More research needed on emissions savings and abatement cost.

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Car clubs	Unclear: Could be substantial, depending on scale of UK driver engagement and impact on car use patterns.	No specific data on £/tC saved but likely to be medium/highly cost-effective.	More research needed on characteristics of car club users and potential role for government policy to promote car clubs. Incentives for car club cars can be linked to low emissions; may create early adoption of low emission vehicles and facilitate adoption of electric cars/charging facilities.
Eco-driving & speed enforcement	Substantial: 10-15% reductions in UK car emissions from eco-driving; 2-3% savings in total UK transport emissions from motorway speed limit enforcement.	Highly cost-effective for training & campaigns: less than £20/tC saved. Mixed evidence on cost of speed enforcement.	Potential for swift results from both eco-driving and speed limits/enforcement. More research needed on securing longevity of eco-driving training. Safety benefits from speed constraint. Political acceptability of speed limit enforcement may be a barrier.
Travel plans: personal, schools, & workplace	Modest/substantial: 5-10% reductions in UK car usage from PTPs; good evidence of impact from schools/workplace plans (6-30% reduction).	No specific data on £/tC saved. Unclear cost-effectiveness for PTPs; variable for schools/workplaces (below £30 to over £500 per tC).	Some concerns re PTP evidence quality. Provision of alternative modes crucial. Safety issues for school plans. Effective marketing needed. Hard policies - parking restrictions, penalties & subsidies are key. Limited level of workplace plan uptake. Large companies easier target than SMEs. More research needed on emissions savings and abatement cost.
Road pricing & congestion charging	Modest/substantial but only if net revenue raising: E.g. possible 7% annual saving in traffic CO ₂ by 2025.	No specific data on £/tC saved but likely to be highly cost-effective as revenue raising.	Possible leakage & rebound effects. Revenue raising vs revenue neutrality. Charges should be CO ₂ -differentiated. Public transport and other alternatives are key. Political acceptability appears limited. Road pricing data based on modelling.
Road space provision & reallocation	Road space provision may increase long run emissions. Modest to substantial benefit for reallocation away from private cars.	Negative cost-effectiveness for road provision (expenditure induces traffic); no data on £/tC for reallocation.	Road capacity can ease congestion and reduce emissions from highly congested roads but induced traffic effects can increase long-run emissions. Potential for induced traffic well established and accepted by government. Possible leakage if traffic diverts from reallocation area. Effective reallocation planning is key. Much of evidence is unrelated to CO ₂ .

Lower carbon vehicles: technology development and consumer choice & vehicle fuels: prices and taxes

Policy/measure	Potential CO ₂ impact	Evidence for cost – effectiveness	Key issues & problems
Vehicle efficiency standards	Could be substantial: E.g. possible g/km savings in excess of 50% through 'best in class' alone. US evidence suggests CAFE doubled on road efficiency up to 1990, but neglects SUV market. Mixed results from measures in EU/Japan.	Can be highly cost-effective: individual (-39 to -21 Euros per g/km saved) & societal (-44 to -10 Euros per tC saved). May increase purchase price.	Effective design essential: continuous improvement; adequate penalties; no loopholes. Consumers tend to discount lower running costs and additional measures (fiscal support, labelling) may be essential to induce purchase, particularly if purchase price increases. Rebound effects and driving style must not be overlooked. Costs for manufacturers, possible loss of fuel tax revenue.
Fiscal measures: Purchase tax and subsidies	Moderate to substantial: E.g. Dutch 'feebate' scheme produced savings of 2-3% of total transport emissions. International experience suggests clear impact on car fleet.	No specific data on £/tC saved but likely high cost-effectiveness.	Key policy to counter-act consumer discounting of long run costs. Policy stability & longevity are important. EU competition rules militate against purchase taxes. Possible rebounds from more efficient cars.
Fiscal measures: Circulation & company car taxes	Evidence not clear: Company car tax successful for that section of car market, but some 'leakage'. VED evidence not disaggregated from other policies and much analysis focused on band differentials.	No specific data on £/tC.	Consumer myopia may undermine effectiveness of circulation tax for some purchasers. Differentials may need to be large to impact purchase choices. Welfare/equity concerns for owners of old and inefficient cars. Scrappage subsidies may mitigate. Possible rebound effects. Possible reduction in fuel tax revenue.
Information on car choice Advertising standards & regulations	Marginal to modest: possible reduction of between 2.7% and 5% in new car fuel consumption. Contradictory evidence on effectiveness. Potentially important complements to taxes and standards.	No specific data on £/tC saved. Expected to be highly cost-effective.	Importance of information prominence/clarity and link to 'real world' cost savings. Comparative best in class information important. Consumer preference for vehicle attributes that increase emissions can be reinforced by manufacturer advertising. Possible rebound effects from increasing fleet fuel efficiency.

<p>Fuel tax/price</p>	<p>Marginal to modest short-term: probable short run price elasticity of fuel demand -0.25 to -0.3 Modest to substantial long-term: probable long run price elasticity -0.6 to -0.7</p>	<p>Highly cost-effective for macro-economy. FDE estimated to yield net benefit of £250 per tC. But direct cost to businesses and consumers.</p>	<p>Clear linkage to vehicle fleet efficiency. Could counteract rebound effects associated with more efficient cars. Income effects can outweigh tax effects and continuous increases may be needed to manage demand. Welfare/equity impacts may be negative. Political acceptability appears low. Total cost of motoring and availability of alternative travel/destination patterns affect price response.</p>
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