Easy on the Gas

The effectiveness of eco-driving

Ivo Wengraf

October 2012

RAC Foundation

The Royal Automobile Club Foundation for Motoring is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

RAC Foundation
89–91 Pall Mall
London
SW1Y 5HS

Tel no: 020 7747 3445
www.racfoundation.org

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About the Author

Ivo Wengraf is Research Analyst at the RAC Foundation. Prior to joining the Foundation in 2011, he held a post-doctoral fellowship at the Institute for Transport Studies of the Technical University, Munich. In Munich, his research looked at the early adoption of electric vehicles in London and the San Francisco Bay Area. Ivo holds a PhD, an MA and a BA – all from the Department of Geography, University of Liverpool.

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Foreword

The rising cost of fuel, and recent record prices, has brought the need to save fuel into sharp focus for many motorists.

While the UK's commitment to meeting carbon reduction targets has helped to bring to the market a range of new vehicles that are highly economical to run, not all of us can afford them. And, when life-cycle emission calculations are done – encompassing not just the usage of cars but also their manufacture and scrappage – the net effect on CO_2 output of a large-scale replacement of the vehicle fleet may well be less than one might hope.

Those who do replace their vehicles may be disappointed to find that the stated fuel economy – the NEDC (New European Drive Cycle) data displayed at the dealership – is not what they get when they actually take to the roads.

But whether cars are new or old, and whether or not they live up to their owners' fuel consumption hopes, there is a proven way in which fuel efficiency can be bettered. It is called 'eco-driving' and does not necessarily mean slower journeys: just cleaner, safer and more affordable ones.

This report shows that by encouraging relatively small changes in how vehicles are set up and then driven, worthwhile sums of money can be saved at the pumps.

This report sets out what motorists can do to start eco-driving now, and quantifies what kind of results it can achieve. It contains examples of how the car industry, governments and NGOs are also using cost-effective ways to encourage eco-driving and asks whether there are further interventions which could achieve more.

A crucial matter is what drivers do with the money they save. If they simply use it to buy more fuel to do more journeys then this will be less beneficial for the environment.

Another significant question is how drivers can be persuaded to maintain good eco-driving behaviour as and when the cost of fuel retreats from current highs. Though for car owners hit by seemingly daily increases in forecourt prices this remains an unlikely scenario.

S. Glaister.

Stephen Glaister
Director, RAC Foundation

Eco-Driving Techniques

There are few motorists who do not want to cut the costs of running a car, not least those incurred when filling up with fuel.

Eco-driving offers real scope to reduce both fuel usage and the associated emissions of CO_2 and other pollutants. It can also lead to improvements in road safety.

Small changes to driving style and vehicle set-up can make car journeys markedly more efficient.

They can also significantly reduce wear and tear and improve the life expectancy of an engine.

Pre-trip

Vehicle maintenance: regular maintenance improves fuel efficiency by as much as **10%**.

Tyre pressure: underinflated tyres increase rolling resistance. Drivers should check tyres monthly to ensure they are at the optimum pressure. The Energy Saving Trust estimates that tyres underinflated by a quarter can cause a **2%** increase in fuel consumption.

Wind resistance: unused roof racks and roof boxes should be removed.

Trip planning: know where you are going and avoid congestion. Link or chain together several short trips to make a single longer one.

Unnecessary vehicle weight: don't overload the car. Every additional 45 kg reduces fuel economy by **2%**.

Short-distance alternatives: cold engines use more fuel than warm ones and catalytic converters may not be effective during the first five miles of a journey. Consider using another mode of transport or chaining those short trips.

During the trip

Air conditioning: only use when needed. All 'ancillary loads' on the engine adversely affect fuel economy – air conditioning most of all. Aerodynamic effects mean that below 40 mph it is more fuel efficient to open a window than to use air conditioning; at higher speeds, the opposite is true.

Unnecessary engine idling: a modern engine is designed to be used 'from cold'. Warming up an engine while stationary wastes fuel and leads to undue engine wear. Engines should be turned off for waits of more than one minute, and can be turned on again without the accelerator, using almost no fuel in the process. Between **5% to 8%** of fuel consumed occurs whilst idling. Stop–start systems help reduce this.

Smooth and reasonable speeds: sharp acceleration and heavy braking wastes fuel, and vehicles tend to be least fuel efficient at quite low or quite high speeds. Aggressive driving can raise fuel consumption by **37%**.

Changing up as soon as possible: gear changes should occur as soon as possible, generally at or below 2,500 rpm.

Anticipation: having good awareness of road conditions and anticipating traffic behaviour ahead will lead to smoother travel and maintained momentum.

Engine braking: when slowing down, drivers should stay in gear but remove pressure on the accelerator early to reduce fuel flow to the engine to virtually zero. Modern vehicles, fitted with fuel cut-off switches, are able to recognise when momentum is moving the vehicle and temporarily stop the flow of fuel to the engine. This is different from coasting in neutral, where the engine still requires fuel, and which is both unsafe and illegal.

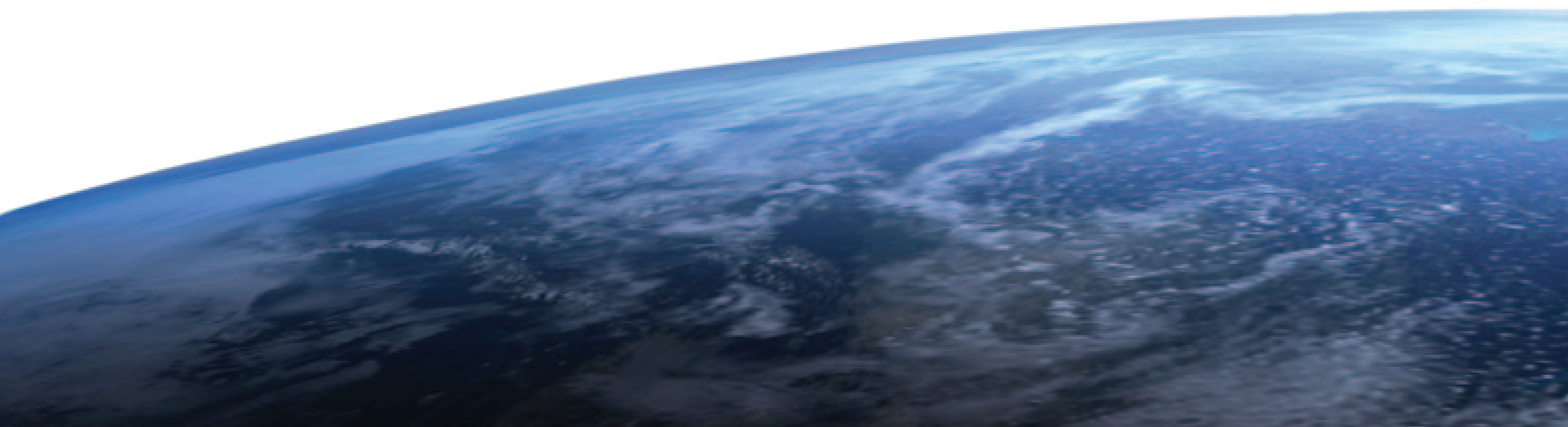
Post-trip

Review trip data: drivers can review trip economy and driving style data after a journey to learn how to improve on their driving style, or to reinforce eco-driving lessons already learnt. A number of apps and satnavs can help with this.

Eco-driving does not require the use of all of these strategies. However, these simple steps can be used in combination to bring about marked improvements in emissions and economy.

1. Introduction

It is now widely accepted that the climate of the world is changing as a result of human activities. Activities which release greenhouse gases (GHGs), amongst which carbon dioxide (CO_2) is the most notable, are leading to an increase in global warming. The potential hazards of climate change could well be significant. Research collated by the Intergovernmental Panel on Climate Change (IPCC) suggests an 80% reduction of GHG emissions by 2050 relative to the levels emitted in 1990 in order to avoid harmful impacts on future generations (Metz et al., 2007).



The United Kingdom has committed to a programme of GHG reduction through a series of targets. The Stern Review (Stern, 2007) makes a compelling case for the economic importance of addressing climate change. In 2008, the UK Parliament passed the Climate Change Act, which established in law the goal of reducing GHG emissions to the 2050 target set out by the IPCC. The Act established the Committee on Climate Change tasked to independently advise government on these carbon targets.

Meeting this target for GHG reduction will be a challenge. New low-carbon technologies frequently come at a high financial or political cost. Similarly, adaptations which reduce the climate impacts of human behaviour without detrimental impacts to the economy or the well-being of individuals can be very difficult to adopt. In the current economic situation, where governments must consider environmental issues in line with pressing economic problems and budgetary constraints, finding low-cost and high-value methods for GHG reduction is crucial.

In the UK, the main sources of GHGs are the energy supply; the activities of business, industry and agriculture; residential energy use; and transportation. According to the Department of Energy and Climate Change (DECC), 2009 saw transport contribute 24% of UK GHG emissions (see Figure 1.1) (DECC, 2012). Of that 24%, road transport accounted for 91% of GHGs, with 58% of those GHGs in turn coming from passenger cars (see Figure 1.2).

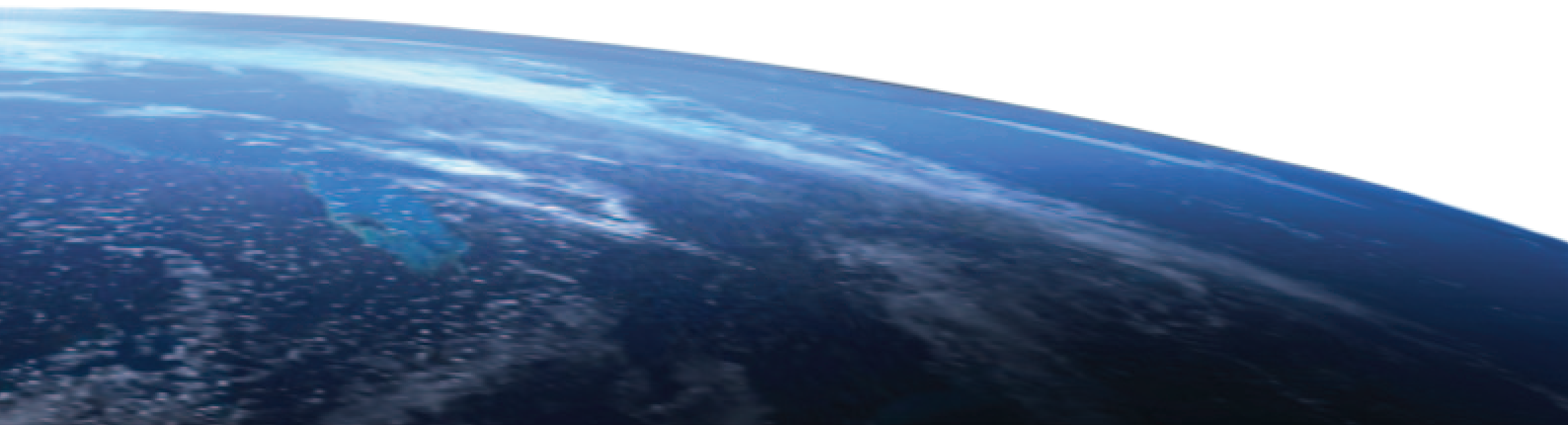
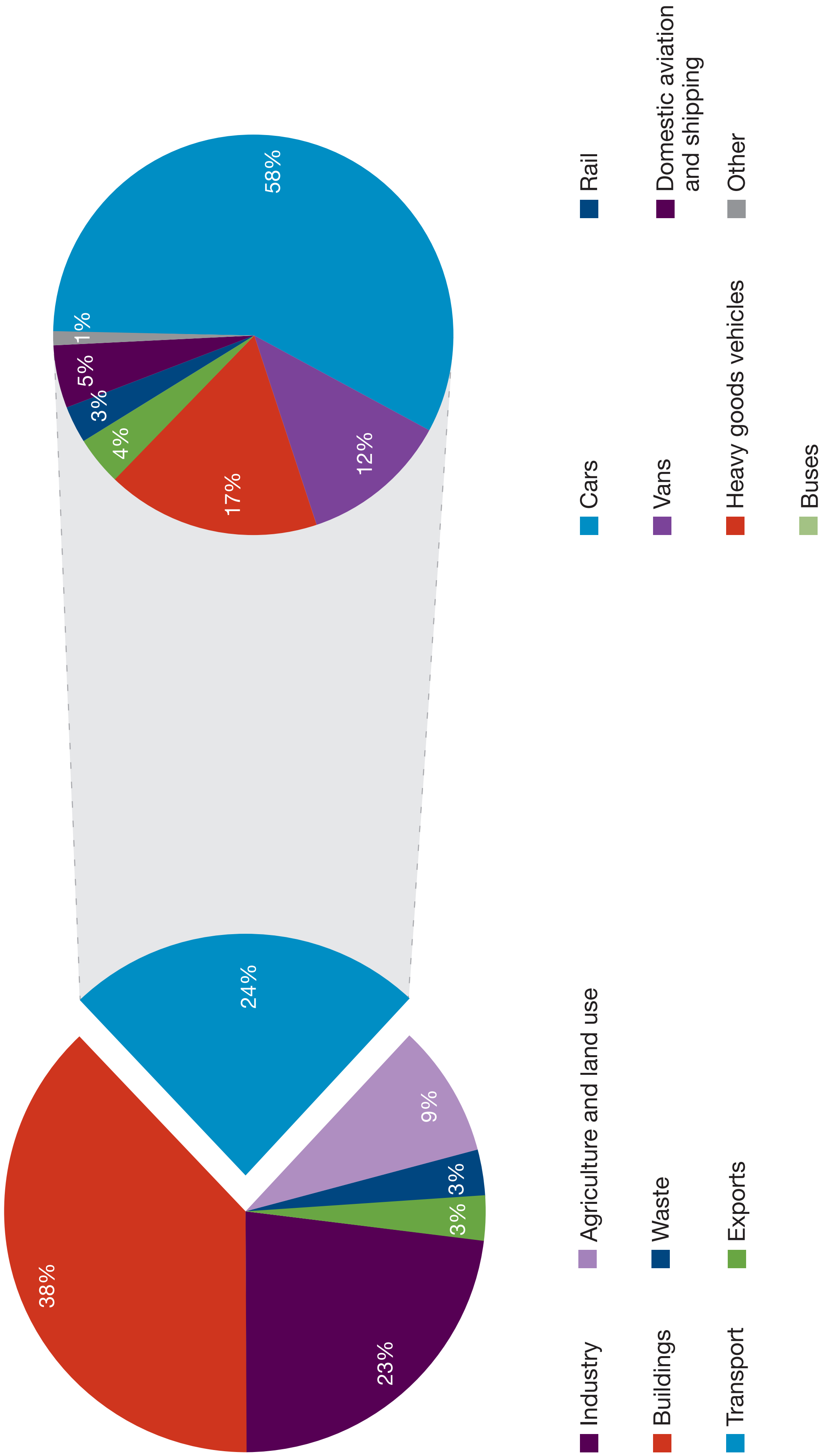


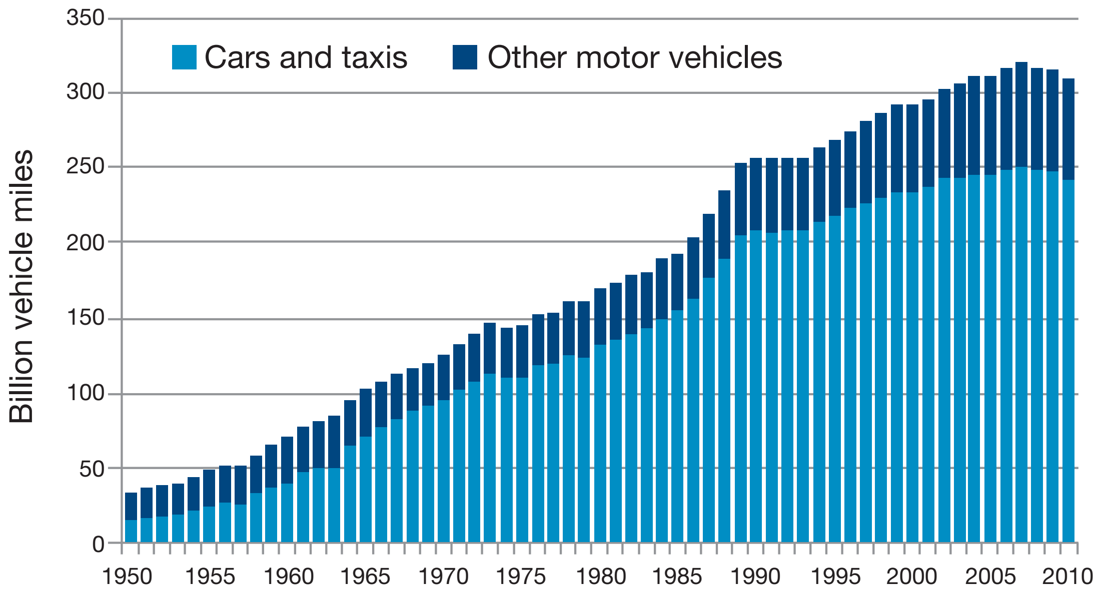
Figure 1.1: UK GHG emissions by sector (end-user basis)



Source: DECC (2012)

There is, therefore, a clear need to address the climate change impacts of passenger vehicles, and road traffic more generally. Demand for car use has increased steadily for many decades now (see Figure 1.2), and Department for Transport (DfT) projections from the National Traffic Model suggest further growth. As the UK population grows, road transport is likely to continue to grow (RAC Foundation, 2011).[1] Government and manufacturers have been making efforts to reduce these climate impacts. The carbon emissions of new vehicles have declined significantly in recent years (Transport & Environment, 2011). However, given traffic and population forecasts, growth in demand for transportation will offset these gains. The rate of growth in demand for transportation may mean that GHG reduction targets cannot be met within the timeframe set, in spite of efforts to make vehicles cleaner. Whether or not overall emissions are decreasing, what is critical is that they need to decrease at the rate required by legislation, or more quickly.

Figure 1.2: All-vehicle traffic, Great Britain, 1950–2010



Source: RAC Foundation (2011)

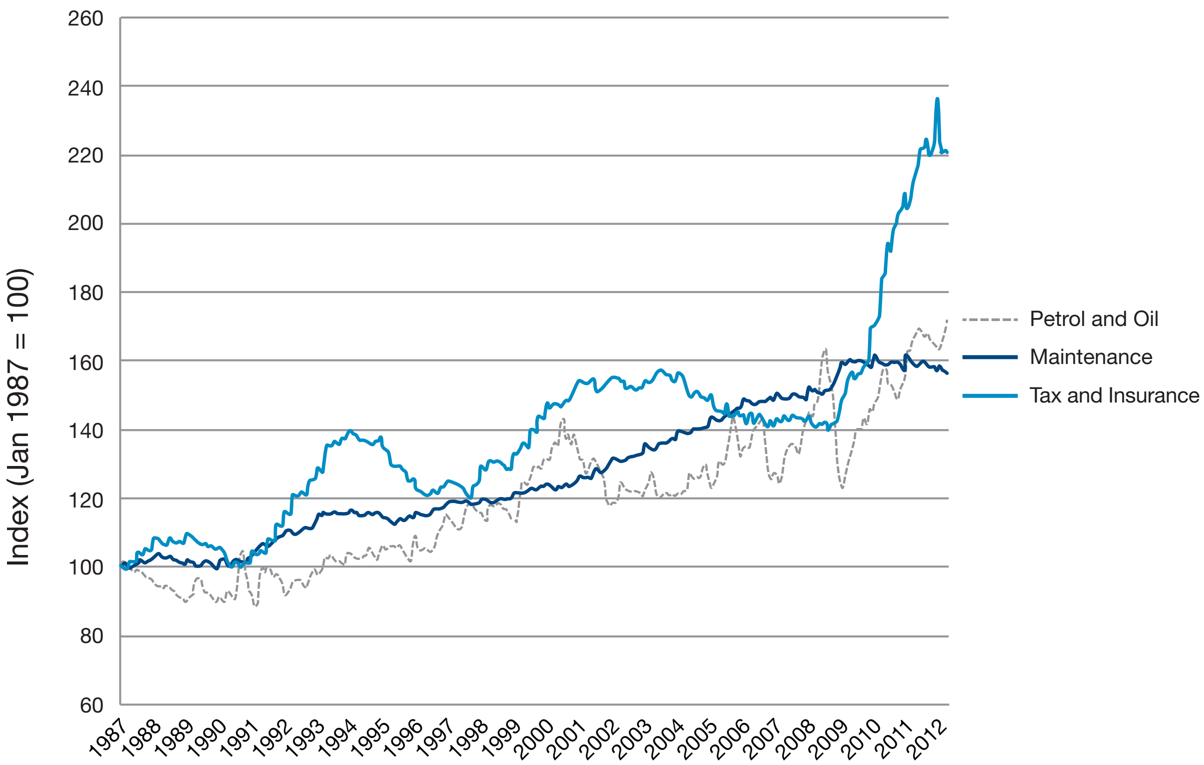
Further to this, road transport is key to the UK economy. Emissions from car travel may need to be reduced, but it is also important to remember the critical role which roads have in moving people, goods and services. It is a popular misconception that motoring in the UK is the preserve of the more wealthy (Lucas & Jones, 2009; Bayliss, 2009). The UK has a very large share of low-income motorists who rely on the car: according to the DfT's National Travel Survey (DfT, 2012b), 49% of households in Great Britain in the lowest income

1 There is some academic debate that suggests that the UK may have reached 'peak car' (Newman & Kenworthy, 2011; Millard-Ball & Schipper, 2010), where personal car travel is at its maximum level. However, given the long-term trend of positive road transport demand growth and the significant role of road transport in GHG emissions, it would seem reasonable not to assume that this is the case in any carbon reduction effort.

quintile group had a car or van in 2009. New carbon emission reduction efforts will not only have to be affordable to government and the UK economy, but also for the motorist.

The costs to consumers of transport have also been rising markedly. Fuel prices, along with bus and rail fares, have risen significantly in the past few years. ONS data shows that in 2009, motoring costs made up 13% of all household expenditure in the UK, and that in January 2011, UK petrol and diesel prices were double those of January 1999 in money terms. For many people, other transport costs, such as insurance, are becoming prohibitively expensive (House of Commons Transport Committee, 2012). The issue of transport poverty is a growing threat to both economic and social well-being. Put simply, consumers need affordable mobility, and they need affordable ways to save fuel (see Figure 1.3).

Figure 1.3: Running cost price indices relative to prices of all items (January 1987 to January 2012)



Source: ONS

There have been significant efforts to lower the carbon impact of the UK parc (the entire population of vehicles on a country's roads) and of new vehicles coming on the market. In terms of new low and ultra-low-carbon vehicles (hereafter abbreviated (U)LCVs to mean both categories together), the RAC Foundation has published reports considering the technologies (Lytton, 2010), their take-up (Lane, 2011), their environmental performance (Lytton, 2011; Lorf

& Lytton, 2012), and their implementation (Hanley, 2011). These reports, and others, highlight that there is a wide range of technologies and policies that are able to lower the emissions of vehicles; there is, likewise, a similarly wide range of costs and benefits associated with them.

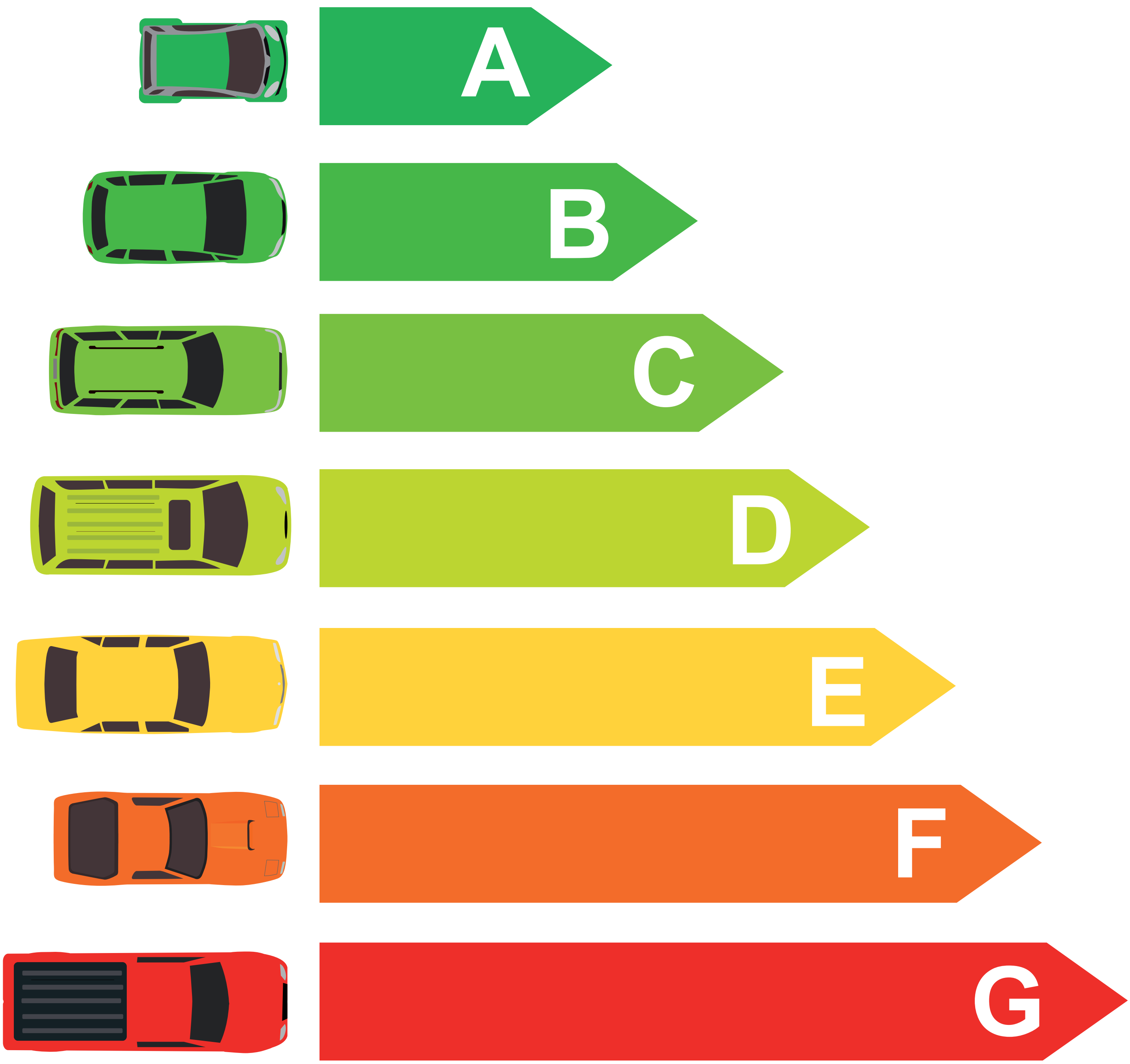
Standards for new vehicles have led to significant improvements in their emissions and economy. For example, in 2011, Toyota had virtually met 2015 CO_2 targets, with PSA [Peugeot Citroën] and Fiat both needing small cuts of 5% or less to meet these targets (Transport & Environment, 2011). Furthermore, low-emissions technologies are now widespread and cater to all sizes of buyer's budget – cleaner, more economical vehicles are now commonplace. According to the SMMT (Society of Motor Manufacturers and Traders), the average lifespan of a car in 2009 (from purchase to scrappage) in the UK was 13.2 years. It will therefore take a significant amount of time for vehicles featuring these new technologies to filter through. The modest turnover rate of the vehicles which make up the UK parc underlines the importance of reductions in carbon footprint that can be applied not only to new vehicles, but also to older vehicles, regardless of their economy or emissions.

In addition, it is important to remember that the impressive improvements in emissions and fuel economy for new vehicles are not based on real-world data, but rather on carefully specified tests – the New European Driving Cycle (NEDC) (Directive 93/116/EC as amended by Regulation (EC) 692/2008) – around which the vehicles have been specifically designed. Real-world data for vehicles can be significantly worse. In fact, the new vehicle technologies associated with low-carbon vehicles (such as hybrid power trains) are particularly susceptible to this difference (ECMT & IEA, 2005; Smokers et al., 2006). This difference is becoming more common (Mock et al., 2012).

This problem of 'shortfall', where vehicles fail to live up to the expectations created by data displayed on the vehicle fuel economy label, can be attributed in part to the differences between test conditions and real journeys, but it also owes much to driver behaviour. Data collected from the 2010 RAC Future Car Challenge, an event which tested the energy economy of 63 new (U)LCVs, highlighted the significant influence of driving style and gross vehicle weight in identical vehicles' fuel and emissions performance. Preliminary analysis of the 2011 event appears to confirm this finding. For example, consumption ranged from 65 mpg to 126 mpg for one hybrid model driven over the same route, and ranged from 38 mpg to 76 mpg for one of the diesel models entered (Howey et al., 2011).

Comparatively simple changes to make driving styles more economical are known collectively as 'eco-driving'. Eco-driving is a driving style that is both *eco*logical and *eco*nomical. These small changes to how one drives can improve the carbon emissions and fuel economy of vehicles regardless of vehicle type, thereby reducing the occurrence of shortfall and 'locking in' the potential gains made by new vehicle technologies. Eco-driving techniques can be implemented at comparatively low cost.

This report reviews eco-driving, both in the UK and international contexts. It considers the potential of eco-driving for reducing carbon emissions from both private motorists and business drivers. It examines the effectiveness of eco-driving training and other techniques to encourage improvements in driving style, both in the short term and over longer periods. It evaluates the various methods that have been used both in the UK and internationally to encourage eco-driving, and considers what role government and other agencies and actors may have in encouraging further take-up of eco-driving methods in the UK.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2. Definition of Eco-Driving

Eco-driving is a set of steps, techniques and behaviours that drivers can employ in preparation of the vehicle before a journey, in planning the journey, in modifying driving style during the journey and in reviewing trip data after the journey, that can, taken together, lead to savings (at times, significant ones) in terms of fuel usage, trip cost, emissions of CO_2 and other pollution, and levels of noise from vehicle use. These savings can be realised for relatively low cost compared to other kinds of efforts to reduce the environmental impacts of car use. In addition, trips made with eco-driving techniques can, in many cases, be linked to improved road safety; moreover, the use of such techniques does not increase journey times.

Although the concept of eco-driving has received less recognition from the public and policymakers than have other efforts to improve vehicle efficiency (for example the use of alternative fuels and hybrid vehicles), programmes for making such efficiency improvements through driver behaviour have existed since the late 1970s (Greene, 1986). In 1976, the US Federal Department of Energy's DECAT (Driver Energy Conservation Awareness Training) programme isolated the driver as a key factor in vehicle fuel consumption, and then began a series of training courses to disseminate fuel-conserving driving techniques for both fleet drivers and private motorists. There are currently a number of schemes performing a similar purpose. Various employers, fleet managers, car and accessory manufacturers, corporations, NGOs and governmental bodies are promoting and teaching eco-driving using a range of differing approaches.

There are a number of measures that drivers can take to improve vehicle efficiency.[2] These can be divided into 'pre-trip', 'during the trip' and 'post-trip' categories (Barkenbus, 2012; European Petroleum Industry Association & European Commission, 2012; Energy Saving Trust, 2012):

Pre-trip

Vehicle maintenance: getting the vehicle serviced regularly and checking oil levels improves vehicle efficiency.

Tyre pressure: drivers should check tyres monthly to ensure the most efficient rolling resistance.

2 Throughout, this paper refers to eco-driving – and associated techniques and technologies – to mean the safe and legal ways to make driving behaviour more efficient. There is a more extreme set of driving techniques often referred to in the literature as 'hypermiling' (Chin, 2008); it should be noted, however, that some use the term hypermiling to express their aim of achieving unusually high fuel economy by means of completely safe and legal eco-driving techniques. For the sake of distinguishing eco-driving and illegal techniques, hypermiling will be used to refer to illegal and unsafe practices. These techniques include the components of eco-driving, along with other unsafe or illegal techniques like coasting (driving in neutral) and drafting (tailgating another vehicle to reduce the effect of wind resistance).

Wind resistance: drivers should keep windows closed at higher speeds. Unused roof racks and roof boxes should be removed. Below approximately 30 mph the effects of open windows and other elements of vehicle set-up which affect aerodynamics are relatively negligible. Below 40 mph, it is more efficient to open a window than to use air conditioning; at higher speeds, the opposite is the case.

Trip planning: drivers should plan journeys to avoid congestion and roadworks. Knowing the route also helps to avoid wasting fuel as a result of getting lost. Trip chaining or trip linking – planning in advance to turn several short trips into one longer one – is another way to make driving more efficient through advance planning.

Unnecessary vehicle weight: drivers should remove non-essential items from vehicles to reduce the strain on the engine from the energy wasted in accelerating and decelerating unnecessary weight.

Short-distance alternatives: a cold engine uses more fuel than a warm engine. In addition, catalytic converters may not become effective until after the first five miles of a journey. It may therefore be better to consider alternative transport modes for short trips, or to combine multiple short trips to create a longer trip chain.

During the trip

Air conditioning: this should only be used when needed. All ‘ancillary loads’ adversely affect fuel economy – air conditioning is the greatest ancillary load on the engine.

Unnecessary engine idling: a modern engine is designed to be used ‘from cold’. Warming up an engine while stationary wastes fuel and creates undue engine wear. Engines should be turned off for waits of one minute or longer, and can be turned on again without the accelerator, using almost no fuel in the process.

Smooth and reasonable speeds: driving with sharp acceleration and heavy braking is wasteful of fuel. Furthermore, vehicles can become inefficient above the speed limit. This is because the relationship between the speed of a vehicle and the power required for the vehicle to move is exponential rather than linear – drag increases by the square of vehicle speed. The effect of this is particularly prominent in vans and other less aerodynamic vehicles. This has an adverse effect on both fuel economy and CO_2 emissions (see Table 2.1 and Figure 2.1).

Table 2.1: Fuel consumption data for vehicles at speed

Vehicle type	Percentage increase in fuel consumption when increasing from:		
	60 mph to 70 mph	70 mph to 75 mph	60 mph to 75 mph
Petrol car	8.8%	5.2%	14.5%
Diesel car	13.0%	7.8%	21.8%
Large diesel van	22.7%	11.8%	37.2%

Source: TRL/DfT in Saynor & Featherstone (2012)

Changing up as soon as possible: gear changes should occur as soon as possible – generally at or below 2,500 rpm.

Anticipation: having good awareness of road conditions and anticipating traffic behaviour ahead will lead to a more efficient driving style, where the driver is more often able to maintain the vehicle’s momentum and will avoid ‘stop and go’ driving where it is needless and thus inefficient.

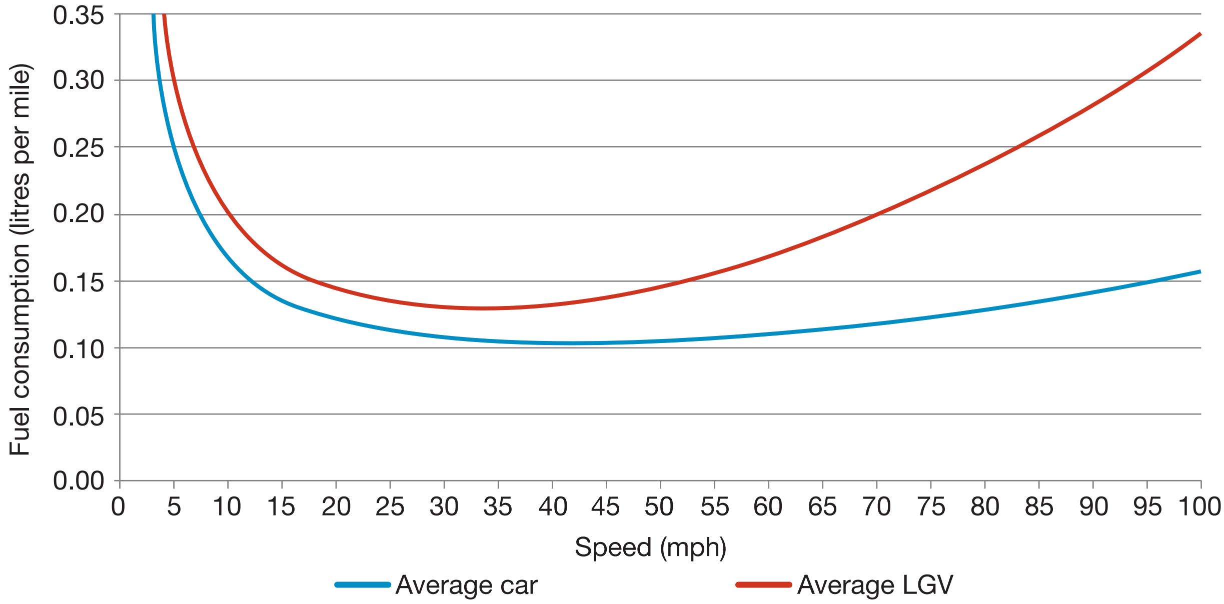
Engine braking: when slowing down, drivers should stay in gear but remove pressure on the accelerator early to reduce fuel flow to the engine to virtually zero. Modern vehicles, fitted with fuel cut-off switches, are able to recognise when momentum is moving the vehicle and temporarily stop the flow of fuel to the engine. This is different from coasting in neutral, where the engine still requires fuel, and which is both unsafe and illegal.

Post-trip

Review trip data: drivers can review trip economy and driving style data after a journey to learn how to improve on their driving style, or to reinforce eco-driving lessons already learnt.

Instruction and competition: collected trip and driving style data can be used in several ways for post-trip competitions and training.

Figure 2.1: Speed and fuel consumption, average cars and vans



Source: RAC Foundation (2011)

Eco-driving does not require the use of all of these strategies. However, all contribute to lowering carbon emissions and improving vehicle efficiency, and they can be used in combination to bring about marked improvements in emissions and economy. There is a common set of false beliefs about vehicles and driving – a set of driving 'old wives' tales' – passed down from those who learnt with different, older vehicles (Vandenbergh et al., 2008; Carrico et al., 2009). These include myths about the need to warm up vehicles, when to change gear, and when idling is appropriate. The components of eco-driving, as set out above, debunk these myths. In addition, drivers also pick up bad habits over the years. Eco-driving seeks to counteract these and encourage more efficient driving styles. Given this potential to realise efficiency gains, it is worth assessing the effectiveness of eco-driving techniques, and the ways in which such techniques are being and could further be encouraged.

3. Effectiveness of Eco-Driving

3.1 The savings available through eco-driving

Although the benefits of driving in a more economical and environmentally responsible style are obvious in theory, measuring the impacts of such behaviour changes on driving itself is very difficult. The efficiency of a vehicle on a journey is dependent upon various factors, a number of which are beyond the driver's control; some may be wholly or partly addressed by effective eco-driving, whereas many are not. In addition, each journey presents a set of unique conditions that are difficult to capture in testing. The assessment of eco-driving effectiveness is therefore very sensitive to the particular method used to measure it.

The effectiveness of eco-driving in carbon reduction cannot therefore be measured as a simple percentage derived by a universally agreed methodology, but rather by an approximate figure based on a range of results obtained from a combination of practical experience and scientific testing. Assuming that eco-driving is maintained as part of the driving style over the longer term – and that is a significant assumption that will be returned to later in this report – fuel savings relative to 'normal' driving are generally referred to as being approximately 10%. However, this is highly variable. Table 3.1 shows the range of savings reported in a selection of eco-driving studies. Research on eco-driving has used a variety of vehicles and participants, driving on a range of road types with differing topography. These studies employ a range of methods and are not scientifically comparable. It is also difficult to set a baseline 'non-eco-driving' figure against which to judge eco-driving savings. However, the results in the table do demonstrate the magnitude of what may be possible through greater use of eco-driving techniques.

Table 3.1: Reported fuel savings from eco-driving studies

Study/project	Fuel savings
Barth and Boriboonsomsin (2009)	10–20%
TNO (2006)	7% (for petrol), 8% to 10% (for diesel)
Fiat eco:Drive	6% (top 10% of participants saved 16% or more)
ECMT/IEA (2005)	5% (for OECD regions, based on literature review)
Wåhlberg (2007)	2%
Zarkadoula et al. (2007)	4.35%
Beusen et al. (2009)	From 12% savings to a 3% worsening
Rowson and Young (2011)	20% (peak savings of 45%)

Study/project	Fuel savings
Greene (1985)	10% or more
Mississippi State Energy Office	10–15%
Caltrans	15%
Maryland High School driver education	10%
WBCSD – VW and Naturschutzbund Deutschland	13% (peak savings of 25%)
Mele (2008)	35%
Bragg/FuelClinic.com (2009)	5.23%
Beusen and Denys (2008)	From 7.3% savings to 1.7% worsening
Taniguchi (2007)	20%
Onoda (2009)	5–15%
Saynor (Ford Motor Company) (2008)	24%
Henning (Ford of Europe) (2008)	20.65– 26.1%
Quality Alliance Eco-Drive	11.7–21%
SAFED, DfT	2–12%
Driving Standards Agency, UK	8.5%
Hamburger Wasserwerke, Germany	5.8%
Dutch Consumer Organisation	7%

Source: Based on Berry (2010), including data from CfIT (2007), Energy Saving Trust (2005) and Greene (1986)

3.2 Eco-driving over the long term

The fundamental issue affecting the usefulness of eco-driving as a form of carbon reduction is the viability of its application in the long term. The effects of eco-driving training vary strongly, both from driver to driver and over time (Beusen et al., 2009). While some drivers may continue to improve the efficiency of their behaviour, others tend to forget (or forget to apply) the skills learnt. In general, the impact of eco-driving training, once it has been completed, tends to decline markedly over time. This persistence of the training (the extent to which learners will retain and apply eco-driving techniques after a length of time) is dependent both upon the quality and nature of the training itself, and also upon the presence or absence of any reinforcing technologies (such as in-vehicle information systems) designed to maintain the effect of that training. Although eco-driving training can make a significant impact on emissions, these savings are not sustained over time. Research (Smokers et al., 2006) showed that while a driver was able to achieve 10% savings in CO_2 emissions directly after a training course, after a year that savings had reduced to only 3%.

3.3 The components of efficient driving style

The different components of eco-driving reduce the carbon emissions by varying degrees. Various driving actions and engine loads each have their own impact on efficiency. For example, the United Nations Environment Programme (UNEP) estimates that engine idling for eight minutes uses 0.1 litres of fuel, or about 14 pence worth at March 2012 prices, while an additional 45 kg of weight added to a vehicle reduces the economy of that vehicle by 2%. It has been suggested that 5% to 8% of fuel consumed by passenger vehicles is consumed during idling (Vandenbergh et al., 2008). Aggressive driving can increase fuel consumption by 37%, and regular maintenance may improve fuel consumption by 10%. The use of air conditioning is often cited as a major source of fuel consumption. However, this can be confusing for drivers who may also want to cool the in-vehicle temperature on the move. Drivers must balance the two interests. The UNEP suggests that 40 mph serves as a boundary between the lower speeds where air conditioning is more wasteful than the air resistance caused by an open window, and the higher speeds where the converse applies. Tyre pressures can also alter consumption by a significant degree. The UNEP suggests that fuel consumption rises by 1–3% for every psi of a tyre's pressure below the optimum, while the Energy Saving Trust (EST) rather more conservatively estimates that tyres underinflated by 25% can cause a 2% increase in fuel consumption.

However, it should be noted that the likelihood of drivers meeting the standards set by eco-driving can differ from one individual to another (as drivers have varying abilities to learn eco-driving, and differ in their motivations for maintaining the practice) and also from place to place, where local topography, road conditions and driving culture may all affect the degree of effective eco-driving. Within the EU, Fiat's eco:Drive programme highlighted differences between participating countries.

4. Methods of Encouraging Eco-Driving

4.1 Introduction

International and UK experience of promoting eco-driving has highlighted a number of possible methods for doing so. These schemes have sought to increase take-up of eco-driving techniques by both fleet drivers and private motorists; they have been run by government agencies, by NGOs, by private sector training providers, and by a number of major automotive companies. This section reviews the various ways of encouraging eco-driving, and provides examples of where such methods have been used.

There are a number of ways that drivers can be informed about and encouraged to employ eco-driving. Examples of these are reviewed later in this report, but they can be broadly divided into four main categories:

- information campaigns;
- driver training;
- in-vehicle technology; and
- gamification: the use of competitions and learning with a social dimension.

Information campaigns promote the benefits of eco-driving in a way that is quite similar to advertising campaigns which encourage other environmentally responsible behaviour. Recent UK campaigns include the provision of eco-driving information as part of the broader government-funded ‘Act on CO_2’ series. *Driver training*, either within traditional learner-driver instruction, or as part of additional or specialist courses, by teaching the components of eco-driving – whether theoretically, or by practical learning, or both – shows drivers how they can achieve the associated cost savings. This has been shown to be very effective in the short term, although the long-term effectiveness is less impressive. Various *in-vehicle technologies* are able to go some way to reinforce driver training by reminding drivers of key behaviours (such as gear-changing), and by presenting and analysing trip data to aid driver learning. Clearly, drivers need to be aware of what their fuel consumption actually is; however, they also need more thoughtfully presented data if their behaviour is to be changed (Kurani, 2007). Real-time feedback for the driver – in a metric that is well understood, such as miles per gallon in the US or perhaps even miles per litre in the UK – is useful, but can be supported by gear-shift indicators (GSIs) and various symbols and colour-coding about real-time economy. It is important to be able to compare economy figures over time, so that drivers make improvements. Retrospective feedback is also important – graphs and historic data present economy in clear and encouraging ways. This is particularly so in the ways that eco-driving can be *gamified* – or imbued with a social, competitive element. Eco-driving is learnt and maintained in part through social ties, and the competition between, and support from, friends or colleagues maintains interest in and development of eco-driving behaviour.

When it comes to underlying motivation – critical for long-term success – it is generally accepted that targeting eco-driving encouragement along the lines of saving money for the user is more effective than appealing to the conscience. There has been much promotion of greener behaviour based on altruistic attitudes to the environment, but although the environmental benefits of eco-driving may be able to convince some drivers, they are for most only a comparatively weak motivator. Successful efforts to promote eco-driving have focused largely on safety and the saving of money, and it is these motivators which are – in the main – stronger, more universal, and less prone to fluctuating than those which stem from environmental concern. In what follows, the diverse methods that have been used to shape and improve the efficiency of driving behaviour are reviewed.

4.2 The driving test

The clearest way to encourage eco-driving is to teach it from the outset. Of course, the main way in which driving instruction is provided in the UK is through the driving test. The consideration of eco-driving training at this early stage has the advantage of reaching drivers before they first independently use a vehicle on the road. The subject of eco-driving, whether considered as a topic in itself or in terms of the constituent parts (e.g. smooth acceleration, appropriate use of gears), is covered both in the training for drivers and as an element of the test itself. The UK Driving Standards Agency's *Driving Standard* (Driving Standards Agency, 2011) requires drivers to understand, amongst other things, "the environmental and economic implications" of travel, including a range of environmental impacts. It requires an understanding of basic vehicle maintenance and checks, along with the effective and environmentally responsible control of the vehicle. In the driving practical test, there is an eco-driving component (although, notably, failure in this area is not listed as a serious fault), and the examiner will give eco-driving feedback at the end of the exam.

However, experience from other countries shows that eco-driving can be covered in a driver licensing syllabus in a number of ways. Levels of eco-driving on UK roads could be increased by placing more emphasis on eco-driving in both training and testing – integrating it more deeply into driving instruction, and making eco-driving behaviours critical elements (i.e. pass-or-fail criteria) of the driving test.

A survey of the coverage of eco-driving in driver licensing and training in 13 EU countries shows a range of levels of integration into curricula and testing. ECOWILL ('**Eco**driving – **W**idespread **I**mplementation for **L**earner Drivers and **L**icensed Drivers') is a Europe-wide project involving sustainability and energy efficiency groups, which aims to reduce carbon emissions by promoting the use of eco-driving. A report by ECOWILL (2010) gives a breakdown of the situation by country (see Table 4.1).

Table 4.1: Level of eco-driving in training

Country	Eco-driving integrated into learner driver education in driving schools		Eco-driving integrated into learner driver education in driving exam	
	Theory	Practical	Theory	Practical
Austria	Y	Y	VARIES	N
Croatia	Y	Y	Y	Y
Czech Republic	Y	N	N	N
Finland	Y	Y	VARIES	Y
Germany	Y	Y	Y	Y
Greece	Y	Y	-	-
Hungary	Y	VARIES	Y	VARIES
Italy	Y	N	Y	VARIES
Lithuania	Y	Y	N	N
Netherlands	Y	Y	Y	Y
Poland	N	N	VARIES	VARIES
Spain	Y	N	Y	VARIES
UK	Y	Y	Y	Y

Source: ECOWILL (2010)

Surveys of this type yield varied results, in part because of the ways that certain elements of eco-driving can be integrated into other areas of training (rather than covered explicitly as eco-driving). As much of eco-driving is also simply good driving behaviour, it can sometimes be a challenge to recognise where eco-driving is being taught in a syllabus. In the case of the UK, the written curriculum for theoretical training meets only 11 of the 28 eco-driving criteria set out in ECOWILL's assessment. In the practical exam, only 12 of the 22 eco-driving criteria are covered in the UK. There is thus clearly scope for further coverage of eco-driving in new driver training.

4.3 Other driver education

Although it is true that eco-driving has begun to enter the driver education syllabus, the majority of drivers have not received instruction in this area as part of their driver training, and those who have may have acquired bad driving habits since the training. Another way to receive eco-driving training is through post-qualification instruction. This can take the form of an eco-driving training course, or be provided as part of professional training or advanced driver qualifications.

In the UK, the EST has provides eco-driving training through their Smarter Driving courses, which are subsidised by grants from the DfT. This training consists of one session which lasts up to 50 minutes with an approved trainer on the road in the car or van. It follows a pre-determined format and has been delivered to more than 30,000 UK drivers. Measurements of fuel consumption before and at the end of the course are taken to demonstrate its effectiveness, and initial savings after training are reported to average 15%. The EST emphasises that eco-driving, in addition to bringing about financial and environmental improvements, also encourages safer and less stressful driving. The EST also offers, as an extension of Smarter Driving, a specialised two-hour course for drivers of electric vehicles. Although eco-driving in these vehicles does not have the same direct environmental impact, it does maximise the range (the distance driven between charges) and boost driver confidence, thereby making electric vehicles a more viable travel choice for longer distances. Improvements in range after training are, on average, 20%.

The DfT's Safe and Fuel Efficient Driving (SAFED) programme is for HGV, van and bus drivers. These larger vehicles can obtain a similar rate of fuel savings as cars – leading to significant reward because of the higher fuel consumption and greater distances travelled. The SAFED programme involves theoretical and practical training for a day or more. However, funding by DfT was withdrawn, and although the courses are still available, participation declined markedly after that point. The Institute of Advanced Motorists, the AA and some private companies also offer eco-driving training courses in the UK.

4.4 Nudging towards eco-driving

Debates about transport policy have recently focused on the scope for behaviour change through behavioural economics and 'nudging' (Thaler & Sunstein, 2009). Driver decision-making – and therefore, by extension, driver behaviour change – is influenced not just by information but also the context within which the decision is presented: the way the choice is framed, our 'choice architecture'. In the same way that a question can be leading, i.e. phrased so as to encourage a particular answer, the way in which information is set out at the point of decision-making can also be biased towards eliciting one choice, which may not be a rational or 'correct' one. A nudge, therefore, is a small characteristic of this choice architecture put in place to alter the outcome. A traditional libertarian approach to policy development would suggest that individuals are rational and act in their own best interests, but it is clear that this is not always the case. Paternalistic policies restrict these 'bad' choices to encourage what are, from a rational standpoint, better ones. The use of nudging, or soft paternalism, suggests that various biases in the ways in which individuals make decisions do exist, but that choice architecture can be manipulated to counteract it. This can be done without resorting to the 'nanny state' policies of outright paternalism.

For example, individuals react differently when presented with good or bad outcomes: in general, they are more interested in avoiding a bad outcome than in experiencing an equivalently sized good outcome. Therefore, the presenting of options in a way that is conscious of these biases and differences in psychological impact is critical. The scope for nudge techniques in transport behaviour change opens up exciting opportunities. There are a number of reports suggesting how such techniques can be used to promote behaviour change, including an RAC Foundation report on older drivers (Berry, 2011) and research conducted by the RSA (the Royal Society for the encouragement of Arts, Manufactures and Commerce) on the psychology of behaviour change in taxi drivers (Rowson & Young 2011a; 2011b). From the RSA research project, which gave training in, and subsequently observed, eco-driving, it is clear that the simple financial rewards of eco-driving (the rational choice) are not the only motivations. There is a social element to the success of eco-driving training – the behaviour change of participants is partly based on the behaviour change of other participants. Understanding the complexity of personal decision-making – taking into account the social and psychological factors in what is too often considered to be a purely 'rational' choice – is, therefore, critical in eco-driving policy creation.

4.5 Intelligent vehicle design

There are a number of vehicle design options available which encourage eco-driving. These can be either built in to the vehicle (for example GSIs, stop–start systems, tyre pressure monitors and telematics systems) or made available as hardware or software accessories (for example eco-driving monitoring and instruction apps to be used with smartphones).

As part of broader efforts to reduce vehicle emissions, GSIs, which inform the driver as to the best point to change into a different gear, will be required for all new manual vehicles by 2012. By indicating when to change into higher gears, eco-driving behaviour is encouraged. However, it is not clear what measureable effect GSIs would have on emissions. There is a range of design options available to use. This may influence how drivers interact with the technology and influence the choice architecture of eco-driving – indeed GSIs designed to meet the letter, but not the spirit, of policy commitments may well encourage more aggressive driving, as the gear shift points have not been agreed.

Research for the DfT (AEA & Millbrook, 2010) suggests that a GSI in a Ford Focus could lead to a 3.9% reduction in CO_2 emissions compared to the baseline NEDC figure obtained in testing. The figures for other vehicles ranged between negligible and reductions of 13.5%, depending on vehicle type and test conditions. However, it is important to note that GSIs, as with other technologies within the vehicle, are only advisory – the driver can simply ignore them. Their design is therefore crucial to their success.

There is a similar programme for making the installation of tyre pressure monitors compulsory in new vehicles available with the EU from November 2012. Tyre pressure monitors alert the driver when the pressure in the vehicle's wheels has lowered to an unacceptable level. This can be detected either directly, using sensors within each wheel to measure air pressure, or indirectly, where rotational speeds and other indicators of low air pressure are monitored.

Stop–start systems reduce unnecessary idling by turning off the engine at points where the vehicle has come to a halt, and rapidly and automatically restarting it as the car is put into gear again. These systems have been shown to provide up to 10% improvements in economy, although that is dependent upon the type of driving. Such systems are especially suited to those drivers who do a lot of urban driving, which tends to include more stopping and starting. They are also becoming increasingly common – for example, they form a key part of BMW's EfficientDynamics programme to lower emissions in BMW vehicles. Fiat research suggests that in real-world conditions, such systems can provide an additional 1.5% of fuel savings for Fiat 500 and Punto owners.

Telematics systems can be of particular use to drivers. They collect data on location, speed and other characteristics of driving behaviour, which can then be presented as (i) real-time driving advice, (ii) post-trip instruction, or (iii) as part of multi-driver training schemes. These systems provide an assessment of overall driving style based on a number of variables, in contrast to other in-vehicle technologies which focus only on one part of eco-driving behaviour (such as the use of gears).

The largest use of telematics systems in passenger vehicles is the Fiat eco:Drive system. Through the Blue&Me entertainment system available on new Fiat 500 and Punto vehicles, owners are able to download eco-driving trip data (on acceleration, braking, gear-changing and steadiness of driving) onto USB flash drives. The data can in this way be transferred to a program on a driver's home computer; the information about the trip is then analysed, and user-appropriate eco-driving lessons provided. In addition, driver performance can be uploaded to eco:Ville, Fiat's eco-drive social network facility, where users can compare their own eco-driving to that of friends and other eco:Ville participants.

There are also a number of telematics accessories. Satnavs and smartphones, which have inbuilt GPS and accelerometers, mean that many drivers already own the hardware necessary for accurate data collection and analysis: specialist software enables use for this purpose. For example, the AA has recently launched an application for the iPhone which monitors speed, and sharpness of acceleration and braking, to provide real-time feedback as well as post-trip analysis. A UK company called DriveGain also has developed iPhone software for eco-driving. Along with the DriveGain application, the firm has developed a special iPhone application (Fueless) as part of the Dutch national eco-driving programme (see section 4.7). Toyota has developed a similar application which presents eco-driving in a less technical way: it simulates a glass of water. Sudden movement of the vehicle creates more spilled virtual water, whereas smoother driving keeps the virtual water in the glass.

Other developers have used smartphones to promote eco-driving through gaming. Buick has developed an eco-driving game that does not use real-world trip data, but rather encourages it through a car driving simulation.

This use of the standard ‘car driving game’ interface is another means of engaging with users and presenting eco-driving in a way that does not imply slow driving or fringe behaviour.

There are other ways to promote eco-driving technology besides regulating for its inclusion in vehicles. For example, such devices could be granted exemption from VAT. This was a policy in the Netherlands until 2005, and estimates suggest that 45–60% of the devices in use would not have been purchased without such tax support (CfIT, 2007). This had a significant influence on their take-up, which rose from 13% to 33% of the entire parc in the Netherlands.

4.6 Eco-driving, safety and insurance

The driving behaviours promoted by eco-driving have natural synergies with safety, and therefore find a ready application in the motoring insurance industry. While the vast majority of insurance products are of the flat-rate annual type, there are some that use telematics to more accurately gauge the insurance risks associated with individual drivers. These pay-as-you-go (PAYG) systems appear likely to become more prominent as insurance costs rise, especially for younger drivers (House of Commons Transport Committee, 2012). There are a number of telematics-based systems available in the UK, and there is great scope to use these not only to ensure safe driving but also for the encouragement of eco-driving, as the devices and data collected are very similar.

For example, Norwich Union, Motaquote, the Co-operative Insurance and the AA have each launched insurance products which use telematics. Not only does this promote eco-driving in the sense that it encourages more careful trip planning, as travel costs are directly linked to the distance travelled, but

in-vehicle feedback can also encourage smoother driving styles. The insurer RSA (formerly Royal and Sun Alliance) also offers a special eco-car discount in addition to a telematics insurance policy.

4.7 Campaigns

While not necessarily bringing the greatest overall savings in emissions, the use of information campaigns to promote eco-driving can be a cost-effective method to employ. There have been a great number of campaigns from governments and NGOs. The EU sponsored ECOWILL programme has reviewed the variety of efforts made across Europe (ECOWILL, 2010).

In Austria, three parties – the Federal Ministry of Agriculture, Forestry, Environment and Water Management; the Austrian Energy Agency; and the Federal Branch Association of Driving Schools – worked together to promote eco-driving as part of the larger 'klima:aktiv mobil' (meaning literally 'climate:active mobile') initiative, as a state-run programme to promote the reduction of GHGs. The 'Spritspar-Initiative' (or 'fuel-save initiative'), as it is known, involves a number of training, promotional and competitive events, and is supported by a significant media campaign.

In Germany, the 'Neues Fahren – clever, sicher, weiter' (meaning 'new driving – clever, safe, further') initiative of the Federal Ministry of Transport, Building and Housing promotes a frugal and safe driving style, but reminds drivers that this will not be at the expense of either fun or comfort.

Normal government public service campaigns are not the only strategy available for attracting the attention of motorists; links between government and private companies can also prove fruitful. In Greece, the owners of a large toll bridge, the Ministry of Transport and other experts from road safety and environmental bodies together developed and distributed brochures on eco-driving to users of the bridge. This provided a weblink so that drivers could measure their own environmental footprint through an associated online tool.

In the Netherlands, the national eco-driving programme (Het Nieuwe Rijden, or 'The New Driving') is a €35 million project to reduce GHGs as part of international climate commitments. It was set up on behalf of the Ministry of Infrastructure and the Environment. Working with a wide range of consumer and transport-related organisations, this programme has made significant gains through the promotion of eco-driving, amongst which is the estimated avoidance of over 2 million tonnes of CO_2. The communications strategy, however, does not promote this environmental angle – rather, safety, comfort, fun and cost savings are highlighted. Environmental benefits are regarded as pleasant side effects of a modern driving style that is projected as more appropriate for modern engine technology and that brings significant and immediate personal benefits. This has been a highly successful and affordable campaign – 82% of drivers were familiar with it in 2009, and it was estimated that for every €10 spent by the campaign, a tonne of CO_2 was saved.

4.8 Competitions

Numerous studies have suggested that social and competitive elements of training are strong motivators for behaviour change. In addition, competitions can provide a testing ground for new technology and a highly visible promotional opportunity for eco-driving.

In the UK, the most prominent eco-driving competition is the ALD Automotive / Shell FuelSave MPG Marathon. This is a two-day efficiency road rally, where participants drive standard production cars and vans over a mixed route to compete against one another in (i) absolute fuel consumption and (ii) consumption relative to stated NEDC data. The event is organised by *Fleet World*, a magazine for those in fleet management, and the event promotes eco-driving to fleet managers.

The RAC Future Car Challenge, in which the aim is to travel from Brighton to London in (U)LCVs using the least energy possible, also has an eco-driving element to it. The 2010 event demonstrated the significant differences possible in energy consumption when comparing identical vehicles travelling along the same course. An analysis of the energy consumption results from the 2011 Challenge by the RAC Foundation (Lorf & Lytton, 2012) reveals that driving style can have a significant impact on fuel economy. It confirms that driving at steady speeds and keeping the foot off the accelerator as much as possible minimises fuel consumption.

The EST and Ford also ran an eco-driving competition in 2008. This involved a number of regional events and one event as part of the British International Motor Show in London. It provided short training courses for 500 participants,

with a prize for the driver who demonstrated the greatest post-training savings. This promoted eco-driving to a wide audience, but also, crucially, provided the data required to demonstrate the effectiveness of such training in a later application for state support for a wider scheme.

As noted in section 4.5, the Fiat eco:Drive system allows the driver to upload driving data onto a home computer. This not only provides instruction, but also allows participation in eco:Ville, an online social network for eco:Drive participants. eco:Ville brings the powerful social and competitive elements to what would otherwise be the rather lonely activity of analysing driving data. It is integrated with Facebook and Twitter, which allows the presentation of driver results to specific friends and for particular competitions (for example women versus men) to be arranged in this virtual space. eco:Ville has, as of February 2012, nearly 70,000 participants, and attributes the saving of over 4.5 million tonnes of CO_2 to the use of eco:Drive software.

4.9 Vehicle and traffic regulation

There are a number of ways in which legal instruments can be used to exert a positive influence on eco-driving – particularly by encouraging responsible vehicle maintenance and facilitating efficient traffic flow.

A well-maintained vehicle is an important constituent of eco-driving. Correct tyre pressures, properly lubricated engines, and vehicles in sound physical condition are fundamental prerequisites for driving as efficiently as possible. The MOT test is one way that regulation can enforce or encourage good eco-driving. The test currently includes evaluation of the state of the tyres, the state of the oil within the engine, and the state of the petrol cap (an ill-fitting cap can allow fuel to evaporate). It also provides an important channel of communication to drivers about the key role of good maintenance in safe and efficient driving.

Traffic enforcement can also be used to counter some particularly inefficient driving techniques. These behaviours come under legislation not specific to eco-driving, but are nonetheless targeted by it. However, enforcement of traffic is already a under significant budgetary pressure, and any enforcement effort which has eco-driving benefits in mind – or reaps eco-driving benefits as a side effect – will need to be considered in the context of broader issues in traffic policing. Road space rationing, such as in Athens, where access to the centre is restricted to alternating days for odd- and even-number plates, is a rather crude way of controlling traffic flow.

A more technically advanced and subtle approach is active traffic management, where automatic systems and human intervention are used to manage traffic flow. The Highways Agency trial on the M42 found that the overall isolated effects of active traffic management from all vehicles were a CO_2 reduction of 4% and a fuel consumption reduction of 4% (Mott MacDonald, 2009).

Traffic smoothing – the design of infrastructure to encourage steady traffic speeds – can improve eco-driving. Regulation of road design is one method of ensuring the prioritisation of smoothing. Phasing of traffic signals, for example, can be used to promote more regular flow conditions. However, as with traffic enforcement, this is a complex matter where the importance of eco-driving must be considered alongside other priorities (see section 5.5).

4.10 Learning from fleets

There is much to be learnt from eco-driving training conducted as part of fleet management. The fleet context is an ideal environment for eco-driving, because:

- fleet managers are already particularly aware of environmental issues in road transport;
- they are sensitive to potential cost savings from eco-driving;
- fleets often have professional drivers (e.g. bus drivers) who are already used to advanced driver training; and
- the employee/employer relationship provides a strong reason to comply with training and maintain eco-driving over time.

In 2011, UK bus firm Stagecoach invested significantly in the provision of telematics systems for 6,500 buses. This investment provides 13,800 drivers with telematics systems to encourage eco-driving, with the goals of reducing fuel consumption by 4% and of accident reduction. Key to the success of this programme is an incentive scheme for drivers, whereby eco-driving success is converted into financial benefits for the driver. Individual monitoring of drivers allows for competitive league tables to be created within fleets. This data can be used for the provision of incentives and improved fleet management.

The professional fleet sector is an especially productive area within which to promote eco-driving, as improved driving techniques meet multiple goals and benefit from staff training and payroll structures already in place. There are clear synergies between eco-driving and safety and comfort (Saynor & Featherstone, 2012). Telematics systems are already commonplace in fleets, and fleet managers benefit from richer data on fuel use. In addition, the professional context can lend itself to training – the contract between employer and employee enables straightforward provision of meaningful reward for long-term application (or, if desired, shorter-term application also) of eco-driving techniques, as well as being a formal relationship in which compliance with instructions is required.

5. Issues in Encouraging Eco-Driving

5.1 Introduction

There are a number of issues and challenges to consider in any discussion on the promotion and adoption of eco-driving techniques. These include:

- How best to encourage the use of eco-driving over the longer term, so that the impressive results from eco-driving training can be maintained by the driver
- How best to market eco-driving so that it is adopted by the widest possible audience
- How best to negotiate the potential adverse interactions between eco-driving and other road transport priorities (principally road safety and infrastructure design)
- How the usefulness of eco-driving to assist in the meeting of carbon reduction targets may be influenced by rebound effects – where the savings made available by eco-driving allow, and even encourage, greater vehicle use, thus negating some of the benefit

These issues could affect the adoption and utility of eco-driving techniques; this chapter looks at them and considers what can be done to mitigate unwanted outcomes.

5.2 Maintaining eco-driving over time

The most significant issue in the encouragement of eco-driving is how eco-driving behaviours can be maintained over longer periods of time. Many of the studies of the effectiveness of training are notable for their short-term analysis – either looking at immediate impacts or those measurable within the first 30 days of driving after training was given. Eco-driving promotions are, of course, ways of reshaping rather than strictly controlling driver behaviour. As a result, any effort is constrained by what is possible to accomplish via teaching, or through various forms of communication and feedback (e.g. GSIs). In many schemes which promote eco-driving, there are few safeguards against drivers ignoring or simply forgetting eco-driving while on the road. Similarly, various onboard technologies (such as telematics training, or real-time vehicle efficiency information presented to the driver) can be ignored, be opted out of, or simply be heeded less and less as time goes by, because they cease to have novelty value for the driver.

The Fiat eco:Drive technology demonstrates the problems associated with securing continued driver commitment to eco-driving which results in a real and permanent behavioural change. Data from the eco:Drive system was analysed by Fiat for 30 days, because this was the length of time for which users actively participated in the scheme (Fiat, 2010; 2011). The 'pull' design of Fiat's technology, where drivers had to choose to move data from onboard systems to their PCs rather than be encouraged by an automated (or 'push') process, allowed greater opportunity for drivers to withdraw from participation. After the novelty value of the scheme subsided, and the lessons from it were initially adopted by drivers, there was little to encourage further use of the technology over a time period appropriate for securing lasting behaviour modification.

Likewise, Rowson and Young (2011a) suggest that eco-driving training needs to be maintained over a much greater length of time than tends currently to be the case. One-day training courses, or telematics systems that stop being used after a month, contrast with research that suggests that it takes more than double that length of time for real, long-term behavioural change to occur. Of course, this is a key reason why fleet and workplace eco-driving has tended to be more successful – the employer is able to introduce and maintain the importance of eco-driving to their employees for a sustained period.

Any effort to encourage eco-driving over the longer term will plainly have to operate with larger timescales than is the case with most current efforts. The design of the programmes and mechanisms to encourage eco-driving thus require careful consideration. Particular focus should be placed on maintaining training beyond the threshold period needed to ensure long-term change. For example, although telemetric training tools have been shown to be effective, they must be designed not only to be 'push', so that drivers are encouraged to maintain their interest, but also to avoid annoying or distracting the driver – they must be push without seeming pushy. Similarly, training courses need to be supported by, for example, promotion campaigns or refresher courses to maintain encouragement over a sufficient length of time. In short, the existence of these schemes is not enough: such efforts need careful, appropriate and thoughtful design.

5.3 Marketing eco-driving

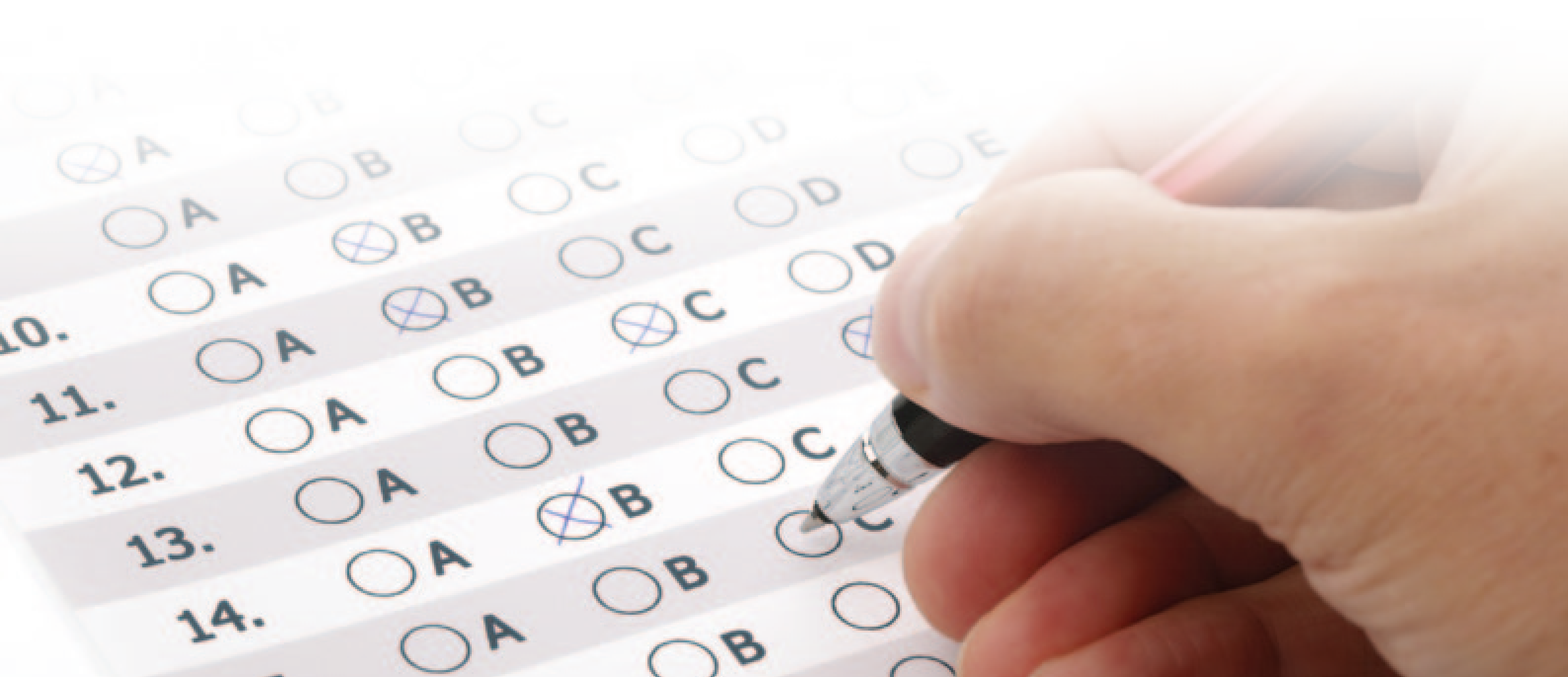
There have been a number of methods employed to promote eco-driving – it has been marketed in ways that highlight environmental responsibility (e.g. 'eco-driving'), financial responsibility (e.g. 'smarter driving'), competition in saving (e.g. the MPG Marathon) and modernity (e.g. the Dutch scheme, Het Nieuwe Rijden). These various methods inevitably attract certain drivers over others because they focus on one single element of eco-driving behaviour.

Successful adoption of eco-driving techniques in fleets and vehicles used for business has shown the importance of marketing eco-driving in ways that suit the context. Bus and taxi drivers have been successfully presented eco-driving in terms of corporate fuel savings and passenger comfort. Similarly, other target audiences can be addressed using appropriate methods. Environmentally conscious drivers can be encouraged to eco-drive, PAYG telematics insurance schemes can encourage 'safer driving', and in-car technology (such as GSIs) can highlight fuel economy, which is especially appropriate at point of purchase.

The priorities of drivers are, of course, not constant over time. What may be a motorist's primary concern at one point may later be pushed aside by other priorities. The DfT conducts research into the public attitudes to climate change and transport as part of the ONS Opinions Survey (prior to 2008 called the Omnibus Survey). Since 2006, belief in and concerns about climate change have been in decline in the UK. Also in decline since 2006 is the number of people who associate transport with climate change without being prompted. In 2011, 61% of full licence holding drivers would be willing to reduce motorway speed to reduce CO_2 emissions and 63% felt that eco-driving should be a greater part of the driving test. However, only 24% were willing to *pay* to learn to eco-drive. In setting up new or promoting current eco-driving policies, it is clear that efforts should focus on strong and *consistent* motivators for behaviour change.

A poll by GfK NOP (2009) suggests that the strongest driver for behaviour change is economic. The main reason given for eco-driving by 51% of drivers polled was the financial savings gained by reduced fuel consumption, with only 18% particularly motivated by the reduction of GHG emissions. Similarly, a Populus survey in 2011 showed that key motivators for eco-driving were related to finance and safety.

On the evidence of these surveys, it is clear that promotion of eco-driving should make best use of the financial savings it offers. So, arguably, eco-driving may not be the best name for it. However, the value in eco-driving comes through its long-term adoption by drivers. Current efforts have done well in showing the possibilities of short-term savings. The logical conclusion of this is that for long-term gains to occur, *eco*-driving should ultimately become *normal* driving: ecological and economical driving behaviour needs to become accepted as standard practice, so that it requires no special title at all. This would reduce the likelihood of driver interest fluctuating as other conditions (particularly interest in the environment and the cost of fuel) vary. Driver training (and this includes further training on modern, greener vehicles more subject to shortfall – the difference between official and real-world measures of vehicle economy), and technical modifications to vehicles made standard by EU regulation, will increase the understanding of eco-driving as normal behaviour, replacing its perception as a worthwhile behaviour change taken up only by a particular niche of enthusiasts.



5.4 Eco-driving and safety risk

The basic principles of eco-driving – planning ahead, preparing early, maintaining consistent speeds and keeping up with responsible vehicle maintenance – are essentially safe driving behaviours. Eco-driving has financial, safety and environmental benefits. However, the sometimes complex relationships between these three benefits should be considered in order to avoid potentially adverse interactions between eco-driving and other priorities for road transport.

A 2004 report which assessed the Finnish programme for what is known in Finland as ‘ecosafe’ driving highlights some concerns in terms of the safety aspects of eco-driving (Hatakka et al., 2004). Eco-driving is one of the seven key competencies for the Finnish practical driving test (although not in itself a pass-or-fail criterion), and it forms part of the theoretical training. The Finnish experience displays the important interactions between environment and safety in training. For example, there needs to be instruction to make clear where to draw the line between genuine eco-driving and techniques that may be inappropriate (for example tailgating to maintain evenness of speed). Some eco-driving training suggests that rapid acceleration up to a target speed (which is then maintained) is the most economical way for the vehicle to progress. This advice can too easily be misunderstood, resulting in unsafe reductions in distances between vehicles. Emphasising consistent speed can lead to some drivers not slowing down until the last possible moment, a habit that carries inherent safety risks. Driving involves interactions with other road users, and for eco-driving to be safe it needs to form part of those interactions: safety is paramount, and other road users may inhibit the safe practice of an eco-driven journey. A responsible driver should, until traffic conditions change, lay aside any eco-driving techniques that are rendered less than completely safe by the behaviour of other road users.

Furthermore, there are challenges inherent in the teaching of eco-driving to learner drivers. Learner drivers may not have the right experience and basic skills for the safe adoption of eco-driving techniques, and may therefore increase safety risks by attempting them. So, while eco-driving’s emphasis on planning, observation and maintenance brings about improvements to safety, it can be misunderstood or misapplied in certain traffic situations, and this risk is particularly high with new drivers. For example, new learner drivers may well misapply the advice to avoid unnecessary braking, because they as yet still lack good awareness of their own vehicle’s stopping distance or what may constitute necessary braking. This suggests that eco-driving training should either be introduced through its thorough integration into new driver training, or left for more experienced drivers who have the skills to safely adapt to a new driving style.

The advantages of eco-driving can be taken too far. Hypermiling, an extreme form of eco-driving (see footnote 2 in Section 2 above), encourages a number of techniques that present risks to safety and may well be illegal. Eco-driving can only be encouraged up to a point, within the boundaries of safe and legal driving. Any possibility that encouraging eco-driving for the many may encourage hypermiling for the few should be borne in mind and responded to appropriately, by both those promoting eco-driving and the police.

5.5 Eco-driving and the built environment

As much of the benefits of eco-driving come from reducing the impacts of idling and change in vehicle and traffic speeds, there is also a relationship with infrastructure and traffic planning and regulation that is worth considering. Eco-driving would be improved by the smoothing of traffic flow, so that more vehicles moved at consistent speeds more often. Some cities in the USA, which have traditionally had traffic lights and stop signs as a way of regulating traffic at junctions are shifting towards roundabouts as a way of improving traffic flow for this reason. However, in the UK context, where there are comparatively few traffic lights or stop signs at junctions, efforts to improve traffic flow should be considered more carefully, especially with regards to adverse impacts. For example, recent discussion about London's road safety in terms of cycling fatalities has questioned the prioritising of traffic smoothing at the expense of other road users. Traffic smoothing may create other problems (for pedestrians or cyclists, for example). Modifications to speed limits will have an effect on emissions, but these sorts of ways of encouraging eco-driving should be considered in their entirety – including consideration of adverse impacts, cost and viability of modification and enforcement.

5.6 Rebound effects

There is a real possibility that any improvement in the efficiency of energy use, instead of leading to a reduction in consumption of that fuel, might instead encourage greater quantities to be used. It is important to be mindful of this 'rebound effect' of improvements in energy efficiency, also called Jevons' Paradox, given that there are a number of factors at play that limit a vehicle's distance travelled.

While eco-driving may encourage some drivers to drive the same distance using less fuel, and thus spending less money, it may encourage other drivers to drive a longer distance using more fuel for the same amount of money. It is true that the amount of fuel used by a driver is not strictly limited by one factor – there are a number of dimensions to consider. Levels of business activity may promote or discourage travel as the commercial need to travel increases or wanes, and the time available for travel limits, to some extent, the amount of travel that occurs. But as recent fluctuations in fuel price have shown, price does play a very significant role in car use – drivers can only drive the distance they can afford, and eco-driving and other fuel efficiency measures allow for more distance to be affordable.

Research from the EST (Saynor & Featherstone, 2012) reinforces this finding. They suggest that to keep fleet drivers eco-driving, economics is key. If drivers with company fuel cards repay their employers the cost of their own personal, non-work mileage in terms of the actual cost of fuel used, they are personally incentivised to be efficient. The drivers are more likely to seek to minimise the amount to be paid back to the employer and, as a result, use eco-driving techniques. However, the alternative form of repayment for personal, non-work mileage – a pence-per-mile basis – does not offer the same incentivisation. The drivers pay back for distance travelled regardless of driving economy over those trips. Small cash rewards – significantly smaller than the money saved by eco-driving – also can be a very strong motivator to continue with eco-driving.

This is not to discount eco-driving as a carbon reduction measure, but it does show the importance of exercising wisdom in the employment of eco-driving and other fuel efficiency measures, along with other policies, to reduce the possible rebound effect whereby more-efficient vehicles lead to less-efficient behaviour. Eco-driving, as a policy in isolation, cannot work on its own. It can, however, work as part of a package of measures to decarbonise transport that recognises the risks involved in its possible misapplication.

6. Conclusions

6.1 Eco-driving and carbon emissions reduction

Eco-driving – the application of a combination of efficient driving techniques – can be an effective means of reducing fuel consumption and hence emissions from road transport. It is particularly difficult to measure the real-world effect of eco-driving, but it is reasonable to assume that fuel and carbon savings of between 5% and 10% are possible. The King Review (King, 2007) suggests that eco-driving could reduce emissions and fuel consumption from cars by 8%. It is clear that even comparatively small and sensible actions (such as properly inflating tyres or reducing wind resistance) can bring significant and worthwhile dividends.

However, eco-driving is by no means a simple, complete solution to either the cost of fuel or the CO_2 emissions from road transport. The effectiveness of eco-driving is influenced by vehicle design, local driving conditions and the behaviour of other motorists. Even when consistently applied, eco-driving cannot, in itself, offer consistent fuel and carbon savings. The consistency of its real-world application is the fundamental issue: however good it is in theory, it must be put into practice. Moreover, that practice must become permanent: the durability of outcomes from eco-driving training needs to be improved.

The various methods of encouraging eco-driving are very cost-effective in terms of CO_2 reduction. For example, the Dutch national eco-driving campaign has been assessed to have cost £13 per tonne of CO_2 saved. Relative to the high cost of fuel, many eco-driving efforts are very affordable – courses, GSIs and suchlike are very often cost-negative. These measures save significantly more for drivers than they cost.

The Committee on Climate Change believes that emissions reductions of up to 0.3 million tonnes of CO_2 are plausible, if around 3.9 million car drivers can be trained by 2020. The savings available through the application of eco-driving, the low costs of promoting it and instituting policies that favour it, and the direct financial benefits that it offers drivers through fuel and insurance savings – taken together these make a strong case for the further expansion of eco-driving in the UK.

6.2 Policy suggestions

While eco-driving does theoretically offer remarkable savings opportunities, the maintaining of such behaviour over the long term and in real-world conditions is a complex issue for policymakers to address. Savings offered by eco-driving may be clear-cut physics, but its adoption is a matter of complex educational psychology and is dependent on social interaction and the priorities of individuals. The long-term application of eco-driving techniques should clearly be central to the goal of any eco-driving policy measure.

These considerations persuasively suggest a range of measures that either (i) target the maintenance of eco-driving techniques over longer periods, or (ii) target those who are more likely to apply such techniques over longer periods. Although almost all policies that promote eco-driving represent comparatively good value in terms of carbon reduction, there is a strong argument, given budgetary constraints and the challenges of regulating for safe driving behaviour, to focus on 'quick wins'.

The following policies are therefore suggested:

- **The driving test.** Training through normal driving instruction represents a good-value training opportunity and introduces eco-driving as standard practice. Further promotion of eco-driving in the test syllabus will go some way to reducing the 'old wives' tales' of motoring that often encourage inefficient driving behaviours.
- **In-vehicle technologies.** As new vehicles become more efficient, the difference between official and real-world measures of vehicle economy – the shortfall – is likely to become a more common problem. In-vehicle technologies, such as gear-shift indicators and tyre pressure monitoring systems, go some way to alleviating shortfall and encouraging a longer-term interest in eco-driving. However, these technologies are only as good as their design. Poorly designed versions of these systems may offer no significant benefit, and may even alienate or distract drivers. Careful thought must be given both to the policies that regulate such technologies and to the designs themselves. The complex nature of human behaviour is a challenge when it comes to achieving greater levels of eco-driving: one solution to this is to design vehicles so that the impact of driving style in real-world vehicle emissions is minimised as much as is possible.
- **Professional and advanced drivers.** The fleet environment provides an excellent opportunity to learn to eco-drive. Fleet training benefits from a number of synergies with other characteristics of business and public transport fleets. Best use should be made of these to create a strong link between promoting eco-driving and achieving other corporate goals. Eco-driving will benefit from being further encouraged through all forms of professional and advanced driver training.
- **Insurance.** If insurance costs continue to rise for certain drivers, pay-as-you-go telematics systems are very likely to become more commonplace. The links between eco-driving and safe driving present an excellent opportunity to encourage eco-driving through the use of such devices in connection with insurance fee structures. As saving money is a strong behavioural change motivator, tying eco-driving to one of the most prominent motoring costs has merit.
- **Data.** Research on eco-driving is dominated by case-study and laboratory data: real-world information is lacking. There needs to be an effort, either via large fleets or through private vehicles already fitted with telematics

systems, to collect larger real-world datasets. This would not only have application in the further study of eco-driving, but also assist in the related fields of traffic management and road safety.

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RAC Foundation
89–91 Pall Mall
London
SW1Y 5HS

Tel no: 020 7747 3445
www.racfoundation.org

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