TRANSPORT RESEARCH LABORATORY

Reducing the environmental impact of driving: A review of training and in-vehicle technologies

Prepared for Vehicle, Environment and Taxation Division, Department of the Environment, Transport and the Regions

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Executive Summary

The Transport Research Laboratory was commissioned by the Vehicle, Environment and Taxation (VET) Division of the Department of Environment Transport and the Regions (DETR) to review the evidence that driver training can reduce accidents, fuel consumption, emissions and noise and also to consider how training schemes could be encouraged more widely.

In this report, the training received by fleet drivers and its effects on driver behaviour has been the main focus. Fleet drivers carry out a large proportion of the annual mileage driven in the UK and have higher than average accident rates even when other factors such as annual mileage are taken into account. There are also a sizeable number of organisations currently providing fleet driver training.

The research has been conducted through a review of relevant published literature and interviews with fleet managers, training organisations and insurers.

The literature review has shown that there is the potential to reduce the environmental impact of driving by encouraging particular behaviours such as: moderating the rates of acceleration and deceleration; keeping to an optimum speed; the careful use of gears, and; switching off the engine during extended periods of idle. Potentially, fuel consumption during a typical journey may be reduced by between 10% and 30% depending on the type of trip and type of driver. The effect on pollutant emissions is perhaps less clear, but reductions of up to about 20% for a typical journey should be possible. Vehicle noise levels may be reduced by about $2dB(A)_{LAeq,T}$ on streets where braking and accelerations are minimised. By minimising engine speed, the average noise energy over a journey may be reduced by 5dB(A) for cars and for motorbikes by 6-8 dB(A).

A driving style that encompasses these behaviours is largely compatible with the training currently offered. The main training organisations predominantly teach defensive driving skills which aim to enable drivers to observe and anticipate the road conditions ahead. Training providers report noticing a shift in emphasis, with more companies and fleet managers requesting that environmental issues be covered in their training. This implies an opportunity to strengthen the environmental content of training courses, for both novice and advanced drivers.

In-vehicle technology could also be applied to reduce the environmental impact of driving. Technologies that help drivers and/or fleet managers to monitor parameters such as fuel consumption, periods of idling, speed violations and harsh accelerations/decelerations, have been shown to be able to produce environmental benefits. Those currently available are generally used to manage the fuel consumption and running costs. Cruise control systems have been shown to reduce fuel consumption by about 4%: the effect of econometers on fuel consumption is not so clear, with one study suggesting savings of 5 to 10% whilst another saw no significant benefits. The systems are more likely to be effective where there is a well-defined management procedure for monitoring, analysis and feedback of information, such as have been adopted by some HGV fleet operators.

The promotional material produced by driver training organisations suggests typical improvements in accident rates of 25 to 50%. However research studies have generally shown little evidence that it is effective in reducing accidents. There is also some debate about the extent to which training alone can make a significant impact on driver behaviour and driving style. Further work to evaluate the benefits of training is needed. Differences between private motorists and the various subgroups of fleet drivers, in terms of the scope for and effectiveness of training, will also be worthy of study.

Some organisations see reducing fuel consumption of their fleet as an important part of their policies on the environment. The organisations most likely to engage in driver training to achieve environmental benefits will be those recognising that this is beneficial to their business. Therefore, raising the awareness of individuals and companies to the environmental impact of driving and its associated costs may be a key action in encouraging a change in behaviour and/or to engage in training.

To build on this raising of awareness, fleet managers will require reliable information on the effectiveness of different initiatives in order to judge whether training or the installation of monitoring equipment is cost-effective. A clearer lead on how environmental benefits can be achieved may improve the willingness of companies to invest in training to improve the environmental performance of their drivers. Best practice literature should continue to be used to inform fleet operators and training organisations of the benefits of training and in-vehicle monitoring techniques and how best they might be applied.

Incentives to undertake training were also investigated. Some insurance companies currently provide discounts for drivers undergoing training offered by specific providers, the main emphasis being on benefits in terms of fewer claims. No published data were found on how effective the incentives are in encouraging fleets to provide training for their drivers.

1 Introduction

1.1 Context of the study

It has long been recognised that inappropriate driver behaviour is an important contributory factor in the majority of road accidents. Driver behaviour is also critical in determining the fuel consumption, vehicle noise and exhaust emission rates during a trip. Technological developments in noise and exhaust emissions control and the enforcement of legislation will probably be key elements in reducing the environmental impacts of road transport, but increasingly the actions of motorists are also being targeted by other means. The Transport Research Laboratory was commissioned by the Vehicle, Environment and Taxation (VET) Division of the Department of Environment Transport and the Regions (DETR) to review the evidence on whether driver training can reduce fuel consumption, emissions and noise and also to consider how training schemes could be encouraged more widely. The review would focus on car drivers, and in particular fleet motorists.

Cars, vans and taxis account for 86% of all passenger transport in the UK (Department of Transport, 1997). Car or van drivers make, on average, 360 journeys per year, with business and commuter travel accounting for almost a third of those journeys. Over the last ten years, traffic has increased by about 36% with the largest increases seen for vans and cars. This growth is likely to continue into the future, and it is expected that the number of cars will increase by 21-29% by the year 2010. During the same period the average distance travelled is expected to increase by 25-39%.

Noise is a pervasive environmental disbenefit of road transport, and one that is directly perceived as a nuisance. Almost 25% of the UK population are exposed to traffic noise levels in excess of 60 dB(A). Some 28% of the population are bothered by noise from road traffic, with 16% feeling it affects their sleep (Grimwood, 1993).

Road transport accounts for almost 26% of the total energy consumed by final users in the UK. It also accounts for 60% of the total consumption of petroleum (i.e. petrol and diesel) fuels.

In 1995, road transport emitted 33 million tonnes of CO_2, which accounts for about 22% of total UK emissions. Over the last 20 years there has been a steady increase in the contribution that road transport makes to CO_2 emissions. This trend is predicted to continue and Figure 1 illustrates the trend in transport emissions from 1984, continuing through to 2020 assuming a low growth in fuel prices (Department of Transport, 1996). Following the agreement of the Kyoto Protocol in December 1997, the UK has a legally binding target of a 12.5 % reduction in the 1990 level of greenhouse gas emissions (which include CO_2) by 2010. In addition, the UK Government is committed to a 20% reduction in CO_2 emissions in the same period. One of the means by which this is to be achieved will be to target emissions from traffic.

Emissions of other air pollutants, including those where road transport makes a large contribution to the total are also targeted in the UK National Air Quality Strategy (NAQS) (Department of Environment et al., 1997). The Strategy, which is at present under review, targets eight pollutants: benzene, 1,3-butadiene, carbon monoxide (CO), lead, nitrogen dioxide (NO_2), ozone (O_3), sulphur dioxide (SO_2) and particles of aerodynamic diameter less than 10 microns (PM_{10}). Standards and objectives, in terms of their concentrations, have been set and these are to be achieved by the end of 2005. Local authorities have a duty to review and assess air quality in their area, and if necessary draw up plans to achieve the objectives. There are concerns that in some areas concentrations of PM_{10} and NO_2 will not achieve the objectives by 2005. This may also be the case for concentrations of CO, particularly beside heavily trafficked roads. Road traffic contributes significantly to the production and formation of these pollutants.

Progressively stricter emissions standards for road vehicles have helped to limit the impact of the growth in traffic since 1990. However as traffic growth is expected to continue, total emissions may start to increase in 2010 unless further action is taken. Various emissions inventories have highlighted the importance of traffic in determining local air quality. Table 1 illustrates the contribution road traffic makes to total emissions in the

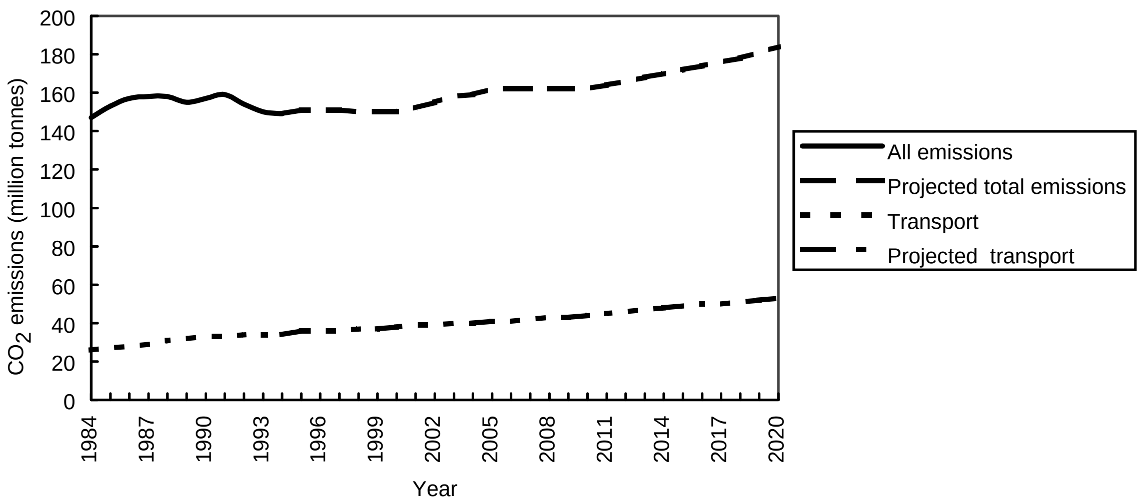

Figure 1 UK emissions of carbon dioxide

Table 1 Percentage contribution of road traffic to total emissions

Area	SO_2	NO_x	*CO*	PM_{10}	CO_2	*Benzene*	*1,3- butadiene*
UK (Department of Environment, 1996)	5	49	76	25	23	Not available	Not available
London (Buckingham et al., 1998)	23	75	97	77	29	83	97
Greater Manchester (Buckingham et al., 1997)	3	63	95	31	21	93	96

UK and in urban areas for a base year of 1995. It can be seen that road traffic makes a large contribution to emissions of the pollutants highlighted in the NAQS, which underlines the importance of targeting road traffic as a means of meeting air quality objectives.

In 1987, a target was set to reduce road traffic casualties by one third by the year 2000 compared with the average figures for 1981-85. By 1997 the number of deaths had fallen by over a third, but the overall number of casualties had remained static. New road safety targets for the year 2010 are to be announced later this year, and it is likely that improvements in the behaviour of drivers and other road users will be sought as part of the solution (Department of Environment Transport and the Regions, 1998).

1.2 Structure of the report

This report brings together evidence from the research literature and interviews with those involved in driver training. Chapter 2 of the report considers the effect of driver behaviour on exhaust emissions, fuel consumption and noise, and examines what benefits could be achieved if drivers' behaviour could be modified. The types of in-vehicle technology that could be used now, or adapted for use, in passenger cars to assist the driver in adopting a more environmentally and safety conscious driving style are reviewed in Chapter 3. In Chapter 4 the training currently available to fleet drivers is described along with the experiences of training providers and fleet managers. Chapter 5 considers the available research evidence on the effectiveness of driver training and Chapter 6 considers the role of incentives and rewards and the use of best-practice literature.

2 The effect of driver behaviour on emissions, fuel consumption and noise

2.1 Emissions and fuel consumption

2.1.1 Background

The complete combustion of a fuel would give rise to emissions of carbon dioxide (CO_2) and water. However in petrol and diesel engines, where thermodynamic equilibrium is never allowed to be reached, incomplete combustion gives rise to emissions of carbon monoxide (CO), unburnt hydrocarbons (HC) and particles (PM), as well as CO_2. Impurities in the fuels also give rise to emissions of sulphur compounds. In addition, nitrogen oxides (NO_x) are formed by the high temperature oxidation of nitrogen present in the air. The most important variable governing pollutant emissions and fuel consumption is the air/fuel ratio of the mixture in the combustion chamber.

Over the past decade manufacturers have modified the design of internal combustion engines and developed new technologies to meet gradually more stringent exhaust emission standards for engines and vehicles. The majority of these technologies are intrinsic to the design of the vehicle and the driver has only limited control over their operation. For example, fuel injection systems have been designed to meter fuel in very precise quantities in relation to signals from the engine management computer (ECU). This in turn operates from a range of inputs, of which two of the most important are engine speed (which the driver can influence by gear selection) and accelerator pedal position. Although the ECU will calculate the most appropriate fuel injection rate for a given engine speed or throttle position, the emissions and fuel consumption will vary considerably over the operating ranges.

In order to determine whether driver training has the potential to affect vehicle emissions and fuel consumption, it is important to understand the relationships between driver behaviour, vehicle operation and exhaust emission rates. The rate of fuel consumption and production of exhaust emissions produced by a particular vehicle depend on a large number of factors which can be divided into two broad categories (Abbott et al. 1995):

- technical factors relating to the design and engineering of the vehicle: its weight, engine type, exhaust after-treatment, aerodynamic properties etc.
- operational factors relating to the way in which the vehicle is used: its speed, rate of acceleration, the use of gears etc.

Driver behaviour affects the way in which a vehicle is operated: the remainder of this review will focus on this area.

2.1.2 Operational factors affecting emissions and fuel consumption

Much of the information relating to the importance of operational factors on emission rates and fuel consumption has been obtained from studies whose main aim was to develop modelling methodologies (e.g. Jost *et al.*, 1992). The effects of some operational factors are better understood than others, and most of the existing work has related to the speed-dependence of emission and fuel consumption rates. More recently, the influence of acceleration has been studied. There is also some information relating to gear selection.

The effect of average speed

The characteristic variation of emissions and fuel consumption rates with speed is well documented, and typical curves based on average speed are shown in Figure 2, for carbon monoxide (CO), hydrocarbons (VOC), fuel consumption and oxides of nitrogen (NO_x). The highest emission rates of CO and HC are generally associated with low average speeds. This is also the case for fuel consumption. Frequent stops and starts, accelerations and decelerations in response to traffic congestion or other disruptions to a vehicle's progress typify journeys of low average speed. These conditions lead to inefficient fuel combustion and inefficient operation of emission control systems. As average speed increases, the operation of the vehicle becomes more efficient and so less fuel is used per kilometre and pollutant emission rates decrease. At the higher speeds there is a tendency for emissions and fuel consumption to increase again as the engine struggles to provide the additional power to overcome aerodynamic drag.

Oxides of nitrogen display a different behaviour because, in general, peak engine temperatures reached during combustion govern their rate of formation. Because temperatures are highest when an engine operates under high speed and load conditions, NO_x emission rates are highest at high average vehicle speeds.

The effect of acceleration

The way in which a particular average speed is achieved is also of importance in determining the fuel consumption and emission performance of the vehicle. Joumard *et al.* (1995) noted that there can be significantly different results for cycles with approximately the same average speed. Figure 3 shows that the CO emission rate at a particular speed increases with acceleration. For example, at a speed of 75 km/h, increasing the acceleration rate from 0 to 0.2 ms^{-2} (i.e. increasing the plotted parameter 'acceleration x speed' from zero to +15) leads to a near doubling in the CO emission rate for ECE 15/04 petrol vehicles. A similar pattern is seen for emissions of NO_x but at the lower speed ranges: at a speed of 15 km/h increasing the acceleration rate from 0 to 4 m/s^2 (i.e. increasing the plotted parameter 'acceleration x speed' from zero to +15) increases the NO_x emission rate by a factor of 4.

2.1.3 The effect of driver behaviour on fuel consumption and vehicle emissions

Fuel consumption

Several studies have shown that different drivers achieve different fuel consumption figures for the same car. Waters and Laker (1980) compared the fuel consumption of cars driven by nine volunteers: there was a difference of 50% between the most and least economical drivers. Laker (1981) asked drivers to drive 'normally' and 'more economically': the more economic drives used about 20% less fuel. Hickman and Waters (1991) suggested the guidance given at that time to owners of cars along with more detailed instruction or training could reduce fuel consumption by up to 10%: such information would include recommendations to keep the car in good condition (engine tuning and correctly inflated tyres), and advice on driving styles (avoiding rapid accelerations and decelerations).

Bongard (1992; described in Theis, 1994) developed a driving style for urban areas with the aim of minimising fuel consumption, emissions and noise. There are four basic steps to the guidance:

- gear changes should be as early as possible, as at a given speed fuel consumption is lowest for the highest gear
- the approach to a red light or other stop sign should be gradual so as to conserve the vehicle's momentum. This would involve coasting and then braking to a stop or to maintain a safe distance
- the anticipation of possible obstacles to flow such as traffic lights
- the distance from a preceding vehicle should be 2.5 to 3s to enable the driver to compensate for small incidents in flow.

Theis claims that adoption of the style was found to reduce fuel consumption and emissions (no figures given) without significantly affecting the journey time for individual vehicles. However there may be implications for overall traffic flow, particularly in congested conditions, should a large proportion of drivers follow this style. This is discussed further in section 5.4.

As part of initiatives in the US to conserve fuel (the DECAT programme; Driver Energy Conservation Awareness Training), An et al. (1994) considered the potential savings in fuel consumption that could be made by modifying the driving style. The study was based on US vehicles, which are quite different to those in the UK, but the general conclusions should still be valid here. Average speed affects fuel consumption as shown in Figure 2. An optimum speed, in terms of fuel consumption, may be vehicle type specific, but increases and decreases in speed from this optimum would increase fuel consumption. The authors suggested that perhaps travelling at the optimum speed could save 10% of fuel. Using moderate acceleration could also save a similar amount: an aggressive driver who delays changing gear when accelerating may use 10% more fuel during that activity. Maintaining a steady speed, and anticipating stops may save 8% of fuel. Turning off the engine might save 100% of the fuel used during idling e.g. in congested traffic (so long as the stop was short enough for the engine to remain hot). General good maintenance practices such as ensuring correct tyre pressures, regular servicing etc. may save 5% of fuel. As a result of following these suggested changes in driving pattern, An et al. estimated that fuel consumption could be reduced by about 10% for a typical journey.

Kemper (1995) studied fuel consumption and journey times for trips made in an urban area. It was found that fuel consumption could be reduced by between 19 and 32 % if drivers were instructed to minimise engine speeds. Journey times were found to have increased by less than 5 %.

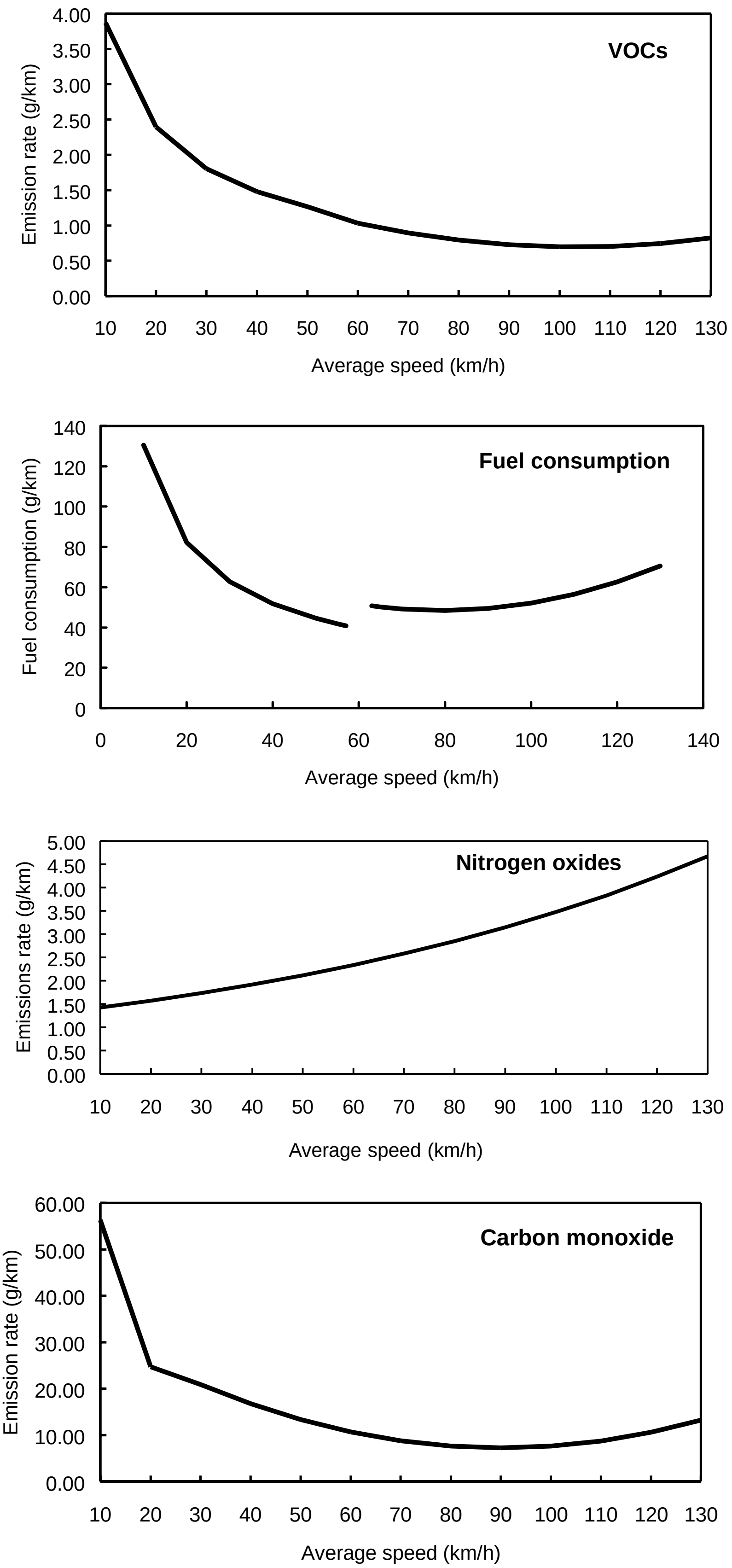

Figure 2 Typical emission rates as a function of average speed for passenger cars conforming to ECE 15-04 regulations (Eggleston et al, 1992)

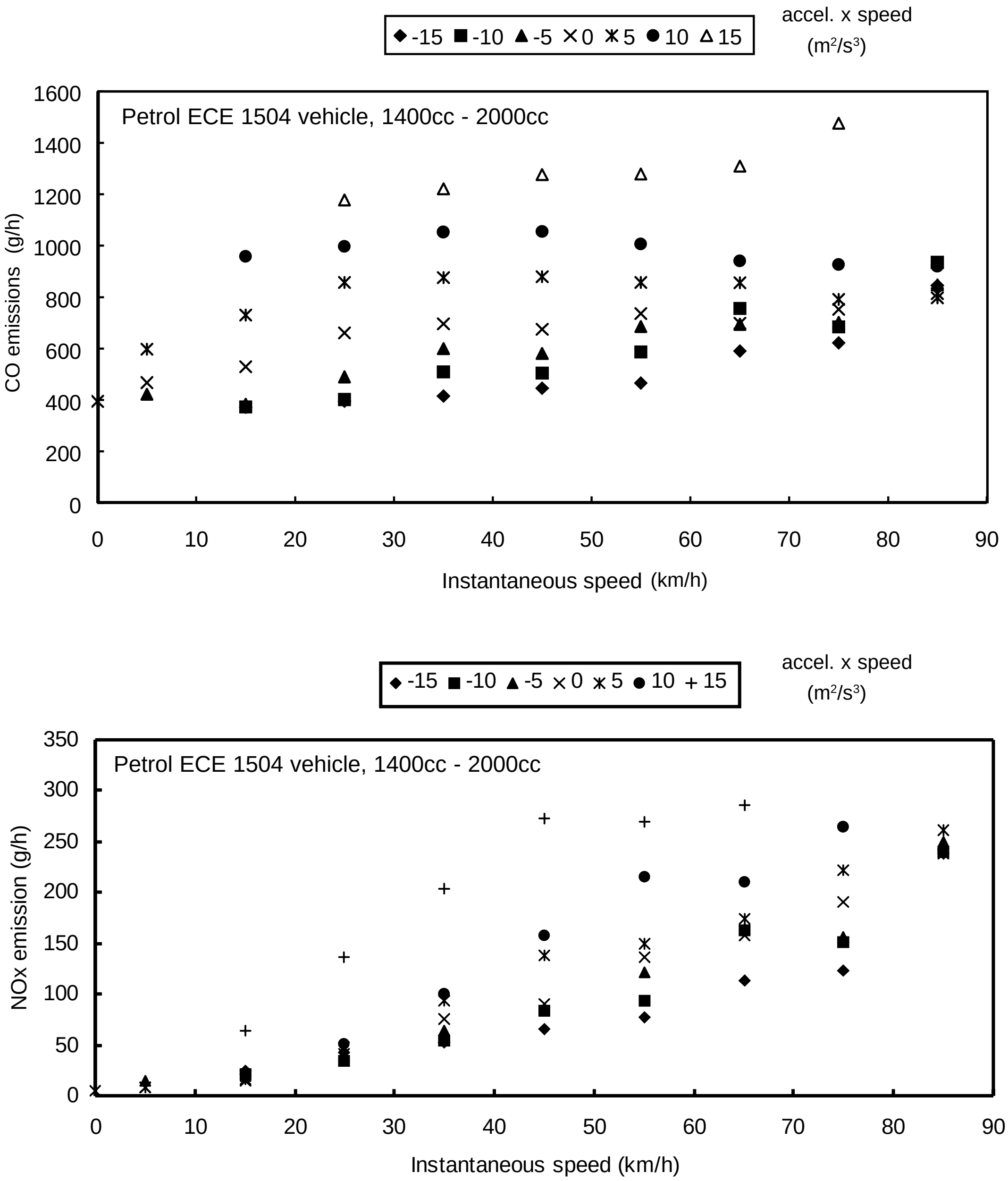

Figure 3 The effect of speed and acceleration on emission rates (from Joumard et al, 1995)

Emissions

Le Blanc et al. (1994) collected evidence of the effect of high vehicle acceleration rates on emission rates. High acceleration rates can cause the engine management system, which aims to ensure stoichiometric[1] operation, to be over-ridden and provide more power by applying excess fuel. The study looked at instances of enrichment events for 79 instrumented vehicles and for a range of drivers. The vehicles were relatively new at the time of the study. Young drivers (25 years and under) were poorly represented in the sample, only one driver falling into this group. Given that younger drivers might be expected to be more aggressive and produce more enrichment events than older drivers do, this may mean that the study underestimates the effects of acceleration on emission rates.

During normal stoichiometric operation of the vehicles, the emission rate of CO was about 0.05 g/s. Severe enrichment events produced average emission rates as high as 8 g/s, with peaks in excess of 15 g/s. Most of the vehicles investigated spent less than 2% of total driving time in the periods of severe enrichment, but the emissions produced can account for up to 40% of total the CO. In general, the sample of vehicle-driver combinations studied gave average emission rates of 0.05-0.1 g/s of CO. The most aggressive drivers in the sample produced up to five times the average rates.

Le Blanc et al. (1995) further investigated the effect of driver behaviour, using instrumented vehicles and emissions modelling. The study examined the variation in driver behaviour between three US cities (Spokane, Atlanta and Baltimore) and assessed the impact of these variations on CO emissions. Data from around 70 vehicles in each of the cities were recorded: in each city efforts were made to select a representative sample of drivers and vehicles. Substantial differences were seen between the three cities in terms of both average speed and acceleration. Atlanta drivers were estimated to have higher CO emission rates, followed by Baltimore and Spokane. Emissions from drivers in Atlanta and Baltimore were estimated to have emission rates 22% and 14% higher respectively than for Spokane drivers. Drivers in Atlanta were more aggressive, in that the sample had the largest standard deviation in acceleration and deceleration values.

An experiment using an on-board measurement system was used to investigate the effect of driver behaviour in urban, rural and motorway situations (Lenaers and de Vlieger, 1996). The types of driver behaviour investigated were classified into three groups:

- **calm**; drivers exhibit anticipation and drive without rapid accelerations (average range of 0.45-0.65 m/s^2)
- **normal**; drivers exhibit moderate acceleration and braking (average acceleration range of 0.65-0.80 m/s^2)
- **aggressive**; drivers use rapid accelerations and heavy braking (average acceleration range of 0.85-1.10 m/s^2).

It was found that emissions for both catalyst and non-catalyst cars decreased according to road type, in the order urban, rural and motorway, i.e. the steadier the flow the lower the emissions. For both catalyst and non-catalyst cars, aggressive driving was found to lead to a general increase in emissions. The increase was by a factor of 1.2 to 3 when compared to normal driving. This trend was particularly apparent for vehicles in urban traffic and with a cold engine, where for catalyst cars, emissions of CO increased by 85%, HC by 65% and NO_x by 80%. Calm driving reduced emissions for catalyst cars by up to a factor of 10 below those for a normal driving style.

Gong and Waring (1996) also demonstrated that emissions are strongly affected by driving activities. Using a remote emissions sensing system, the emissions performance of a vehicle travelling through an urban driving cycle on a dynamometer (comprising periods of accelerations, gear changes, constant speed and braking) was measured. Also measured was the fuel consumption. Peaks in the emissions of CO were seen during gear changes, which were thought to result from delays in the response to the releasing of the accelerator. Increased CO emissions were also observed during braking. This was also thought to be as a result of delays in the response to the accelerator pedal: The vehicle suddenly required less power and so more fuel was present in the cylinders than was needed.

At the same time the differences between an experienced and an inexperienced driver were explored. For the inexperienced driver, it was found that the increase in CO at the beginning of an acceleration period was higher. It was suggested that the inexperienced driver used the accelerator too early. Also within the constant speed periods it was noted that the inexperienced driver tended to use the control pedals rather more frequently than the experienced driver does, presumably in an attempt to maintain the required speeds. It is suggested that this type of behaviour was largely responsible for the higher emissions and fuel consumption returned by the inexperienced driver.

2.2 Noise

2.2.1 Vehicle noise

Vehicle noise is generated principally from two sources: the power train[2] and the interaction of the tyres with the road surface. Power train noise and tyre/road interaction noise are logarithmically related to engine speed and vehicle speed respectively. At typical urban traffic speeds, power train noise is generally the dominant source. At speeds above approximately 60 km/h on dry roads, tyre/road noise tends to become the most significant source of noise.

Permissible levels of vehicle noise are regulated by legislation that requires all new vehicles entering service to meet type approval noise limits specific to the class of vehicle. The specified test involves accelerating the vehicle passed a fixed microphone position under specified conditions on a standard test site. Since joining the European Community the UK has adopted the test procedures and limit values prescribed by EC Directive 92/97/EEC relating to vehicle noise. This Directive has been amended several times since its introduction and the type approval noise limits have been successively tightened as vehicle noise control technology has improved. The noise limits are enacted in the UK via the Construction and Use Regulations (HMSO, 1986).

The maximum noise level of a vehicle passing a fixed receiver position increases in proportion to the logarithm of the vehicle speed. In the case of a typical car, maximum noise levels would be expected to increase by approximately 9 dB(A)[3] per doubling of speed at speeds greater than 60 km/h (Lamure, 1975). This assumes a vehicle travelling at steady speed in top gear. At lower speeds the use of different gear ratios, and therefore different engine speeds, reduces the dependency of noise level on vehicle speed.

Whilst the vehicle is accelerating, the noise levels generated will increase with the rate of acceleration. This can occur for a number of reasons. Firstly, in the case of vehicles with petrol engines, the wide throttle opening during acceleration causes noise from the air intake to increase (Priede, 1971). Also, in order to achieve higher rates of acceleration at low vehicle speeds, the driver is likely to operate the engine at a greater speed in each gear to develop more power (Kemper, 1985). Although less significant than power train noise sources at low speeds, tyre noise also increases during acceleration as a result of increased tyre deformation at the road surface. Studies of noise close to a range of different truck tyres during rapid acceleration showed that tyre noise levels could increase by over 20 dB(A) for certain tyre types compared with noise generated at an equivalent steady speed (ERGA-

NOISE, 1993). These tests were carried out only with truck tyres under very high traction forces. However, it can be assumed that the same mechanisms that cause increases in truck tyre noise generation during acceleration also apply, to some degree, to 'light vehicle' tyres.

During deceleration, vehicle noise generally decreases with reducing speed as would be expected. The effect of braking however, can cause significant increases in tyre noise generation. For example, at test speeds of 15 km/h, tyre noise levels were found to increase by over 20 dB(A) for one particular truck tyre type undergoing severe braking (ERGA-NOISE, 1993). However, increases in tyre noise levels were generally greater during periods of rapid acceleration than severe braking. Whilst braking at higher speeds, the increases in noise were smaller. Again, these tests were carried out only with truck tyres, but the same principles can be assumed to apply to light vehicle tyres to some extent.

The contribution these increases in tyre noise make to the overall noise radiating from a vehicle will depend on the tyre type, the rate of acceleration or braking, and the vehicle speed. At low speeds power train noise tends to be dominant, but rapid acceleration can produce significant increases in tyre noise. For example, Stevens (1991) found that when vehicles accelerate at the lower speed ranges, noise from tyres can make a significant contribution to overall noise levels. This is particularly true for high-powered vehicles capable of producing large traction forces during rapid acceleration. Although increases in tyre noise are generally slightly less under braking conditions this is offset by lower levels of power train noise during deceleration. It is therefore likely that increases in tyre noise during braking can also contribute significantly to overall noise levels, especially at low speed.

2.2.2 Traffic noise

The general relationship between overall A-weighted traffic noise exposure level, mean traffic speed and composition is illustrated in Figure 4, which is taken from the prediction model developed by TRL and described in the Technical Memorandum 'Calculation of Road Traffic Noise' (CRTN) (Department of Transport and Welsh Office, 1988). The prediction method estimates levels of traffic noise exposure in terms of the $L_{A10,18h}$ noise index[4]. This index is currently used in the UK for assessing the impact of traffic noise from new and altered road schemes. It serves as the basis for determining the entitlement to sound insulation treatment of residential properties as part of the Noise Insulation Regulations of the Land Compensation Act.

The relationship between noise level and average speed shown in Figure 4 depend on the proportion of heavy vehicles in the traffic stream. The lower curve shows the relationship for traffic composed only of 'light' vehicles (or cars). In this case L_{A10} noise level increases at a rate of approximately 6 dB(A) per doubling of mean traffic speed at speeds above 30 km/h.

Figure 4 also confirms the diminishing dependency of noise level on speed at low traffic speeds. For example, in the case of traffic composed only of light vehicles, the model predicts a noise level increase of 1 dB(A) for a change of speed from 70 to 80 km/h. At lower speeds, increases of 10 km/h, say from 20 to 30 km/h do not result in any significant change in noise level. This can be attributed to the effect of gear changes at the lower speeds

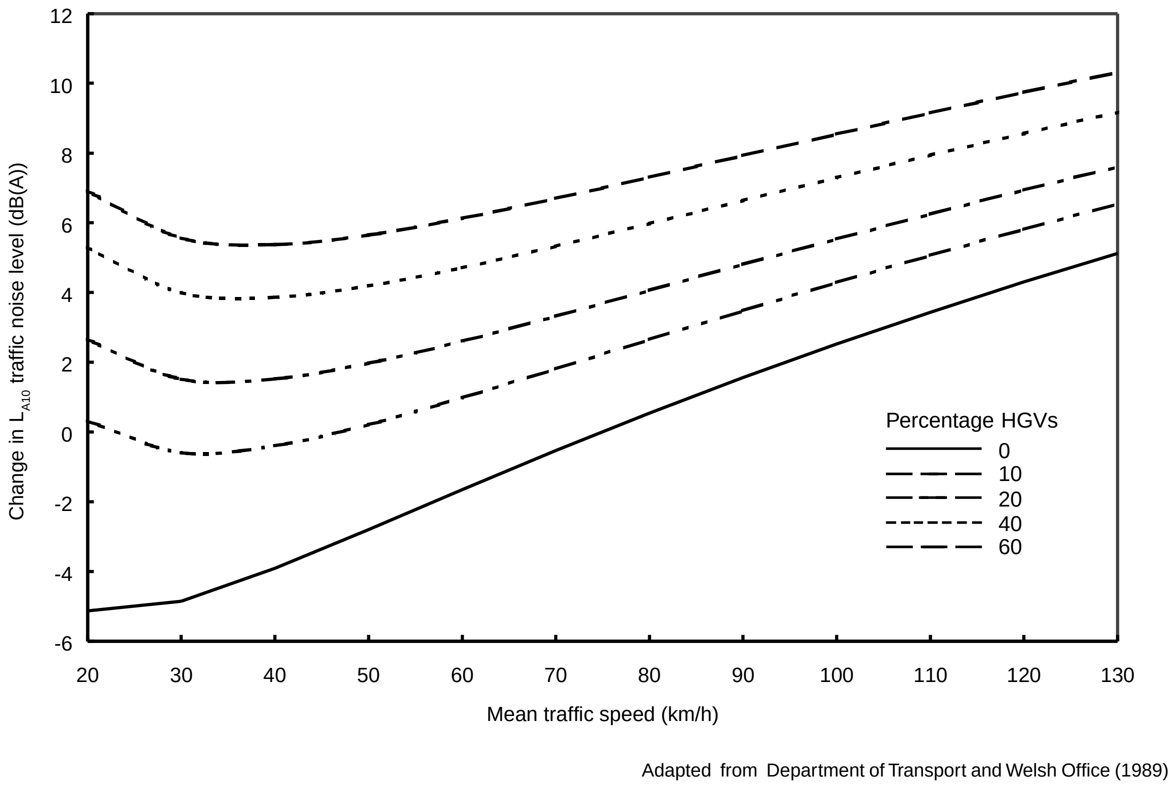

Figure 4 The relationship between traffic noise level, mean traffic speed and composition

which effectively produces a smaller overall change in engine speed as the vehicle speed changes.

2.2.3 The effect of driver behaviour on vehicle noise generation

The aspects of driver behaviour most likely to affect vehicle noise levels are the choice of speed, the rate of acceleration (particularly from low speed), the choice of gear, and rate of braking. Abelsson (1997) suggested that low noise driving behaviour is likely to have most effect in urban situations where there is considerable scope for drivers to influence noise via their choice of speed, gear and acceleration/braking rate. Travelling on higher speed roads, drivers can only have a significant influence on vehicle noise emission by their choice of speed. He identifies the following characteristics of low noise driving: smooth driving, no hard braking, no full throttle, and low speed.

A study of changes in maximum pass-by noise from individual light vehicles on an urban street was conducted by Kemper (1985) following a rigidly enforced change in speed limit from 50 to 30 km/h. The speed change resulted in a reduction in the mean pass-by noise of over 5.5 dB(A). In a study of traffic noise levels in an urban street before and after a change of speed limit from 50 to 30 km/h, noise reductions up to 2 dB(A) ($L_{Aeq,T}$[5]) were recorded (Wernsperger and Sammer, 1995). In this case the mean traffic speed did not decrease significantly despite the introduction of the low speed zone. The reductions in traffic noise level were accounted for by a change in driving style. It was observed during the 'after' study that drivers travelled at steadier speeds, tending not to accelerate and brake as rapidly as before.

The influence of acceleration rate on vehicle noise level can be considerable. Measurements of noise have been taken alongside a typical petrol engined passenger car whilst the vehicle accelerated between 0 - 40 km/h at different rates using different gear settings (Favre and Pachiaudi, 1974). As the noise was measured throughout the entire acceleration period T, the $L_{Aeq,T}$ noise index was used to record the noise level over the time period T. At the highest rate of acceleration, the target speed was achieved within 5 seconds using only first gear. Other tests were carried out at more moderate acceleration rates, taking up to 14 seconds to reach 40 km/h using first, second and third gears. The noise results from these tests showed a variation of 10 dB(A) in $L_{Aeq,T}$ depending on the rate of acceleration to the target speed.

It has also been found that the rate of acceleration is dependent on the target speed (Kemper, 1985). Pass-by noise was recorded at various vehicle speeds during accelerations to speed limits of 30 km/h and 50 km/h for a large sample of light vehicles on an urban route. For comparable speeds the highest noise levels were typically registered for vehicles accelerating up to a speed limit of 50 km/h. Drivers of vehicles accelerating only to 30 km/h did so at a more moderate rate, shifting to higher gears at lower engine speeds.

Kemper (1985) reports the potential noise benefits of training drivers to drive in a manner intended to minimise vehicle noise. Measurements of engine and exhaust noise were taken in close proximity to five different types of passenger car and four motorcycles whilst being driven around an urban route. The average noise energy over the driving period was calculated for each vehicle at a reference distance. As tyre/road surface noise was not measured, the calculation included an estimated contribution from the tyres based on vehicle speeds throughout the journey.

For each vehicle tested the driver was asked to drive the route once in their normal driving style and again using minimum engine speeds to reduce the noise emission of the vehicle. The reductions in average noise level during the journeys by adopting the low noise driving style was typically about 5 dB(A) for the cars, which represents a significant improvement. The results also showed that journey times were lengthened by less than 5 per cent in most cases and that fuel savings of between 19 and 32 per cent had been achieved.

Average noise levels for the motorcycles were reduced by between 6 and 8 dB(A) when driven in a low noise manner. Kemper also describes a similar study of noise from commercial vehicles travelling an urban route. In this case the noise measurements were performed before and after drivers had been instructed in techniques of economical driving. Reductions in vehicle fuel consumption of approximately 14% were achieved following the course. As part of the training, which gave no mention of reducing noise levels, drivers were taught to maintain low engine speeds. The results of the noise measurements showed that at speeds below 50 km/h average noise levels were reduced by about 5 dB(A).

The driving technique developed by Bongard (1992) to reduce vehicle emissions (see section 2.1.3) was designed to be taught to newly qualified drivers. As part of the method, drivers were taught to accelerate moderately, selecting higher gears as soon as possible to avoid engine speeds in excess of 2000 rpm. No results regarding the influence of the method on vehicle noise levels were reported, but it can be concluded that this type of driving behaviour would be expected to reduce vehicle noise levels as well as emissions.

2.3 Summary

Modifying driver behaviour and hence how a vehicle is operated can lead to reduced fuel consumption, noise and emission rates.

The effect of speed on pollutant emission rates, fuel consumption and vehicle and traffic noise levels has been demonstrated in the previous sections. The speed of an individual vehicle may, of course, be dictated by the presence of other vehicles in the traffic stream. However, unrestricted by slower vehicles, many drivers may elect to drive at high speed and in excess of the limit leading to increases in noise, emissions and fuel consumption. Conversely, if drivers can be encouraged to reduce speed, these adverse environmental impacts can be expected to decrease in most cases. The optimum average speed to minimise fuel consumption and emissions is about 60 km/h: for noise it is about 40 km/h.

The influence of acceleration rate on noise and pollutant emission rates has also been found to be considerable. When vehicles accelerate from stationary or low speed, the driver's choice of throttle settings and use of the gears will determine the rate of acceleration and therefore environmental impact.

Levels of tyre noise generation increase during braking operations, and therefore contribute to overall vehicle noise emissions. The degree of increase is in relation to the braking force applied and the degree of deformation caused to the tyre; the greatest increases tend to occur at low speed for a given braking force.

Several studies have considered the effect of driving style or driver behaviour on noise and pollutant emissions and fuel consumption. Potentially, fuel consumption during a typical journey may be reduced by between 10% and 30% depending on the type of trip (i.e. in urban areas or on high speed roads) and type of driver (e.g. aggressive or normal). The effect on pollutant emissions is perhaps less clear, but from the differences observed between groups of drivers in three US cities, reductions of up to about 20% for a typical journey should be possible: there is also some data to suggest that reductions could be as high as a factor of 10. Vehicle noise levels may be reduced by about 2dB(A) $_{LAeq,T}$ on streets where braking and accelerations are minimised. By minimising engine speed, the average noise energy over a journey may be reduced by 5dB(A) for cars and for motorbikes by 6-8 dB(A). Such modifications to driver behaviour or driving style may lead to a 5% increase in journey time.

3 In-vehicle technologies

3.1 Technologies to reduce emissions and fuel consumption

3.1.1 Background

The optimum driving conditions for minimising fuel consumption and the various pollutant emissions are different and depend upon a complex range of factors. Technologies can provide assistance to the driver by passively providing information on how to drive to minimise fuel and emissions or by actively changing the engine speed and load[6] to a more suitable operating condition.

Market requirements favour technologies[7] that are designed primarily to reduce fuel consumption or running costs rather than emissions. These are often orientated towards reducing the fuel consumption of Heavy Goods Vehicles (HGVs) that utilise diesel engines. There are also several devices available, which can be incorporated into cars to provide information on fuel use and other driving related variables. On some 'executive' car models a reading of fuel consumption is provided as standard. Some of the principles used to reduce fuel consumption could be adapted for pollutant emissions, since they encourage or dictate the use of particular operating conditions of the engine. However, since the optimal operating conditions for the emission rates for individual pollutants (and also fuel consumption) are different, the design or strategy used to provide information to influence driver behaviour may have to be more complex than that for fuel consumption alone.

3.1.2 Econometers and cruise control systems

An econometer is usually fitted on or in the vehicle dashboard, and provides real-time feedback to the motorist about fuel consumption. The econometer is intended to encourage drivers to drive in a more fuel efficient manner by providing them with an analogue or digital signal indicating the inlet manifold vacuum pressure (which is related to throttle position) or the rate of fuel flow.

Cruise control systems allow the driver to maintain a certain speed whilst the foot is removed from the accelerator. Its aim is to enable drivers to drive more smoothly and fuel efficiently and keep within speed limits. A typical modern electronic cruise control system would be able to preselect a speed, accelerate, decelerate, switch off, or set the speed to a previous level. When the brake or clutch pedals are touched the control system is disengaged, which allows the system to be used in congested traffic.

In 1993 a survey was carried out among motorists in the Netherlands who already had econometers installed in their cars (Dutch Ministries of Transport, Economic Affairs and Environment, no date). The motorists claimed that they could achieve fuel savings of between 5% and 10%. This survey was followed by a controlled experimental trial on the effect of econometers and cruise control systems on fuel consumption. It was concluded that in the case of private motorists the use of either the econometer or cruise control system would produce significant fuel savings of about 10% compared to a control group. A further controlled trial on business drivers showed that the use of a cruise control system improved fuel efficiency by 4.2% on average and this was considered to be a long-term effect. It was also concluded that private motorists prefer econometers because of their lower cost. Business motorists preferred cruise control systems and found the econometer irritating.

Pearce (1986) also performed similar trials on a more basic design of econometer. The device consisted of a vacuum operated light that was mounted on the facia of a car and was sensitive to the pressure in the inlet manifold. It was activated when the accelerator pedal was depressed beyond a certain level. Driving subjects chosen from TRL laboratory staff were instructed to drive economically by 'trying to drive without allowing the light to come on'. Results showed that the econometer had no significant effect on journey time or fuel consumption. It was concluded 'the device appeared to be of limited use in normal driving. Although it was possible to see the light using peripheral vision, unless an excessive amount of concentration was used, it was soon ignored. The aid, however, could have a use as a driver education device by showing the maximum acceptable throttle opening for economical driving'.

The reasons for the difference between the conclusions of the Netherlands and UK studies are not known. One possible explanation could be the peripheral location of the UK device, referred to as a shortcoming by Pearce. However differences in other aspects of the experiments may also be significant such as the design of the econometer, the choice of subjects, the instructions given to the drivers and the driving routes and types of journey. In addition, the survey sample for the Netherlands econometer derived financial benefits from any reduced fuel consumption that occurred.

3.1.3 On-board computers and integrated monitoring systems

On-board computers are sometimes included as a standard piece of equipment on some 'executive' models of car or they can be fitted retrospectively. The devices use data from a range of sensors measuring fuel flow, engine speed and vehicle speed and provide digital information back to the driver on a comprehensive range of driving related variables based around speed, driving time and fuel use. On-board computers can be used in conjunction with econometers and cruise control systems, but the attitude and responsiveness of the driver will again limit the effectiveness.

It is likely that integrated monitoring systems will be more effective in a situation where there is a well defined management procedure for monitoring, analysis and feedback of information, as has been adopted by some HGV fleet operators. An integrated monitoring system could consist of various sensors and logging equipment installed on the vehicle to monitor and record vehicle and engine speeds and brake use in terms of deceleration and duration. The user can set limits for these parameters, for instance the data logger can be programmed to record violations of maximum engine speed which if exceeded will provide a signal to the driver. Fuel consumption can also be measured, although this is usually determined by using a fuel meter, fuel tank probe or a continuous record of fuel used at the filling station by the driver.

The information collected on the logger can be downloaded to a computer via a cable, infra red signal or modem and subsequently analysed by software. Some of the logging systems can also serve as electronic tachographs providing more accessible, reliable and detailed information on driving hours and speed profiles for accident analysis purposes. The vehicle operations manager can also compare fuel use with fuel consumption targets for each vehicle.

One possible use of monitoring systems is to award demerits for inefficient driving behaviour such as speeding and excessive use of the brake (Goldrick, 1995). A league table can then be drawn up comparing each drivers' performance. This builds up friendly competition between the drivers who aim to get to the top of the league table. Incentives to drive well can be further increased by introducing a bonus scheme for drivers who consistently beat targets.

P&O Roadtanks Middlesborough have used this type of equipment aboard all their vehicles to provide instantaneous driving information to the drivers and allow fleet managers to analyse the drivers performance. 'The saving has varied but on average over the past year P&O estimate a 5% fuel saving' (March Consulting Group, 1995) whilst Goldrick (1995) estimates that 9 to 12 months would be required to reclaim the costs of the equipment.

This system is primarily designed for vehicle operators where the data can be processed and analysed by a fleet manager and in its present form would be unsuitable for private motorists. However it is possible that the process could be automated, simplified and integrated with the ECU and other sensors to provide straightforward, real-time guidance on how driving style could be changed to reduce fuel use.

3.1.4 Semi-automatic controls for fuel efficient driving

Electronic engine controls have been used with a range of heavy vehicle diesel engines to assist in fuel efficient driving by providing drivers with semi-automatic control of the engine fuelling. In a diesel engine emission and fuel consumption requirements limit the maximum fuelling rate in relation to engine speed. Some diesel engines now use two fuelling curves, one for the purposes of fuel efficiency and another for when extra power is required such as during hill climbing. This allows an engine to attain the performance of a larger power unit whilst possessing the fuel economy of one that is smaller. The decision to switch from one curve to the other is made by an electronic driving management system.

One such engine is the Cummins 310 ESP which uses electronic monitoring of the vehicle speed. It searches for the condition of a falling road speed and compares this with the speed history to identify whether the truck is demanding more power than the engine can provide, if this is the case then the engine switches to the higher fuelling curve.

Caterpillar has been developing similar dual rated diesel HGV engines since 1990. Its 'multi torque' series uses electronic controls to compare engine revs with road speed to determine the change over point to a high fuelling mode. Unlike the Cummins ESP, it is dependent upon the driver easing of the throttle to revert to a low fuelling mode.

Detroit Diesels' 'Cruise Power' system incorporates a cruise control into the engine electronics that responds to a slowing engine by increasing the fuelling until the required speed is obtained. A less skilled driver can use this feature to avoid having to move the accelerator for best economy.

Experienced drivers can replicate many of the multi-rating features with a higher powered engine by avoiding high engine speeds, high vehicle cruising speeds, and restricting full accelerator to hill climbing without having to change gear. However, this sort of driving requires discipline, an electronically controlled multi-rated engine can remove the need for that discipline.

Cars with petrol engines use a fundamentally different method of combustion than diesel powered HGVs and their power to weight ratio (which determines the maximum acceleration) is considerably greater. Therefore the devices described here, which were developed for diesel heavy-duty vehicles, may not be directly transferable to petrol cars. However, there are analogous methods in which fuel consumption or emission rates for cars can potentially be reduced by using a semi-automatic in-vehicle device or by using the accelerator more effectively.

The three-way catalyst used in modern petrol operates most effectively with a stoichiometric air fuel mixture. At high throttle openings a rich mixture, is required to achieve smooth acceleration; under these conditions the oxidation catalyst (which lowers CO and HC emissions) is less effective and relatively large quantities of these emissions will be produced. It is therefore likely that a method of limiting the throttle or fuelling level could be used to lower CO and HC emissions. This could be achieved by a semi-automatic method similar to that described for HGVs or by a passive system providing a warning to the driver when the critical fuelling level is exceeded. The total benefit will depend on how often vehicles normally exceed the critical fuelling level and to what level drivers will change their driving characteristics accordingly.

3.1.5 Speed limiters and speed limits

In August 1992 speed limiters became mandatory on all new HGVs. The speed limit was initially set to 60 mph but was reduced to 56 mph for new vehicles from January 1994 (Montgomerie, 1994). For coaches speed limiters became mandatory on all new vehicles greater than 7.5 tonnes GVW, capable of exceeding 70mph and with more than 16 seats. In addition, a retrofit programme was inaugurated requiring all coaches registered after 1984 to be fitted with limiters by April 1990.

Cars are not normally fitted with speed limiters, but these may be used to improve fuel economy. A speed limiter may save fuel in two ways: by limiting the maximum speed of the vehicle and by restricting the engine operating speed to the most efficient range. By limiting the engine speed, in effect the power available from the engine is also reduced. Therefore in some respects, using a speed limiter is similar to using a smaller engine: the power and maximum fuelling rate are both reduced. However, the operating conditions of the two engines are likely to be different, and in some cases using a smaller engine would be more beneficial, in terms of fuel efficiency, than using a larger one fitted with a speed limiter.

In the summer of 1995, a variable speed limit pilot scheme was introduced onto part of the M25 Motorway to avoid the start/stop and ‘bunching’ that sometimes occurs during periods of heavy congestion. The legal speed limits were reduced to 97 or 80 km/hr (60 or 50 mph), depending upon the amount of congestion. TRL was commissioned to investigate the effect of the variable speed limits by using an instrumented car to collect speed data before and after the speed limits were implemented (Barlow, 1997). This information was used to develop high-speed emission factors to establish the short-term effect of the variable speed limits on CO_2, CO, HC and NO_x emissions. The overall effect of introducing the variable speed limits was a reduction in CO and NO_x of 10% and 12% respectively, a 14% reduction of particulates from diesels, little change in CO_2 and fuel consumption, and an increase in HC emissions of 19%.

3.1.6 Transport telematics

Transport telematics has the potential to reduce fuel consumption and emissions in a number of ways. First, by improving traffic management procedures, congestion should be reduced. This would decrease the proportion of transient driving such as starting and stopping in congested traffic. Secondly, an interactive system could take account of traffic conditions and provide the driver with information on optimum acceleration and deceleration rates and speed so as to minimise fuel consumption and emissions without significantly affecting transit times. There is also scope for direct, automatic limitation of vehicle speeds and accelerations to suit specific locations and prevailing conditions. This would provide a far more flexible alternative to the speed limiters discussed previously. However, minimum levels of speed and acceleration may be necessary for safety in certain situations, and it would be possible to provide an override facility in which the limit can be temporarily disabled. As an alternative to automatic control, the telematics system could activate a warning to the driver that could be ignored if necessary, or could be used to change the ‘feel’ of the accelerator pedal.

Limiting the acceleration and speed of telematics-equipped vehicles could affect, perhaps adversely, fuel consumption and emissions from other traffic e.g. by causing other vehicles to brake. Such effects need further investigation if we are to be able to identify the types of situation where a positive net effect could be expected.

There are a number of telematic systems that have the potential to use two-way communications between the vehicle and road infrastructure for the purposes of controlling accelerations and speeds. These are based on Dedicated Short Range Communications (DSRC) systems (Ove Arup & Partners 1997). In their present form these involve communication between roadside beacons and In Vehicle Units (IVU) such as a ‘smartcard’ interface. A typical application of this technology would be in road tolling. This technology is being developed further in the Road Traffic Advisor Project (RTA)[8] which will demonstrate the use of telematics to inform drivers and passengers of road congestion, traffic speeds, weather conditions and estimated time of arrival. The information will also be used by the driver to set the cruise control or ‘haptic’ throttle system with the appropriate speed. A haptic throttle system is a mechanical device that increases the resistance the driver experiences on an accelerator pedal in relation to a set speed. There is also provision in the project to investigate the potential of using a remote control signal to re-program elements of the engine management system so as to vary emission rates in accordance with the prevailing environmental conditions. For example, in some circumstances, it may be environmentally beneficial to reduce emissions of one pollutant at the expense of an increase in another.

3.2 In-vehicle technologies to encourage quieter driving

Existing information feedback systems such as those described above might promote an economical driving style if used effectively. As a secondary benefit they may also reduce vehicle noise levels if low engine speeds are maintained and acceleration moderated. In principle it would be possible to include a separate instrument registering vehicle noise emission. This would either calculate approximate exterior noise level based on parameters of engine speed, road speed and throttle setting, or would detect exterior vehicle noise levels at some location on the vehicle.

The noise experienced inside the vehicle may also influence driving style. Developments in vehicle interior noise refinement have enabled car manufacturers to optimise the character of the noise transmitted to the vehicle cabin. To this end, research has been conducted to identify and enhance noise characteristics that drivers consider desirable for different driving conditions. For example, at constant speeds a quiet, regular noise free of mechanical harshness is considered synonymous with luxury and reliability (Bisping, 1997). During acceleration certain engine noise characteristics suggestive of high engine power are often favoured, especially by drivers of high performance cars (Alt et al., 1996). The effect of this type of noise refinement on driving behaviour is perhaps to make the driver more likely to accelerate rapidly. Hutchins et al. (1992) reports that driving style is affected by interior noise quality. In their study, changes in the interior noise of a test vehicle to give it the sound of a higher performance car, led to the use of higher engine speeds and more frequent gear changing. Other modifications to interior noise may act to reduce speed and acceleration. Psycho-acoustic research carried out by Bisping (described in an article by Lewis, 1997) for a major vehicle manufacturer suggests that the character of the interior noise may be effective in countering certain driving behaviours. For example, Bisping’s studies using synthesised sounds inside cars indicate that if a driver is speeding, making the car sound as though it is travelling even faster will cause the driver to slow down. It is also claimed that changes in interior noise quality can counteract aggressive driving such as excessive acceleration and braking.

If interior noise can influence speed and acceleration, it can also influence external noise emissions from vehicles. This raises the possibility that noise control technology might be applied to encourage quieter driving. An on-board computer capable of monitoring driving style and synthesising the appropriate modification to the existing interior noise might therefore be effective at modifying driving style, thereby changing external noise emissions, exhaust emissions and safety.

Despite the potential safety and environmental benefits of a reactive interior noise system such as this, vehicle manufacturers might be reluctant to deliberately introduce noise into their vehicles because of concerns that it might detract from the image and enjoyment of their product.

3.3 Summary

Most current in-vehicle technologies that may be used to encourage environmentally friendly driving are designed to reduce fuel consumption or running costs rather than emissions. Two of the most common types of system that have been employed in cars are econometers and cruise control systems. Cruise control systems may reduce fuel consumption by about 4%. In one study econometers were shown to reduce fuel consumption by 5 to 10%, although in another no effect on fuel consumption was observed.

Some vehicles are now fitted with an on-board computer that can provide information to the driver on a comprehensive range of driving-related variables associated with speed, driving time and fuel use. These can be used in conjunction with econometers and cruise control systems, but the attitude and responsiveness of the driver will be important in determining their effectiveness. Such systems are more likely to be effective in a situation where there is a well defined management procedure for monitoring, analysis and feedback of information. Such monitoring systems have been adopted by some HGV fleet operators with one operator claiming fuel savings of about 5%.

Variable speed limits on motorways can reduce congestion and certain emissions. It is estimated that the recent M25 variable speed limit trial reduced emissions of CO, NO_x and particulates, increased HC but produced little change in CO_2 and fuel consumption.

Limiting acceleration or maximum speed could reduce CO and HC emissions from petrol fuelled vehicles. A telematics based system could be used to activate speed/ acceleration limiters, provide warning information to drivers, or change the feel or response characteristics of the accelerator pedal within sensitive environmental areas or during periods of poor air quality.

To the extent that feedback systems designed to reduce fuel consumption and exhaust emissions are effective in changing driver behaviour, they may also produce useful reductions in noise emissions. However, feedback systems dedicated to noise reduction for its own sake would also be feasible. As with econometers and cruise control systems, effectiveness would depend on drivers’ motivations to reduce noise. Modifying vehicle interior noise has been shown to have the potential of influencing both speed and acceleration, and if such effects can be shown to persist, interior noise could be used as a form of feedback to encourage low-noise driving behaviour. It is possible that this would be less reliant on drivers’ motivations, than would other types of feedback. Telematics systems that control vehicle operation directly (e.g. by limiting speed and acceleration) or which assist drivers to choose acceptable speeds and accelerations, could be effective in reducing noise in particular areas, just as they could in reducing exhaust emissions.

4 The provision of driver training

4.1 Background

Most car drivers in the UK receive no extra driver training after passing their driving test. A small number of individual drivers choose to undertake an advanced driving test that may require additional training. The most popular of these tests are provided by the Institute of Advanced Motorists (IAM), with about 100,000 members currently, and the Royal Society for the Prevention of Accidents’

Advanced Drivers Association (RoSPA) which has about 10,000 members.

In 1995 a Government initiative (‘Pass Plus’) was introduced with the objective of reducing the number of novice driver accidents by encouraging newly qualified drivers to undertake additional driver training (see section 6.3). The incentive for undertaking this training (apart from becoming a safer driver) was to receive discounts from the insurance companies and agents that support the scheme. An evaluation of the Pass Plus scheme (Simpson, 1995 and 1997) found that the take-up of training at that time was very low with only about 2% of eligible novice drivers deciding to take part. The DETR has recently ‘re-launched’ the scheme to try and increase the numbers of drivers taking part.

Fleet drivers represent a significant proportion of UK drivers (especially when compared to other EU countries) and typically their annual mileages are higher than average. They are also involved in more accidents than other drivers: Lynn and Lockwood (1998) showed that company car drivers had about 50% more accidents than ordinary drivers, even after allowance had been made for their higher than average mileage. A sizeable number of organisations currently provide fleet driver training and, in the first instance, it may be more effective to target fleet drivers in order to encourage the uptake of environmentally friendly driver training. Ultimately the aim would be to encourage private motorists to undertake further training to modify their driving behaviour in a more environmentally beneficial way.

It is estimated that approximately 2-3% of the 1.95 million fleet drivers in Great Britain receives formal training each year (Kompfner and Divey, 1992). A survey conducted by a major insurance company in 1990 found that, although nine per cent of fleets provided some training, only one per cent of drivers had actually been on a course (Social Surveys (Gallup Poll) Ltd, 1990).

The following sections describe the types of courses currently available in the UK and the views of training providers and fleet managers on the effectiveness of training.

4.2 Training courses in the UK

4.2.1 Introduction

Post-test training providers and fleet managers were interviewed as part of this project. Four training providers were asked about their courses and their views on training for ‘greener’ driving. Four fleet managers/operators were interviewed to discuss possible incentives and training experiences. A summary of the key findings is given below. It should be noted that the views expressed in this section are those of the company representatives interviewed as interpreted by the TRL researchers. These views should not necessarily be taken to be those of the company as a whole, or of the authors of this report.

4.2.2 The objectives of fleet driver training

The main reasons a company may wish to have its drivers undergo a driver training course were said to be to:

- address general Health and Safety issues;
- reduce the fleet’s incidence of accidents;
- reduce repair costs;
- reduce vehicle replacement costs;
- reduce insurance costs;
- reduce fuel costs by increasing driver efficiency;
- improve or maintain company image.

4.2.3 What does driver training currently entail?

The number of drivers trained in a year, by the training providers interviewed, varied considerably, from 1,500 to 33,000. The majority of these drivers are from fleet organisations, but the training providers estimated that less than four per cent of fleet drivers receive driver training. The cost of a training course generally starts from £225-£250 per trainer per day with one trainer working with between one and three drivers.

The training providers interviewed generally tailor the course to the client’s needs. In almost all cases, the courses concentrate on ‘defensive’ driving. Police training is focused on the ‘Roadcraft’ driving manual on defensive driving (Roadcraft**,** 1994). Other ‘defensive driving’ training providers also work to the general principles of this textbook.

Defensive driving uses a ‘system’ of car control. Observation, positioning, speed, and the use of accelerator, brakes and gears, are all held to contribute to:

> *‘a way of approaching and negotiating hazards that is methodical, safe and leaves nothing to chance...It is a systematic way of dealing with an unpredictable environment’ (Roadcraft, 1994).*

Some training providers who do not focus on this style of instruction instead specialise in particular aspects of driving such as anti-skid training. Others attempt to create an awareness of the need for good observation and anticipation skills, without emphasising vehicle control.

All those interviewed said that the training they offer attempts to develop skills in concentration, observation and anticipation. The intention is to reduce accident risk by teaching drivers to observe, recognise and deal effectively with hazards in a planned way, understanding what aspects of driving will cause them to be at greater risk:

> *‘If you can get people to look further ahead, recognise where the hazards are, what problems might arise and what they are going to do about it, automatically it gives them more time to plan and more time to be able to reduce their speed and control what they are doing and think about a suitable safety option.’*

Drivers are taught to manage both space and time, on the argument that accidents occur when the driver runs out of either of these. The training aims to give drivers the tools to be creative in their use of time and space. Although their perceived speed may be reduced, their actual rate of progress increases.

Environmental issues are often discussed with the client when planning the course. Where the client is more interested in the safety benefits of the training, the provider may stress the economic benefits of teaching awareness of fuel consumption and how to reduce it. For some clients, environmental concerns are seen as an additional benefit from the training but not the major focus. Not surprisingly, the training providers have all found that some companies are mainly interested in the cost savings that could result from training. The AA has carried out its own unpublished research on the aspects of driving that affect fuel consumption and has built these findings into the course content.

It was noted that the emphasis on training is changing: more clients are specifying that the course cover 'green' driving styles and requesting that the training provider has an environmental policy. As a response to this, the IAM has an environmental mission statement that is part of its company policy. The companies that would be particularly keen to see this type of training were said to be those that are more aware of the environmental issues of their activities, such as the chemical, pharmaceutical and petrochemical industries, and those with a high public profile keen to promote their environmental performance.

The training providers teach environmental issues explicitly or implicitly, depending on the requirements of the company requesting the training. They maintain that defensive driving leads to a more environmentally friendly way of driving, i.e. to reduced fuel consumption and emissions. Some courses explicitly link the training to potential reductions in fuel consumption. None of the training providers perceived a conflict between safety and environmental training.

Where the training providers address environmentally beneficial driving, drivers are taught how to:

1 Use the gears, accelerator and brake pedals economically. Drivers are taught economical use of the gears by being shown where gears can be skipped. This means, when slowing down, that the gear change is left until the driver can judge which gear they need. Similarly, when changing up, gears can be skipped, depending on the vehicle and road conditions. In fact the extent of the benefits obtained by skipping does not appear to have been directly measured and it may turn out that speed and acceleration are the more important parameters. One of the training providers noted that as vehicle technology changes, so does the most efficient way of driving the vehicle, so that aspects of environmental training may need to be updated frequently.

2 Relate driving styles to reductions in fuel consumption. For example, longer distances between vehicles means less harsh braking and in most cases, fewer excessive accelerations. Harsh braking and accelerating can lead to higher fuel consumption, higher noise levels and more rapid wear of tyres.

3 Carry loads efficiently by optimising weight distribution and removing roof racks when not in use to reduce fuel consumption.

4 Judge when to switch off the ignition when at a standstill.

5 Be 'lighter' on the accelerator so as not to waste fuel. Drivers are shown that accelerating rapidly does not lead to an appreciably shorter journey time.

The training discussed above relates mainly to driving style, but other aspects of environmentally friendly driving for example route planning, are being considered by some training providers for inclusion in courses.

4.2.4 Views on the effectiveness of fleet driver training and factors affecting its uptake

Evidence on the effectiveness of training is reviewed in Chapter 5, but it is instructive here to examine the views of training providers and their customers on this issue.

The fleet managers and haulage operator interviewed stated that companies considering whether to purchase driver training are strongly influenced by cost-effectiveness, but that the costs and benefits are difficult to quantify. Whereas driver training is a very concrete cost to the company (both in terms of the actual cost of the training and the 'down time' whilst the driver is on the course), any benefits are not guaranteed. It is very hard, for example, to quantify the hidden costs of accident involvement to the client and to predict how much these will be reduced by training. These potential consumers of training see a lack of any substantial information regarding the effectiveness of training as a major problem. One of the training providers suggested that fleet operators are, in some case, reluctant to accept that a driver's behaviour can be modified. This makes it difficult to provide a convincing case for training to a fleet company concerned with the cost effectiveness aspect of the course.

The haulage company, McKelvie & Co. developed its own comprehensive in-house training scheme which was evaluated and detailed as a case study within the Energy Efficiency Best Practice Programme (EEBPP) (Department of the Environment, 1995). The scheme is one of the few where an in-depth evaluation is available to show extensive savings in accident involvement, accident costs and fuel consumption over a four-year period.

Since that study, McKelvie & Co. has been absorbed into the Transport Development Group (TDG). The company maintains its commitment to driver training for safety and fuel conservation and continues to provide in-house driver training. It currently employs four to five training managers, fifteen training providers (whose sole role in the company is to provide driver training), and over 100 driver assessors. Every applicant for a driving job is assessed by means of a one-hour test drive and a written test. The applicant has to pass both to qualify for an interview. TDG has developed a Five Star Driver Development Plan and, through this, every driver in the company undergoes a continual five-year training programme. The training follows a predetermined curriculum for each of the five years, and at the successful completion of each year the driver receives a certificate. The training is broadly aimed at defensive driving and driving to improve fuel conservation. TDG believes that a successful programme is dependent upon ongoing training and assessment.

Due to factors such as vehicle and driver replacement, the TDG believes that accurately measuring reductions in fuel consumption is very difficult. To help overcome such problems TDG is using various in-vehicle technologies to measure, for example, running times, drop times, over-revving and braking (these activities have also been shown to reduce fuel consumption as reported in section 3.1.3). The company was not willing to provide details of actual savings but maintains that the programme is still producing reductions in fuel consumption. By 1994 TDG claimed to have achieved a fuel saving of at least 11% on 1990 levels. The company also maintains that its accident rates are reducing and claims a 35% improvement over four years (1995 to 1998). TDG states that whilst benefits are still being seen, there is a threshold that cannot be exceeded by any training.

The focus of the TDG training is now being extended to particular types of accidents such as those occurring at low speeds. It is hoped that this will help achieve even greater reductions.

Some car fleets, e.g. those with sales representatives, have a high staff turnover. This leads to difficulties in evaluating the effectiveness of training programmes. It was commented that such companies also tend to have the highest accident rates because their drivers are predominantly young males whose primary concern is the speed at which they can get to the next appointment. Such drivers were said to require training but it was not seen as cost effective to train people who may not stay with the company. Agency drivers may also be employed. One company was particularly interested in training its company car drivers as they, unlike its van drivers, had not been employed on the basis of their driving skills.

Through its accident management function, the role of one of the companies interviewed is to provide an accident risk analysis for each client’s fleet. Part of this includes recommendations as to whether driver training is needed. In some instances, the company will then attempt to quantify the costs and benefits of training. Due to the number of issues involved and the company decision making process, a decision as to whether to carry out driver training can take at least 6-12 months after the initial suggestion.

A number of ‘accident/risk management’ firms stress this fundamental need for a change in a company’s ‘safety culture’ rather than just promoting driver training. Some training providers aim to improve driving skills, some focus on changing attitudes while some include stress management as part of their programme. Most training providers acknowledge that companies are different and each one needs a specially tailored training and/or management solution.

There is general agreement that objective and independent information about the role of company culture and driver training on safety and fleet costs is urgently required. Some organisations now offer monitoring software to assist fleet managers in understanding and correcting their safety problems. Improvements are typically based on cost and efficiency savings rather than obtaining ‘simple’ safety or environmental benefits.

It was noted that whilst training companies may claim that training can improve the resale price of vehicles, in practice resale prices are usually based on vehicle mileage and no attention is paid to how well the vehicle has been driven.

It was commented that perhaps the only way to encourage training would be to offer incentives comparable to those offered by the insurance companies in relation to standard driver training. The current situation was said to offer no incentive to engage in post-test training. To remedy this, it was suggested that the Government would need to take an approach that either forces companies to take action, or provides convincing evidence that any training would prove cost effective.

Training is not the only means by which companies seek to change the behaviour of their drivers. Some organisations employ environmental managers, who are very involved in environmental issues and concerns, setting targets for fuel consumption and providing incentives for staff to choose more efficient vehicles as company cars. One of the companies interviewed had gained ISO 14001 accreditation for its environmental management systems. The award does not set standards or measures that must be followed, instead it ensures the company as a whole has an ‘ongoing programme of environmental improvement’. Both this and another company had considered relating fuel consumption to an incentive scheme, but both had rejected it because of difficulties in its administration.

4.3 Driver training in Canada

A search of the Internet revealed that both Canada and the Netherlands have driver training programs to reduce fuel consumption and vehicle emissions. Only a limited response has been received from the organisations involved in the Netherlands. Contact was made with the organisations involved in Canada and this section details their relevant initiatives.

Formed in April 1998, the Office of Energy Efficiency (OEE) manages programmes in energy efficiency and alternative fuels for Natural Resources Canada (NRCan), the federal Ministry responsible for energy, minerals, forestry and geological work. Two of the programmes, Auto$mart and FleetSmart, are aimed at fleet managers and motorists to help them reduce fuel costs and vehicle emissions.

Within both programmes, the OEE offers tools to train drivers in fuel-efficient driving (Paton, 1998). The Auto$mart programme promotes energy efficiency to the motoring public through publications, promotional initiatives and joint projects with the vehicle industry. Examples are the EnerGuide label for vehicles (a voluntary fuel consumption labelling programme with vehicle manufacturers), and Auto$mart’s role in AutoLink (a private sector initiative in the motor repair industry which promotes regular vehicle maintenance as a means to save money and reduce emissions).

The Auto$mart Student Driving Kit was introduced to driver training providers over the past year. The Kit provides tools for instructors of new drivers, generally in the 15 to 18 year age group. It is the result of considerable market research with other agencies in this field, and with driver trainers and their youth audience. The Kit includes Instructor materials, handout materials, a video and a CD-ROM. The OEE involved stakeholders in the field of driver training, energy efficiency and/or consumer associations in the development of the training materials and have entered partnerships with other government agencies and with driver training associations to deliver the materials. Over 500 driver trainers are currently using the Kit, reaching over 300,000 new drivers each year. Evaluation is at a very early stage. There are no formal policies or incentives to encourage take-up. The OEE experience is that it is difficult for the driver training industry to find good materials. It is hoped that the quality of the Kit ensures easy take up by trainers and incorporation into their programs.

The FleetSmart programme encourages energy efficiency in fleet operations. Over 330 fleets have registered with the program, representing over 85,000 vehicles. Participants receive a FleetSmart Tool Kit and work with the OEE to develop strategies to improve energy management in fleets. The OEE is in the process of setting up stakeholder committees in a number of sectors to develop strategies and plans to improve energy use data, better information on barriers to energy efficiency, best practices, topical workshops and benchmarking.

Driver training is a priority within the trucking industry in Canada and the OEE has worked with stakeholders over the past year and a half to develop SmartDriver, a training package for trainers of professional drivers. The package includes material on energy efficient driving, hand-outs including a booklet for professional drivers which will be published shortly, a video, an interactive card game (to stimulate discussion) and overhead projector transparencies. Market research with trainers showed that there was real interest in such materials and recent industry surveys show that over 50 percent of drivers are interested in training in energy efficient driving skills. The SmartDriver package was to be introduced autumn 1998. A similar training package for the logging industry will be produced over the coming year.

A number of case studies have been carried out of companies involved in the FleetSmart programme (Natural Resources Canada, 1996, 1997a, 1997b, 1997c, 1997d, 1997e, 1997f). The companies involved have fleets of mainly HGVs, but some included cars and light vans. Two of the fleets are municipal departments whilst the others are involved in the distribution or transportation of goods.

Many of the companies have installed equipment into vehicles to monitor and log for example fuel consumption, the use of brakes, speed limit violations, the time spent idling (inefficient use of fuel and increased engine wear), and the time spent in cruise control (more efficient use of fuel). This data is then analysed and used to track these parameters for particular vehicles or drivers or journeys. Some of the companies use a computerised fleet management system for tracking. At least one company also uses a computerised system to optimise delivery routes.

All of the fleets have some form of driver training, but the content and length of training is variable. Some of the training programmes are in-house and are part of the induction to the company. Training generally involves classroom and practical demonstrations tackling both fuel efficiency and safety issues. Drivers are taught to reduce idling, progressive use of gears, smooth driving techniques and compliance with speed limits.

The use of incentives was only reported in one case. Here there was an acknowledgement of individual achievements and also rebates for departments according to their contribution to the overall fuel savings of the organisation

The companies involved reported fuel savings of between 5% and 10%.

4.4 Summary

Fleet driver training in the UK generally emphasises improved concentration, observation and anticipation skills as the key to safer driving. Courses specifically dedicated to environmental training are not provided by any of the organisations interviewed, but the level of coverage of environmental issues within the existing safety training courses varies considerably. It was felt that the level of environmental training requested by clients was increasing, primarily for cost-related reasons. All training providers believed that due to the nature of the driving styles they emphasise throughout their training, safe driving is also environmentally beneficial, and the two aims are compatible. Case studies of haulage fleets both in the UK and Canada report that driver training, along with in-vehicle monitoring, can lead to savings in fuel of up to 11%.

Whilst training is available, fleet managers are often reluctant to purchase driver training due to its costs. This reluctance is demonstrated in the literature, which shows that low proportions of companies have their drivers trained. A lack of evidence on the quantified effects of engaging drivers in a training programme, combined with a lack of incentives, were cited by participants in the present study as limiting the uptake of training.

In contrast a small proportion of organisations have a strong commitment to environmental issues and reducing fuel consumption of their fleets. Within these organisations driver training tends to be part of a company-wide environmental policy. The organisations most likely to engage in a programme of driver training to achieve environmental benefits are those where an awareness of environmental issues is recognised as beneficial to their business.

5 Effectiveness of driver training - the evidence

5.1 Safety benefits of driver training

As discussed in section 4.2 the training organisations contacted as part of this study tend to claim that professional post-test driver training results in significant benefits in terms of safety, economy and maintenance, as well as reducing driver stress. Other providers and consumers of driver training hold similar views. For example, RoSPA's Driver Services estimate 'that driver training can result in a reduction in blameworthy accidents of the order of 30-70% in the first two years' (RoSPA, undated). The Association of Car Fleet Operators (ACFO) published the results of a small survey of UK fleet operators and key training providers (ACFO, 1997). Although the sample sizes used are unclear (comprising 50 member companies and 50 non-members), the results showed that 37% claimed to have seen a benefit in insurance premium reductions following driver training. There were also claims of fewer accidents (76% reported this) and 53% claimed the cost per accident was reduced. The report gave no estimates of the monetary values that could be attributed to these savings. It was also concluded that the statistics available relating to training effects are 'sparse, confusing and occasionally contradictory'. The numbers of companies mentioning any environmental benefits were too small to register in the results. A review of the promotional material provided by the UK's main training organisations found statements that their programmes had produced significant improvements in terms of safety, fuel costs and vehicle maintenance. Accident reductions as large as 75% have been cited, although claimed improvements of between 25 and 50% are more typical.

Although training providers and their clients believe that post-test driver training improves safety, the evidence on which such beliefs are based is usually difficult to pin down. No doubt this is due in part to a lack of opportunities to conduct properly designed evaluative studies involving large enough samples of drivers, although there may have been good studies that fleet operators are reluctant to release for commercial reasons.

Where research studies have been undertaken, their findings are generally less supportive of the link between training and safety. Hoinville et al. (1972) found that drivers who passed the IAM test had about 25% fewer accidents than those who failed, indicating that the driving skills required to pass the IAM test can have significant benefits in terms of safety. However, it does not necessarily follow that training the general population of drivers in such skills would yield the same benefit: IAM candidates are unlikely to be representative of the general population of drivers in terms of attitudes and motivations towards safe driving. Kompfner and Divey (1992) also showed that car drivers who had passed the IAM test were involved in fewer accidents (about 17% fewer) than 'ordinary' drivers after factors such as age, gender, experience, exposure and socio-economic group were taken into account. Again, though, we cannot be sure whether it is the IAM training, or the self-selected nature of the sample that produces this difference in safety.

Jones (1993) conducted a survey of 186 British companies to see if the introduction of driver training courses resulted in a reduction in insurance costs. Only 19% of the companies in the sample had introduced driver training. Of these 22% reported that insurance costs had been reduced while 44% reported that costs had not reduced. Of those companies that had taken any action to reduce insurance costs, 44% said that simply monitoring accidents was effective, 15% reported that driver training was found to be effective, and 1% reported that paying a small 'no-accident' bonus worked.

A number of studies outside the UK have examined whether training reduces accident rates. For example, studies by Manders (1984 and 1986) in Australia were also unable to show significant reductions in accident numbers as a result of training. However introducing a package of initiatives, which included actions such as appointing an individual with the responsibility for reducing accidents, did produce safety benefits.

Lund and Williams (1985) conducted an extensive review of the literature evaluating the defensive driving course and concluded that there were no clear safety benefits that could be attached to the training. The study found that the training resulted in a 10% reduction in the numbers of driving convictions, and thus appeared to have modified behaviour. However this was not enough to be able to detect a significant drop in accident involvement, and the report also suggested that the sample of drivers undergoing training was not representative of the general driving population.

In a more recent review carried out for the Insurance Institute for Highway Safety, Mayhew and Simpson (1996) found little evidence to support the claim that driver training is an effective safety countermeasure. They therefore recommended that training should not, in the current state of knowledge, be introduced as part of a graduated licensing system, or allowed as a way of obtaining accelerated progress through a graduated licensing system. The authors suggested that it may be possible to improve driver training so that it does improve safety, but that this has yet to be demonstrated.

Perhaps the most promising published evidence for the effectiveness of driver training has been provided in a study by Gregersen et al (1996). The study investigated the effect of four different fleet management techniques on the accident involvement and average cost per accident of professional drivers at a Swedish telecommunications company. The driver training program was developed as a result of research into skid training, which is mandatory across Scandinavia. Previous research had shown skid training to increase the accident rate of young, novice drivers for accidents involving single vehicles and loss of control on slippery roads. This was attributed to drivers' lack of insight into their limitations. The successful course developed by Gregersen et al. (1996) therefore provided the drivers with the basic skills to control the car in specific situations on icy roads and also 'insight' training to make the driver aware of situations on icy roads that they cannot handle.

The course was specifically designed for use in the study and hence not comparable with that provided by commercial training organisations. It was found to reduce significantly the accident involvement of the drivers in the trained group from over 0.14 accidents per 10,000 km to just over 0.08 accidents per km, the average accident costs were also reduced by approximately 300SEK per 10,000 km; after training had been received.

A programme of group discussions was also shown to be effective in reducing accidents. The three, one hour sessions concentrated on identifying problems, identifying the solutions and the measures and changes in driver behaviour that individual group members would take forward. This activity was shown to reduce accident involvement from 0.17 to under 0.08 accidents per 10,000 km.

The training used in the study also used a fuel consumption meter to demonstrate how different driving styles influence this. It was believed that convincing the driver that secondary motives such as economy or protecting the environment are important for the company, society and the individual, would lead to a safer driving style even in the absence of an explicit safety motive.

There are many possible reasons for the discrepancy between the research literature's generally pessimistic conclusions regarding the effectiveness of driver training, and the more optimistic views of trainers and fleet operators. One is that the introduction of training within an organisation often takes place alongside other safety-related management changes, reflecting the 'safety culture' of the organisation. It is therefore possible that improvements attributed by the company to training may in fact be due the other safety interventions. Such interventions may be effective in themselves, for example Lynn and Lockwood (1992) report that drivers offered a reward had 35% fewer accidents, and were usually offered less than £60 a year. It also seems likely that there is a synergystic relationship between training and other safety interventions: it may be that training gives drivers the ability to perform better, but needs to be supported by other measures that persuade them to make use of this ability. This is taken up further in the next section.

It should be noted that apparently successful safety initiatives may in fact have their effect by distorting the accident reporting system. For example, Ney (1990) found that 35% of fleet accidents were reported as 'hit while parked'. Furthermore, companies that introduce training because they have experienced a peak in accidents may then attribute a subsequent fall in accidents to the training, whereas in fact a fall would be expected even if no action were taken. This tendency for accident rates to fall back to usual levels after a chance peak is known as the 'regression' effect.

5.2 Why are the benefits of training largely unproven?

5.2.1 Motivational factors

Given the general lack of good quality evidence showing that post-test driver training has safety benefits it is necessary to ask why this should be, and what the implications are for the present project.

McKenna and Crick (1994) suggested several reasons why the benefits of driver training remain largely unproven. For example, there may not have been enough 'good' evaluative studies, the best training may not have been evaluated, or the training currently available may not address aspects of driving that are related to accidents, such as hazard perception.

The underlying assumption here is that training with the 'correct' content will have benefits that could be detected if enough good evaluation studies were done. There may, however, be a more fundamental limit on what can be achieved by training alone, in an environment such as driving which gives people a great deal of choice about how they behave.

Driving involves a variety of skills and abilities. As well as the ongoing task of manipulating the car's controls, drivers need to continuously monitor their environment and take decisions about their own speed and direction as well as anticipating the actions of other road users. The way a driver behaves will be influenced to a greater or lesser extent by:

- psychomotor and perceptual skills (e.g. steering and visual search);
- cognitive skills (e.g. hazard recognition and assessment; decision making);
- transient factors (such as fatigue, alcohol consumption, mood);
- motivational and attitudinal factors.

The effects of driver training may be limited because, although it has a positive effect on improving perceptual and cognitive skills, it is less able to influence other factors affecting behaviour. Training may provide drivers with the necessary skills to *enable* them to drive in a desired way (e.g. safely, economically, quietly), but it does not necessarily change the way they *choose* to drive. This is the distinction often made by traffic psychologists between a driver's performance and his or her actual driving behaviour. It implies that whilst training may (sometimes) be necessary if a desired change in driver behaviour is to be achieved, it is not always sufficient to ensure that the change takes place. In short, it appears that training may need to be supported by measures that seek to encourage drivers to choose to drive in a safe and environmentally friendly manner.

Whilst engineering (of both the road and the vehicle) and enforcement (for example, of speed limits) will have an important role to play in influencing how drivers choose to drive, it is likely that education will play a key role as well. In vehicle fleets, incentive schemes and other management controls are appropriate, as is the removal of working pressures that encourage excessive speeds. Education of fleet and private drivers would need to target the attitudes and beliefs that influence the way a driver chooses to behave. To achieve this, it will be desirable to use and build on existing models of human behaviour such as the Theory of Planned Behaviour (Ajzen, 1985). This has been used recently to examine different aspects of driver behaviour such as drink-driving and speeding (Stradling et al., 1992; Parker et al., 1995).

Advertisements that stress a car's power, acceleration and speed may influence behaviour, encouraging people to choose vehicles, and to drive them, in a way that is not compatible with environmental and safety objectives.

Social Dilemma Theory (Van Vugt, 1997) could be considered when attempting to persuade drivers to drive in an environmentally friendly manner. This theory is concerned with conflicts between what an individual likes to do and what he or she recognises as being good for the whole of the community or society (a *social dilemma*). A 'selfish' non co-operative behaviour (e.g. driving instead of using public transport) has a positive effect on the individual but the negative costs (pollution, congestion etc.) are shared by everyone. This results in a *social dilemma*. Reaching a solution to such dilemmas is complicated, as individuals often believe that they can only contribute a tiny amount to the common good. A number of important issues still need to be researched in this area

5.2.2 Limitations in the research methodologies

Another possible explanation of the apparent lack of positive effects of training in the research literature may be to do with limitations in ability of the research studies to detect changes in accidents. Accidents are rare events, and it may be that with the sample sizes that have generally been available for study, accident rates are too low to allow a reduction to be detected. The reported studies may therefore conclude that training courses are ineffective, whereas a study with a larger sample of participants, accumulating accidents over a longer period, might have been able to detect an effect.

Evaluations of training courses may provide more positive findings if alternative indicators, known to be related to accident involvement, are chosen. Whilst correlation does not guarantee causation, studies addressing the measurable aspects of behaviour shown to be linked with accident involvement, could provide more positive evidence of training effects than at present. Possible indicators include hazard perception ability, (e.g. McKenna et al., 1992; Horswill and McKenna, 1997) self reported 'traffic violations' (Reason et al., 1990; Parker et al., 1995), and convictions for traffic violations (Peck et al., 1969).

5.3 Environmental benefits of driver training

There is limited published data on the effectiveness of driver training to improve fuel consumption and to reduce noise and pollutant emissions. As reported in section 2.1.3 various studies have suggested that guidance for drivers on adopting a more 'economic' style of driving might save between 10% and 30% of fuel for a typical journey. Similarly section 2.2.3 suggests that the average noise energy over a journey may be reduced by 5dB(A) if drivers are encouraged to minimise engine speeds, acceleration and braking.

As with safety, it may be difficult to isolate the effects of training from those of other initiatives that companies may introduce at the same time, e.g. monitoring fuel consumption and purchasing more fuel efficient vehicles.

5.4 The effectiveness of best practice literature

Several organisations, such as DETR, ETSU (e.g. ETSU and Fleet Audits Ltd., 1998) Hertfordshire County Council (no date) the Society of Motor Manufacturers (no date) and Vauxhall Motors (no date), have produced a variety of examples of 'best practice' literature. However, few published accounts of the effectiveness of the literature are available. In general, any evaluation of 'best-practice' literature has involved simple distribution counts, 'penetration' measures or surveys asking about reported behaviour.

As part of the EEBPP, ETSU has produced best practice literature aimed at encouraging companies to consider the environmental impact of their operations. ETSU claim that the case study literature has been positively received by the industry, notably the study of McKelvie and Co (described in section 4.2.4). However, ETSU found that it is the companies with a positive attitude towards the environment that are more likely to make use of the case studies. This means, as is often found in publicity research, that it is difficult to influence companies that have little interest in environmental issues. ETSU deal predominantly with freight operators and the case studies have received little interest from car fleet managers:

An evaluation of the attitudes of managers of car/van and haulage fleets to the EEBPP literature on fuel efficiency was carried out recently (DataBuild Ltd, 1998a and 1998b). The evaluation found that 60% of the haulage fleets questioned could mention measures that were, or could be, adopted to save fuel: this is in sharp contrast to the 22% of responding car/van fleets. With freight operators, the motivation to save fuel is very clear, i.e. to reduce operating costs, but this may not be so for car and van fleets. Restricting the choice of vehicles to the most efficient in their class was the main method of reducing fuel consumption used by car and van fleets. In only 16% of car/van fleets were there any other policies to reduce fuel consumption. These policies were generally part of a wider company policy on energy use and the environment. Amongst car/van fleets that had attempted to save fuel, those making using of the EEBPP case studies saved twice as much as those that did not. Discussions with other researchers, both in the UK and in a number of other countries, have failed to identify further examples of research conducted to evaluate the effectiveness of 'best practice' literature in this field. This is unfortunate as it is generally accepted that evaluation should be part of any targeted education, publicity or public awareness campaign.

One other notable exception to this is the DETR's 'Greener Vehicles Campaign', which seeks to raise public awareness of the impact of cars on the environment. The campaign is primarily focussed on publicising the roadside emissions testing which is being piloted in seven local authorities, but information on the benefits of adopting a 'greener' driving style are also included in the publicity leaflets. An evaluation of the effectiveness of the campaign is on going.

5.5 Implications for road capacity

Concern has been expressed that driving styles that promote safety and minimise environmental impacts (i.e. with increased headway, slower accelerations and slower speeds) may have an effect on capacity. Theis (1994) drew on the research of Bongard (1992) into environmentally beneficial driving profiles (see section 2.1.4) and put these hypotheses into a computer simulated model of single driver-vehicle elements, called MISSION (Wiedemann, 1974). The aim of the research was to determine whether Bongard's model of green driving styles, if adopted by many or all drivers, would have any effect on lane capacity, speed and the number of acceleration and decelerations. When modelling an urban road with traffic signals, it was found that capacity was reduced both when the following distances were enlarged to 2.5 and 3 seconds headway and when the modelled drivers changed up gears earlier. The author concludes that drivers should only maintain a larger headway of 2.5 or 3 seconds when traffic volumes are low. Otherwise, the capacity may be reduced, with the consequence that vehicles have longer standing times, leading to increases in emissions and fuel consumption. Looking ahead to anticipate future actions was not found to have a negative effect on capacity.

5.6 Summary

Whilst the promotional material for driver training suggests typical improvements in accident rates of 25 to 50%, research studies have generally shown little evidence that it is effective. The most promising evidence that training can be effective came from a study of a course tailor-made to reduce skidding accidents on icy roads: this training concentrated on providing the drivers with the basic skills to control the car on icy roads and to make them aware of situations that they cannot handle.

Many examples exist of the use of publicity campaigns and best practice literature to encourage motorists to undergo training and modify their driving style but there is limited evaluation of their success. Recently however, the use of EEBPP literature was evaluated and it was reported that car fleet managers who had made use of the case study materials had saved twice as much fuel as those that had not. Commercial fleet managers appear to be much more aware than car fleet managers (and also the general public) of ways of improving fuel consumption figures, probably because fuel is a significant proportion of their operating costs.

The expected effects of driver training on safety remain largely unproven as far as published evidence is concerned, although there is no doubt that some trainers and fleet operators are convinced that training is highly effective. The potential benefits of training could certainly be very significant for both safety and the environment, and so further attention needs to be given to its evaluation and optimisation. It also seems possible that training will need to be supported by other measures. On its own training may not be particularly effective in changing driver behaviour: it may enable people to drive in a safe or environmentally friendly way, but they may then choose to drive differently. To address this, there is a need to understand the psychological factors that are important in influencing the way drivers choose to behave, so that ways can be found to persuade drivers to make use of their new skills. Measures designed to change attitudes towards safety and the environment may be useful here, as may incentives and other systems that bring management influence to bear on drivers' behaviour.

As mentioned earlier, there is currently a lack of evidence to support training companies' claims regarding the effectiveness of their schemes in improving safety. However in the light of the limitations of existing research, it is advisable to emphasise the possible benefits of developing a strong safety culture within the organisation and to stress that any benefits achieved are likely to be the result of a package of measures of which driver training forms one part.

6 Encouraging the uptake of training and the use of in-vehicle technologies

6.1 Introduction

6.1.1 Uptake

The main determinants of whether fleet managers choose to purchase training would appear to be the effectiveness, cost and the perceived importance of environmental issues to the company. The key to the first two is to develop and publicise effective training courses. Educational materials and promotional campaigns may be effective in promoting the importance of environmental concerns, and in showing what can be achieved. Legislation giving companies duties to manage risk and minimise the impact of their operations on the environment is also relevant here. Further possibilities are incentives to purchase training and/or equip fleets with in-vehicle devices.

6.1.2 Effectiveness

For training to be effective it is necessary to develop:

- effective driving techniques and behaviours, i.e. effective in reducing environmental impact;
- effective training techniques.

It may also be desirable to develop:

- effective supporting systems, e.g. feedback devices;
- effective secondary measures to support training by influencing driver's choice of driving style.

These secondary measures could include incentives and penalties operated by the company, education on the importance of reducing environmental impacts, and publicity campaigns. To be most effective, the education and publicity will need to be informed by research into the attitudes and motivations of drivers, and the way that these influence driving style.

6.2 Incentives for drivers

6.2.1 Rewards and incentives to influence driving style

Wilde (1994) who argued that they should be employed more widely to improve driver safety reported the effectiveness of incentive schemes in a variety of occupational settings. Schneider (1990) described a long term scheme in Germany in which professional drivers in a large fleet were offered a financial reward for every half year of driving without culpable accidents. The result was a marked and sustained reduction in accidents. Gregersen et al. (1996) reported that a bonus scheme resulted in a significant improvement in fleet driver safety in Sweden (see also section 5.1).

In the UK, the only evidence of the effects of incentives comes from a study conducted in 1989 by Lynn and Lockwood (1998). In their survey of company car drivers, 4% of the respondents received some form of reward for accident-free driving. However, drivers receiving rewards had 21% fewer accidents than those that did not. The size of the average reward was generally small, with the majority being less than £60: some were as little as £5. The authors suggest that the lower accident rates may to some extent reflect the non-financial aspects of the scheme, such as official recognition as a good driver and the status this might bring.

Bower (1990) considered a wide range of incentive programmes for promoting safe driving. The analysis of driver behaviour considered a range of behavioural changes, based on psychological learning theory, and the use of currently and potentially available technologies. The review is mainly theoretical in nature and provides no actual trials of the sort currently being considered as part of TRL's LINK programme extending the SAMOVAR ('black-box') programme started as part of the European DRIVE programme.

In general, there appears to have been very little research on the use of and incentives to influence driver behaviour, as opposed to negative rewards such as fines. This situation is likely to change as improved technology makes the monitoring of vehicle operation more practical. However, research will be needed to know how to maximise its effectiveness.

6.2.2 Incentives to undertake post-test driver training

The only large-scale scheme in the UK to encourage drivers to undertake post-test driver training is the Pass-Plus programme. The aim of Pass-Plus is to encourage newly qualified drivers to undertake additional driver training. Participants are offered discounts on their insurance cover as an incentive. The role of insurance companies in encouraging driver training in this way is discussed in the following section.

6.3 The role of insurance companies

The possible role of the insurance industry in encouraging driver training, was explored in discussions with a number of insurers, the insurance industry's trade association, fleet operators, providers of fleet management services and fleet audit companies.

Insurance cover for private motorists is offered by a sizeable number of organisations. A much smaller number of companies are involved in fleet insurance and for some it is a major part of their business. Many of the fleet companies do however cover their vehicle insurance as part of more general policies (i.e. buildings, contents and staff insurance). Others (especially those with larger fleets of vehicles) may undertake their own accident repairs and so only require third party cover for their fleets.

Insurers take into account many factors when determining insurance premiums for their customers, the main ones being: a bonus for no claims in the previous year(s), discounts for members of the IAM, a one year no claims bonus for newly qualified drivers completing the Pass-Plus training.

The insurance business has become increasingly competitive, with a very strong emphasis being given to operating costs and prices, and insurers are very aware of the need for a financial 'edge' over their competitors. Several insurance companies have developed strategic partnerships with fleet training providers, offering incentives to those who enrol in their partners' courses. The practice is not widespread but appears to be increasing. One insurance company offering incentives to undergo training claims that savings in accident numbers and costs can be as high as 80% (although more typically of the order of 20 - 40%): Another offers a 'guaranteed 10% reduction in accident rate or 10% of drivers will be retrained free of charge'. However, the data supporting these claims were not made available for evaluation at the time of writing.

There is little available data on the uptake of fleet driver training as a result of the incentive schemes. For the private motorist, an incentive scheme, 'Pass Plus', was designed to encourage newly qualified drivers to undertake additional training by offering discounts on insurance. The overall take-up of the scheme has so far been disappointing, with only about 2% of eligible drivers taking part. In general, the incentives on offer depended on drivers taking out a particular policy (e.g. the policy might have to have been in their own name, be fully comprehensive, or they had to be a named driver): many novice drivers drive under the insurance of another family member or take out only 3rd party cover.

The commercial and novice drivers' markets are substantially different and the effectiveness of incentives is unlikely to be the same for fleet drivers. It is invalid therefore to infer from the disappointing results of Pass Plus the probable effectiveness of incentives offered to fleet drivers. However, in encouraging the private motorist to take up additional training, the experiences gained in the Pass-Plus scheme may be valuable in devising an effective incentive scheme for these drivers'.

6.4 Summary

To encourage the uptake of driver training for environmental reasons companies and individual drivers need to be made aware of the environmental impacts of driving and their associated costs. There also needs to be evidence that training can be effective in changing driver behaviour and that there are clear cost benefits as a result. Organisational culture changes may be enough to encourage fleet drivers to drive more safely and to conserve fuel.

Some insurance companies do offer incentives for fleets to undergo driver training and this practice appears to be on the increase. We were able to find no data on how effective the incentives are in encouraging fleets to provide training for their drivers. However, the experience with incentives for drivers has not been wholly successful, and only 2% of those eligible have taken part in the Pass-Plus training for newly qualified drivers.

7 Discussion

7.1 The role of training in reducing the environmental impact of driving

The driver training currently available teaches ‘safe’ driving skills using defensive driving techniques that encourage greater observation and anticipation. This type of driving may also help to reduce fuel consumption and exhaust emissions because it encourages smoother acceleration and less harsh braking. Therefore, although current courses may not explicitly cover environmental issues, drivers adopting the driving styles taught would nevertheless tend to achieve environmental benefits. Training providers and fleet managers interviewed during this study recognised the growing importance of environmental issues and often promoted their training as a way of reducing fuel consumption. No conflict was seen between training for safety and for ‘greener’ driving. Thus, at present, environmental benefits are generally seen as a side-effect of training designed primarily to improve safety. Courses devoted more explicitly to environmental issues could, no doubt, have their content optimised to deal directly with environmentally friendly driving.

There is little evidence available on environmental benefits that have actually been achieved by driver training, and the evidence on the link between training and safety is equivocal. There are many possible reasons for this, one of them being that training alone may not be particularly effective at producing significant changes in driver behaviour. Training may be seen primarily, though not exclusively, as a means of improving drivers’ abilities to drive safely, or in an environmentally beneficial way. Whether then they choose to make use of these abilities may depend on attitudinal and motivational factors that are usually outside the scope of training courses. This suggests that training needs to be supported by measures aimed at influencing drivers’ choices. Such measures include management systems such as league tables and incentive schemes, as well as education and publicity aimed at changing attitudes.

Post-test driver training is unlikely to be widely adopted on a voluntary basis unless there are clear and quantifiable benefits to the companies or individuals involved. Further work to evaluate the benefits of such training is needed. This should consider whether training can lead to sustained changes in driving style both in terms of safety and the environment, and the extent to which effectiveness can be improved by means of supporting measures such as incentives and education. With such information, fleet managers and motorists will then be able to assess whether the benefits outweigh the costs. Differences between private motorists and the various subgroups of fleet drivers, in terms of the scope for and effectiveness of training, will also be worthy of study.

7.2 What should driver training cover to reduce the environmental impact of driving?

The review has identified two different aspects of driving that need to be addressed as part of any driver training aimed at minimising the environmental impact of driving. The first is concerned with driving style, while the second involves more general instruction on ‘good practice’:

Driving style

From the available literature and also discussions with training providers, three aspects of driving style (acceleration, braking and gear control) are viewed as being of primary importance in minimising the environmental impact of driving. Training courses should therefore cover:

- The use of acceleration. Smooth, rather than harsh, acceleration reduces unnecessary fuel consumption. Also over-revving the engine will increase fuel use and noise levels whilst not necessarily decreasing the overall journey time.
- The use of brakes. Similarly, smooth braking reduces unnecessary fuel consumption and minimises noise levels. Braking harshly effectively wastes the fuel that has been used to accelerate up to that speed.
- The use of gears. In order to maximise the fuel efficiency of the vehicle, most should be driven in the highest gear possible for the speed that is being driven, but not so as to labour the engine. Both over-revving of the engine and labouring in too high a gear, lead to increased fuel consumption and noise levels.

One major issue relating to the use of gears that needs to be addressed during training, relates to exceptions to the rule that environmental and safety issues are usually complimentary. Whilst for environmental purposes the aim should be to choose the highest gear (without labouring the engine), this may compromise safety if the gear selected presents problems with maintaining a speed compatible with the speed limit. A modern car can be driven at 30mph in fourth gear, however in a 30 mph limit area it may be safer to drive in third gear (not the highest possible) as this allows more control within the 20-30 mph range.

Good driving practice

Similarly, there are a number of other more general ‘good practice’ driving behaviours that may also reduce the environmental impact of driving. These would need to be addressed in training courses focusing on environmental impact:

- Removing roof racks, caravan mirrors and other external fixtures when not in use. These types of external fixing reduce the aerodynamic efficiency of the vehicle, hence increasing fuel consumption and tyre wear.
- Not carrying unnecessary weight. Weighty items should not be left in the vehicle if they are not required, as this will increase fuel consumption and general wear and tear of the vehicle.
- Keeping tyres inflated to recommended pressure. Tyre rolling resistance is a significant factor in fuel consumption. Therefore, from the point of view of both safety and fuel consumption, tyre pressures should be checked regularly and, if recommended by the manufacturer, adjusted depending on the weight being carried.

- Opening windows only when necessary. Driving with the windows open can increase the aerodynamic drag of the vehicle, and hence its fuel consumption and emissions.
- Using air conditioning only when needed. Many modern cars are now fitted with air conditioning. The system may remove the need to open windows, however it can use a significant amount of fuel itself. Therefore in order to increase fuel economy it should only be used when necessary; and not simply left on and forgotten about.
- Reversing into parking spaces. Manoeuvring a car when the engine is cold uses more fuel and increases engine wear. Reversing into a parking space when the engine is hot will use less fuel than reversing out when the engine is cold.
- Switching off the engine if the vehicle is to remain stationary for some time, such as in traffic jams or while waiting for someone.

8 Summary and recommendations

8.1 Summary

The review has shown that there is the potential to reduce the environmental impact of driving by encouraging particular behaviours such as:

- keeping to an optimum speed;
- moderating the rates of acceleration;
- minimising the severity of braking;
- using a high gear wherever possible;
- switching off the engine during extended periods of idle.

Average vehicle speed affects pollutant emission rates, fuel consumption and noise levels. The relationships between speed and these parameters vary, but in general it can be said that the optimum average speed to minimise fuel consumption and emissions is about 60 km/h and for noise it is about 40 km/h. Many drivers choose to drive at high speeds and in excess of the limit leading to increases in noise, emissions and fuel consumption. If drivers can be encouraged to reduce their speed, these environmental disbenefits can be expected to decrease in most cases. The influence of acceleration rate and braking on noise and pollutant emission rates can also be considerable. The driver’s choice of throttle settings and use of the gears when accelerating will determine the environmental impact. Tyre noise generation increases during braking and the degree of increase is in relation to the braking force. The greatest increases tend to occur at low speed for a given braking force.

Several studies have considered the effect of driving style or driver behaviour on noise and pollutant emissions and fuel consumption. Potentially, fuel consumption during a typical journey may be reduced by between 10% and 30% depending on the type of trip and type of driver. The effect on pollutant emissions is perhaps less clear, but reductions of up to about 20% for a typical journey should be possible: there is also some data to suggest that reductions could be as high as a factor of 10. Vehicle noise levels may be reduced by about 2dB(A) $_{LAeq,T}$ on streets where braking and accelerations are minimised. By minimising engine speed, the average noise energy over a journey may be reduced by 5dB(A) for cars and for motorbikes by 6-8 dB(A). Such modifications to driver behaviour or driving style may lead to only a 5% increase in journey time.

Most of the currently available in-vehicle technologies that could be applied to reduce the environmental impact of driving are used to manage the fuel consumption and running costs. Two of the most common systems employed in cars are econometers and cruise control systems. Cruise control systems may reduce fuel consumption by about 4%. The benefits are not so clear for econometers where one study has shown a reduction in fuel consumption (by 5 to 10%) and another has shown no significant effect. In addition, some vehicles are now fitted with an on-board computer that can provide information to the driver on a comprehensive range of driving-related variables associated with speed, driving time and fuel use. These systems are more likely to be effective where there is a well-defined management procedure for monitoring, analysis and feedback of information, such as have been adopted by some HGV fleet operators. Although not specifically designed to reduce noise levels, such systems may also produce useful reductions in noise emissions. Technologies that help drivers and/or fleet managers to monitor parameters such as fuel consumption, periods of idling, speed violations and harsh accelerations/ decelerations, may also produce environmental benefits.

Fleet driver training in the UK generally emphasises improved concentration, observation and anticipation skills as the key to safer driving. Courses specifically designed to address environmental issues are not generally provided but all of the training providers interviewed believed that the driving styles they emphasise are also environmentally beneficial: the two aims of improving safety and reducing environmental impact are compatible.

More companies and fleet managers seem to be requesting that environmental issues be covered in the training provided for their drivers. Some organisations see reducing fuel consumption for their fleet as an important part of their policies on the environment. The organisations most likely to engage in driver training to achieve environmental benefits will be those who recognise that an awareness of environmental issues is beneficial to their business. Therefore, raising the awareness of individuals and companies to the environmental impact of driving may be a key action to encourage a change in behaviour and/or to engage in training.

Fleet managers require reliable information on the cost-effectiveness of different initiatives before engaging in training and/or installing monitoring equipment. However this is very difficult to quantify, particularly for environmental effects and this may be a barrier to increased take-up of training. For a company to invest in driver training, the benefits must be transparent and preferably based on financial returns. There is a view that company culture may be the most important factor in the up-take of training.

The promotional material produced by driver training organisations suggests typical improvements in accident rates of 25 to 50%. However research studies have generally shown little evidence that it is effective. The most promising evidence that training can be effective came from a study of a course tailor-made to reduce skidding accidents on icy roads. Further work to evaluate the benefits of training is needed; this should consider whether training can lead to sustained changes in driving style in terms of both safety and the environment, and the extent to which effectiveness can be improved by means of supporting measures such as incentives and education. Differences between private motorists and the various subgroups of fleet drivers, in terms of the scope for and effectiveness of training, will also be worthy of study.

The expected benefit of formal training on accidents remains largely unproven. The lack of positive results may be due to limitations within the research itself, and alternative indicators of accident reduction may be required. There is also concern that training on its own may not be particularly effective in changing driver behaviour. Training is probably best seen as a means of improving drivers' abilities to drive safely, or in an environmentally beneficial way. Whether then they choose to make use of these abilities may depend on attitudinal and motivational factors that are largely outside the scope of training courses. To address this concern, there is a need to understand the psychological factors important in determining driver behaviour. Methods of persuading drivers to change their behaviour can then be developed and introduced. Training may need to be supported by measures aimed at influencing drivers' choices, such as management control and incentive schemes, education and publicity aimed at changing attitudes.

Many examples exist of the use of publicity campaigns and best practice literature to encourage motorists to undergo training and modify their driving style but there is limited evaluation of their success. More recently the use of EEBPP literature was evaluated and it was found that car fleet managers who had made use of the case study materials had saved twice as much fuel as those that had not. Managers of commercial fleets appear to be much more aware of ways of improving fuel consumption figures, probably because fuel is a significant proportion of their operating costs.

Incentives to undertake training or use in-vehicle technologies were also investigated. Some insurance companies do offer incentives for fleets to undergo driver training and this practice appears to be on the increase. We found no data on how effective the incentives are in encouraging fleets to provide training for their drivers. The experience of the Pass Plus scheme for newly qualified drivers may be valuable in devising an effective incentive scheme for private motorists.

8.2 Recommendations

The review has shown that the driving techniques generally taught in post-test driver training are broadly compatible with the actions that are required to minimise the environmental impact of driving. However more needs to be done to encourage drivers to undergo effective training and then to continue to drive in a safe and environmentally aware manner. The following are recommendations for future actions and also areas where additional research may be required.

It was noted by one of the providers of best practice literature that the organisations most interested in reducing their fuel were those with an awareness of environmental issues. To encourage further uptake of training or to change drivers' behaviour, additional publicity to raise public awareness of the impact of driving on the environment would be useful. Initially this could be achieved on the back of existing campaigns until more firm evidence of the benefits of driver training could justify a separate initiative. To achieve this, additional survey research will be required to understand drivers underlying beliefs and motivations towards the environment

The environmental content of training courses, from novice drivers to advanced drivers, should be strengthened. Greater emphasis in the Theory Test could be achieved by increasing the proportion of questions on environmental issues. A 'stuffer' leaflet could be targeted at newly qualified drivers to reinforce the message.

In order to deliver the best environmental training possible, additional research will be required to determine the behaviours that need to be taught and also the motivations required to support the training. The motivations to undergo training and then to maintain those taught behaviours are likely to be different for different types of driver. For example haulage fleets may value fuel savings more than sales fleets who may value more the time saved.

Best practice literature should continue to be used to inform fleet operators and training organisations of the benefits of training and in-vehicle monitoring techniques and how best they might be applied. Additional material will be required, and the leaflets should clearly quantify the benefits that can be achieved. To provide this information there is a need for more evaluations that consider cost-effectiveness.

The effectiveness of driver training should generally be evaluated more rigorously. Many training providers give estimates of savings in terms of accident and fuel costs but it has proven difficult to verify them. Many of the independent studies that have been carried out are flawed in their methodology.

Incentives will probably play a key role in encouraging the use of training and in-vehicle technologies particularly where environmental benefits are targeted. The experience of the Pass-Plus scheme has so far been disappointing, but the possible role of insurance companies may still be worth pursuing.

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Notes

[1] a mixture which contains just enough air to burn all the fuel

[2] The engine, engine ancillaries, transmission and exhaust.

[3] The A-weighted decibel scale gives the noise measuring instrument a frequency response approximately equivalent to that of the human ear. For many noise assessment purposes the dB(A) scale has been found to correlate well with the subjective perception of noise.

[4] LA10,18h is derived from noise levels measured in an 18-hour period from 06:00 to 24:00. For each of the one-hour periods, the A-weighted noise level exceeded for 10 per cent of the time is calculated to give the noise index LA10,1h. An arithmetic average of the 18 individual LA10,1h values is then calculated to give the LA10,18h.

[5] The $L_{Aeq,T}$ index describes the ‘equivalent continuous noise level’ of time varying noise over the time period T and represents the total noise energy during the period. This alternative index for assessing the impact of traffic noise is widely used in Europe and the USA. Although the L_{A10} and L_{Aeq} indices give different absolute noise levels when used to assess time varying noise such as traffic noise, changes in noise level expressed in either index should be numerically similar and therefore comparable.

[6] In this context, load refers to engine torque and it is closely related to accelerator or throttle position

[7] Technology in this context refers to systems that assist or dictate driving style.

[8] The RTA Project is a three year collaborative project funded by the DTI/EPSRC, and managed by TRL, involving a wide range of academic and industrial organisations.

Abstract

It has long been recognised that inappropriate driver behaviour is an important contributory factor in the majority of road accidents. Driver behaviour is also critical in determining the fuel consumption, vehicle noise and exhaust emission rates during a trip. Technological developments in the control of noise and exhaust emissions and the enforcement of legislation will probably be key elements in reducing the environmental impacts of road transport, but increasingly the actions of motorists are also being targeted by other means. This report reviews the evidence on whether driver training can reduce fuel consumption, emissions and noise and also considers how training schemes could be encouraged more widely. The use of in-vehicle technologies to reduce the environmental impact of driving is also examined. The research has been conducted through a review of relevant published literature and interviews with fleet managers, training organisations and insurers.

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