DRIVING TO REDUCE FUEL CONSUMPTION AND IMPROVE ROAD SAFETY

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Abstract

As part of an ongoing project, this paper examines the possible safety benefits of driving in a manner that results in lower fuel consumption and emissions. Generally, a reduction in driving speed and a smoother driving style would be expected to decrease crash risk and improve fuel economy. However, a review of the literature indicated that the relationship between speed and fuel consumption or emissions is quite complex. Furthermore, some methods of encouraging a reduction in speed, such as local area traffic management, may actually increase fuel consumption. The paper reviews the effects of various driver training programs (particularly in Europe) that aim to reduce fuel consumption. The environmental benefits coupled with reduced running costs of an altered driving style may be an attractive message to some segments of the community. Such changes are also likely to be a more popular choice than measures that attempt to reduce vehicle travel, at least in the short term.

Introduction

A great deal has been written about the safety aspects of driving style. Well-researched issues include the relationships between driving speed and variables such as crash rate and severity of injury or likelihood of a fatality (1, 2, 3, 4). Aggressivity of driving has received considerable public attention. With an increase in concerns about air pollution and the greenhouse effect, there has also been extensive research examining the effect of driving style on the emissions of motor vehicles. However, there is not a large volume of research examining the interface between the two – the safety and environmental effects of driving style.

One potentially useful outcome of such research may be a new way of encouraging individuals to drive in a less risky manner. Organisations and governments have sponsored many campaigns to promote changes in driver behaviour, such as discontinuing habitual speeding, in order to decrease the annual fatality rate of the road transport system. However, drivers still speed and fatalities still occur as a result of speeding drivers. By tapping into the increased awareness and concern for the environment, this may provide a motivation for some drivers to slow down in order to decrease the emissions from their vehicles. The financial savings of reduced fuel usage due to slower driving may also provide a useful incentive for drivers to change their behaviour.

The effect of speed on safety

There is substantial international evidence that higher speeds result in more collisions, and a greater severity in the crashes that do occur. According to Taylor et al. (1), accident frequency rises approximately with the square of the average traffic speed, and a 1 km/h reduction in speed across the network leads to a 3% drop in accidents. Andersson and Nilsson (2) state that the probability of a fatal accident is related to the fourth power of the speed – a 10% reduction in mean speed results in a reduction of the number of fatalities of approximately 40%.

Australian research has also shown evidence of the increase in crash risk with increasing travel speed. For example, a study in metropolitan Adelaide reported that travelling at 5 km/h over the speed limit doubles the risk of an injury crash, the same effect as a Blood Alcohol Content (BAC) of 0.05 (3). For pedestrian crashes, McLean et al. (4) reported a strong relationship between impact speed and injury severity.

Several studies (described in 4) have shown that the risk of a pedestrian receiving fatal injuries at an impact speed of 50 km/h is approximately 10 times higher than at an impact speed of 30 km/h. About 90 percent of pedestrians struck at 65 km/h will be killed in comparison to about 10 percent for those struck at speeds at or below 35 km/h (5). The change from mainly survivable injuries to predominantly fatal ones takes place between 50 and 60 km/h.

Despite the considerable evidence about the role of speed in crashes and the public education and enforcement resources devoted to reducing speeding, 80% of Australian drivers reported driving 10 km/h over the speed limit on an at least an occasional basis and 20% had been caught speeding by the police in the previous two years (6).

The relationships between travel speed and fuel consumption rate and emissions

A number of curves relating emissions and fuel consumption to average speed have been developed. Figure 1 presents typical car emission and fuel consumption rates as a function of average speed (Eggleston et al., 1992, cited in 7). Emissions of Volatile Organic Compounds (VOCs or HCs) and carbon monoxide (CO) generally decrease as average speed increases and then increase somewhat over 100 km/h. Emissions of nitrogen oxides increase more than proportionally with average speed. The relationship between fuel consumption and average speed is somewhat more complex. It appears to decrease as average speed increases to about 60 km/h to 80 km/ and then increase.

Other authors have presented curves of similar shapes but with different gradients or minima. For example, Samaras and Ntziachristos (1998, cited in 8) report that CO emission reaches a minimum at about 70 km/h, similar to Figure 1, whereas Joumard et al. (1999, cited in 8) report that CO emissions decrease monotonically with speed.

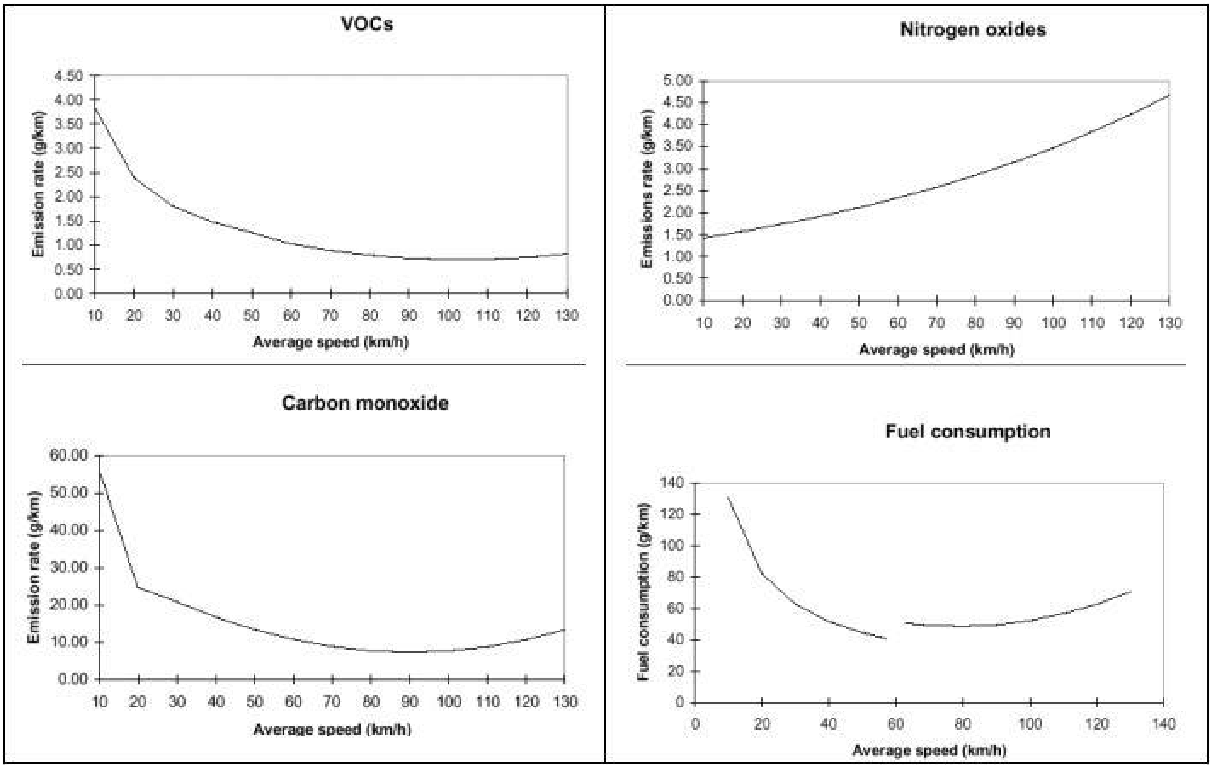

Figure 1. Typical emission rates for Volatile Organic Compounds (Hydrocarbons – HC), carbon monoxide, nitrogen oxides and fuel consumption as a function of average speed for passenger cars conforming to ECE 15-04 regulations (Eggleston et al., 1992, cited in 7).

While Figure 1 summarises the relationships between average speed and emissions and fuel consumption, the situation is complicated by the fact that any change in speed requires acceleration (or deceleration). During acceleration, the fuel to air ratio is higher than optimal. This results in large increases in CO and HC emissions (9) as well as increased fuel consumption. The acceleration characteristics of the vehicle and driver contribute significantly to actual emissions and fuel consumption. Heavy acceleration, which characterises aggressive driving, results in larger increases in fuel consumption and emissions. If many drivers who exceed the speed limit also accelerate heavily, they are not only using more fuel due to their high speed, but are further increasing their fuel consumption and emissions by their pattern of acceleration and deceleration.

On the open road, passenger cars and light trucks use approximately 50% more fuel travelling at 120 km/h than at 88 km/h and emit 100% more carbon monoxide, 50% more hydrocarbons and 31% more nitrogen oxides (10).

Given the strong relationships between travel speeds, crashes and fuel consumption and emissions, there is a clear case to reduce travel speeds. This paper discusses the safety and environmental effects of reducing travel speeds by:

?? reducing speeding using enforcement and traffic calming,
?? reducing speed limits, and
?? training in smoother driving.

Effects of reducing speeding by enforcement

A study of the costs and benefits of reducing the speed of private cars in the Netherlands concluded that the maximum enforcement of current limits alone would reduce hospital admissions by 15% and deaths by 21%. Fuel consumption and carbon dioxide emissions would decline by 11%, and nitrogen oxide emissions by 15%. These benefits would lead to savings of about $US260 million per year (11).

Meers and Roth (12) estimated fatality and greenhouse gas savings from major Queensland road safety and environmental programs. They found that the speed camera program reduced speeds at speed camera sites by approximately 10 per cent and across the network by about five per cent. This resulted in a decrease of an estimated 164 fatal crashes in the period 1998-2000. The speed reduction equates to approximately a three per cent reduction in CO_2-e (carbon dioxide-equivalent gases) emissions, a decrease of 400,000 tonnes per annum using 1999 emission data.

The Random Road Watch (RRW) Program encourages more prudent driving behaviour and has resulted in an annual average saving of 83 fatal crashes. In terms of CO_2-e reductions, the lower speeds from RRW are the primary benefit. RRW saves about 40,000 tonnes per annum of CO_2-e emissions (12). While it is targeted at drink driving, random breath testing (RBT) also encourages more prudent driving behaviour in a similar manner to RRW. Similar CO_2-e reductions would be expected from this program.

Nairn and Partners et al. (13) estimated the potential effects of strategies to reduce cruise speeds to reduce fuel consumption and emissions in Melbourne. They estimated that if education and enforcement of existing speed limits resulted in all drivers travelling at or under posted 60 km/h speed limits, the average fuel consumption rate would reduce from 8.2 L/100 km to 8.1 L/100 km. Similar calculations for 75 k/h speed limits (which have been largely superseded by changes to speed zoning practices in Victoria) gave estimated reductions from 9.1 L/100 km to 8.8 L/100 km. Unfortunately, much of the data on speed profiles used in the calculations were collected before full implementation of the speed camera program and therefore may no longer be applicable.

Effects of reducing speeding by traffic calming measures

Traffic calming measures aim to slow traffic travelling through residential areas to a safer level. This primarily relates to those exceeding the local speed limit, however most devices require drivers to slow down substantially to negotiate them, even if they are travelling at the posted speed limit. The driver must then accelerate to return to a preferred cruising speed, depending on variables such as how long the street is and how far it is to the next device. These episodes of acceleration can be very fuel intensive, depending on the driver.

A number of studies have assessed the effects of traffic calming measures on fuel consumption and emissions. Physical speed control devices can increase fuel consumption by 30-50% beyond that expected whilst driving at a consistent speed (14). A theoretical study by Webster (1993, cited in 9) found that road humps produced an increase in fuel consumption of between 10% to 25%. Smaller increases were associated with assumptions of smoother driving between the humps. Webster found an increase in emissions of CO, CO_2 and HC with a slight increase in NO_x.

A study of a range of measures to reduce speed in several German towns and cities demonstrated an increase in fuel consumption and emissions of CO_2 and CO as a result of the implementation of extensive traffic calming measures (German Ministries of Regional Planning, Transport and Environment, 1992 cited in 9). NO_x emissions were reduced, but there was no clear effect for HC emissions.

Roundabouts appear to have both safety and environmental benefits (15). Hyden and Varhelyi (15) found that roundabouts were effective in reducing the number of conflicts between cars and pedestrians and lowering the speed of any conflicts that did occur. Trip time was also decreased when the roundabout replaced a signalised intersection. In contrast to the effects of speed humps, emissions (CO and NO_x) also decreased overall. There were also speed reductions in the links between the roundabouts if the length was less than 300m. Average speeds throughout the city did not increase during the trial, indicating that drivers did not attempt to make up for lost time elsewhere. The number of expected injury accidents went down by 44% and bicycle and pedestrian-involved crashes decreased by 60% and 80%, respectively. The roundabouts produced a very significant risk reduction for vulnerable road users, but there was no reduction for car occupants.

Effects of lower speed limits

Meers and Roth (12) examined the effects of the change in Queensland of the local speed limit from 60 km/h to 50 km/h. They concluded that over the period 1998-2000, this initiative saved 19 fatal crashes each year in south-east Queensland (a decrease of 15% in fatal crashes). A 10 km/h speed reduction equates to a 5 per cent reduction in CO_2-e at around 60 km/h. Based on that data, a saving of 33,000 tonnes CO_2-e per annum has resulted from the 50 km/h initiative.

The European Union research program entitled “MAnaging Speeds of Traffic on European Roads” (16) developed a framework to estimate the impacts of speed management policies on vehicle operating costs, travel time, crashes, air pollution and noise. Haworth et al. (17) used this framework to assess the benefits and costs of the implementation of a default 50 km/h speed limit in urban areas. While the costs associated with the increase in travel time were generally greater than the savings in casualty crash costs, modest benefits were identified from reductions in vehicle emissions.

Similarly, the German study cited earlier (German Ministries of Regional Planning, Transport and Environment, 1992 cited in 9) found that implementation of 50 km/h speed zones led to a reduction in CO_2 and other emissions and a reduction in fuel consumption.

The environmental effects of lowered residential speed limits may be affected by the layout of the street network, however. Dyson et al. (18) present simulation data showing that the length of the street may affect the optimum speed profile in terms of fuel consumption and emissions (at least for medium to hard acceleration). For streets shorter than 550 metres, CO_2 emission (which is proportional to fuel consumption) is less for travel up to a 40 km/h speed limit than for travel up to a 60 km/h speed limit. For streets longer than 550 metres, the reverse is true.

Training in smoother driving

There is a strong impetus in many European countries for drivers to improve their fuel economy through changes in their travel behaviour. The EcoDrive concept includes advice for car manufacturers and policy changes for roads and infrastructure changes, but its primary thrust is a smoother driving style – gliding through the traffic.

The basic principles of EcoDriving are (19, 20):

?? When heading off change up to second gear as soon as possible and then to higher gears at one-third to half-throttle.
?? Engine speed should not exceed 3000 rpm (or level of highest torque).
?? Drivers should look and plan ahead and coast to traffic lights or intersections so that there is no unnecessary braking and the timing is such that the vehicle does not need to come to a complete stop.
?? Driving to match the rhythm of the traffic.
?? Use the upper gears as much as possible and keep engine speeds down.
?? In vehicles of increased power and higher torque make the engine work more rather than changing down a gear.
?? Skip gears when it is appropriate.
?? Keep engine idling to a minimum
?? No “warming-up” time when a car is first started.

Many of the practices of EcoDrive differ from the driving style generally advocated a generation ago. With many new drivers being taught how to drive by their parents, EcoDrive proponents suggest that many people are driving new cars with an obsolete and inappropriate driving style. In a bid to counter faulty driving practices already learned and teaching novices the new ‘correct’ way to drive, EcoDrive concepts are being used by driver trainers, taught in schools and instituted as part of fleet training programs.

Effects of EcoDrive training

A number of studies have measured the effect of EcoDrive training on fuel consumption and emissions. According to Wilbers (21), drivers can save 5-10% in fuel use, and some drivers have reached 20% with the right changes to driving style. Wilbers reported that a group of driving instructors undergoing training saved 13% over a 40 km journey.

Using an unfamiliar car and unfamiliar 10 km route, Johansson (19) compared a group of EcoDrive trainees pre- and post-training and found that the average speed did not change, nor did the average acceleration. The degree of deceleration decreased, indicating less use of the brakes, and so drivers were anticipating forward conditions and driving more smoothly. The students spent more time in top (fifth) gear and there were 25% fewer gear changes. The maximum engine speed (according to EcoDrive principles) was exceeded before and after instruction but the percentage of time during which it was exceeded declined after instruction. However the amount of time spent at half-throttle doubled after instruction. It was suggested that this was a failing in the teaching of this concept.

Fuel consumption and carbon dioxide emissions were reduced by an average of 10.9% (19). All students reduced their fuel consumption. Other emissions did not provide a clear picture and could not be statistically analysed – some students increased their emissions while others demonstrated a reduction. It was suggested that the use of the accelerator can be reduced to decrease the emission of hydrocarbons and carbon monoxide without increasing fuel consumption and the emission of nitrogen oxides. Time taken to travel the test route also decreased in many instances. Drivers were looking further ahead and planning more. However, those drivers who initially had an aggressive driving style tended to maintain that style after instruction.

Bongard (22) claimed that it takes about 3 months to adopt a new style of driving – gliding through traffic. Experienced drivers can save up to 30% on fuel consumption. Beginners save on average 1 litre per 100 km in comparison to conventionally trained drivers.

The effects of EcoDrive training on safety have not been as widely examined. Preben (20) claims that EcoDrive training has led to safety improvements but gives no further details. Johannson (19) cited a long term study in Finland that found a significant decrease in fuel consumption and a reduction in costs associated with accidents in a government fleet.

Other studies have examined the effects of EcoDriving both in terms of fuel consumption and crash risk. Reinhardt (23) analysed the results of a training scheme instituted in a corporate fleet. He found 35% fewer accidents, 22% higher mileage per accident, 28% less fleet driver-induced accidents, 50% less CO, 31% less CH and 23% less NO_x. With the publicity surrounding the scheme, there was also an image improvement for the company and driver motivation increased. Another company training program claimed an 11% fuel saving from 1990 to 1994, and 35% improvement in accident rate (7).

EcoDrive and similar programs are aimed primarily at drivers of manual cars. While manual cars might predominate throughout much of Europe, the majority of passenger cars in Australia (and the US) have automatic transmissions. The principles are the same in that the driver should gently accelerate to allow the transmission to change itself into either higher or lower gears at lower engine speeds – driving smoothly rather than aggressively. Driving with an increased awareness of what the traffic is doing downstream rather than only focusing on a car or two in front is also transferable between manual and automatic cars.

Australian work in this area

In Australia, promotional material has been developed by environmental agencies and motoring organisations. For example, the Australian Greenhouse Office Fuel Consumption Guide 1999-2000 (24) includes “10 top tips for fuel efficient driving”, which are consistent with the EcoDrive principles.

In Victoria, the Environment Protection Authority and the Sustainable Energy Authority Victoria are developing a driver education program that highlights the commonality of driver behaviour that improves safety, fuel use and environmental aspects of car use. The course is initially being developed for EPA and SEAV staff but it is intended that through the development of new approaches and new course materials where necessary, it might serve as a pilot project for the development of a driver education program for drivers across the Victorian public sector. The course has a one-day format and was trialled in June and July 2001.

Clifford (25) discusses a financial incentive scheme in an Australian trucking company, where drivers share in the savings in fuel consumption. The company also experienced savings in maintenance costs. Clifford suggests that as drivers pay more attention to their driving style to drive more efficiently, they are paying more attention to driving in general, which should make it significantly safer. The fleet fuel consumption over a 12-month period improved by 3.5%, and the financial savings more than covered the cost of the bonus scheme. Individual drivers had improved by as much as 15% and there was a slight reduction in accident/incident frequency.

Other links between driving style, safety and fuel consumption

While speed and aggressivity of driving style are the primary considerations in the common relationships between driving style and both speed and fuel consumption, there are other factors. For example, the use of a vehicle's cruise control device has the potential to increase safety and fuel economy. Assuming that it is not used to exceed the speed limit, cruise control can save an average of 5% in fuel use (21). If it is used to prevent inadvertent speeding, the maximum speed of the vehicle will be lower and the likelihood or severity of a crash will be decreased.

Public support for a change in driving style

Many surveys have found that there is a concern for environmental issues within the community. For example, a survey of 1623 Australian drivers found that 75% of respondents were concerned about the environmental effects of the car – particularly air pollution (26). However, concern for the environment does not seem to be bringing about a reduction in vehicle travel, nor is it rated as a greater concern than the cost of running a private vehicle. The survey found that environmental issues rated second highest, behind fuel prices. Additionally, cost is the major factor considered in the purchase of household vehicles (54% of survey respondents), followed by fuel economy or running costs, and vehicle size (both 36%) (27). These findings suggest that the financial incentive of saving fuel is strong, and so a program to encourage motorists to save fuel and therefore money by driving more smoothly is also likely to produce safety benefits as well. Promotion of the environmental benefits of a change in driving behaviour may provide an added impetus to program implementation, but it is likely to be the smaller incentive for many people.

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