SAFE DRIVING AND THE ENVIRONMENT

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1 A BRIEF STATEMENT OF THE ISSUE

Road safety and the environment are two particularly topical areas of concern, although they are generally discussed separately and the proponents for one often do not consider the other as equally important. Because a number of policies can have positive impacts in both realms, the opportunity exists to capitalise on the increasing concern for the environment to deliver a beneficial road safety outcome. This paper briefly examines leading road safety countermeasures affecting safe driving which also have consequences for the environment.

2 A REVIEW OF THE RESEARCH

Factors that have implications for both road safety and the environment can be classified into three areas: those that affect the fuel economy of vehicles; infrastructure-related aspects; and driving patterns. This division is one of convenience and some factors can be in more than one category.

2.1 Fuel economy

Higher fuel consumption results in greater depletion of fossil fuels and increased emissions – both air pollution and greenhouse gases. All new cars sold in Australia from January 2001 must carry a sticker specifying its fuel consumption rate in terms of litres per 100 km. However, a more common term in the marketplace is fuel economy: distance travelled per unit of fuel used. Due to its wider acceptability, the latter term will be used. Factors that impact on both fuel economy and road safety can be either vehicle-related or driver-related. Driver factors will be considered in Section 2.3.

Vehicle weight

A vehicle's weight affects both fuel economy and the safety level of its occupants and others who may be involved in a crash with it. Despite the use of lighter materials, newer vehicles are generally increasing in mass (Bouwman & Moll, 2000), therefore tending towards increased fuel consumption. A heavier vehicle often results in a more powerful vehicle: while a powerful vehicle is not necessarily unsafe, it seems that at least some drivers of larger, heavier vehicles – particularly SUV-type vehicles – are likely to drive more aggressively and less safely than others (Thomas & Walton, 2006). However, an engine that can produce more power at lower engine speeds may use less fuel than a car that requires higher engine speed to produce the same power (Van den Brink & Van Wee, 2001), particularly if the power is increased without a corresponding increase in the size and weight of the engine. A larger engine will also absorb more energy in a crash, and thus may decrease injury risk for the car's occupants, depending on the car's design.

The general environmental disbenefit of a heavier vehicle has an ambiguous safety outcome. All else being equal, in a crash between two vehicles of different weights, the occupants of the heavier vehicle will fare better than those of the lighter one (IIHS, 1998) and result in greater damage for both frontal and side-impact crashes (Attwell & McFadden, 1999). However, the market's apparent preference for heavier vehicles (Heavenrich & Hellman, 1999) may actually be a preference for *larger* vehicles, perhaps (not necessarily correctly) presumed to be both heavier and therefore safer (Thomas & Walton, 2006). As alloys and carbon fibre materials are increasingly used in the construction of vehicles, size may be maintained (or increased) with possible weight loss and accompanying fuel savings. Bouwman and Moll (2000) suggested that a 20% improvement in fuel economy due to weight changes should be possible by 2015 on current trends. This may lead to a decrease in the mismatch between vehicle weights and an overall safety improvement. Larger vehicles also have greater space for safety measures such as crumple zones.

Car size and construction materials are not the only elements that determine fuel economy and safety. Many safety features, such as airbags, decrease the severity of injury to a car's occupants, but each feature increases the weight of the vehicle, which in turn increases the amount of fuel the vehicle uses per kilometre travelled. While the mass increases due to such devices may be minor in relation to the overall weight, a major marketing component of many small cars is their exceptional fuel economy: any weight saving that produces a superior fuel economy relative to a manufacturer's competition may be an attractive option to the manufacturer, resulting in fuel economy being developed at the expense of safety.

Other vehicle features

Other measures also have an environmental and safety effect beyond a simple increase in the vehicle's weight. For example, the use of *air conditioning* is a significant drain on a vehicle's fuel economy – up to 10-15% (Wilbers, 1999). Yet it is has been argued that air conditioning is a positive safety feature for counteracting fatigue (Mackie & O'Hanlon, 1977).

Another common feature is *cruise control*. Used appropriately, cruise control can save an average of 5% in fuel use (Wilbers, 1999). 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. Cruise control may also decrease the likelihood of driver fatigue by decreasing mental load. Balanced against this is the danger of a severely fatigued driver using cruise control crashing at full speed rather than at a lower speed. Anecdotally, many long-distance truck drivers turn their cruise control systems off when driving at night: if they fall asleep their vehicle is likely to slow before crashing. Additionally, the added concentration required to maintain a preferred speed without the assistance of technology may actually help to stave off potentially catastrophic losses of attention.

Tyres are another example of a vehicle-related factor where improvements in technology benefit both environmental and safety outcomes. Newer tyre compositions and treads have improved road holding and grip and decreased rolling resistance. A 3% decrease in fuel consumption can be obtained from a 10% decrease in rolling resistance (Van den Brink & Van Wee, 2001). Tyre pressure is also important for both safety and fuel economy. Up to one-third of all light vehicles in the US have significantly under-inflated tyres, and this factor alone was responsible for at least 0.8% of all road crash fatalities and injuries in 1999 and 1.2 billion gallons (or 0.9% of the total fuel consumed by light vehicles) of wasted fuel in 2005 (Siggerud, 2007). From 2008 all new passenger cars and light trucks produced in the US need to be fitted with a tyre pressure monitoring system to alert the driver when a tyre is 25% under-inflated. According to Wilbers (1999), if all vehicles in the Netherlands had the correct tyre pressure 100 million litres of fuel could be saved per year.

Regular *vehicle maintenance*, including a pollution systems check, ensures that a vehicle maximises its fuel efficiency and minimises emissions and pollution. Regular engine tuning can reduce fuel consumption by 15% (AGO, 2001), and a well maintained 10 year old car can use up to 30% less fuel than a badly maintained car of the same age (DETR, 2000). According to the ABS (2000), 48% of Australian households owning motor vehicles service their vehicles once every six months. Coupled with, or completed in preparation for, compulsory annual roadworthy checks, regular maintenance might also ensure that the vehicle is safe, particularly in terms of items such as tyres, suspension, windscreen, etc. According to Rechnitzer, Haworth and Kowaldo (1999), vehicle defects are a contributing factor in over 6% of crashes, and periodic vehicle inspections could reduce the crash rate up to 16%. However the extent to which compulsory vehicle inspections would result in increased 'junking' of older cars with the consequent environmental impact, needs to be set against these possible safety benefits. A fully comprehensive cost-benefit analysis taking account of all factors (including safety and environmental) would indicate whether an annual compulsory check should be applied to all vehicles, just to those of a minimum age or not be applied at all.

However, anything that makes cars more efficient, and therefore cheaper to run, is likely to encourage more car use, which would be both an environmental and road safety disbenefit. Based on different studies, Kaegson (2000, cited in European Commission Expert Group on Transport and the Environment, 2000) estimated that improving fuel efficiency by 25% may increase total mileage travelled by 7%.

While they are important, the most immediate wholesale effects in both fuel economy and safety will not come from car and engine design improvements, but more probably from changes to the road system and the behaviour of its users. A single initiative to significantly improve a busy traffic area or increase public transport use will likely affect many more people in terms of both safety and fuel economy than tweaking an engine to improve fuel efficiency.

2.2 Infrastructure factors

Travel speed

Travel speed impacts both road safety and the environment. The travel speed for optimum fuel efficiency is around 60-80 km/h for most cars (Andre & Hammarstrom, 2000). Accordingly, low-speed residential areas may promote safety at an increase in fuel consumption, particularly where local area traffic management measures such as speed humps have been installed. The braking and acceleration cycles negotiating each such measure are particularly fuel consumptive. However, it is not a linear relationship. According to Van Every and Holmes (1992), physical speed control devices could increase fuel consumption by 30-50% beyond that expected whilst driving at a consistent speed. Dyson Taylor, Woolley and Zito (2001) found that for streets shorter than 550 metres, CO2 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; the longer the link the more likely a driver will accelerate to a higher speed.

'Optimum speeds'

Several studies have attempted to assess the optimum travel speed when both safety and environmental factors are considered. Cameron (2000) concluded that the optimum speed on residential streets depends on the actual values of crash cost savings that are used. If the "human capital" valuations of road trauma costs are used (as in BTE, 2000), then the optimum speed is 55 km/h. If costs are based on willingness to pay (as in BTCE, 1997), the optimum speed on residential streets is 50 km/h. If higher values of crash cost savings are used, then the optimum speeds would be lower. According to the European Commission Expert Group on Transport and the Environment (2000b), a study conducted in the Netherlands found that if all drivers adhered to the present maximum speed limits then the number of hospital admissions would decline by 15% and the number of traffic fatalities by 21%. Emissions would decrease by 10-15%.

Besides residential areas, there are other urban roads where maintaining a cruise speed within the optimum range is not possible. Slow speeds are also often encountered on major arterials and freeways, especially during peak business periods. These periods may be a relatively small proportion of the day, but the aggregate fuel consumption is high due to the number of vehicles involved. Freeways are a special case, where fuel consumption and crash risk form a curvilinear relationship with congestion. At very low and very high levels of congestion there are fewer crashes due to the lack of cars and lack of movement respectively. The highest crash rate occurs at some intermediate point when the congestion reaches a level where drivers have to stop and accelerate repetitively and individual cars change between lanes at an increased rate (although the risk of a fatality increases with increasing speed, regardless of degree of congestion).

Roundabouts

Hyden and Varhelyi (2000) determined that roundabouts were effective in reducing the number of conflicts between cars and pedestrians and lowering the speed of any conflicts that did occur. In addition, overall trip time and emissions were decreased, particularly when the roundabout replaced a signalised intersection. They determined that if the inter-intersection separation distance was less than 300 metres, drivers were less likely to significantly re-accelerate, and overall speed reductions also result in the links between roundabouts. They also noted no increases in speed in the general area, indicating that drivers did not attempt to make up for lost time elsewhere. Roundabouts reduce fatalities by 90% (Haworth, Tingvall & Ward, 2000), and can result in a 75% reduction in injury crashes (IIHS, 2001). In an additional environmental benefit, if the traffic calming measures are considered successful by the residents there is an increase in the number of children and adults who walk or cycle, and therefore a decrease in car use (Silcock, 1999).

Clearing roadside reserves

Around forty percent of those who die as a result of a road crash do so after running off the road and colliding with some fixed object, such as a power pole or a tree (Haworth, et al, 2000). Some other crashes occur when a vehicle crosses a median strip into the path of oncoming traffic on a divided roadway. Clearing roadside reserves has obvious safety benefits, however Gillian (2001) lists a bevy of environmental costs: increased exposure to weather, more grasses and weeds (causing a fire risk and requiring cutting, the use of herbicides, etc); an increase in animal pests; habitat fragmentation; reduced aesthetic quality (detracting from tourism – a critical economic factor in many rural areas); increased greenhouse production due to the construction and decreased carbon sinks due to vegetation; and problems with salinity, higher water tables, etc. Increased grass growth and insects will also lead to a larger number of animals at the roadside and crossing it, which increases the number of predators (and carrion eaters of road kill), and so the likelihood of a crash may actually increase. A lack of vegetation on the roadside may also increase the perception of safety by drivers and so encourage higher speeds. New road works also consume what is often the remaining flora that was once protected by the road verges.

Public transport

Measures that aim to increase public transport usage promise both environmental and safety benefits simply by reducing the cars and drivers on the road at a given time. However, the full effects can be more complex and result in either additional benefits or unintended disbenefits. For example, as well as increasing public transport use, relocating CBD and strip parking to park and ride-type initiatives (and possibly imposing a London-style CBD entry tax) can also reduce the particularly uneconomical and emissions-intensive practice of looking for convenient and cheaper parking. Such a distracted driver is probably also at a higher risk of a crash. However, park and ride schemes need to be carefully planned as they may actually *increase* the number of car trips (Parkhurst, 1995). Some public transport users may drive further than they did previously to meet public transport if the facility is better or the public transport service more frequent than it was from their nearer stop. Thus park and ride may not reduce the number of trips, just their length. There may also be increased congestion on the feeder routes to the centralised parking facility. Parkhurst also notes that there is no evidence of a long-term decrease in congestion downstream of a park and ride facility – any capacity freed by those switching to park and ride is usually quickly taken up by new drivers. Alternatively, the increased capacity could be immediately re-assigned to high-occupancy vehicles, particularly buses leaving the park and ride.

Other road use factors

By minimising traffic conflicts, smoothing traffic flows and minimising enforced stopping points (e.g. at traffic lights), *freeways* have 70% fewer accidents, 30% less fuel consumption, and more than 50% less emissions compared with other arterials (Metcalf, 2000, Cox, 1994). The construction of freeways and bypass routes also serve to remove through-traffic from residential areas and shopping strips (although this benefit may not be fully realised if the new roadway is a toll road), decreasing potential crashes between vehicles and crashes involving pedestrians and other vulnerable road users. However, such construction has environmental costs and often results in the destruction or long-term disruption of wildlife habitat areas, and the increased capacity is generally quickly filled by an induced demand as some travellers switch from public to private transport.

A potential means of mitigating some of the induced demand may be to specify dedicated *high occupancy vehicle (HOV) lanes* (i.e. lanes that can only be travelled by buses, minivans, taxis or ride-share vehicles) (McCann, DeLille, Ditmar & Garland, 1999). Further, *decreasing* capacity through reallocation of lanes may not actually increase congestion (Cairns, Hass-Klau & Goodwin, 1998), particularly if public transport alternatives are in place. This somewhat counter-intuitive finding was based on 100 separate case studies in a range of countries, but more rigorous research is needed to better estimate whether any of the previous traffic actually disappears or is simply relocated.

McCann et al (1999) point out that significant time savings may be achievable without any road construction. For example, according to their data half of all traffic tie-ups are caused by non-recurring events such as crashes. *Incident management systems*, especially those that use ITS elements, may significantly reduce the amount of lost time for each incident. They also describe a scheme where 217 miles of congested freeway network were continuously patrolled by a fleet of 50 tow trucks who provided free assistance as required by motorists. There was an 80% reduction in time spent in incident-related traffic jams.

Choosing a route that has better vertical and horizontal curvature can have both road safety and environmental benefits. Improved vertical curvature is estimated to lead to crash reductions of up to 52 per cent, and improved horizontal curvature will also have crash reduction benefits (Ogden, 1996, cited in Meers & Roth, 2001). Improved vertical and horizontal curvature can also result in smoother speed profiles and thus lower fuel consumption. This is particularly true for heavy vehicles.

2.3 Driving patterns

Fuel economy for a particular vehicle can vary markedly from driver to driver or situation to situation for the same driver. Faster and/or more aggressive driving, such as accelerating quickly, will result in an increase in fuel consumption by 30-40% (Van den Brink & Van Wee, 2001, Department of Primary Industries and Energy, 1991, De Vlieger, Keukeleere & Kretzschmar, 2000) and 4-8 times the emissions (De Vlieger, et al, 2000). Such driving will also increase the risk of a crash, and a faster speed will increase the severity of any crash that does occur.

Driving aggressively is both uneconomical and unsafe. The EcoDrive concept seeks to encourage drivers to drive more economically than an "average" driver, with improved safety as an additional benefit. Originating in Europe in the late 1990s, EcoDrive includes advice for car manufacturers and policies for roads and infrastructure changes, but its primary thrust is a smoother driving style – "gliding through traffic". The basic principles of EcoDriving are (Johansson, 1999, Preben, 1999):

- When starting off, change up to second gear as soon as possible and then to higher gears at one-third to one-half throttle.
- Engine speed should not exceed 3000 rpm (or the 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 vehicle does not come to a complete stop.
- Drive to match the rhythm of the traffic.
- Use the higher gears as much as possible and keep engine speeds down.
- In vehicles of increased power and higher torque make the engine work harder rather than changing down a gear.
- Skip gears when it is appropriate.
- Keep engine idling to a minimum.
- No "warm-up" time is required when a modern car is first started.

Some of these elements are less relevant to Australian conditions with the preponderance of automatic transmissions in light vehicles.

Preben (1999) cautioned that there are potential negative side effects of EcoDriving. The increased freewheeling and less use of brakes can lead to shortened headways (even if they are only transient), and therefore increase the risk of a crash. As such, the safety components may be at least as important as the fuel efficiency components of any training program.

According to Wilbers (1999), EcoDriving can save drivers 5-20% in fuel use. In one particular study (Wilbers), a group of driving instructors saved 13% in fuel over a 40 km journey, even though their driving time remained the same, and their students were 4% more efficient immediately after the course compared with students undertaking a standard course, although their average speeds were identical. Johansson (1999) found that after EcoDrive training students reduced their fuel consumption and CO2 emissions by an average of 10.9%, and all students made a saving. Yet there was no change in average speed or acceleration, and time taken to travel a 10km route also decreased in many instances. Drivers simply drove more smoothly, with less deceleration (suggesting more anticipation), fewer gear changes. Apart from an initial training program, the apparent lack of a time or financial penalty for practising EcoDriving should make it more attractive to fleet operators.

Studying a training scheme instituted in a corporate fleet, Reinhardt (1999) found 35% fewer crashes, 22% higher mileage per crash, 28% less fleet driver-induced crashes, and 50% less CO2 emitted. 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 and 35% improvement in crash rate (Smith & Cloke, 1999).

Clifford (1988) discusses a financial incentive scheme in an Australian trucking company, where drivers shared in the financial savings of a decrease in their own fuel consumption. The fleet fuel consumption over a 12-month period improved by 3.5%, and the financial savings in terms of fuel and reduced maintenance costs more than covered the cost of the bonus scheme. Individual drivers improved by as much as 15% and there was a slight reduction in crash/incident frequency.

Runnion, Watson and McWhorter (1978) describe a scheme implemented in a US trucking company that produced a significant improvement in driver fuel consumption and other driver-related behaviours. Tangible rewards were limited to occasional free dinners, but there was an element of competition between the drivers. In the second year of the program the company recouped enough in terms of fuel savings to run its entire fleet at no cost for one month. According to Bongard (1995) it takes about 3 months to adopt a newer, smoother style of driving.

3 POLITICAL, SOCIAL AND OTHER FACTORS

Road safety is not generally considered a vote winner, but the environment seems to be increasingly important to the public. This tendency is reflected in a recent driver survey conducted across four European countries, which found that vehicle-based technologies to improve fuel economy were consistently valued more highly than technologies to improve road safety (Harris Interactive, 2007). It is clear, however, that a choice does not necessarily need to be made between championing the environment or road safety, or striking a compromise that may not maximise either cause. There are a range of issues in which carefully considered policies can result in both environmental and safety benefits, or at least making improvements in one realm without detriment to the other. For example, there are currently rating systems for both road safety and fuel economy. A combined rating system that included safety, environment and an overall score could assist consumers to try to strike the right balance. For example, Haworth and Symmons (2002) plotted MUARC's used car safety ratings against vehicle fuel economy and found that vehicles rated as less safe were also more likely be uneconomical. A dual rating system is not without precedent, with many household appliances now rated for both energy and water efficiencies.

There is also a political 'hotspot' related to freeway expansion and the perceived trade-off against public transport. Any measure that encourages public transport usage is beneficial for the environment and generally safety positive, whereas freeway expansion is detrimental to the environment and likely to be disadvantageous to overall road safety. Setting lanes aside for buses, carpooling or freight can help to strike a balance.

4 CONCLUSIONS

Clearly there are a number of measures that could result in both environmental and road safety benefits. Additionally, given an increasing concern in Australia about the environment and the cost of fuel, either or both of these issues could be used as the selling point to achieve road safety gains as an adjunct. There is scope for action at the government level through infrastructure, and at the company and individual level through changes in behaviour. For example, the gains to be made at a fleet level with an EcoDrive-type training program are significant and can achieve a "triple bottom line" benefit – financial, environmental and safety improvements, with the additional advantage of positive corporate social responsibility publicity.

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