AA Research: Standard Metrics for Transport and Driver Safety and Fuel Economy

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Executive summary

This report looks at the main factors by which drivers, while actually carrying out their driving task, can influence vehicle fuel economy, and the metrics by which their performance may be measured. It also looks at how these metrics are currently used in the real world by drivers, fleet managers and driver trainers, and the use of insurance based incentives to encourage good behaviour. The report points out that fuel efficient behaviours though generally improving safety, may in some situations, become unsafe behaviours if employed overzealously. Any scheme using metrics to measure the effectiveness of the human element in fuel efficient driving needs to monitor safety parameters related to acceleration/deceleration and driver distraction.

The main factors influencing vehicle consumption are:

- The behaviour of the driver while driving;
- Route choice;
- Route topography and traffic conditions;
- Vehicle choice, including tyres and differences related to automatic and manual transmission;
- Use of heaters, air-conditioning systems, audio systems etc.;
- Vehicle maintenance including tyre pressures; and
- Loading of vehicle.

The driver's direct influence on fuel consumption is limited. About 82% of the energy expended in propelling a vehicle goes in heat lost in the engine. The remaining 18% which is the mechanical energy out of the motor is evenly split with 6% going towards overcoming rolling friction, 6% powering acceleration and 6% overcoming rolling drag which is speed related. Drivers can reduce only the mechanical energy out of the motor. Overcoming rolling friction is related to tyre-choice rather than driving so the driver's direct influence on fuel consumption is capped at around 12% maximum.

Drivers can influence the rolling drag by staying within the speed envelope in which air resistance is least, and minimise powered acceleration. They can also minimise stops and idling, where mechanical energy is coming out of the motor with no kilometres being travelled. Key driver behaviours related to fuel consumption are:

- Speed during highway driving;
- Frequency and intensity of braking and acceleration;
- Frequency of stops; faster acceleration may be acceptable if it means that a stop is avoided;
- Timing of gear changes, but only for manual vehicles;
- Following distance; and
- Idling

These behaviours need to be carried out safely.

Except speed, all these behaviours relate, in the final analysis, to acceleration. Stops and idling are obviously substantively a product of smoothness of driving and, to some extent, speed so these factors are not mutually independent. The main ranking of factors is in fact a dichotomy; speed is more important on the highway and smoothness of driving is more important in the city.

This is clearly a function of the lower opportunity for acceleration and deceleration and attendant stopping and idling on the highway. In all situations aggressive driving leads to more fuel use than less aggressive driving.

This report has discussed the relative importance of the identified factors in terms of how much of the variability in fuel efficiency they explain. However, this has not been done very precisely. This is because at present, the information is not available in the literature to do it precisely.

The impact of fuel saving driver behaviours can generally be expected to result in an improvement in safety. These benefits can accompany such behaviour improvements as less speeding and reductions in harsh braking events and. a more anticipatory driving style. However there are some safety issues including

- Advice to accelerate rapidly to target speed[1] could be taken too literally and could cause shorter safety distances in traffic if not combined with proper anticipation.
- Maintaining a constant speed, if misunderstood, could lead to insufficient safety margins because of delayed slowing down.
- Applying engine braking too early may result in a different pattern to that of normal traffic and increase the risk of a rear-end collision.
- Avoiding stopping could cause problems, as if it is applied near pedestrian crossings or intersections without a clear view.

Another safety issue which has not yet been fully explored is the potential driver distraction associated with driver feedback devices for providing fuel efficient driving messages.

There is great scope for placing more fuel efficient driving technology into the vehicle itself so that it happens automatically without driver intervention. This is appearing now with such measures as technology that turns engines off rather than idling, sophisticated engine management systems and vehicle stability control which dampen overly aggressive driving and speed limiting technology. There is also the possibility of setting up the on board computer to use its intelligence to advise the driver, and when required, managers and course supervisors both for fuel efficiency and safety purposes. This has already been done by Fiat (Eco-drive), Ford (EcoMode) and aftermarket suppliers like PLX Devices, maker of the KIWI device.

At present metrics are used to varying extents in New Zealand by:

- Individuals who utilise dashboard displays or propriety systems like the “Kiwi” to gain feedback to improve their driving.

[1] This action may not necessarily be correct in all situations.

- Trainers in “eco-driving” courses who use various displays to feedback information to drivers.
- Fleets to improve fleet safety and fuel economy-in this case they are often combined with information from GPS.

In the case of fleets both here and overseas the following is generally true:

- Speed and idling time are used;
- Other metrics are little used or emphasised;
- GPS is used;
- Most claim insurance savings but this is just through normal channels like “no claims bonuses”;
- Safety gains are claimed; and
- Fuel consumption is measured.

There is little systematic analysis of engine management system outputs as yet although some have plans to do so.

Accelerometers seem to be used not very much and there have been reports of issues with heavy vehicle accelerometers. Generally, the approach is relatively ad hoc, but holistic including route choice, tyre care, vehicle maintenance etc. Drivers are generally compared via their fuel economy on similar routes. The approach seems generally effective in bringing down fuel consumption and improving safety. However, there appears to be room for improvement

What data is held and in what form is unclear, and it is propriety data. The more organised fleets have driver training providers who, on a proprietary basis, analyse the data.

Apart from the normal “no claim bonuses”, insurance incentives for safe economical driving are unknown here, and, if they exist, very uncommon elsewhere. Overseas there are “pay as you drive” schemes where the cost of insurance is on a per kilometre driven basis, but this is an incentive to reduce driving rather than increase driving quality.

Looking at the future, it is recommended that a pilot study be done where driver performance as measured in a bespoke instrumented car is compared with performance as measured by Fiat’s Eco-drive or an aftermarket device like KIWI. In the event of Eco-drive being used:

- The project would indicate how Eco-drive assessment compares with measured performance in the driver’s own car.
- It will also allow evaluation of the latest European based eco-driver assessment metrics in the New Zealand context and facilitate inter-country comparisons.

For the AA it will provide direction for the way forward to either entering into a licensing agreement with Fiat to use the Eco-drive software but adapted for use on AA training vehicles or developing a New Zealand-specific alternative to which the AA will retain the rights.

Contents

Part 1: What is the minimum set of factors that can validate claims of personal eco-driving behaviour such that traffic, vehicle-type, and topographic confounders can be excluded?

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1 Introduction to Part 1

This report is Part 1 for an AA Research project on Standard Metrics for Transport and Driver Safety and Fuel Economy. It looks at the factors that have the greatest impact in determining driver fuel efficiency whilst excluding confounding factors that are not under the driver's influence. The question is concerned with identifying which factors have the greatest impact in determining driver fuel efficiency whilst excluding confounding factors that are not under the driver's influence. The work attempts to rank the relative importance of the identified factors in terms of how much of the variability in fuel efficiency they explain so that factors with a minor influence can be excluded

The brief for this project calls for a minimum set of factors that can provide feedback to drivers and validate claims of personal eco-driving behaviour such that traffic, vehicle-type and topographic confounders can be excluded. The aim is to assist driver trainers, particularly those in a fleet context, by developing a "gold standard" for the measurement of improvements in fuel efficiency and safety achieved by interventions that modify driver behaviour (in particular education) (Personal Communication, Peter King, undated).

The Standard Metrics for Transport and Driver Safety and Fuel Economy project, of which this report forms part, concerns only the behaviour of drivers while driving. Other behaviours related to minimising the overall use of fuel but not directly driving related are excluded. Thus the project and this report do not consider the following important aspects of behaviour which impact upon fuel consumption:

- Route choice;
- Vehicle choice (including tyres), apart from differences related to automatic and manual transmission;
- Use of heaters, air-conditioning systems, audio systems etc.;
- Vehicle maintenance including tyre pressures; and
- Loading of vehicle

It also is not concerned with topography or traffic conditions except where there is an effect on the relative importance of the human factors related to fuel consumption as in the case of highway versus city driving.

It is also a basic assumption of this project that the reduction of fuel consumption is a worthwhile activity.

Part 2 of the project (into which this part leads) is concerned with how the critical factors identified in Part 1 can be collected at least effort and cost to provide feedback to drivers and performance monitoring to third parties (referred to in this report as the manager). A major component of Part 2 will be an examination of GPS-based fleet management systems to identify their ability to meet the above requirements.

2 The mechanisms by which drivers can minimise fuel consumption

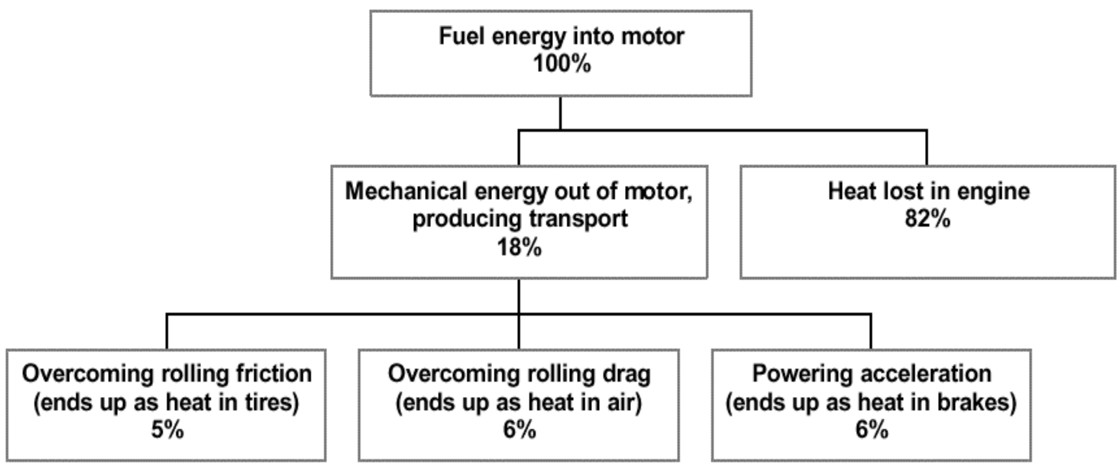
Fuel efficiency as defined by Haworth and Symons (2001) is:

> *"the work output of an engine in terms of vehicle travel as a function of the energy content of the fuel expended in the operation of the vehicle." (p.6)*

Thus the fuel economy of a vehicle (defined as the litres of fuel used per kilometre travelled; the quantity we want, in the end, to improve) can be enhanced by improving the fuel efficiency of driving.

Haworth and Symons (2001) provide the diagram shown in Figure 1 derived from DOT (1998)[2]

Figure 1: Energy consumption by petrol engines



Perusal of this diagram gives an immediate rough idea of how drivers can influence fuel efficiency once they have committed to a particular vehicle[3]. The options by which drivers can influence fuel consumption relate to reducing the mechanical energy out of the motor. They can influence the rolling drag by staying within the speed envelope in which air resistance is least, they can minimise powered acceleration and they can minimise stops where mechanical energy is coming out of the motor with no kilometres being travelled. The behaviours that best achieve these influences will be further discussed in the following sections.

[2] In the subdivision of "mechanical energy out of the motor", "rolling friction" has the same meaning as rolling resistance and "rolling drag" has the same meaning as aerodynamic drag. The three subdivisions add up to 17% rather than 18% presumably due to rounding error.

[3] Rolling friction is not influenced by driving but by choice of tyre and tyre pressure.

3 The driving behaviours which have most impact on fuel consumption

The driving behaviours that most affect fuel consumption are well understood and have been discussed in the literature by a number of authors including, McGordon et al (2011) Berry (2010), Smit et al (2010), Haworth and Symons (2001), Gonder et al (2011), Van der Voort and Dougherty (1998) and earlier Evans (1979). An excellent overview of the literature is available in Luther and Baas (2011) who, as well as looking at the behaviours, look at the effectiveness of measures to improve them. The behaviours described in the listed articles do not differ markedly by year of publication or by author, differing mainly in the nature of the metrics used to describe the behaviours. As an example, Gonder et al (2011) mention:

- Speed during highway driving.
- Frequency and intensity of braking and acceleration
- Frequency of stops – faster acceleration is acceptable if it means that a stop is avoided
- Timing of gear changes - but only for manual vehicles
- Following distance
- Idling

The last five in the list above are all related to braking and acceleration.

4 The impact of fuel saving driver behaviours on safety

The impact of fuel saving driver behaviours can generally be expected to result in an improvement in safety. Luther and Baas (2011) quote a number of studies to illustrate this point, using both heavy and light vehicles. These benefits accompany such behaviour improvements as less speeding and reductions in harsh braking events. While pointing out that hard evidence is lacking, Luther and Baas also express a belief that benefits are also "likely to arise from a more anticipatory driving style" (p14).

However Luther and Baas (2011) do also mention some potential safety issues which would need to be taken into account in any teaching of fuel efficient driving. These potential issues (p15) included:

- A principle of rapid acceleration to target speed[4] could be taken too literally and could cause shorter safety distances in traffic if not combined with proper anticipation.
- Maintaining a constant speed, if misunderstood, can lead to insufficient safety margins because of delayed slowing down.
- Applying engine braking too early may result in a different pattern to that of 'normal traffic' and increase the risk of a rear-end collision.
- The principle of 'avoiding stopping' could cause problems, as if it is applied near pedestrian crossings or intersections without a clear view 'it is possible that the learner driver's observation skills may be inadequate'

Another safety issue which has not yet been fully explored is the potential driver distraction associated with driver feedback devices for providing fuel efficient driving messages. Gonder et al (2012) refers to a US National Renewable Energy Laboratory (NREL) review of existing devices which found that the cognitive effort needed to interpret the visual and audible feedback was not excessive and that visual systems should be designed to limit the time when the driver's eyes are not on the road to less than two seconds.

In terms of safety, any management tool using metrics should also include controls for violation of safety parameters associated with acceleration/deceleration and driver distraction.

[4] This action may not necessarily be correct in all situations.

5 How training can produce fuel saving behaviours

It can be taken as read that these behaviours, when carried out appropriately, do reduce fuel consumption and thus greenhouse gas emissions which are directly linked to fuel consumption. Fiat (2010) estimates that in a study by Fiat, on average eco-driving reduced fuel consumption by 6% with the top 10% of drivers achieving a 10% reduction. However, the evidence of success in attempts to teach these behaviours is mixed (Luther &Baas, 2011; Smit, 2010). The aforementioned authors found few soundly constructed or peer reviewed studies among the many attempts to teach these behaviours which have claimed positive results. It is thus important to obtain metrics which are readily measurable to be able to tell the difference between success and something less than success.

How these behaviours may be shaped in a fleet situation, to produce better fuel economy is covered thoroughly in Baas (2012). This work will be covered in more detail in Part 2 of this project which looks at how metrics may be used most effectively to produce driving with lower energy intensity.

6 The measurement of the influence of various behaviours on fuel efficiency

Driving behaviours may influence the fuel consumption of vehicles as drivers go through the various stages which characterise typical driving cycles. Driving cycles in this context are simulations of driver behaviour under various conditions, based on field observations.

The behaviours taken account of typically include speed, acceleration deceleration and stopping behaviour. A good reference is Smit et al (2010). Driving cycles have various parameters which relate to fuel consumption, which may be used as measures or “metrics” for the effect of behaviour on fuel consumption when other influences can be removed.

Typically the relative influences of behaviours are estimated by putting vehicles through various simulated driving cycles under different conditions. These simulations may be supplemented with results from real world driving. Thus all estimates of factor influence carry with them the background under which the driving cycles and/or real world driving are carried out.

Such studies using different driving cycles with different types of driving under different conditions are generally how the relevant information is obtained. Other examples are Berry (2010), Gonder et al (2012), Smit et al (2010) and Tamsanya et al (2004).

7 The roles of speed, acceleration/deceleration, stops and idling

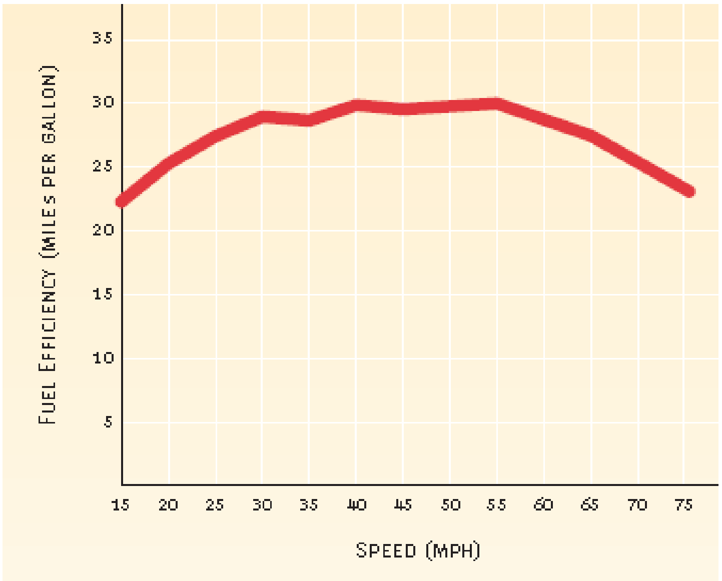
7.1 Speed

In the literature, speed per se is generally considered the more important factor in highway driving. This is because in highway driving, speed variations, with their associated acceleration/deceleration related economy losses, are less important than in urban driving. Haworth and Symons (2001), referring to highway speeds, state that fuel consumption increases with speed because the total tractive force needed to drive the vehicle increases and aerodynamic resistance increases more than uniformly with speed. This results in the sort of fuel economy curve shown in Figure 2 from ACC/LTSA (2000, p. 63) where fuel economy increases with speed until the vehicle reaches around 55mph (~ 90km/h) where the increasing air resistance impact starts to overcome other factors and drive fuel economy down.

The lower fuel efficiency at lower speeds occurs because of engine friction, tyres, and accessories (such as power steering) (TRB, 1998). These impacts vary with the vehicle, and accordingly the optimal speed also varies with the vehicle but the shape of the curve is generally similar to that in Figure 2. Thus, on the highway, keeping speed at around the optimal point for the particular vehicle being driven is important (subject to keeping within legal limits). One can notice from Figure 2 that the shape of the curve is fairly flat at the top followed by a fairly sharp drop off. Therefore travel below the optimum has fewer negative consequences than travel above the optimum. Owner's manuals may provide information on the optimal speed for the vehicle.

For non-highway driving, speed is less important compared with smoothness of driving although as one can see from the curve, fuel economy drops off considerably below about 25mph or ~40km/h.

Figure 2: Fuel efficiency as a function of speed –model year 1988-1995, automobiles and light-duty trucks



Source: Davis (1997, p3-51, cited in TRB, 1998, p69).Note: 1 mph = 1.609 kph; 1 US gal = 3.8 L, The New Zealand Light Vehicle Fleet had an average age of 12.7 years in 2011 (MOT, 2011)

7.2 Acceleration/deceleration

Haworth and Symons (2001), quoting (Robertson et al., 1998), point out that travelling at a constant speed in modern vehicles allows the engine management system to optimise the fuel flow into the combustion cylinder. This minimises fuel consumption and emissions. Therefore, whenever accelerations/decelerations occur some optimality is lost.

7.3 Stops/idling

Acceleration/deceleration losses are accentuated when a stop occurs; eliminating stops is therefore more important than the acceleration/deceleration both on the highway and in cities (Gonder et al., 2012). Also (Evans, 1979) pointed out that fuel used while idling is of great importance in urban driving. Evans (1979) for vehicles of that time estimated that

> *"a driver who stops, idles for 30 seconds while waiting for a light to change and accelerates to resume a speed of 60km/hr uses about 70ml more fuel than a driver who passes through the signal at a constant speed of 60km/hr" (p 397).*

Thus stops are best avoided by judicious driving through faster (acceptable in this case) or slower acceleration. The advent of technology which automatically stops engines when the vehicle is stationary (e.g. Kia's Idle Stop-Go (ISG) technology) will in the future help ameliorate the problem of fuel being burnt while idling.

7.4 An illustration of potential fuel savings and the relative importance of these factors under different conditions

This section illustrates what might be achieved and under what circumstances using the work of Gonder et al (2011).

Gonder et al carried out a simulation assessment of fuel consumption optimised by eliminating stop-and-go driving and unnecessary idling, and adjusting acceleration rates and cruising speeds to ideal levels. They then followed up with real world assessments using different driving techniques. To compare vehicle simulations over each real-world cycle and its corresponding ideal cycle, a midsize conventional vehicle model was used. The comparisons of “ideal” cycle performance and real world performance were done by calculating fuel savings on an “ideal” driving cycle, at varying levels of Kinetic Intensity (KI) and journey length and comparing with real world performance.

KI is a metric linked to the magnitude and frequency of accelerations. The bigger the magnitude and frequency of accelerations, the larger the value of the Kinetic Intensity. The unit of Kinetic Intensity is reciprocal distance. KI tends to be larger for city driving and smaller for highway driving.

To identify maximum potential fuel savings, the project simulated five driving cycles, in conditions of differing KI .which eliminated stop-and-go driving and unnecessary idling and adjusted acceleration rates and cruising speeds to “ideal” levels as shown below:

- Eliminate stop-and-go and idling within each trip.
- Set the acceleration rate to 3 mph/s. (~5km/h/s)
- Set the cruising speed to 40 mph (~60km/h).
- Continue cruising at 40 mph (~60km/h) until the trip distance is reached.

These “ideal” levels were chosen by Gonder et al so are somewhat arbitrary in nature.

The results indicated a fuel savings potential in excess of 30%-40% if the “optimization” above was carried out over the whole of each cycle. The authors concluded that while these results would not be achievable in reality without full automation of vehicles and traffic control, it was promising to note such significant fuel savings from cycle modifications alone with no changes to the vehicle or powertrain.

Other key results of their work were:

- In city driving decreased acceleration, decreased stops and decreased idle are more important fuel savings sources than speed which comes into its own with highway driving.
- Overall, the results indicated that in real world driving conditions substituting efficient driving techniques for the most aggressively driven trips could result in fuel savings of around 20%, and improving more moderate driving styles could reduce fuel consumption by 5%–10%.

- For city trips over 20mph (30km/h)[5], higher average acceleration was associated with higher fuel consumption while for highway trips; higher speed was the strongest indicator of poor fuel consumption. This was contributed to by the large aerodynamic drag accompanying high driving speed which exacerbates higher fuel consumption.

[5] Under 20mph, fuel economy was unsatisfactory even with low acceleration.

8 Driving behaviour parameters (or metrics) for driver/manager feedback

8.1 Introduction

This section will look at the metrics available for use to input feedback on the driver's level of fuel efficient behaviour. Drivers may receive feedback in three main contexts:

- As drivers of fleet vehicles '
- Through education programmes
- As private motorists.

This feedback needs to be given to drivers as they drive and after they drive. It also needs to be available to, and used by managers and course providers. These metrics include the factors which have already featured in this report. Possible future directions in influencing drivers towards more fuel efficient driving will also be discussed.

This report has already discussed the relative importance of the identified factors in terms of how much of the variability in fuel efficiency they explain. However, this has not been done very precisely. This is because at present, the information is not available in the literature to do it precisely.

Some of the metrics can be presented as rates or absolute numbers, and over various time periods. The time periods can vary from instantaneous to averages over an entire journey. Where rates are chosen, there is a choice of rates. The minutiae of this are not discussed here but would need to be grappled with, and implemented, so that driver distraction issues do not later emerge.

As discussed earlier the importance of the factors to which these metrics relate is dependent on how road conditions and the metrics themselves interact. For example the number of stops and the duration of stops clearly have an interactive impact on fuel economy. How they are used will differ between whether the purpose is driver feedback or course manager feedback.

For the manager a system whereby the vehicle can be interrogated post journey to give a normalised view of the driver's fuel-efficient performance would seem a sensible option. Systems which attempt to do this have been implemented in a number of places and will feature in Part 2 of this project.

Whether the information is being imparted to the driver or the manager, simple, easily assimilated messages are essential if the message is to reach its target successfully. Thus simple metrics like stops, acceleration, speed, duration of stops should be those directly communicated. Some of the metrics described here are complex and hard to grasp if you are not an automotive engineering professional and should not be used for lay communication. The more complex metrics have value as quantities used by engine management systems to inform the driver or manager about the fuel efficient driving characteristics of the driver.

8.2 Measurement of Metrics and the use of OBD

It is very important that metrics are easily measured. It is fortunate these days that there are a large range of metrics that can be obtained easily from engine management systems. All modern vehicles have complex engine management systems which are accessible via an On-board Diagnosis (OBD) port. Through this port it is possible to download a large array of information including much which is relevant to the degree of fuel economy driving being shown by the driver. There are already hardware and software systems on the market which use the OBD port in this way. It would seem that the use of this information, linked with Global Positioning Systems (GPS) and Geographical Information Systems (GIS) would be a sensible way for managers to evaluate the fuel efficient driving of their students. Thus it would be sensible that metrics used be harmonised with the outputs of the OBD ports of vehicles. It is the intention that this aspect and the use of OBD port information be discussed in more detail in the Part 2 of the project.

8.3 Discussion of Metrics associated with factors pertinent to fuel efficient driving

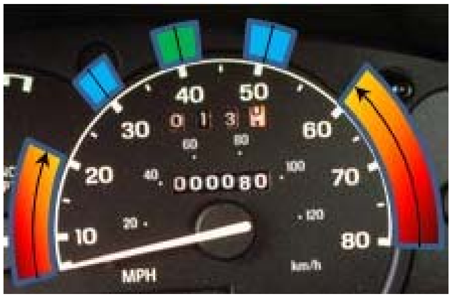
This part of the report will discuss metrics associated with the most important factors related to fuel efficient driving in sections headed by the name of the relevant factor. The order of presentation of the factors is of no significance.

8.3.1 Factor 1: Speed

The available metrics are instantaneous speed, average speed (where the time unit includes time stopped) and travel speed (where time stopped is not included). Instantaneous speed is already available in all vehicles via the speedometer, while the others are also available from displays on some vehicles.

The crucial thing about speed is keeping it within the envelope of optimality of the vehicle. There are various ways in which this can be communicated to the driver. The most simple, but probably not very effective (as anecdotally, handbooks are little used), is instruction in the driver handbook. The handbook for the 2004 Toyota Avensis states that the most economical speed for the car is 90km/hr. Another very simple method is attaching stickers to the scale on the speedometer of an existing vehicle to indicate the most efficient speed range of the vehicle, or better having such an indication as standard equipment. Figure 3 shows a speedometer display augmented to advise the driver to keep the vehicle in the range 20 to 60 mph.

Figure 3: Speedometer display augmented with speed advice



Other options are voice advice or alarms to indicate when you are outside the economical speed range for the vehicle.

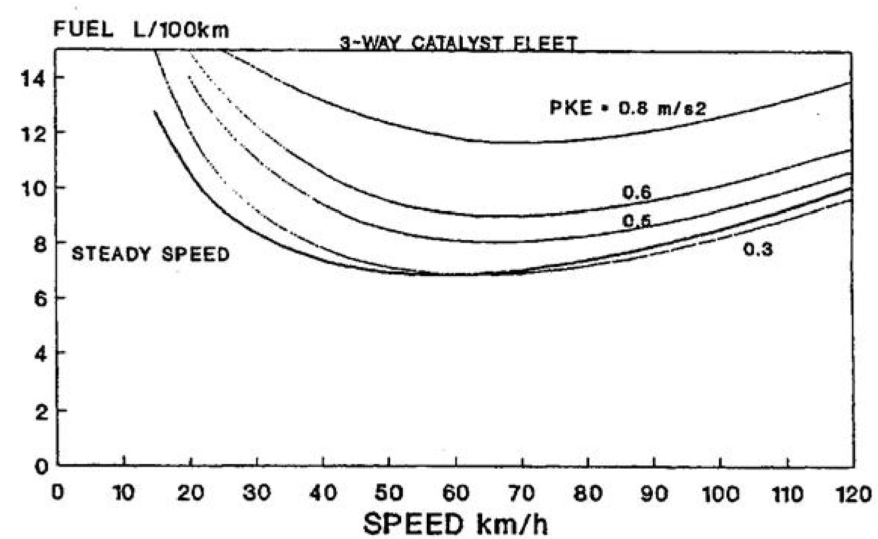
8.3.2 Factor 2: Smoothness of driving (Related to frequency and intensity of braking and acceleration)

Metrics used in drive cycle studies include Kinetic Intensity (KI), defined in O'Keefe et al (2007), Positive Kinetic Energy (PKE), defined in Nairn et al (1994) time to collision (defined in Gonder et al., 2011) and simple acceleration and deceleration (negative acceleration). These metrics are all directly related to smoothness of driving.

KI is a metric linked to the magnitude and frequency of accelerations. The bigger the magnitude and frequency of accelerations, the larger the value of the Kinetic Intensity. KI is the measure of driving smoothness used by Gonder et al (2011). The unit of Kinetic Intensity is reciprocal distance.

Positive Kinetic Energy is the energy required per unit of distance by a vehicle when it increases its speed and is obviously related to acceleration and thus smoothness of driving. Its units are m/sec^2. An example of its use as a metric follows in Figure 4 from Nairn et al (1994) quoted in Haworth and Symons (2001).

Figure 4: Estimated effects of Positive Kinetic Energy (PKE) and average speed on fuel consumption. From Nairn et al., 1994



Howarth and Symons (2001) observe from Figure 5 that for average speeds within the range of 40 km/h to 90 km/h, the fuel consumption rate varies significantly with PKE. Compared to steady speed (PKE = 0), fuel consumption at PKE = 0.8 m/s^2 is increased by between 50% and 100%. At each part of the speed range in Figure 5 the change with PKE is much greater than the change with varying speed[6] indicating the importance of acceleration to fuel economy.

Time to Collision (TTC) is a metric defined by Van der Voort et al (2001) as the following distance from one car to another divided by the speed difference, where the second car is approaching the first from the rear. The metric is directly related to driving smoothness as a driver trying to drive smoothly will not approach a vehicle from behind in such a way that rapid braking is necessary to avoid a collision.

In the case of use as an indicator to drivers, raw acceleration would appear to be preferable to the three more technical measures as the understanding by drivers would be higher. A bar chart of instantaneous speed would also provide good information on the acceleration or lack thereof happening at any particular time.

Acceleration/deceleration or smoothness of driving can be measured by the variation in speed (i.e. the smoother the driving the lower the speed variation). Developing user-friendly ways to present this to drivers and encourage improved driving may be worth consideration.

Another visual indicator to the driver of smoothness of driving is the instantaneous fuel consumption of the vehicle which is available as a bar chart on most modern vehicles. This reading also provides, arguably the best metric for gauging economical driving.

8.3.3 Factor 3: Stops (associated with smoothness of driving)

The obvious metric here is number of stops.

8.3.4 Factor 4: Idling time (associated with smoothness of driving)

The obvious metric here is time spent idling.

8.4 The place of engine revolutions in this discussion

The “rev-counter” may be used by drivers as a rough indicator of how hard the engine of their vehicle is working. Thus it has a place as one of the tools drivers may use to regulate their driving. However, it is vehicle specific, and is not generally recognised in the literature as a metric used in reducing fuel consumption. It is rather used as an indicator in manual

[6] This is consistent with speed having a greater real world impact in rural areas than acceleration/deceleration as there is much less acceleration/deceleration going on in rural driving than urban driving.

vehicles of when to time gear-changes. An example is advice given by Renault to drivers of Renault vehicles.[7]

- Shift down at approximately 1,000rpm
- Shift up to the next gear at approximately 2,000rpm in diesel vehicles and at 2,400rpm in a petrol engine
- At 50kph, you should already be in fourth or fifth gear.

8.5 Comparing the results of different providers of fuel efficient driving tuition

Tuition providers' claims may be hard to evaluate as to their veracity. To compare the results of different providers it would be best if common criteria were used involving common metrics with some sort of a normalisation procedure for traffic conditions and terrain. Otherwise complicated experimental approaches, like those of Van der Voort and Dougherty (1998), would be required.

[7] http://www.renault.com/en/capeco2/eco-conduite/pages/eco-conduite.aspx Viewed 20/9/2012

9 Possible future directions

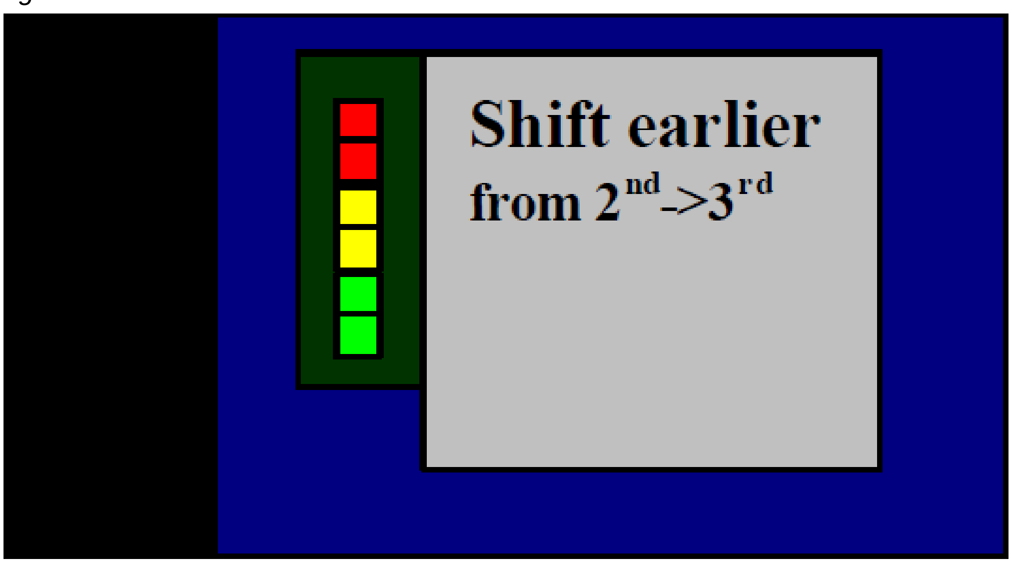
This report is about measuring and ranking the factors for driver fuel economy, for driver feedback and for use by managers and course providers to assess the degree of fuel efficient driving being exhibited by their staff and students and to compare the efficacy of different methods. It must be remembered however, that any such ranking of factors in terms of impact in determining driver fuel efficiency is a relatively blunt instrument.

The logical end would be the vehicle taking over, obviating the need for driver feedback. Gonder (2012), suggests for the future that

> *"the vehicle intelligently selects optimal acceleration/ deceleration rates and cruising speeds. The driver's full attention could then remain on the road to ensure safe operation (rather than occasionally diverting attention to a feedback device)."*

This of course already happens to some extent within engine management systems. The precursors of such vehicle intelligence related systems have already been used in Europe as part of experiments involving design of a fuel-efficiency support tool. The impact of such a tool has been described in Van der Voort and Van Maarseveen (undated). The support tool includes a normative model that formulates optimal driver behaviour to minimise fuel consumption. If actual behaviour deviates from this optimal behaviour, the support tool presents advice to the driver on how to change driver behaviour. The advice is presented by a human machine interface an example of which is shown in Figure 5 from Van der Voort and Van Maarseveen (undated).

Figure 5: The human machine interface for extended advice



Van der Voort & Dougherty (1998) considered that to be effective in improving fuel economy, a driver support tool must exhibit the following characteristics:

- provide the driver with clear, accurate and non-contradictory information
- take into account the present context of the vehicle

- place no requirements on the driver which are too high to safely combine with the actual driving task
- work within both urban and non-urban environments.

The experimental tool used inputs readily available from existing technologies. These included vehicle speed, engine speed, clutch, gear position, accelerator position, steering angle, braking force and headway. These were combined with specific parameters peculiar to the vehicle being used including the fuel consumption map of the engine, gear ratios, vehicle weight, rolling resistance and air resistance. One of the basic aims of the advice system is to keep the operation of the engine as close to optimal as possible, particularly during acceleration.

A driving simulator experiment (see Van der Voort & Dougherty, 1998) revealed that drivers were able to reduce fuel consumption by 16% compared with 'normal driving' and by 7% compared with driving fuel-efficiently without support. The experiment being European, where manual transmissions predominated at the time, dealt only with manual vehicles. Presumably a system for automatic vehicles would need to include optimisation of gear change control mechanism of the automatic transmission.

For the manager, once such a support tool was validated, evaluation of the student could be carried out simply by looking at compliance with the support tool. This has already been done by Fiat as reported in Fiat (2010) where the engine management systems of Fiat vehicles were set up to feed back to the drivers and also give a star rating to drivers. This sort of information was also in a form to be easily available to managers or course supervisors.

10 Discussion

The main factors related to a driver's fuel efficient driving are:

- Speed (most important in highway driving)
- Smoothness of driving
- Number of stops (related to smoothness of driving)
- Duration of idling (related to number of stops and also smoothness of driving)

Stops and idling are obviously substantively a product of smoothness of driving and, to some extent, speed so these factors are not mutually independent.

It is clear from the literature, that on the highway, speed is of greater importance than smooth driving with the opposite occurring in the city. This is clearly a function of the lower opportunity for acceleration and deceleration and attendant stopping and idling on the highway. In all situations aggressive driving leads to more fuel use than less aggressive driving.

This report has discussed the relative importance of the identified factors in terms of how much of the variability in fuel efficiency they explain. However, this has not been done very precisely. This is because at present, the information is not available in the literature to do it precisely.

The main ranking of factors is in fact a dichotomy; speed is more important on the highway and smoothness of driving is more important in the city.

In terms of smoothness of driving acceleration/deceleration, stops and idling time are all important and very interactive and should all feature in information presented to the driver. It is not possible to rank these due to the interaction and the dependence of what drivers can achieve on the conditions in which they are driving. However, this should be no bar to progress in improving the fuel efficiency of the driving population.

Any scheme using metrics to measure the effectiveness of the human element in fuel efficient driving needs to monitor safety parameters related to acceleration/deceleration and driver distraction.

There is great scope for placing more fuel efficient driving technology into the vehicle itself so that it happens automatically without driver intervention. This is appearing now with such measures as technology that turns engines off rather than idling, sophisticated engine management systems and vehicle stability control which dampen overly aggressive driving and speed limiting technology. There is also the possibility of setting up the on board computer to use its intelligence to advise the driver, and when required, managers and course supervisors both for fuel efficiency and safety purposes. This has already been done by Fiat as reported in Fiat (2010) which will be reported on in greater detail in the task 2 report.

11 Conclusions

1. The main factors related to a driver's fuel efficient driving are:
   - Speed (most important in highway driving)
   - Smoothness of driving
   - Number of stops (related to smoothness of driving)
   - Duration of idling (related to number of stops and also smoothness of driving)
2. The relative importance of these factors varies with the driving conditions. There are a number of metrics which relate to these four factors. These metrics differ in their level of clarity to the lay person who may be a driver or a manager
3. In terms of driver feedback, the usefulness of the various metrics is fairly well-known.
4. In terms of manager feedback, the relative usefulness of various metrics may become clearer after the examination of their use in the fleet context which is within the scope of Part 2 of this project.
5. With the advent of On-board Diagnosis Ports on vehicles a wealth of information is available including information related to fuel economy and driver behaviour. This information, in conjunction with GPS and GIS information, has the potential to make much clearer the driver's contribution to fuel economy on a particular journey. It is sensible that any set of metrics be compatible with outputs from these diagnostic ports.
6. It is possible at this stage to provide a minimum list of factors, as listed above. It is not however possible at this stage to provide a minimum set of metrics.
7. In terms of safety, any management tool using metrics should also include controls for violation of safety parameters associated with acceleration/deceleration and driver distraction.
8. Part 2 of the project will reveal to what extent such tools are available and being used in practice.

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Part 2: The practical use of metrics to provide driver, fleet manager, and trainer feedback, including insurance incentives

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12 Introduction to Part 2

This report is Part 2 of an AA Research project on Standard Metrics for Transport and Driver Safety and Fuel Economy. This report will look at how the types of metrics described in Part 1 of the project are used in practice, in New Zealand and overseas, in situations where fuel efficiency is a prime driver of their use. It will also detail where discounts on insurance costs have accompanied the successful achievement of fuel efficiencies. These discounts are not from special insurance schemes but in all cases are just the result of safety gains, achieved along with the fuel efficiency gains reducing insurance premiums through such time-honoured mechanisms as no claim bonuses.

The main emphasis will be on fleet users but feedback systems such as the American “Kiwi” system from PLX Devices and that provided by Fiat for its own vehicles will also be discussed. These information presentation systems using metrics give an idea of the potential of devices in this area. Such devices are becoming increasingly, and more cheaply, available to interested individuals and to fleet managers and driver educators.

Overseas there are schemes called Pay As You Drive (PAYD) insurance which incentivises drivers to reduce their driving, but these are outside the scope of this project.

Outside of insurance, the fuel efficiency schemes looked at in many cases include elements outside the scope of this project. These include improving route choice, travel distance reduction, improving vehicle choice, and improving the aerodynamic qualities of vehicles by covering loads. In many cases the fuel efficiencies obtained and quoted are overall figures, so the impact of driver related measures cannot be separately assessed.

It is also seldom that all the metrics are being used, and in many cases they are not in fact being used as metrics, but more as triggers. For instance many fleets speed limit their vehicles to below the speed limit and thus access fuel efficiency gains as well as safety gains and avoidance of expenditure on speeding tickets.

Similarly the other measure commonly used in fleets is turning off the engine instead of idling. Measures related to acceleration are less reported, with problems with congestion being dealt with often by route choice.

A number of vehicle fleets use GPS sometimes in conjunction with engine information to aid them in their endeavours. GPS is a help in detecting stationary vehicles, where an automatic alert can be sent to drivers to turn off the engine. Vehicle tracking can also provide information on what the engine is doing, speed, acceleration etc. and the driver’s identity.

The amount of this information utilised by fleets varies widely and there is room for improved usage overall.

Much of the information in this area is of an anecdotal nature, from web sites, many of them of advocacyr organisations, or the non-peer reviewed literature. Peer reviewed information is not common. Thus comprehensive, demonstrated to be technically sound, information is rare.

13 Examples of commercial devices to provide feedback on fuel efficiency of driving from the engine management system

There are systems available which use information from the engine management systems of vehicles to inform users and their managers /teachers on their fuel economy. Two examples of this are the Fiat "Eco-drive " system and the Kiwi System from PLX Devices (http://www.plxdevices.com).

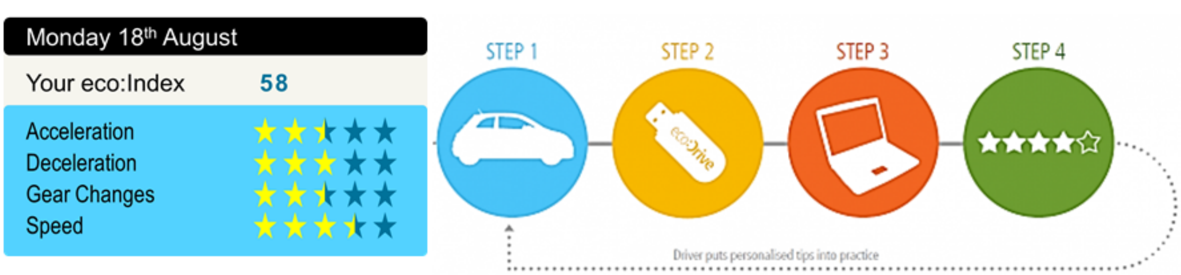
Fiat Eco drive uses the engine management system to give drivers "eco-indices" and star rating using fuel efficiency metrics.

- The system is proprietary (the free Fiat-specific software was developed jointly by Fiat and Microsoft).
- Although it may be completely sound, exactly how the ratings are calculated is not public information.
- It is also not known how or if an allowance for safety is incorporated into the system.

However, it is, arguably, the European gold standard for the assessment of fuel-efficient driving.

Figure 6 illustrates the type of information available from eco-drive and also how the information is obtained- i.e. via a computer analysing information collected using a flash drive from the engine's diagnostic port.

Figure 6: Information available from the Fiat eco-drive system; and how it is obtained



As can be seen an overall eco-index is provided along with star ratings against four metrics. At the time when Fiat (2010) was written Fiat was on track to produce a real time version for drivers in 2011. A version for fleet managers was produced in 2010.

The Kiwi provides the displays shown in Figure 7 for drivers again providing an overall score and ratings against four metrics. The Kiwi system shares the same unknown quantities as have been detailed earlier for the Fiat eco-drive system.

Figure 7: Displays provided for the Kiwi Device

PLX Devices also markets a Bluetooth interface and an Android APP whereby engine management system information can be displayed in real time on an Android smartphone as well as downloaded and analysed using the phone. Figure 8 shows a screen shot of an Android Phone displaying analyses of such data.

Figure 8: Screen shot of an Android Phone displaying analyses of engine management system data

PLX Devices also provides free software to analyse data from the engine management system and an OBD 2 port to Wi-Fi adapter which can communicate with Apple mobile products.

Ford is also using metrics to provide feedback to drivers on fuel efficient driving. Ford EcoMode (http://media.ford.com/article_display.cfm?article_id=33965) is a software application available on the Ford Focus that rates driver behaviour impacting fuel economy and provides simple hints on how to improve behaviour to the driver.. EcoMode uses metrics like gear shifting, constancy of driving and speed as inputs to a performance display on the instrument cluster. Focus drivers can review their generated scores against the software's optimized patterns for each of the disciplines measured by the metrics. Performance is logged cumulatively but the system can be restarted by resetting the average fuel consumption.

The Ford EcoMode display is shown in Figure 9.

Figure 9: Ford EcoMode display

Ford of Europe also runs a service called Ford Econo Check (http://www.ford.ie/FordService/FordEconoCheck) whereby among other eco-driving related services, Ford dealers fit a data logger to the client's car and measure such metrics as speed,, acceleration, braking and gear changes for 7 days. The client can then obtain an e-mailed report on the fuel efficiency of his/ her driving.

Smartphones as well as being connectable to the engine management systems of vehicles via Bluetooth or Wi-Fi also are becoming increasingly loaded with sensors like accelerometers and can of course access GPS which gives them the ability to estimate speed. Thus there is increasing ability to write APPs which use the phone's own capabilities to provide information relevant to safe fuel efficient driving or to combine the phone's capabilities with information from the vehicle engine management system to provide a more refined report. Thus smartphones may become an important source of driver, manager and trainer feedback in the future

14 Examples of Metric and GPS use by fleets of vehicles

14.1 Examples from the literature and the internet

Mu et al documents how using GPS is combined with information on speed, engine status, who the driver is etc. to better optimise the operations of a large Taiwanese trucking firm. By mining these data the firm is able to identify where, when and by whom behaviours like speeding, excess idling, and excess acceleration/deceleration are happening and take decisive action.

According to FleetMatics (2011), FleetMatics has a GPS vehicle tracking system which allows owners to locate and deploy their vehicles with live, real-time tracking, Both Ballard (2010) and FleetMatics[8] (2011) nominate speed and idling time as the most important contributors to lower fuel efficiency in a fleet setting and recommend GPS tracking, which can detect speeding and stopped vehicles as part of the answer. They both also put down the idling as a human problem caused by drivers seeking to keep conditions in the cabins of their vehicles comfortable. No mention is made on the possible driver welfare or road safety implications of controlling this behaviour, given that climate control is a given in other workplaces. An example of how this works out in practice is a FleetMatics user who runs coaches and has an i-phone app which alerts him whenever a coach idles for more than 5 minutes and claims to have had substantial fuel savings.[9]

Oehlerking (2011) developed a regression model named StreetSmart that can serve as a transfer function between 4 traffic classification parameters called "Energy Indices" and the fuel consumption of specific vehicle makes. The energy indices are terms related to acceleration/ deceleration, idling time, time moving and the length of the road segment being analysed. (The quotient of segment length and time moving being speed).The detailed acceleration profile of individual vehicles on a road segment is analysed. Using data logged on OBD-II and smartphone devices from over 600 miles of driving the model predicted fuel consumption with an average accuracy of over 96% using regression coefficients obtained from the same vehicle make and similar road types. Mean prediction error for all cases ranged from -2.43% to 0.06% while the max prediction error was 7.85%. One goal of the project related to in the future being able to use crowd sourced mass quantities of smartphone accelerometer and GPS data from drivers.

Teang et al (2007) discussed an intelligent fleet management system .incorporating Global Positioning System (GPS) and Global System for Mobile Communications (GSM) to

[8] FleetMatics (http://www.FleetMatics.com) is a leading US provider of GPS based fleet management for small and medium-sized businesses.

[9] http://www.FleetMatics.co.uk/testimonials/FleetMatics-fleet-management-system-helps-coach-hire-firm-realise-a-10-fuel-saving/936 Viewed 15/10/2012

ensure the positioning of vehicles is available in parts of urban areas where GPS coverage is limited. This dual positioning system is combined with information from the vehicle's on board computer to gather information on such quantities as distance travelled, speed, and fuel consumption etc.so that the driver's behaviour can be studied. The proposed system was described as successfully implemented and evaluated on twenty vehicles including buses and cars but no specific information was given on how these metrics were used to influence more fuel efficient driving.

Fleetsafe (http://fleetsafenz.co.nz) is one of a number of driver training providers to fleets in New Zealand. Peter Shepherd of Fleetsafe in discussion reports that in the Fleetsafe programme observation and modification of driver behaviour and information from the engine management system is combined to produce a picture of the student with regard to safety and fuel efficiency. Peter Shepherd considers such areas as controlling speed and engine revolutions and braking very important as is scanning the road ahead, both for safety and fuel efficiency. He sees driver foot movement as a key indicator of safe, fuel efficient behaviour. The Fleetsafe trainers compare the performance of their students on the same circuit thus eliminating as much as possible road conditions from the equation. In the fleets served by Fleetsafe the main metrics used are speed, acceleration and deceleration (braking), and idling time, with GPS aiding by telling management where the vehicle is, and what it is doing.

14.2 Some Fleet Case Studies

There are a number of vehicle fleets both in New Zealand and overseas where fuel savings .and safety gains have been accessed by better fuel efficient practices including better driving practices. In some cases it has been stated that the safety gains have resulted in lower insurance costs. Those cases where the information available makes them relevant to this project are detailed in this section.

14.2.1 UPS (USA)

UPS which runs a fleet of over 65,000 delivery trucks has developed a Telematics[10] system to track over 200 metrics covering everything from tire pressure, idle times, speed, engine RPM, to the number of times the truck is put into reverse and if the driver's seatbelt is fastened. The data is stored on board and uploaded daily via a radio link. Information is presented in a clean "dashboard" format for clear analysis and decision-making: Information presented on fuel efficiency and safety includes among other driver performance metrics driver braking patterns, engine RPM, speed, seat belt use, and idling time. UPS claims that telematics data has led to decreased average vehicle idle times of 24 minutes per driver per day.

[10] http://www.triplepundit.com/2008/05/brown-continues-getting-greener-telematics-helps-ups-squeeze-out-higher-efficiencies-and-increased-safety/ Viewed 15/10/2012

14.2.2 Alexander Petroleum

As reported by Baas (2012). Alexander Petroleum became concerned in 2005 with excessive speeding by drivers thus increasing the risk of vehicle rollovers, motor vehicle accidents, driver fatigue and damage to the company's reputation and also negatively impacted the bottom line. The company then decided to carry out a multifaceted endeavour to improve fuel consumption and safety of its fleet. The measures directly related to driving which were instituted included.

- limiting the speed of all vehicles to 88km/h
- resetting all vehicle default idle time cut-offs to three minutes
- monitoring all idle override exceptions
- maximising the use of OEM-fitted driver displays recording fuel consumption
- reprogramming the electronic transmissions to facilitate earlier upshifting
- feedback to drivers and management and reward of positive driver behaviour

These measures along with a number of other measures resulted in:

- Over a two- to three-year period reduced fleet fuel consumption of 17.8%
- improved the recordable incident rate across all key health, safety and environmental areas by reducing the total number of incidents by over 50% from June 2005 (23 incidents) to June 2008 (10 incidents)
- A reduction in the occurrence of >90km/h speed exception reports recorded by vehicle instrumentation of 99% from 4754 in January 2006 to 44 in January 2008
- reduced insurance premiums

14.2.3 Downer

Downer (Baas, 2012) operates in 80 locations around New Zealand and has one of the country's largest transport fleets (around 4,000 vehicles).of many sizes. In 2008 Downer introduced a wide-ranging sustainability programme to minimise energy use across all of its business.

This included a fuel efficient driver training programme and monitoring and feeding back driver improvements via smart GPS technology. The emphasis in this area was on reducing speed and unnecessary idling. Idling was partly caused by engine-powered flashing traffic control lights. These were replaced by battery powered LEDs and along with driver training this reduced idling fuel use significantly Speeding has significantly reduced through monitoring using GPS and appropriate feedback to drivers. The programme showed an immediate 30% fuel use reduction with longer term reductions expected to be around 10% (an achieved 15% with no stated time frame according to Baas (2012). Other benefits include better safety awareness and behaviours, and lower insurance premiums.

14.2.4 NZL Group

The NZL Group (Baas, 2012) has over 350 staff and a contracted network of several hundreds of transport companies. As part of an effort to improve fuel efficiency it instituted a trial with the following components:

- using telematics technology to capture information
- SAFEDNZ[11] driver training to raise driver skills and awareness (making improvements)
- monitoring what was happening and why (measuring the change)
- providing feedback to drivers/trainers and managers

Wireless engine management system units were used to capture the vehicles' engine information. The data collected was analysed to determine how the vehicle was being driven (idling, speeding etc.) and its fuel consumption and fed back to drivers and management.

The results of the trial as they relate to drivers were:

- 5% fuel saving from drivers that were involved in the trial and have been SAFEDNZ trained
- These drivers improved by a further 2% after phone-text feedback to drivers several months after the trial
- 33% reduction in time spent speeding
- 47% reduction in time and 65% reduction in distance for which brakes are on after SAFEDNZ training

With regard to insurance premiums Cherie Hawkins of NZL group has e-mailed to the effect that

"With regards to insurance benefits it is based on results and it is a reward system. We have not had a company truck roll over for 4 years now so having two in-house qualified Driver Trainers who focus on SAFEDNZ training benefits all stakeholders within the organisation."

14.2.5 Winstone Aggregates

According to Baas (2012) Winstone Aggregates is New Zealand's largest aggregate company with 26 quarries nationwide providing its fleet covers about 5.5 million kilometres each year. It has 26 quarries nationwide providing 4.5 million cubic metres of material yearly.

Winstone Aggregates[12] uses GPS tracking to monitor driver performance, and provide feedback particularly focusing on speed and idling time. The importance of this was

[11] http://safednz.govt.nz/

[12] http://www.eecabusiness.govt.nz/sites/all/files/winstones-drive-down-transport-energy-costs-case-study-june-09.pdf

highlighted recently when no GPS was available during a system changeover. Because of this they were unable to provide drivers with individual performance feedback. During that time average idling times increased from 6% to 9% which again reduced once the changeover was complete and drivers once again received regular feedback.

In the area of driver behaviour, Winstone has among other measures, reduced fuel consumption by reducing idling time and speed limiting its vehicles to 90 km/hr. By encouraging drivers to turn their engines off when picking up loads, and avoiding congestion, idling times have reduced from 12% of time to 6%. Thanks to these measures, Winstone Aggregates is saving around $335,000 every year in fuel costs.[13] There is no information available about its insurance premiums.

14.2.6 Smith and Davies

According to Baas (2012) Smith & Davies Ltd was established in 1927, and is now one of the largest heavy vehicle and equipment fleets in the upper North Island and has over 215 employees. It specialises in large transport and civil engineering construction contracts and uses GPS. It is working with the TR Group to develop an automated vehicle monitoring system that will provide reports in fuel efficiency, speeding, idling and other factors at the manager and driver level. At the time of writing of Baas (2012) there were some encouraging results with at-work and motor vehicle accidents decreasing. The decreasing motor vehicle accidents presumably had a positive impact on insurance premiums although none was stated.

14.2.7 Z Energy[14]

Z Energy is developing its efforts in the area of reduced fuel use in the context of its four sustainability pillars:

- Producing less waste
- Reducing carbon intensity,
- Reducing fossil fuel use
- Supporting New Zealand.

Two specific goals are to reduce the distance travelled to deliver fuel and to reduce delivery emissions by 25% independent of the reduction in kilometres travelled; Z Energy's vehicles are currently speed limited to 88km/h, and all are GPS monitored with exception reporting sent to management if vehicles speed. Regular audits of GPS reports are made to check speed compliance in areas with lower speed limits. The vehicles have 3 axis accelerometers to measure longitudinal, lateral and vertical accelerations/decelerations however the data integrity is generally poor, so much so that earlier systems providing exception reports have been disabled.

[13] http://www.eeca.govt.nz/news/three-businesses-star-campaign-curb-energy-waste Viewed 23/10/2012
[14] Thanks to Dom Kalasih Logistics Manager Z Energy for providing this information

Currently idle time is not monitored but this will be considered as a more rigorous fuel savings/monitoring programme is developed. The main metric used is truck fuel consumption and driver league tables are under development as a means of sharing this information more widely.

Generally there is good acceptance and awareness by drivers that on occasion comparative consumption performance is not appropriate.For example, drivers using the same truck to complete local deliveries will not be compared with the same unit doing a long distance run. However, typically there are sufficient like-for-like runs where fair comparison can be made.

Integrity of data is a very real and challenging issue. It is believed that the only way to maintain data integrity is to have clear refuelling policies and to use GPS systems to monitor the vehicles and co-ordinate with each re-fuelling so that accurate consumption data (for example km/l) is collected. The technology is now available. However it is still a challenge convincing operators that the level of investment in this data collection justifies the benefit

No savings in insurance costs have resulted from this work.

14.3 Summary of information from vehicle fleets on the use of fuel efficient driving metrics and GPS.

Information related to the use of fuel efficient driving metrics and GPS by New Zealand vehicle fleets and UPS is shown in Table 1.

Table 1 Use of fuel efficient driving metrics and GPS by New Zealand Vehicle fleets

	Speed	Acceleration	Idling	Stops	GPS	Insurance saving?	Improved safety?
UPS	Yes	Yes	Yes	Not stated	Yes	Yes	Yes
Alexander Petroleum	Yes	Not stated	Yes	Not stated		Yes	Yes
Downer	Yes	Not stated	yes	Not stated	YEs	Yes	Yes
NZL Group	Yes	Not stated	Yes	Not stated	Yes	Yes	Yes
Winstone Aggregates	Yes	Not stated	Yes	Not stated	Yes	Not stated	Yes
Smith and Davies	Yes	Not stated	Yes	Not stated	Not known	Not stated	Yes
Z Energy	Yes	No	No	No	Yes	No	Yes

It is also relevant that as all the fleets are interested in overall fleet performance rather than just driver performance, they all directly measure fuel consumption, and for them, this is a key metric for the overall operation of the fleet.

14.4 Data integrity and multiple drivers

There is little information on these areas except that each fleet have their own methods of dealing with them, and the information from Z energy that data integrity is a real problem. GPS data differs with the system used, and the knowledge fleets have of who is at the wheel at a particular time and place is dependent on their management systems. In terms of data from the engine management system, the integrity of the data is not disputed. The variable is the analysis method used, and what other data may be injected into the analysis, and with what justification, to achieve the final numbers which are fed back to the driver, manager, or trainer.

15 Insurance-based incentive schemes

The literature so far is light on reports of discounts from insurance companies for eco-driving behaviour except for "pay as you drive" (PAYD) schemes which encourage reduced travel, which are outside the scope of this document.

On its website[15], ITS America foreshadows a report entitled "Insurance Telematics An Emerging Opportunity" to be published in 2013. It mentions that Insurance companies in the 2000's have used technology to evaluate driving habits and analyse risks, offering discounts for safer drivers. This future report will look beyond the issue of driver distraction and focuses on how feedback and insurance incentives may encourage and improve safe driving behaviours.

What literature there is focuses on safety, but given that improving safety is highly related to improved fuel consumption, this literature is included here. Thus this report will focus on safety related insurance incentives which are accessed through fuel efficient driving schemes.

There is also the possibility of "pay as you speed" (PAYS) schemes which are within our scope, where people may be given insurance or other incentives to stay within the speed limit, or indeed any efficiency based speed. These are merely experimental at present. Hultkrantz and Lindberg, Gunnar (2011) reported a study where some car owners were offered a monthly bonus which was reduced every time they broke the speed limit. Their speeding behaviour was compared with a group of similar owners given the bonus but not with the threat of reduction were they to exceed the speed limit. The owners all had vehicles equipped with systems to relay their speeds to a third party. It was found that the scheme impacted only severe speeding The study suggested that such schemes, in the form of insurance programmes or otherwise, coupled to the use of speed monitoring devices may reduce severe speeding

Baas (2012) suggests insurance discounts to reward fleets for adopting best-practice but does not quote any existing ones. He does however mention (p 64) that in the case of Alexander Petroleum "A focus on eliminating speeding over 90km/h and saving fuel" has reduced insurance premiums. This has not been done by incentives from the insurance companies aimed directly at the company's practice, but indirectly through the safety record of the fleet involved improving and that being reflected in premiums. This sort of change has been noted in a large number of case studies and is bound to happen with fuel efficient driving owing to the well-established positive relationship between safety and fuel efficient driving and the well-established policy of the insurance industry to reward good claims histories with lower premiums.

Fleetsafe (http://fleetsafenz.co.nz) is one of a number of providers of driver education to New Zealand vehicle fleets. Peter Shepherd of Fleetsafe remarks that Fleetsafe is about to embark on an alliance with ACC which should culminate with some form of ACC accreditation of fleets which meet certain standards. This would lead to lower ACC levies

[15] http://www.itsa.org/knowledgecenter/market-data-analysis/insurance-and-its Viewed 16/10/2012

for accredited fleets and members of the insurance industry have informally indicated that they could well follow with reduced vehicle insurance premiums. The programs leading to accreditation are safety programmes which have a significant fuel savings component.

16 Summary

This summary relates to the use of the metrics associated with the safe fuel efficient behaviour of drivers discussed in Part 1of this project and the possibility of insurance incentives for safe, fuel efficient driving.

It must be borne in mind that many fleets use overall fuel economy as a major metric and use other means to compare drivers, like comparing them over similar runs under similar conditions. However, as this is outside the scope of this project it is not discussed in any depth.

1. ***Devices to provide metric related feedback on safe fuel efficiency***
   - Such devices are on the market and work through interfacing with the vehicles engine management system, and may like the Fiat Eco-drive use other information from databases of prior driving as inputs.
   - Nobody knows their inner workings as they are propriety devices.
   - Thus their usefulness locally requires independent assessment
   - Smartphones are able to use their own capabilities (like accelerometers and GPS) in conjunction with information gained by connecting, via Bluetooth or Wi-Fi with engine management systems of vehicles. As such they have an important potential as future feedback devices.
2. ***Fleet Management***
   - A number of fleets use at least some of the fuel efficient driving metrics mentioned in Part 1 of the project in endeavours to improve the fuel efficiency of their fleets.
   - Mostly, the fleets involved are predominantly heavy vehicle fleets although Downer, for instance, has a significant number of light vehicles.
   - As most of the fleets do a lot of driving in rural areas an emphasis on speed is not surprising with some fleets using speed limiters.
   - The vehicles in the fleets also tend to stop a lot, so minimising idling is also a feature of their fuel savings programs.
   - The other metrics tend to be used by teaching the drivers good practice regarding braking, acceleration, scanning the road ahead and driving with fore thought through educational programs like Fleetsafe
   - GPS is used to find out where the vehicle is, and what it is doing. This can be followed up with such measures as text messages to drivers reminding them, if they are stopped, to turn their engines off or reminders to slow down if they are speeding. It can also be used in more detailed tracking of drivers' driving habits en mass and fed back to the drivers in education and incentives.
   - GPS may be used to assess a vehicle's speed but it is not clear where this, or other means are used to make this assessment.

- At present the automation of warnings where metrics indicate undesirable behaviours is in practice at a fairly basic level with most warnings done by such means as text messages etc.
- .Insurance discounts which such fleets receive, via no claims bonuses etc. are as a result of safety gains which come with the fuel savings, rather than the fuel savings per se. These are just the normal gains normally associated with a good safety record. Lumley states that the possibility of such discounts are on its radar.
- The level of data held, or planned to be held by fleets, or organisations connected with fleets like Fleetsafe appears to be very diverse and information about it is only general in nature.
- Fleets are not able to isolate the contribution of individual drivers to fuel efficiency. They can only work out the changes in the fuel efficiency of their fleet or vehicles in their fleet and that is contributed to by many factors outside the driver. The way Fleetsafe looks at the fuel efficiency of a vehicle is by measuring its fuel consumption directly using a dipstick.
- There appears to be no technology in use at present which can use metrics to compare different drivers' fuel saving performance while excluding other effects. Fleetsafe compares different drivers by taking them around the same course in similar vehicles-a similar strategy to that used by Z Energy which compares different drivers on the same run.
- Most claim insurance savings but this is just through normal channels like "no claims bonuses"
- All claim safety gains
- All measure fuel consumption

3 Judging who are the most economical /safe drivers

- Fleets generally do not yet systematically analyse output from engine management systems.
- Some have alerts from the GPS and the engine management system if someone is idling for too long.
- Some just have GPS alerts if someone is stopped too long, which results in a reminder to turn the engine off.
- Devices like text reminders are used.
- Some have alerts from GPS if someone is speeding and some use speed limiters.
- Accelerometers seem not to be used very much
- The approach is holistic including route choice, tyre care, vehicle maintenance etc.
- Generally the approach is relatively ad hoc, but effective in bringing down fuel consumption and improving safety.
- What data is held, its quality and in what form, is unclear, and it is propriety data

- The more organised fleets have driver training providers who, on a proprietary basis, analyse the data

Overall there appears to be room for improvement.

4 Insurance discounts for safe and fuel efficient driving

- Apart from the normal “no claim bonuses”, insurance incentives for safe economical driving are unknown here, and, if they exist, very uncommon elsewhere.
- Overseas there are “pay as you drive” schemes where the cost of insurance is on a per kilometre driven basis, but this is an incentive to reduce driving rather than increase driving quality
- Lumley say such schemes are “on their radar” for the future
- ITS America on its website foreshadows a report entitled “Insurance Telematics An Emerging Opportunity”, to be published in 2013.
- Fleetsafe is forming an alliance with ACC where safe fleets will attain some sort of ACC accreditation.., and may receive lower ACC levies. Representatives from the motor vehicle insurance industry have informally indicated that if this happens they may reduce the insurance costs borne by the accredited fleets.

17 Where to now?

17.1 Discussion

This project has discussed the most important metrics, related to driver fuel efficiency, and has ascertained that the importance of the various driver actions to which they relate varies with the road/traffic conditions.

It has also found that these metrics are all available through the engine management systems of modern vehicle and some are available through GPS and the metrics can be used more effectively in association with GPS. Some of the metrics are also available, or becoming available through Smartphones, either as capabilities of the Smartphone itself or by the Smartphone accessing GPS information of information from the engine management system of the vehicle.

Their availability through Smartphones varies in accuracy and technological advances can be expected to improve this availability and accuracy.

There is use of these metrics by fleets, but it would appear that better fuel efficiency and safety may be accessed through greater use of them. The utility of the metrics may be improved by combined use with GPS.

At present engine management system data and GPS data appear to be used in a fairly ad-hoc way to improve safety and fuel economy at present. There is room for improvement.

The special interest motivating this project is the assessment of safe, fuel efficient driving so that drivers may be compared for their own information or for the information of fleet managers or trainers. It would be good to use the information gained in this project to move on towards providing the AA with practical information on how it might move towards being able to compare the safe fuel efficiency of drivers within its own operations.

A possible way forward would appear to be the pilot experiment outlined in the bulleted list below:

- Drivers' safe fuel economy could be assessed over a predetermined course in a systematic way by instrumenting their usual vehicles.
- The same drivers could then drive Fiats over the same course, under similar conditions and be assessed by Eco-drive[16], as a European gold standard for the use of metrics to grade drivers.
- The comparative performance of the drivers as assessed by Eco-drive, and analyses from the instrumented vehicles could be compared.

[16] Eco-drive compatible Fiats are available in New Zealand

- Optionally, another overseas assessment tool (e.g. Kiwi) could be included or substituted for Eco-drive.
- The assessment would include consideration of whether the tools were taking safety into account.
- Subjective assessments of travel time, safety, fuel efficiency as well as the usability of the human-machine interface (HMI) system for the driver would be made for each condition

In the event of Eco-drive being used, the project would indicate how Eco-drive assessment compares with measured performance in the driver's own car.

It will also allow evaluation of the latest European based eco-driver assessment metrics in the New Zealand context and facilitate inter-country comparisons.

For the AA it will provide direction for the way forward to either:

- Entering into a licensing agreement with Fiat to use the Eco-drive software but adapted for use on AA training vehicles (or a similar arrangement with PLX Devices for Kiwi)

or

- Developing a New Zealand-specific alternative to which the AA will retain the right

17.2 Recommendation

That the AA Research Foundation consider following up this work with a pilot experiment to trial a method to ascertain the suitability of Eco-drive or Kiwi as safe fuel efficient driver grading mechanisms in the New Zealand context.

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