The effectiveness of an ecodrive course for heavy vehicle drivers

Symmons, M.A.[1], Rose, G.[2], & Van Doorn, G.H.[1]
[1]Psychological Studies, Monash University
[2]Institute of Transport Studies, Monash University
email: mark.symmons@muarc.monash.edu.au

Abstract

Amongst other changes, ecodriving requires drivers to drive more smoothly – to "flow" the vehicle. In order to save fuel and reduce emissions drivers must operate at lower engine revolutions, change up gears as soon as possible, and anticipate traffic conditions and drive defensively. A field trial was conducted using a 30 km metropolitan circuit and B-double heavy vehicles. Compared to their pre-course measures, the trained group reduced their fuel consumption by an average of 27%, the number of gear changes by 29%, and the number of brake applications by 41%. Importantly, these gains were not offset by increases in the time taken to complete the circuit – indeed average speed increased slightly. Further, the benefits did not lose any strength 12 weeks after the training, at which point the pilot trial concluded – in fact for some variables the results continued to improve over time. The number of drivers participating in the trial was relatively small and some questions remain unanswered, including actual road safety implications, building a strong case for a larger trial.

Keywords

Heavy vehicle safety, fuel economy, ecodrive, training, sustainability

Introduction

Developed primarily in Europe, ecodriving emphasises a smooth driving style. Drivers are encouraged to "flow" the vehicle, anticipate potential interactions and look further down the traffic stream. Amongst other behaviours, ecodriving also involves skipping gears when changing up when possible, changing gear at lower engine revolutions, and braking less forcefully and less often. The primary, immediate purposes of ecodriving are to save fuel and reduce emissions. The change in driving behaviour can also reduce crash risk, potentially resulting in a sustainable triple-bottom line with advantages for the driver (and company), the environment and society.

The results reported in the literature demonstrate a high degree of variability in fuel consumption reduction. Most of the previous research has focused on passenger cars, with fuel savings ranging from 10% to 25% [1,2,3]. Some research has taken a longitudinal approach and found reductions of 9-20% immediately after training, and 5-13% in the long run [4,5]. There are fewer published instances of ecodriving being applied to larger vehicles, but here reductions have also been found: 4-15% for buses [6,7] and 5-9% for trucks [2,8].

With a less aggressive and more anticipatory driving style, road safety benefits could be expected with ecodriving, but this aspect has received less attention in the published literature, possibly because a longer-term trial would be required. A long term study in a government fleet in Finland found a reduction in costs associated with crashes [9]. Another study based on a corporate fleet found 35% fewer crashes, 22% higher mileage per crash, and 28% fewer fleet driver-induced crashes [10].

Many of the evaluations reported in the literature provide insufficient detail to replicate the study, leading to concerns about their scientific rigour. af Wahlberg [11] argues that "[the claims] regarding the Eco-drive benefits were mainly made by educators and bureaucrats, and lack scientific backing". For instance, it would seem to be rare for a control group (who do not receive training) to be included, against which the performance of the trained group could be compared – most studies employ a before versus after training comparison.

The results reported in the literature are encouraging in terms of the potential for reducing fuel consumption and improving road safety. However, the rigour of many of these studies can be questioned. In addition, much of this research is European based and it is not clear whether the findings will transfer to Australia given that driving conditions, the makeup of the fleet and attitudes of Australian drivers may

not be sufficiently similar to those found in Europe. Careful research conducted in Australian conditions is clearly needed to provide a reliable indicator of the potential for ecodrive programs to reduce fuel consumption here. The current study concerns a pilot trial of an ecodrive course for drivers of heavy vehicles. It is expected that those completing the training will reduce fuel consumption, braking applications and gear changes – all measures of a smoother and more economical driving style – compared with their performance before the training, and compared with a group of drivers who do not complete the training.

Method

Participants
A pool of thirty drivers was drawn from three sites operated by a single company. To be eligible to participate, a driver had to possess a current B-double combination heavy vehicle driver's licence and not be scheduled for leave on the testing day. Twelve drivers were randomly selected from the pool to participate in the trial. The trial drivers had between 6 and 45 years of truck driving experience, with an overall average experience of 22 years (SD=12 years).

Design
The data to be collected was a mixture of objective and subjective measures and included both quantitative and qualitative variables. The principal variable of interest was fuel consumption, however number of gear changes and number of brake applications were also recorded, as was the time taken complete a test circuit. Other variables included the number of instances the driver was judged to be following too closely to the vehicle in front, instances in which the driver was considered to not be looking far enough down the traffic stream, and the number of times the driver revved the engine to greater than 1800 rpm before changing gear. All data was recorded on a separate scoring sheet for each driver.

The current study employed a mixed design, with both within- and between-groups comparisons. The principal set of within comparisons was whether the driver's scores and behaviours changed after the training course compared to their before-course scores. The main set of between comparisons was whether the scores of the fully trained drivers differed from those for a group who undertook a classroom training session only, and a third group who undertook no training – a control group.

Procedure
Twelve drivers were randomly chosen from the available pool of 30 and four were randomly allocated to each of the three study groups: fully trained, classroom only, and control. They each drove one of two almost identical, late-model heavy vehicles for the field trial. Both were 25 metre, 68 tonne B-double trucks, with 18 speed gearboxes and 550 horsepower engines.

A 30 kilometre test circuit that started and finished at a fuel station was used for data collection. It included a section of freeway as well as outer urban arterial roads, strip shopping and residential areas, and a segment of rural arterial. Speed limits ranged from 50 km/h to 100 km/h. There was also a mix of traffic controls and grades of road, with slight to moderate climbs and descents. All of the drivers were familiar to some degree with the route and did not require assistance with navigation. The circuit was specifically chosen in order to be representative of the mixture of roads and traffic environments that these drivers must negotiate on a daily basis.

During each circuit the driver was accompanied by one of two observers who sat in the passenger seat of the truck and made tallies for each variable. Both observers possessed a heavy vehicle licence and had varying degrees of heavy vehicle driving experience.

At the beginning of a test session both trucks were driven to a fuel station that marked the beginning and end of the circuit, and their dual fuel tanks filled to a set point on the tank's inlet pipe. At the conclusion of each circuit the tanks were topped up to the same point. To ensure consistency, the re-fuelling was supervised by the same researcher each time.

In order to evaluate the longevity of any effects of the ecodrive training, measurement was taken at three times: the day of the training (before and after the course), six weeks after the training, and twelve weeks

after the training. The same trucks were used for each day of testing such that drivers drove the same truck each time. The drivers who completed the full ecodrive course were assessed for their driving behaviour and fuel consumption immediately prior to and after the training session (ie on the same day) and again six and twelve weeks after the course. Due to logistical constraints the drivers who completed the classroom session only and those in the control group were assessed only at the six-week point. Comparisons are made within the fully trained group – before versus after training – and between the fully trained group and the other two groups.

Results

Fuel consumption

The average fuel consumption across the experimental groups and across the trial is displayed in Figure 1.

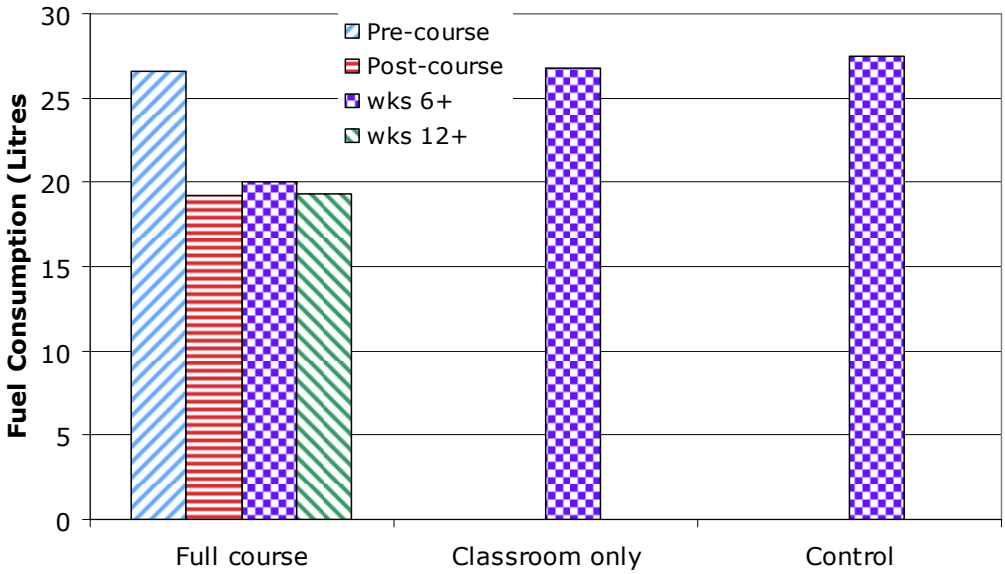

Figure 1: Fuel consumption across time for fully trained group and between groups at 6 weeks post-course.

On average, the fuel consumption of the drivers who completed the full course decreased by 27% (with a maximum reduction of 28% immediately after the course) between the pre-course drive and the post-test drives – a substantial seven litres across 30 kilometres (see Table A1 in the Appendix for the means and standard deviations). Despite the magnitude of this reduction, however, a within-groups ANOVA test indicated that the main effect was not statistically significant ($F(3,9)=2$; $p>0.05$), though the difference between the pre- (M=26 litres) and immediately post-course (M=19 litres) consumptions approached significance according to post-hoc testing ($p=0.05$).

Due to logistical constraints in terms of truck, trainer and driver availability, data was not collected for the classroom training only group and the control group on the day of training. The pre-course fuel consumption for the full course group is of the same order as that obtained for the control group tested six weeks post-course, with a difference of 3%. The lack of difference here indicates that the four drivers chosen for the full course group were not particularly different in any way to the other drivers in the pool. This lack of difference also indicates that no particular event or environmental aspect of the circuit (such as a change in traffic conditions) that may have occurred in the six weeks between tests has had any effect on fuel consumption. The only difference between the groups was participation in the course.

The data across the three groups were compared using a between-groups ANOVA at the six week point. The difference in fuel consumption was significant ($F(2,9)=7$; $p<0.05$) such that the fully trained drivers differed from both the classroom and control groups (M=20.1 litres vs M= 26.8 litres, $p<0.05$ and M=20.1 litres vs M=27.5 litres, $p<0.01$ respectively). Additionally, the classroom group did not differ significantly from the control group (M=26.8 litres vs M=27.5 litres, $p>0.05$) at the six-week point.

Gear changes

The average number of gear changes across the experimental groups across the trial are displayed in Figure 2.

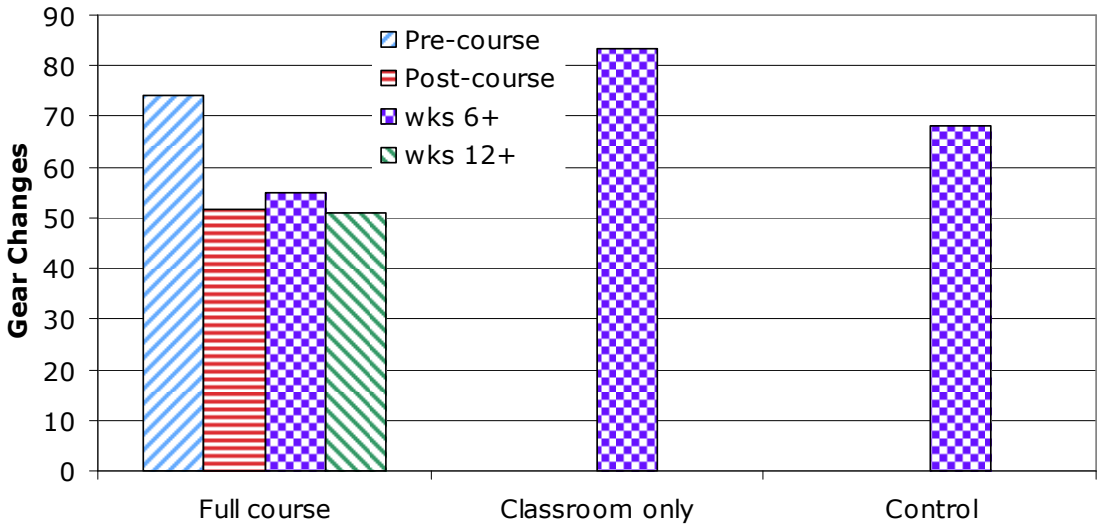

Figure 2: Gear changes across time for fully trained group and between groups at 6 weeks post-course

Participants in the ecodrive course were encouraged to reduce the number of gear changes they make when driving, using the brakes rather than the engine to decelerate when appropriate, and using the high torque at low revolutions of modern diesel engines to allow changing up as soon as possible. Drivers in the full course reduced the number of gear changes they employed to complete the circuit by an average of 29% (and a maximum of 31% at week 12) – 22 fewer gear changes over 35 minutes of driving. According to a within-groups ANOVA, the main effect for gear changes was statistically significant across the trial for the full-course group ($F(3,9)=7.9$; $p<0.01$). Post-hoc testing revealed a significant difference between pre-course and immediately post-course ($M=74$ vs $M=51.8$ changes respectively, $p<0.01$) and pre-course and 12 weeks post-course ($M=74$ vs $M=50.8$ changes respectively, $p<0.05$).

The fully trained drivers again seem broadly representative of the pool of drivers. The control group used 8% more gear changes (or 13 separate shifts) than did the fully trained group. The classroom-only group's gear changes at six weeks post course indicate that their training has had no benefit – indeed they used more gear changes than either the fully trained or control groups. A between groups ANOVA comparison of gear changes across the groups at six weeks post-training revealed a significant difference ($F(2,9)=7$; $p<0.05$), driven only by a significant difference between the fully trained and the classroom only groups ($M=55$ changes vs $M= 83.3$ changes, $p<0.01$).

Brake applications

The average number of brake applications across the experimental groups and across the trial are displayed in Figure 3.

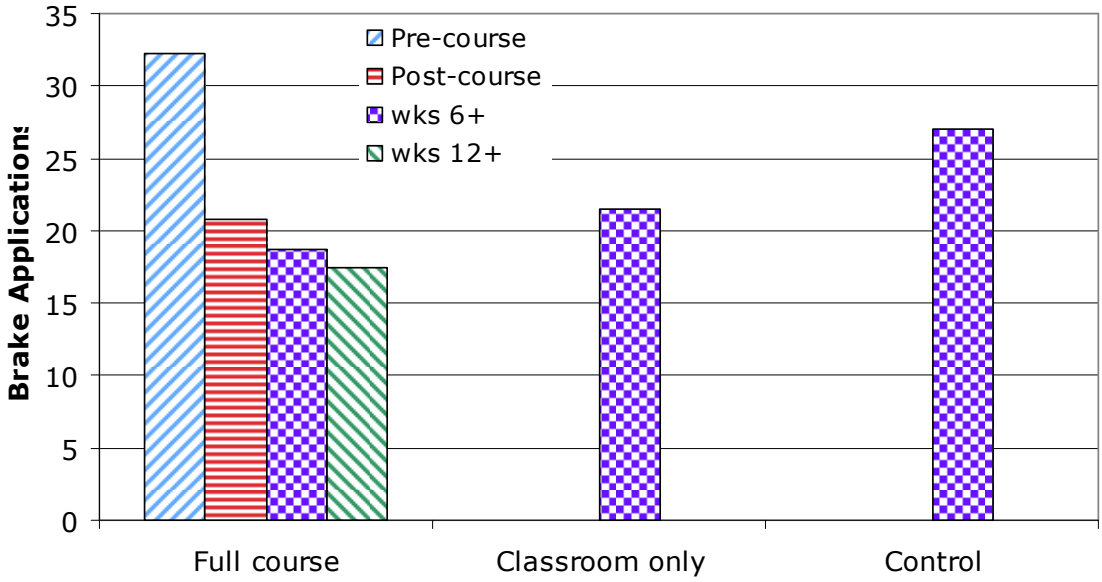

Figure 3: Brake applications across time for fully trained group and between groups at 6 weeks post-course.

Ecodrive principles dictate that braking should be reduced commensurate with better reading of the traffic and scanning ahead. The fully trained drivers reduced their braking by an average of 41%, ranging from a 36% reduction immediately post-course to a 46% reduction 12 weeks after training. After the initial substantial drop this group would seem to be progressively further reducing their braking over time. It should be noted, however, that the measurement here is the number of brake applications rather than the amount or intensity of braking. The main effect for brake applications was statistically significant ($F(3,9)=4.1$; $p<0.05$). According to post-hoc testing the differences between pre-course and immediately after training ($M=32.3$ vs $M=20.8$ braking episodes respectively), and between pre-course and six weeks later ($M=32.3$ vs $M=18.8$ braking episodes respectively) both approached statistical significance ($p=0.05$ in both instances).

Interestingly, the classroom-only group and the control group both used their brakes less often than the full course participants prior to undertaking the course, making the comparison between groups more conservative. However, the six-week measure of the fully trained group was less than both of the other groups. The difference in brake applications at six weeks post-course was not significant ($F(2,9)=3.5$; $p>0.05$), though post-hoc testing revealed a statistically significant difference between the fully trained group and the control group ($M=18.8$ applications vs $M=27$ applications; $p<0.05$).

Time taken & average speed

The time taken to complete the 30 km circuit was also recorded for each drive, and these results are shown in Figure 4.

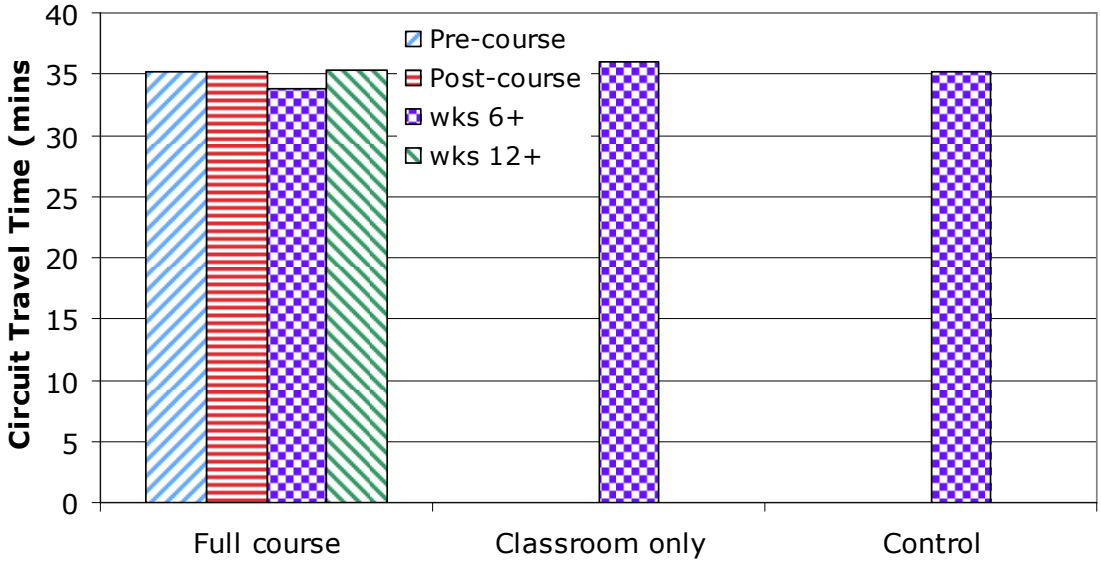

Figure 4: Circuit travel time across time for fully trained group and between groups at 6 weeks post-course.

There was very little variation in the average time taken to complete the circuit – ranging from 34 minutes for the fully trained group at six weeks up to 36 minutes for the classroom-only group at six weeks post course. The overall average circuit time of 35 minutes corresponds to an average speed of around 51 km/h. In total 24 circuits were completed, with a maximum of 3% difference between the fastest and slowest laps. This result may seem to be counterintuitive in that one might expect that a smoother, more anticipatory, and therefore cautious, driving style may sacrifice driving time for reductions in fuel consumption, but this does not seem to be the case. The course was intentionally chosen for its mix of driving conditions in order to approximate everyday in-service situations for the drivers in question. The seemingly more cautious ecodriving approach may lose time in heavier traffic as other motorists cut into the additional headway allowed by the heavy vehicle driver to the leading vehicle. Conversely, anticipating traffic light changes at greater approach distances may result in a reduced loss of momentum and reduce travel times. A closer examination of the traffic conditions is required to address these questions.

Each truck was equipped with a portable GPS device that logged position as a function of elapsed time while completing the circuit. The circuit itself was divided into six separate segments defined on the basis of major intersections. Bordering segments also represented different combinations of traffic density, road type, speed zone, and density of traffic control, such as roundabouts, traffic lights, pedestrian crossings, etc. The three post-training speed scores (immediate, +6 weeks and +12 weeks) were averaged for each segment for the fully trained group to make comparison with the classroom-only and control groups. Interestingly, the fully trained group's speeds after training were consistently higher than the either the classroom or control groups in all but one of the segments. The overall improvement of the fully trained group was an 8% gain in speed.

Headway, over-revs & traffic anticipation
Data was also collected for following distance to the vehicle in front, how often the driver exceeded 1800 rpm, and how often the driver did not seem to be looking far enough down the stream of traffic to anticipate changes in traffic conditions. There were too few occurrences of any of these events in any of the groups to make for a useful analysis

Discussion

While some differences approached rather than reached statistical significance, the overall pattern of results points to a substantial saving in fuel, gear changes and braking applications for those drivers who complete the full ecodrive training course. These positive outcomes relate to the comparison of results pre- and post-course for the fully trained drivers, as well as the comparison between the fully trained

drivers and a control group. Importantly, the benefits were not lost after 12 weeks, and critically the savings did not necessitate a sacrifice in travelling time or overall travel speed.

It is puzzling why the classroom-only group did not also improve. The only difference between this group and the fully trained drivers was that the latter were observed on a pre-course circuit and again immediately post course. Ordinarily the trainer would use these sessions to provide feedback to the drivers from the passenger seat of the truck to consolidate the lessons of the course. However, in the trial the accompanying observer provided no feedback. It should be noted that the two groups completed the course separately, though the content, instructor, teaching aids and duration were the same. While the instructor was not blinded to driver group allocation, he had a vested interest in *both* groups delivering a superior performance relative to the control group. It would seem that either or both of the circuit drives on the day of the course (pre- and post-course) are important for achieving the fuel consumption improvements, despite the fact that no feedback was provided by the in-cab observers. Many or all of the classroom-only drivers drove a heavy vehicle on the day of the course anyway as part of their job, so just driving on the day of the course would not seem to be important. Perhaps the immediacy and connection of driving the circuit after the course is a critical elements. Additional research is needed to establish how and why the pre- and post-training driving seem to be critical to success.

The measures of road safety, following distance and reading the downstream traffic, did not yield useful data in that there were too few instances of "unsafe" driving in all groups. Given the handling characteristics of a fully-laden 68 tonne B-double heavy vehicle this outcome should perhaps not be surprising. It is also possible that the presence of an observing passenger may lead to a moderation of driving behaviour. More useful safety data could be derived from in-service driving in a longitudinal study with a longer timeframe. This question is particularly pertinent given that the average travel speed for the trained drivers did not decrease, and indeed may have increased, a finding consistent with previous research [8].

The magnitude of the reductions in fuel consumption and the retention of the ecodriving skill by the trained drivers over the 12 weeks, and for some variables a progressive improvement, suggests that this form of training could play a valuable role to in reducing vehicle fuel consumption and related emissions. The employer who provided the trucks and drivers for the trial uses approximately 1.5 million litres of diesel fuel per annum – even a reliable 1% reduction in consumption would translate into a financial saving of about $15,000 per annum and a reduction of about 40 tonnes of CO_2 per annum – the results reported here suggest up to 27% savings are possible. Further, the reductions in gear changes and brake applications and a smoother driving style would be expected to have implications for vehicle repair and maintenance costs as well as for driver fatigue, and in turn these variables would positively impact road safety outcomes. Indeed in post-trial discussions the fully trained drivers noted, unprompted, the reductions in stress and fatigue in their new driving style. Recognising these benefits means that the drivers need not be encouraged to adopt or maintain the new driving style simply to save their employer in fuel costs.

While very promising, the results of the pilot field trial need to be interpreted with some caution. The outcomes are certainly in line with previous European findings [2,6,7,8], though they are at the top end of the savings the previous research would predict. It is not known whether the results will transfer to non-experimental conditions or whether the transfer will be at the same level. The use of a test circuit and the presence of an observer in the cab recording data are somewhat artificial. However, all of the trial and control drivers used the same circuit, which was on the open road in ordinary traffic conditions, and all were accompanied by an observer, and so neither of these contributed to the differences found between the groups in the trial. Additionally, the individual variability within driver performance is large (see the tables in the Appendix), and the small group sizes used here, governed primarily by logistical constraints, is not enough to smooth that variability. A larger trial is certainly warranted, making use of automated in-service monitoring to measure fuel use, gear changes, brake applications and so on, in everyday driving. Such devices are already in use in heavy vehicles and are relatively inexpensive. A larger range of road safety variables could also be assessed with a longitudinal, in-service study.

References

1. af Wåhlberg, A.E. (2007a) 'Long-term effects of training in economical driving: Fuel consumption, accidents, driver acceleration behavior and technical feedback'. International Journal of Industrial Ergonomics, 37(4), 333-343.
2. Holcim (2005) 'Diesel club – one possible measure – aim to reduce fuel consumption and CO2 emissions by 5%'. Presentation to a Logistics Forum, Antwerp.
3. Treatise UK (2007) 'Treatise Ecodriving manual: Smart, efficient driving techniques'. Viewed 14 November 2007. http://www.treatise.eu.com/downloads-uk.html.
4. Bon Beter Leefmilieu (2008) 'Eco-Driving: Belgian EcoDriving website'. Viewed 15 May 2008. http://www.bondbeterleefmilieu.be/eco-driving/index.php/294
5. Zarkadoula, M., Zoidis G. & Tritopoulou, E. (2007) 'Training urban bus drivers to promote smart driving: A note on a Greek eco-driving pilot program'. Transportation Research Part D: Transport and Environment, 12(6), 449-451.
6. Quality Alliance Eco-Drive® and SwissEnergy (2004) 'Summary: Evaluation of Eco-Drive, Training Courses' Zurich. Viewed 15 November 2007. http://www.ecodrive.org/Downloads.203.0.html.
7. EcoDriven (2006) 'European Campaign On improving DRIVing behaviour, ENergy-efficiency and traffic behaviour (ECODRIVEN) – Benefits of EcoDriving'. Viewed 14 November 2007. http://www.ecodrive.org/Benefits-of-ecodriving.277.0.html
8. Ford Motor Company (2008) 'Driving skills for life: Eco-Driving'. Viewed 15 May 2008. https://www.drivingskillsforlife.com/index.php?option=com_content&task=view&id=3&Itemid=14#
9. af Wåhlberg. A.E. (2007b) 'Fuel efficient driving training – state of the art and quantification of effects'. Viewed 15 November 2007. http://www.ecodrive.org/Downloads.203.0.html.
10. Reinhardt, E. (1999) 'EcoDrive in Switzerland: A success story of Energy 2000'. EcoDrive Conference proceedings, Graz, Austria, 56-61. http://www.ecodrive.at/download/proceedings.pdf
11. Johannson, H. (1999) 'Impact of Ecodriving on emissions and fuel consumption, a pre-study'. Swedish National Road Administration report 1999:165E. http://www.vv.se/publ_blank/bokhylla/miljo/ecodrive/ecodrive_e.pdf

Appendix A.

Table A1. Means and standard deviations for fuel consumption, brake applications & gear changes for the fully trained group at each test time.

Time	Fuel consumption		Brake applications		Gear changes	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Pre-course	26.4	5.8	32.3	8.8	74.0	18.1
Post-course	19.2	4.8	20.8	4.8	51.8	13.9
6 weeks post-course	20.1	3.4	18.8	1.7	55.0	5.7
12 weeks post-course	19.3	4.5	17.5	6.8	50.8	7.1

Table A2. Means and deviations for fuel consumption, brake applications & gear changes for each of the experimental groups at 6 weeks post-course.

Group	Fuel consumption		Brake applications		Gear changes	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Trained	20.1	3.4	18.8	1.7	55.0	5.7
Classroom	26.8	3.3	21.5	5.6	83.3	15.6
Control	27.5	2.6	27.0	5.2	68.3	6.8