The role of a driving simulator in driver training to improve fuel economy

Helen Scott [1], Michael Knowles [1], Adrian Morris[1] Dirk Kok [1],
(1) The Institute for Automotive and Manufacturing Advanced Practice (AMAP), University of Sunderland, The Industry Centre, Enterprise Park West, Colima Avenue, Sunderland, SR55 3XB, UK. E-mail :{Helen.Scott, Michael.Knowles, Adrian.Morris, Dirk.Kok}@sunderland.ac.uk

Abstract *– The use of driving simulators in driver training has become widespread. With the global push to reduce C02 emissions and achieve greater fuel economy, driving simulators are now being used in initiatives aimed at training drivers in Eco-Driving techniques, with varying levels of success. The Institute for Automotive and Manufacturing Advanced Practice (AMAP), at the University of Sunderland, UK, has recently used a Forum 8 driving simulator to deliver and evaluate a new Eco-Driving course for safe driving. Thirty participants took part in the study in the age range 20-64 years. Half were trained in Eco driving (intervention group) and half took part in two simulated drives without training (control group). The results indicate lasting positive effects of the training intervention on fuel economy. Results also highlight a positive role for driving simulation in the evaluation and delivery of Eco-Driving training.*

Key words: *Driving Simulator, Eco-Driving, Fuel Economy, C02 Emissions, Driver Training.*

Introduction

Driving simulators have become widely used in driving research and driver training over the past two decades [Abo1] [Bla1] [ESR1]. In comparison, the application of driving simulators in the field of Eco-Driving research and training is relatively new, applying various methodologies with varying levels of success [CAR1; Vir1].

Research has shown that fairly simple modifications to driving style can improve drivers fuel economy and C02 emissions [Aut1] [Bar1] [Ber1] [FIA1] [Gos1] [Van1] and many organisations now offer recommendations on driving style, and training in techniques to help driver's to refine their driving in order to reduce fuel consumption, wear and tear on the vehicle and cut C02 emissions [IAM1] [Ene1] [Gos1] [Aus1]. A variety of titles have been used for such techniques according to the extent to which safety is a consideration. Possibly the most commonly used term to describe energy efficient use of vehicles is 'Eco Driving' [ECO1].

The Institute for Automotive and Manufacturing Advanced Practice (AMAP) [AMA1], at the University of Sunderland, UK, has recently used a Forum 8 driving simulator [For1] in the delivery and evaluation of a new Eco-Driving course for safe driving. The course, named the DROPLET Course (Driver Optimisation for Low Emissions Transport), is based on a theoretical model of driver training, Goals for Driver Education (GDE) by Hattaka et al (2002) [Hat1]. Hatakka [Hat1] provides a comprehensive framework for goals and content of driver education. A driving simulator, classroom-based, and on-road driving techniques were used to modify driver behaviour. This paper reports on the rationale and methodological approach underpinning the course. Procedures, accompanying research, and results are discussed, and the role of driving simulators in the delivery of such courses is considered.

The aim of the DROPLET course is to raise individual's awareness of how to modify their driving to achieve optimum safety and fuel economy, and to start the process of implementing it. Research has shown that it is possible to optimise fuel economy by applying a smooth and progressive driving style [FIA1]. The DROPLET course combines best practice from the research on how drivers interact [Ful1] with methodologies, and advice from existing driver training initiatives [IAM1] aimed at maximising drivers attentional and observation skills, the ability to anticipate what will happen, and plan safe, timely, controlled responses through smooth application of vehicle controls. Components of best practice in Eco-Driving applications were mapped to the GDE model of driver training [Hat1] and applied within the course methodology, according to the most appropriate method of delivery for each. The mapping of the various pieces of advice and techniques to the different levels of the GDE model are shown in table 1.

Table 1. GDE/DROPLET Matrix

Goals for Driver Education (GDE) Model	DROPLET Course Content
Goals for Life & Skills for Living (general) • Importance of cars in driving & to self development • Skills & self-control • Driver preconceptions	General awareness of social and personal benefits of Eco - Driving and available Low Carbon Vehicle (LCV) technologies. Skill enhancement awareness Self awareness and evaluation
Goals & Context of Driving (trip related) Purpose, Environmental, Social context, Company	Plan ahead before driving. Consider using alternative modes of transport. Avoid short journeys. Plan the most direct route. Drive during off peak times if possible. Check tyres (inflation/tread depth etc.). Avoid carrying unnecessary luggage around. Only fill the fuel tank with the necessary amount of fuel. Consider turning the engine off if stuck in traffic. Close windows to reduce drag. Turn air conditioning off unless it is necessary.
Mastering Traffic Situations • Adapting to the demands of the situation at hand.	Use appropriate observation, anticipation and planning. Leave space and time to react, between yourself and other road users. Obey speed limits. Avoid stop starting in traffic. Reverse into parking bays if possible. Do not over rev the engine when conducting manoeuvres.
Vehicle Manoeuvring • Controlling speed, direction and position of the car.	Use smooth and gradual acceleration. Change gear early and keep the revolutions low. Use the correct gear for the speed and control, using block changing where and when appropriate. Maintain a constant cruising speed once the target speed is reached, when and where it is safe to do so. Use gradual and smooth braking to slow, making maximum use of engine braking. Then apply the brakes gently to stop.

Research involving two groups of volunteers was conducted to evaluate the effectiveness of the training course. One group took part in the training course (intervention group). This group drove a short route in the driving simulator before and after taking part in the DROPLET driver training course. The other group received no training (control group) and drove the same short route in the simulator, on two occasions. It was proposed that participants in the training condition would show a greater reduction in fuel consumption and C02 emissions on their second drive in the simulator, compared to the control group.

Method

Participants

From an original sample of thirty three participants, data for three of the participants was discarded due to difficulties adapting to using the driving simulator. The study therefore utilised data for thirty participants in the age range 20-64 years. The intervention group consisted of fifteen participants in the age range 31 – 64 years (mean age 47.53 years, SD 11.154; mean estimated annual mileage 10,667 miles, SD 3,266; mean duration since obtaining full driving licence 27 years, SD 12). Of these 12 were male and 3 were female. The control group consisted of fifteen participants in the age range 20-63 years (Mean age 44.07 years, SD 11.310; mean estimated annual mileage 13,567 miles, SD 9,081; mean duration since obtaining full driving licence 24 years, SD 11) of which 11 were male and 4 were female. All participants were members of the general public or staff from the University of Sunderland who had volunteered to take part in an Eco-Driving study. All volunteers had a full and valid UK driving licence, had been driving for at least three years, and reported having normal or corrected-to-normal eyesight.

Apparatus

A Forum 8, fixed base driving simulator was used for the lab based element of the study [For1]. The hardware component of the simulator is illustrated in Figure 1. The hardware is based upon a typical vehicle cockpit comprising all the usual primary and secondary controls including steering wheel, automatic transmission selector, parking brake, accelerator and brake. Instruments include directional indicator, speedometer and engine revolution counter. The display consists of three 32 inch LCD screens, each with a resolution of 1024x768 pixels and a fourth, smaller 8.4 inch LCD TFT screen with a resolution of 800x600 pixels which can be used for display of navigational information or other data to the driver. The simulation runs at a 20 Hz frame rate (50 mS), which is also the data sampling rate. Real time information on speed km/h and fuel consumption km/L, in bar format, is also displayed in the bottom right hand corner of the central display screen. The simulator currently runs the Uc-win/Road Plug-in [Ucw1], which has an Eco-Drive module for calculating carbon footprint. A Dell Latitude D505 lap top computer was also used to display video clips of driving scenarios for the classroom element of the course.

Materials

Simulated road user scenarios

Three scenarios requiring the driver to interact with other road users were included in the simulated drive. The first scenario occurred at cross roads, in an urban setting, during a right turn manoeuvre and involved moving and stationary opposing traffic (cars, buses and lorries). The next scenario involved an opposing motorcycle passing through the junction. This was followed by a child on a bicycle crossing the road into which the driver was turning. The final scenario involved heavy traffic flow (cars and lorries) travelling in the same direction as the driver during a merge manoeuvre on a dual carriageway road.

Fig.1. Forum 8 driving simulator

Video clips

A series of five video clips was developed. The video clips lasted for one minute each and were filmed from the drivers perspective during real world, on-road driving. Two of the video clips were designed specifically to help participants to contrast the effects of poor driver observation techniques with those of an effective and efficient observational technique, two were designed to enhance driver's anticipation skills and one provided a demonstration of safe, fuel efficient, cornering techniques.

Questionnaires and interview materials

A driver perception questionnaire was developed for pre course, post course and follow up use. This contained five questions requiring responses on a five point Likert scale, The questions were designed specifically to tap driver's perceptions of their own ability on a series of dimensions that have been shown to be important in Eco-Driving. More specifically, the questions were designed to tap driver's perceptions of their own ability with regards to concentration, observation, anticipation, keeping a safe distance from other vehicles, and Eco-Friendliness while driving. A set of ten structured interview questions was also used in the follow-up study which took place three months after the course. The questions were designed to investigate the extent to which any improvements in driving style were maintained over time.

Procedure

Lab session 1

One participant at a time took part in the study. Each participant was taken to the lab and provided with an explanation of what their participation in the course would involve. After a driving documentation check, they were then asked to complete a participant consent form and pre-course driver perception questionnaire before being asked to sit in the driving simulator. The participant was then shown how to adjust the seat and asked to make them self comfortable assuming their usual driving position. They were then given an explanation of the primary and secondary controls and instructed to turn the ignition key to start the engine. The participant took part in a short 1.23 km drive on the simulator to capture a pre-training baseline measure of Eco-Driving performance. A plan view of the route and surrounding simulated environment, with numbered feature points, is shown in Figure 2.

The simulated drive started with the drivers vehicle stationary in the left hand lane of an urban dual- carriageway (start point [1]), with a 50 km/h speed restriction, on the approach to crossroads (which were situated at 0.09 km from start [2]). The driver was instructed to turn right into a triple-carriageway road. The participants view from within the vehicle, at the starting point, is shown in Figure 3.

Fig.2. Plan view of the route and surrounding environment

The driver was required to move across into the right hand lane in order to carry out the right turn junction manoeuvre. The driver then had to navigate the various road user scenarios, turning right when safe to do so. Upon turning right the driver had to get over to the far right hand lane so that they could exit the triple-lane carriageway via a single lane slip road on the right of the carriageway (situated at 0.25 km from start [3]). The slip road followed a steep incline then levelled out (at 0.55 km from start [4]) onto a short dual carriageway strip of road in which the left hand lane was closed with a series of cones. The driver was then faced with two toll booths (at 0.74 km from start [5]) and instructed to go through the one on the right hand side. Upon approach the toll booth barrier opened to allow the driver to pass. Shortly after the toll booth, the driver was required to merge with heavy traffic to join a dual carriageway on the left. The dual-carriageway continued until reaching a fork in the road (at 1.15 km from start [6]). At the fork, the driver was required to branch left and drive for a short distance before a sign appeared on the screen signifying the end of the simulated drive (at 1.23 km from start [7]).

Fig.3. The drivers view at the start of the simulated drive

No feedback on performance was given to the participant at this initial stage. In instances where a participant had difficulty in adapting to driving the simulator, a minimal amount of practise drives were allowed to enable the participant to adapt.

On-road driving session

Following the first drive in the simulator each participant took part in an on-road drive. For this part of the course, the participant was first introduced to a qualified Advanced and Fleet Driver Training, DfT Safed Trainer [Fle1] who explained what would be happening during the on-road training. The trainer used a combination of recognised on-road fleet training techniques [SAF1] combined with the relevant ‘Mastering Traffic Situations’ level and ‘Vehicle Manoeuvring’ level DROPLET course content according to the GDE model [Hat1]. The on-road element of the course lasted for approximately ninety minutes, starting and ending at AMAP, and involved driving on a standardised route including a variety of dual-carriageway and urban roads in the Sunderland area. Upon completion of the on-road element the participant returned to the lab to take part in the classroom session and second simulated drive.

Classroom session

The classroom session began with a general discussion and opportunity to reflect upon what had been learnt during the on-road session. In particular, the participant was given further advice and reinforcement on how to implement and continue improving on the various GDE ‘Mastering Traffic Situations’ and ‘Vehicle Manoeuvring’ level Eco-Driving techniques. During the classroom session the participant was also given general strategic advice and advice on attitudes to driving, according to the specified course elements for the ‘Goals for Life and Skills for Living’ and ‘Goals and Context of Driving’ levels of the GDE model [Hat1]. Participants were then shown a series of videos to reinforce further what had been taught and discussed during the on-road session and earlier part of the classroom session.

Lab session 2

Following the classroom session, the participant was reminded how to implement all of the ‘Mastering Traffic Situations’ level and ‘Vehicle Manoeuvring’ level Eco-Driving techniques they had been taught during the course. They were then asked to take a final drive in the simulator, this time putting into practise everything that they had learnt during the course. The procedure and content of the second simulated drive was the same as for the first except the participant was given feedback on their performance upon completing the drive, according to on-screen feedback as shown in Figure 4. The participant’s scores on fuel consumption and C02 emissions were compared for the first and second drive in order to demonstrate any improvements. Where a participant wished to work on gaining further improvement they were allowed to have further practise on the driving simulator, but in every case data from the first and second drive only were saved for use in the analysis. Finally, the participant was asked to complete a post-course driver perception questionnaire. Participants in the control group drove the simulator on two occasions but did not take part in any of the training interventions. However, feedback on individual’s Eco-Driving performance was provided, following the second drive in the simulator.

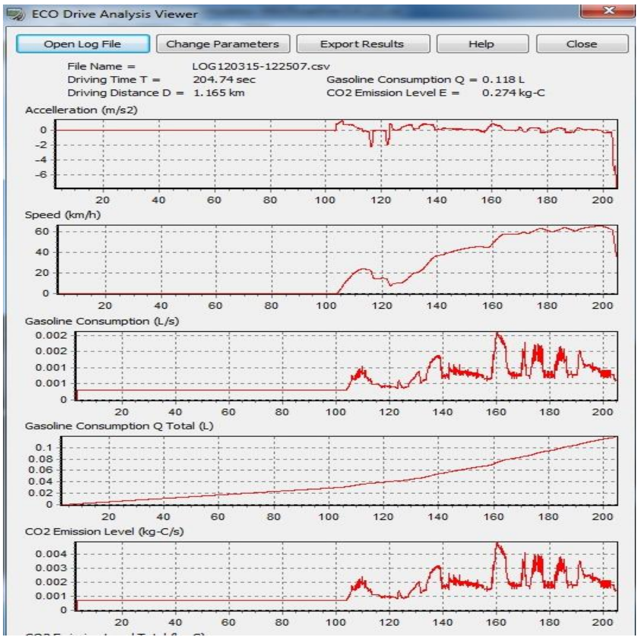

Fig.4. Screenshot of Eco-Drive performance feedback. The graphs show acceleration, speed, fuel consumption and CO2 emissions plotted against time.

Debrief

All participants were thanked for taking part in the study and given an opportunity to comment on the course. They were also asked if they would be willing to be contacted three months after taking part in the training study, to take part in a follow-up interview, and to complete a follow-up driver perception questionnaire.

Results

Using an Eco-Drive module located in the UC-win/Road tools menu and using the ‘Calculate Carbon Footprint’ function, results showing values for travel Time (T), Travel Distance (D), Fuel consumption (Q), and Carbon Footprint over time are displayed and can be output as a CSV file for use with Microsoft Excel and other statistical packages. Fuel consumption and carbon footprint across a journey, with a vehicles carbon dioxide emission is assumed to be proportional to its fuel consumption, and is estimated using the model proposed by Oguchi, Ktakura and Taniguchi (2002) [Ogu1] as described in equation 1 below.

$$Q = 0.3T + 0.028D + 0.056\sum_K \delta_k\left(v_k^2 - v_{k-1}^2\right) \quad (1)$$

Where Q is the fuel consumption in cubic centimetres, T is the travel time in seconds, D is the travel distance in meters, K is the number of measurements, δ_k=1 when the current speed is greater than the previous speed or 0 otherwise, v_k is the speed at point k in ms^{-1}.

Data on fuel consumption and C02 emissions captured using the UC-win/Road Eco-Drive module, was exported to IBM Statistical Package for the Social Sciences (SPSS) for further analysis. Fuel consumption and C02 emission is linearly related therefore only the results for fuel consumption are reported below. All results are reported according to standard statistical notation, where t is a statistical measure of how many standard errors the coefficient is away from zero, df is degrees of freedom (the number of values in the final calculation of a statistic that are free to vary), and p is the level of marginal significance.

Intervention group

A paired samples T-Test was used to compare driver's fuel consumption (L) before (Drive 1) and after training (Drive 2). Fuel consumption was significantly lower after training than before training for drivers in the intervention group. ($t = 6.578$, $df = 14$, $p<0.0005$)

Control group

A paired samples T-Test was also used to compare fuel consumption (L) for the first and second simulated drive (Drive 1 and Drive 2), for drivers in the control group. Results are shown in table 2.Fuel consumption was also significantly lower for the second drive compared to the first drive for drivers in the control group. ($t = 6.037$, $df = 14$, $p<0.0005$)

Table 2. Mean fuel consumption (L/km) for drive 1 and drive 2 for the two experimental groups [standard deviations of means are shown in brackets].

Group Measure	**Intervention Fuel**	**Control Fuel**
Drive 1	0.119 *[0.02]*	0.102 *[0.014]*
Drive 2	0.085 *[0.011]*	0.084 *[0.007]*

Intervention group versus control group

The difference between pre and post-training scores (Drive 1 & Drive 2) was calculated for each participant in the intervention group, and the difference between scores for the first and second simulated drive (Drive 1 & Drive 2) was calculated for each participant in the control group. An independent groups T-test was then conducted to compare the relevant differences between the two groups and to establish whether or not there was a significant effect of training intervention. The results show that the reduction in fuel consumption for the intervention group was significantly greater than that for the control group. Results are shown in table 3. ($t = 2.663$, $df = 28$, $p = 0.013$)

Table 3. Mean difference in fuel consumption (L/km) and percentage improvement (%) between drive 1 and drive 2 for the two experimental groups [standard deviations of means are shown in brackets].

Group Measure	**Training Fuel**	**Control Fuel**
Difference Between Drive 1 & Drive 2	0.034 *[0.009]*	0.018 *[0.007]*
Improvement	(28.57%)	(17.65%)

Analysis of data for the driver perception questionnaires and follow-up interviews is currently on-going and is not reported in-depth in the current paper. However, an initial review of content suggests general improvements in driver perceptions on elements of driving associated with Eco-Driving following participation in the DROPLET course. Furthermore, these improvements appear to be reasonably well maintained over time.

Discussion and Conclusion

Participants first drove a short un-instructed route in the driving simulator to obtain a baseline measure of Eco-Driving performance. They then took part in some on-road and classroom based training. Following participation in the training course, drivers were required to take a final drive in the simulator, following the same route as for the baseline drive. This time drivers were asked to put into practise everything they had learned on the course, and Eco-Driving related scores for the first and final drive were compared to evaluate the effects of training. Participants completed pre-course, post-course and follow-up driver perception questionnaires. Follow-up interviews were also conducted three months after participants took part in the course, to investigate the extent to which any effects of the training were durable over time. Results from the control group were used to examine and control for exposure related learning effects associated with simulated driving. The results show a significant reduction of 28.57 % in driver's fuel consumption following participation in the DROPLET driver training course. As fuel consumption and C02 emissions is linearly related, this is also assumed to indicate a significant reduction in driver's C02 emissions as well as general improvement in driver's application of Eco-Driving techniques. Nevertheless, data for the control group also shows a significant reduction of 17.65 % in fuel consumption between the first and second simulated drive, and although this reduction is 10.92% less than that for the training condition, it highlights the fact that there may be some Eco- related benefits associated with simply being exposed to simulated driving practise. This is something that could be exploited in future studies.

The results of the present study highlight the important role of driving simulators in the research and evaluation of Eco-Driver training. Furthermore, the results indicate that there are benefits to providing drivers with the opportunity to practise improving upon their driving techniques in a driving simulator. Driving simulators do not require fuel and do not produce C02 emissions. Driving simulators also provide experimental control and guarantee safe driving conditions, something that can not be achieved with on-road driving. One limitation of the current study however, is the simple fuel consumption formula currently used for the Eco-Drive module of the UC-win/Road tool of the Forum 8 driving simulator. While this formula makes it possible to discriminate between different accelerator behaviour (for example, aggressive high speeds and inconsistent speed will be penalised), it is not possible to infer many of the manoeuvre specific consumption factors such as gear changes and the use of smooth and gradual acceleration to an optimum and stable engine speed, with the current calculation. While previous studies have indicated that this model is adequate for the current study, future work will involve the application of a more realistic fuel consumption model based on engine physics. More extensive road networks and road user interaction driving scenarios should also be developed for use in the Forum 8 driving simulator. This would enable a predominantly simulator based Eco-Driving course and research study to be developed, utilising and expanding upon Modules from the GDE Matrix. Initial results from the driver perception questionnaires and follow-up interviews indicate lasting benefits of participation in the course. Further analysis is being conducted and results will be reported in a future paper.

Acknowledgements

The DROPLET study and Forum 8 driving simulator were funded by The Regional Development Agency ONE NORTH EAST, as part of the Zero Emissions Transport (ZET) Programme. We would like to thank David Whiting of Fleet Technique for conducting the on-road training element of the course.

References

[Abo1] Abou-Zeid, M., Kaysi, I., & Al-Nagtu, H. Measuring Aggressive Driving Behaviour using a Driving Simulator: An Exploratory Study. 3rd International Conference on Road Safety and Simulation. September 14-16, 2011. Indianapolis, USA. http://onlinepubs.trb.org/onlinepubs/conferences/2011/RSS/1/Abou-Zeid,M.pdf Accessed 15/03/2012.

[AMA1] AMAP, The Institute for Automotive Manufacturing and Advanced Practice. http://www.sunderland.ac.uk/university/factsandfigures/universitystrengthsandoverview/amap/ Accessed 15/03/2012.

[Aus1] Australian Energy Agency Eco-Driving Europe Project http://www.aatas.com/files/eco_driving.pdf Accessed – 01/02/2012.

[Aut1] Automobile Association [AA] eco driving advice http://www.theaa.com/motoring_advice/fuels-and-environment/drive-smart.html Accessed 02/02/2012

[Bar1] Barkenbus, J.N., 2010. Eco-driving: An overlooked climate change initiative. *Energy Policy,* V 38 (2), 762-769.

[Ber1] Berry, M.I (2010). The Effects of Driving Style and Vehicle Performance on the Real-World Fuel Consumption of US Light-Duty Vehicles, Thesis submitted in Partial Fulfilment of the Requirements for the Degrees of Master of Science in Mechanical Engineering and Master of Science in Technology and Policy, Massachusetts Institute of Technology. http://web.mit.edu/sloan-auto-lab/research/beforeh2/files/IreneBerry_Thesis_February2010.pdf. Accessed 15/03/2012.

[Bla1] Blana,E.(1996). Driving Simulator Validation Studies: A Literature review. Institute of transport Studies, University of Leeds. White paper. 480. http://eprints.whiterose.ac.uk/2111/1/ITS169_WP480_uploadable.pdf Accessed 15/03/2012.

[Car1] CARNETSOFT.COM http://www.carnetsoft.com/index.html?gclid=COq8q6mG6q4CFc4LtAodYE3MKw Accessed 15/03/2012.

[ECO1] ECOWILL, What is Ecodriving? http://www.ecodrive.org/en/what_is_ecodriving-/Accessed 02/02/2012

[ENE1]Energy Saving Trust: Fuel Efficient Driving http://www.energysavingtrust.org.uk/Transport/Consumer/Fuel-efficient-driving Accessed 19.01.2012

[ESR1] ESRA Consulting Corporation (2005). Driving Simulators: Yesterday and Today http://www.esracorp.com/559DRIVINGSIMULATORS.pdf Accessed 15/03/2101

[FIA1] FIAT eco: Drive (2010), Eco-Driving Uncovered: The benefits and challenges of eco-driving, based on the first study using real journey data. http://www.lowcvp.org.uk/assets/reports/Fiat_Eco-Driving%20Uncovered.pdf Accessed 01/02/2012

[Fle1] Fleet Technique. http://www.fleettechniquetraining.com/ Accessed 15/03/2012.

[For1] Forum8 http://www.forum8.com/ Accessed 15/03/2012.

[Ful1] Fuller, R. (2005) Towards a general theory of driver behaviour. Accident Analysis and Prevention, Vol. 37, pp461-472.

[Gos1] Gosford City Council project report for the Local Air Education Project (2011) http://www.gosford.nsw.gov.au/environment/education/documents/Economic%20Driving_Ver2.pdf Accessed 01/02/2012.

[Hat1] Hatakka, M., Keskinen, E., Gregersen, N.P., Glad, A, Hernetkoski, K., (2002). From control of the vehicle to personal self-control: broadening the perspectives to driver education, Transportation Research Part F 5 (2002) 201-215.

[IAM1] IAM, The Institute of Advanced Motorists (2007). Advanced Driving the Essential Guide, How to be a better driver, Motorbooks, China.

[MIT1] MITei (2010). Electrification of the Transportation System. *An MIT Energy Initiative Symposium. April 8, 2010.* http://web.mit.edu/mitei/docs/reports/electrification-transportation-system.pdf Accessed 10/02/2012

[Oug1] Ouguchi, T., Kytakura, M., & Taniguchi, M. (2002). Carbon Dioxide emission model in actual urban road vehicular traffic conditions, Journal of Infrastructure Planning and Management (JSCE), No.695/IV-54, pp. 125-136

[SAF1] SAFED Safe & Fuel Efficient Driving http://www.fleetnews.co.uk/fleet-management/safed-for-vans/35928/ Accessed 15/03/2012.

[UCw1] UC-win/Road Eco-Drive Plug-in http://www.forum8.co.jp/topic/up78-p11-e.htm Accessed 14/03/2012.

[Van1] Van Mierlo, J.V., Maggetto, G., van de Burgwal, E., & Gense, R. Driving style and traffic measures – influence on vehicle emissions and fuel consumption. Proceedings of Institute of Mechanical Engineers, Vol. 218 Part D: Journal of Automobile Engineering – DI 3902 IMechE: 2004.

[Vir1] Virage Simulation. Driving Simulation Based Ecodrive Training Presentation. Sustainable Communities Conference and trade Show, 2011. http://www.fcm.ca/Documents/presentations/2011/SCC2011/Driving_Simulator_based_Ecodrive_Training_EN.pdf Accessed 15/03/2012.