The Effect of Ecodrive Program in Simulated and Real-World Driving Modes on the Fuel Economy of Manila Drivers

Anabel A. ABUZO[a] , Yasunori MUROMACHI[b]

[a,b] *Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology, Nagatsuta-cho, Midori-ku, Yokohama-shi, Kanagawa, 226-8502 Japan*
[a] *E-mail: aaabuzo@yahoo.com*
[b] *E-mail: ymuro@enveng.titech.ac.jp*

Abstract: Ecodrive or Ecodriving technique is a prearranged driving style that drivers can use to optimize vehicle fuel economy and reduce CO_2 emissions in the environment. This study investigates the effects of the Ecodrive program of candidate drivers in Manila. It particularly compares the resulting engine power, fuel consumption flow rate, fuel economy and speed values during normal driving and Ecodriving conditions alongside the driving mode operations: cruise, deceleration, acceleration and idling. This study also enumerates in detail the outcome of the training day and real-world driving conditions of the thirty drivers. The study has successfully demonstrated that Ecodriving significantly affected driver's driving operations and fuel consumption values. The results of the study revealed that Ecodriving improved driver's driving operations during the training day and the real-world driving condition.

Keywords: Driving Modes, Simulated Driving, Ecodrive, Fuel Economy, Real-World Driving

1. INTRODUCTION

Today's global environment is defined by population growth, price inflations, urban sprawl, motorization and global warming issues. Awareness of these issues and the need for sustainable development are growing concerns in developed and developing countries especially in the area of motorization. Motorization is the major cause of pollution and carbon dioxide (CO_2) emissions, noise, congestion, fuel dependency and road accidents which significantly affect the transportation environment.

One solution for ensuring sustainable transportation environment is to pursue sustainable mobility that, in part, means being energy efficient (i.e., reduced CO_2 and increased fuel economy) or driving efficiently. And, the key to this energy efficiency is Ecodriving. Ecodriving is primarily a driving technique designed to improve fuel economy and reduce CO_2 emissions to mitigate the adverse impact of road transport on the surrounding environment. Ecodriving is the attitude of driving in an environmentally-conscious and energy-efficient manner. In principle, on-road fuel consumption and emission values are influenced by driving patterns which in turn, are influenced by external factors such as traffic characteristics, road characteristics, vehicle characteristics, driving characteristics, travel characteristics, and other variables. Nevertheless, if drivers would be driving their vehicle in an efficient manner -*ceteris paribus*- the resulting vehicle performance could be optimized. Studies on Ecodriving investigation in real-world application particularly those that address specific driving mode (i.e., acceleration, cruise, deceleration and idling) are very limited. More specifically, those that examine which specific driving mode "before and after" the Ecodrive program significantly affects the fuel economy and vehicle performance have rarely been conducted. Thereof, this paper investigates the outcome of Ecodriving program and its effect on fuel economy. It particularly examines the effect of the Ecodrive program in the simulated and real-world road environment; the vehicle performance (i.e. speed, engine power, fuel efficiency etc.); and the four elements of the driving modes or driving operations, namely: acceleration, cruise, deceleration, and idling.

2. REVIEW OF RELATED STUDIES

2.1 Ecodriving and Fuel Economy

Ecodrive or Ecodriving (Vagverket, 2000) is defined as a way of driving or the broader attitude of driving in an environmentally-conscious and energy-saving manner. Ecodriving is defined by specific driving techniques which are consistent with the optimal condition of the engine performance that is designed to minimize fuel consumption and reduce vehicular emission.

A driver's driving style can be characterized in terms of driving operation and energy efficiency that defines driving performance. Energy efficiency is measured in terms of fuel economy and fuel efficiency. Fuel efficiency relates to the fraction of the energy content of the fuel used to move the vehicle and fuel economy is fuel efficiency relationship between distance traveled by an automobile and the amount of fuel consumed. Driving operation is classified according to specific driving modes, namely: acceleration, deceleration, cruise and idling (ADCI).

A study by Sah, *et al.* (2003) on modal analysis revealed that the outcome of driver's driving operation on specific driving modes influenced the outcome of fuel economy. While, studies on driving patterns by Ericsson, 2001; Mierlo, *et al*., 2004; El-Shawarby 2005; Ericsson et. al., 2006; Pandian *et al*., 2009, revealed that road network and traffic conditions influenced drivers' driving operation. The study of Berry (2010) also indicated that increased engine speeds (RPM), fluctuations of speeds, and erratic accelerations affected the outcome of vehicle performance and fuel economy. This was further highlighted in the report of the Treatise Project (2005) on modern fuel injection engines (petrol and diesel) that produced high torque values at lower engine power (rpm). The report indicated that efficient engine operation should be between engine speed of 2000rpm-3000rpm and at torque values between 150Nm-250Nm.

2.2 Ecodriving Programs and Initiatives

The Ecodriving program started as economical driving styles in Finland and Sweden. These programs encouraged the widespread European Union Ecodriving initiatives (Vagverket, 2000; Treatise, 2005; GTZ, 2005; CIECA, 2007; EEA, 2008). Initiatives within Europe include: Finland, Sweden, Netherland, Scotland, Germany, United Kingdom, Iceland, Norway, Czech Republic, Spain, and Poland. Ecodriving programs outside of Europe also include: Australia, Canada, and New Zealand. The approaches of these successful programs were primarily centered on the diffusion of the Ecodriving technique among drivers (novice drivers, professional drivers and fleet owners) especially on the integration of such technique within the novice drivers' education (technology, culture, and legislation). In Asia, Japan had become an expert country promoting Eco-driving (ANRE and METI, 2007; JARI, 2012) following after the trend in Europe. In 2003, the Liaison Committee formulated the "Eco

Drive 10 Advices" and "Soft Acceleration, e-Start" which became a national action plan in 2006. Ecodriving program was also initiated in developing countries, particularly, Asia and Latin America under the Gessellschaft Fur Technische Zusammenarbeit (GTZ) project. These initiatives were patterned after European Ecodriving but were mostly applied for bus operation (private and public buses). GTZ successfully demonstrated five pilot Ecodriving activities in Chile, Costa Rica, Nicaragua, and Indonesia. Considering the great difference between road and traffic environment in developed and developing country settings, this initiative encouraged the promotion of Ecodriving in developing countries which posed a greater challenge in application. The Ecodriving program timeline of Abuzo and Muromachi (2011) revealed that consistent with increased worldwide motorization and increased global demand for petroleum, the program which started in 1995 became a growing global trend. Moreover, the more recent Ecodriving initiatives were keenly associated with the global CO_2 reduction goal of the Kyoto protocol, world fuel consumption and fuel economy targets, environmental protection and environmental sustainability. This prompted countries like the United States, the automobile manufacturers, and industries to consider adopting Ecodriving. Now, most Ecodriving program is focused in marketing further the techniques and training as well as developing Ecodriving related technologies (e.g., simulators, on-board electronic driving systems, etc.). However, aside from the cases of the GTZ, the application of Ecodriving program in developing country settings has rarely been conducted where traffic and other factors are quite different from developed country settings.

2.3 Ecodriving Savings and Benefits

The successful results of Ecodriving program in developed countries such those in Europe and Japan revealed that significant reduction in fuel consumption values were due to prudent practice of Ecodriving. Studies of Van Mierlo *et al.*, (2004), Rafael-Morales and Cervantes-de Gortar (2002), and Saboohi and Farzaneh (2005) revealed that changing one's driving behavior and improving one's driving style in an optimal manner, in anticipation of vehicle's surrounding conditions and other external constraints, improved the overall fuel economy. Overtime, improved fuel economy translates to accumulated fuel savings. This was supported by studies (Evans, 1979; Hooker, 1988; De Vlieger *et al*., 2000) on adverse driving behavior (e.g. aggressive driving) and driving characteristics (e.g., gentle driving), particularly, along city driving conditions that increased the fuel consumption by 20% - 45%. Studies on European Ecodrive program (Hornung 2000; Zarkaduola, *et al.*, 2007; Onoda, 2009) that targeted on improving drivers' driving operation revealed that the fuel savings can be up to 10% - 20%. While, Japanese Ecodriving studies (Ukita and Shirota, 2003; Miyasaka, *et al.* 2005; Katayama and Taniguchi, 2005; Taniguchi, *et al.*, 2006) also revealed that as much as 25% fuel savings can be attained, and stressed that Ecodriving success would depend on the driving lecture and skill-transfer of the driving technique. European Climate Change Program (ADB, 2008) also estimated that the savings in European Ecodriving programs alone would yield a potential reduction of at least 50 million tons of CO_2 emissions and saving about 20 billion Euros. Ecodriving programs, therefore, will serve a global benefit. Potential benefits of Ecodriving were not only limited to CO_2 and fuel economy. Ecodriving programs that include practical advisories and driving techniques were just as important. Studies (Wilbers, 1999; Hornung, *et al.*, 2000, 2001 and 2003; Fujikawa and Taniguchi, 2002; Ukita and Shirota, 2003; Saboohi and Farzaneh, 2005; Matsuki, 2006; Iagarashi *et al.*, 2006; Barth and Boriboonsomsin, 2009; IEE, 2008) encouraged Ecodrive advisories and techniques that contributed to the overall improvement of vehicle performance and fuel economy. The driving advisories include: improving maintenance practice and car aerodynamics, anticipating traffic condition, choosing appropriate fuel and engine oil, regulating the use of in-vehicle electronics, employing on-board computers and navigational systems (e.g., cruise control, GPS, rev counter, etc.) in aid of driving. Moreover, these studies also highlighted that drivers' adopting Ecodriving would also gain the following benefits: reduced shortfall; reduced air pollutants; reduced noise as a result of driving at lower engine speed; enhanced traffic safety due to greater anticipation of traffic; reduced erratic and unpredictable behavior of driving; reduced drivers stress and improved driving comfort; reduced vehicle wear and tear or maintenance; reduced costs (fuel, safety, repair and maintenance); improved trip time and improved service (timely delivery).

However, past studies in relation to Ecodriving savings and benefits were extensively limited only to two groups of methodology: (1) the evaluation of Ecodriving in static or pre-defined test routes (Taniguchi, 2002-2006; Tsutomo, 2002; Nader, 1991; Ericsson, 1999; Hooker, 1988; van der Moort, et al., 2001; De Vlieger, et al., 2000; Rafael, et al., 2006) and (2) the evaluation of Ecodriving using simulation or virtual-world driving routes (van der Moort, et al., 2001; Decicco and Ross, 1996; Ericsson, et al., 2006). Because of a significant difference in Ecodriving application between developed and developing countries, the effect of Ecodriving program should also be studied in the settings of real-world driving as well as in the settings of pre-defined test route driving or virtual-world driving if Ecodriving program is to be promoted in developing countries.

3. METHODOLOGY

3.1 Instrumentation

Thirty candidate drivers and vehicles equipped with on-board data-logging equipment were considered in this study. Invitation letters for drivers interested to join the research and survey were distributed among the universities in Manila and also sent thru emails. The list was then trimmed down to include drivers with vehicles compatible to instrumentation requirements of the study. Vehicle with compatible On-Board Diagnostic (OBD) ports were prerequisite for data collection. Thereof, only Japanese cars (models 2005 and up) that passed vehicle specification requirements for the monitoring equipment of the study were considered. The Fuel meter equipment from the Energy Conservation Center of Japan (ECCJ) was employed to monitor driving operation. This was installed as a monitoring system to the vehicle system through the OBD ports. The equipment then collected instantaneous data parameters per 0.10 second which included: velocity, distance, fuel consumption, engine velocity and acceleration. The vehicles were also equipped with Global Positioning System (GPS) from the center of the Institute of Behavioral Sciences (IBS) to monitor the movement and location of the tested vehicles. Instantaneous values of location (latitude, longitude, and altitude per 0.10 second) were collected from traces of driver's trip data. Each driver's data logs from the Fuel meter and GPS readings were collected, lumped, processed, cleaned, and filtered from noise and finally logged into the drivers' database. The data were used for the evaluation of driver's driving operation, route mapping, and statistical analysis.

3.2 Calibration

Prior to actual data collection, there was an initial pre-testing evaluation for compatibility of monitoring instruments and vehicles. This involved vehicle-instrument calibration. When selected vehicle passed the initial prequalification stage, drivers were then required to take an initial driving test to check if the data logging of GPS and Fuel meter equipment were successful. Drivers who owned vehicles that passed the calibration test became candidate drivers for the Ecodrive training program.

3.3 Data Collection

Data collection of this study was divided into two separate stages, namely: the data collection from driver's real-world trips, and the data collection from Ecodrive training which served as a simulation of the actual city driving environment. The study area for this simulation was along the road network inside the University of the Philippines (UP-Diliman) campus. The traffic condition was fairly without congestion and the test vehicle moved alongside the usual traffic stream of Manila vehicles. The collections of the data were then summarized as driver's daily trip data and Ecodrive training day data.

3.3.1 Drivers Real-World Driving Data

To test the effects of Ecodrive training, a pretest-posttest study with intervention or treatment was used. In this case, the intervention is the Ecodriving training program and two rounds of data collection were conducted: (1) normal real-world driving dataset and (2) real-world Ecodriving dataset. The first round of this dataset was collected as pretest normal real-world driving dataset which were collected at least for three days before the Ecodrive training day. After the Ecodrive training day, the second round of data collection resumed, and drivers were again subjected to three days data collection which served as the posttest real-world Ecodriving dataset. It was assumed that during the training day (i.e., intervention), drivers had learned the Ecodriving techniques of driving in an efficient manner. Thus, the second dataset would reveal a change of driving style.

3.3.2 Ecodrive Training Day Driving Data

The Ecodrive training of Manila drivers were handled by three proficient trainers trained by the Ecodrive expert from the office of the Energy Conservation Center of Japan. On the Ecodrive training day, the drivers were given specific driving orientation, Ecodrive training, driving test, and diagnostic evaluation. The orientation session introduced the normal driving operations of drivers and its corresponding effects on fuel consumption and emission values. Next, Ecodrive techniques were presented to enhance the difference between normal driving and Ecodriving. The training session was then followed by a test drive activity. During the test drive activity, drivers were asked to (1) drive in the normal way and (2) to drive applying what they learned as Ecodriving. As a control, one test route was used for both test drives. The route was carefully selected from a road network which simulated or represented the city driving condition of the downtown areas (where acceleration, cruising, deceleration and stopping operation were evident). After the test drives, diagnostic reports were distributed among the drivers with one-on-one consultation on the Ecodriving improvement. This report elaborated in detail the normal driving and Ecodriving performance of the driver during the test drives. It particularly highlighted the differences of fuel consumption and other engine parameters according to the driving modes: acceleration, cruise, deceleration and idling (ACDI).

3.4 Data Evaluation

Drivers' data were logged thru vehicle monitoring equipment (i.e., GPS and Fuel meter). The data were then statistically evaluated to examine the outcome of the parameters before and after the intervention as well as to measure the effectiveness of the training intervention. The statistical evaluation of the data were specifically focused on the driving operation which were described in the driving modes that included: 'gentle start' or gentle starting acceleration at the beginning of the trip, maintaining a good constant speed during cruising, gentle deceleration or coasting the engine when approaching a signal stop, switching-off of the engine or "idling stop" (e.g., during signal stop, parking etc.) and gentle acceleration during the signal green or "go" at intersections. These driving modes were evaluated because during the Ecodrive training, the Ecodriving operational techniques were intensively taught and were supposed to contribute to reducing fuel consumptions considerably.

4. ANALYSIS AND RESULTS

4.1 Drivers Training Day Driving Characteristics

4.1.1 Drivers Training Diagnostic Results

The diagnostic reports of the thirty Manila drivers' driving data (Appendix A) during training day revealed significant improvement after Ecodrive training. A paired-sample t-test (two-tailed) was conducted to evaluate the effect of Ecodrive training on the fuel efficiency (km/liter), fuel consumption (cc), distance (kph), trip time (seconds), specific acceleration ($m^2/s^2/km$), fuel consumption during idling (cc/sec), number of stops, and stopping time duration (seconds). Table 1 shows the summary of the Ecodriving program during training day.

Table 1. Normal driving and Ecodrive training day results

Driving Parameters	Mean	Std. Dev.	T- value	Sig.
Fuel Economy, km/liter	-0.927	0.485	-10.472	***
Fuel Consumption, cc	57.127	42.148	7.424	***
Distance, km	0.009	0.026	1.810	n.s.
Trip Time, sec	-37.833	58.916	-3.517	***
Fuel Consumption during Idling cc/sec	0.176	0.102	9.423	***
Specific Acceleration, $m^2/s^2/km$	56.017	101.367	3.027	***
Duration of Stops, sec	-27.150	39.384	-3.776	***
Number of Stops	0.900	1.668	2.955	***

Values of the driving parameters were calculated as before minus after (before – after); ***significant at 5% level; n.s. not significant.

The results revealed that there were significant changes in the values of the vehicle parameters after Ecodriving training particularly on fuel economy, fuel consumption, trip time, fuel consumption during idling, specific acceleration, durations of stops, and number of stops except the value of distance.

Travel distances were not significant since the routes before and after the training were the same and therefore considered as a constant value. The fuel economy, trip time, and duration of stops were significant ($p<0.05$). For fuel economy, the mean values were 6.758 km/liter and 7.685 km/liter before and after the training, respectively. The comparison of before and after training values revealed that there were significant increased values of fuel economy after the training. The comparison of trip time before and after the training also revealed that there were significant increased trip time values after the training. For trip time, mean values were 612 seconds and 649 seconds before and after the training, respectively. This result might be attributed to the drivers adopting for the first time the overall Ecodriving techniques: gentle acceleration at the beginning of the trip while warming-up the engine, gentle starting the engine at signal green, coasting the engine when decelerating, cruising at constant speed and idling-stop (switching off the engine at signal stop). For duration of stops, there were significant increased values in the duration of the stops during Ecodriving driving test when compared to the normal driving test values. The duration of stop, mean values were 129.97 seconds and 157.12 seconds before and after the training, respectively. The result was attributed to the application of idling-stop technique during the Ecodriving driving test. Slow manipulation of switching -on and -off the engine caused delay time.

There were also significant changes in the values of fuel consumption, fuel consumption during idling, specific acceleration and the number of stops after Ecodriving training. The significant difference of these parameters before and after the Ecodriving training revealed (i.e., positive t-values) that specific acceleration decreased, fuel consumption during idling also decreased and the total fuel consumption decreased as well during the conduct of Ecodriving driving test. These changes could be attributed to the Ecodriving techniques that were rigorously taught during the training and drivers' prudent observance of the techniques. There was also a significant decrease in the number of stops when the difference between normal driving test and Ecodriving driving test results were compared. According to drivers' feedback, the reduced number of stops was attributed to driving with gentle deceleration towards the traffic signal. When drivers applied the deceleration technique at the approach of the traffic signal, the vehicle gently slowed down towards the queue of vehicles at the approach. However, this gentle deceleration towards the approach also presented an opportunity for the drivers to "catch in-time" the green light (i.e., signal for go) thereby terminating the actual stop at the traffic signal.

In summary, the training day results revealed that Ecodriving training significantly affected the outcome of the driving parameters as reflected in the normal driving test and the Ecodriving driving test data. The idling mode was significantly affected with the idling-stop technique application as reflected in the fuel consumption during idling. The acceleration mode, cruise mode, and the deceleration mode were significantly affected with the application of the Ecodriving techniques as reflected in the reduced values of the specific acceleration, and fuel consumption. Moreover, deceleration mode was also significantly affected as revealed in the reduced number of stops. And overall, Ecodriving significantly affected the ACDI modes as reflected in the increased values of fuel economy and increased trip time.

4.1.2 Drivers Training Driving Operation Results

The important parameters that were investigated in this section included speed, engine speed, fuel economy and fuel consumption. These parameters were found in some recommendations, for example, Ecodriving suggests driving at efficient and constant speed using higher possible gear while controlling engine speed (less than 3000rpm) to keep a good cruise mode. Fuel economy and fuel consumption variables are also related. Fuel efficiency is related to the fraction of the energy content of the fuel used to move the vehicle while fuel economy is the relationship between distance traveled by an automobile and the amount of fuel consumed. These two parameters are related to Ecodriving promotion of the driving techniques in the ACDI modes.

In order to check which mode of the driving operation the drivers are most likely to adopt the Ecodriving technique, the training data were further examined. The driver's driving operation during the training day was assessed by comparing the speed, engine speed, fuel economy, and fuel consumption against the driving modes before and after Ecodriving training. A paired-sample t-test (two tailed) was conducted to evaluate the effect of Ecodriving techniques on drivers' driving operation: starting acceleration (beginning of the trip), cruise, deceleration and acceleration (beginning of the signal green) and the corresponding specific vehicle parameters: speed, fuel economy, fuel consumption and engine speed. The summary of the comparison is presented in Table 2.

Table 2. Normal driving and Ecodriving during training-day driving operation results

Driving Parameters	Driving Modes			
	Starting Acceleration	Cruise	Deceleration	Acceleration at signal Green
Speed, Kph	***	n.s.	n.s.	n.s.
Engine Speed, RPM	***	***	***	***
Fuel Economy, km/liter	n.s.	n.s.	***	n.s.
Fuel Consumption, cc/sec	n.s.	n.s.	n.s.	n.s.

Values of the driving parameters were calculated as before minus after (before – after); ***significant at 5% level; n.s. not significant.

The Ecodriving technique for starting acceleration, promotes gentle and increasing acceleration below the 20kph mark at the first 5seconds of driving. The results among the thirty drivers in Manila revealed that there was a significant effect of the Ecodriving technique during the starting acceleration as explained in the outcome of their speed and engine speed ($p < 0.05$). This means that in the normal driving test, the speed and engine speed indicated higher values compared to the values during the Ecodriving driving test. Therefore, there was a significant decrease in both parameters after the training, which was in consonance to the instruction of Ecodriving technique at this mode. However, in this mode, only small time interval was examined at 5 seconds duration, thus, the fuel consumption rate was not significant.

For cruising mode, Ecodriving technique directs that drivers should maintain a "good constant speed by operating the accelerator in accordance to the surrounding traffic flow". The results in the cruise mode revealed that there was a significant effect in the engine speed (RPM). This means that before the training (i.e., normal driving test) their engine speeds were higher compared to the values after training (i.e., Ecodriving driving test); the drivers were therefore able to decrease their engine speed as prescribed in the Ecodriving technique at this mode. Moreover, the drivers were also able to lower the fuel consumption rate, to increase the fuel economy and to lower their speed values; however these values were not significant.

For deceleration mode, Ecodriving technique promotes "releasing gently the accelerator early to coast the engine" at intersection signal stop. The results in Table 2 revealed that there were significant effects ($p < 0.05$) in the engine speed and fuel economy parameters among the thirty drivers. The drivers engine speed were reduced (decreased values) and the fuel economy improved (increased values) after the Ecodriving training. These would imply that drivers were able to lower the engine RPM values in the deceleration mode enabling them to optimize on their vehicle performance as reflected in the increased fuel economy at this mode.

Lastly, for the evaluation of starting acceleration at the traffic signal green at intersection when the traffic signal indicates green or “go”, the Ecodriving technique directs that drivers should again gently accelerate; switching the engine-on and gently stepping on accelerator similar to the technique of driving at the start of the trip. The results in this mode revealed that there were significant effects in the engine speed (RPM). The engine speed values during Ecodriving driving test were lower compared to the engine speed values during normal driving test. This means that Ecodriving training significantly contributed to the decrease of the engine speed values during the Ecodriving driving test. Drivers managed to reduce the fuel consumption rate and speed values at this mode; however, these parameters were not significant.

In summary, for the evaluation of the acceleration, deceleration and cruising modes during the training day, the results revealed that Ecodriving training significantly affected drivers engine speed, speed and fuel economy. More specifically, across these three modes the drivers were able to control their engine speed by reducing the RPM values during the Ecodriving driving test. During the acceleration (i.e. starting acceleration) mode the speed was significantly reduced, and during deceleration mode the fuel economy values were significantly increased.

4.2 Drivers Real-World Driving Characteristics

The first round (three days) and second round (three days) of collecting drivers real-world driving data from the GPS and fuel gauge were examined for the real-world driving characteristics of the Manila drivers. The GPS data were plotted on GIS road network map. By matching the location with fuel gauge data, we built the dataset containing the same routes (matched routes) for both normal driving and Ecodriving days as database for the real-world driving data. These were then used as “before-and-after” information for the test comparison of the driving modes of each driver and the vehicle parameters (fuel consumption, speed, engine power, and fuel economy). The vehicle modes considered in this evaluation included: the starting acceleration at the beginning of the trip, cruise, deceleration (mostly due to traffic signals), and acceleration at the traffic signal green or “go”. The final dataset were reduced to twelve drivers’ dataset with matched routes and with ample duration of trips for the analysis.

This section examined which ACDI mode during real-world application; the drivers were able to perform the Ecodriving techniques. Therefore, for real-world driving evaluation, the normal driving and Ecodriving data of driver’s daily trip before and after the Ecodriving training day was examined. The drivers’ driving operations were assessed by comparing the speed, engine power, fuel economy, and fuel consumption against the driving modes. A paired-samples t-test (two tailed) was conducted to evaluate the effect of Ecodriving techniques on drivers’ driving operation: starting acceleration (beginning of the trip), cruise, deceleration, and acceleration (beginning of the signal green) and the corresponding specific vehicle parameters: speed, fuel economy, fuel consumption and engine power. The result of the analysis on the effectiveness of the Ecodriving program is shown in Table 3.

For cruising mode, there were significant changes in the fuel consumption and fuel economy values after the training ($p < 0.05$). The fuel consumption values were significantly decreased with corresponding increased fuel economy values after the Ecodriving training. This could suggest that in this mode the drivers were attempting the technique of “efficient driving speed and engine speed application” as the fuel economy values were improved after the training. However, they still needed more improvement in this technique. There were increased values in the speed and engine speed values after the training but the values were not significant.

Table 3. Normal driving and Ecodriving during real-world driving operation results

Driving Parameters	Driving Modes			
	Starting Acceleration	Cruise	Deceleration	Acceleration at signal Green
Speed, Kph	n.s.	n.s.	n.s.	***
Engine Speed, RPM	n.s.	n.s.	***	n.s.
Fuel Economy, km/liter	n.s.	***	***	n.s.
Fuel Consumption, cc/sec	n.s.	***	***	n.s.

Values of the driving parameters were calculated as before minus after (before – after); ***significant at 5% level; n.s. not significant.

In terms of deceleration mode, the results revealed that there was a significant ($p < 0.05$) effect of the Ecodriving training. This was revealed in the decreased values of the fuel consumption and engine speed parameters with a corresponding increased fuel economy values after the Ecodriving training. The speed increased, however it was not significant. This result suggested that drivers were able to adopt the Ecodriving technique of decelerating by "releasing gently the accelerator early to coast the engine" at signal stops (or intersection red).

The evaluation of the starting acceleration at traffic signal stop was also conducted. This part of the acceleration mode happens when the vehicle stops at the red light, and then begins to accelerate as the signal turns green. This mode revealed that there were some improvements in the fuel economy, fuel consumption and engine speed (RPM) values before and after the Ecodriving training; however, these values were not significant. Only the value of speed was found to be significantly reduced. This result indicated that drivers were not able to demonstrate effectively the "gentle starting acceleration" technique. Furthermore, it was observed that there were deceleration events which suggested that the traffic condition at the intersections might have influenced this mode.

Lastly we compared the results of the training-day driving in Table 2 and the results of the real-world driving in Table 3, however, we could not find consistent trends. This might be because of the difference between the traffic conditions on the route for the training-day and on the routes for the real-world driving where frequent traffic congestion might constrain the application of Ecodriving considerably especially in Manila.

In summary, the evaluation of the ACDI modes during the real-world driving results revealed that Ecodriving training significantly affected drivers' engine speed, speed, fuel consumption and fuel economy. More specifically, during the cruise mode the fuel economy values improved as fuel consumption values were reduced after Ecodriving training. During deceleration mode the fuel consumption reduced as engine speed was reduced and thus the fuel economy increased after Ecodriving training. For the starting acceleration at the traffic signal locations, only speed was significantly reduced after Ecodriving training.

5. CONCLUSIONS AND FURTHER STUDIES

The study focused on the effect of Ecodrive program on the driver's driving modes during the training day and real-world driving conditions in developing country settings. Particularly the effects of the Ecodrive program before and after Ecodrive training were studied in relation to fuel economy, fuel consumption, engine speed and speed values during the acceleration, cruise, and deceleration modes. The study was able to demonstrate that Ecodrive program significantly affected the overall fuel efficiency performance during the training day suggesting that drivers could adopt well the Ecodriving techniques. Manila drivers were in general able to demonstrate that Ecodrive program during training improved significantly fuel economy values.

However, according to the analyses by the acceleration, deceleration and cruising modes, the changes of fuel efficiency were not significant. Across the acceleration, deceleration and cruising modes the drivers were able to control their engine speed by reducing the RPM values during the Ecodriving driving test. During the acceleration (i.e., starting acceleration) mode the speed was significantly reduced, and during deceleration mode the fuel economy values were significantly increased.

The evaluation of the modes during the real-world driving results revealed that Ecodriving training significantly affected drivers' engine speed, speed, fuel consumption and fuel economy. More specifically, that during the cruise mode the fuel economy values improved as fuel consumption values was reduced after Ecodriving training. During deceleration mode the fuel consumption reduced as engine speed was reduced and thus the fuel economy increased after Ecodriving training. For acceleration mode, or the starting acceleration at the traffic signal locations, only speed was significantly reduced after Ecodriving training.

We also compared the results of the training-day driving and the real-world driving, however, we could not find consistent trends. This might be because of the difference between the traffic conditions on the route for the training-day and on the routes for the real-world driving where frequent traffic congestion might constrain the application of Ecodriving considerably especially in Manila.

The real-world Ecodriving results may be affected by factors such as: road condition, traffic environment, and drivers' driving culture. These factors have to be explored to further understand the influence on the driving performance of the drivers to improve the Ecodriving program for developing country application such as those in Manila. It would also be prudent to consider in future policy application, the recommendation of JAMA on the safety and mechanical issues related to the application of idling-stop technique from the viewpoint of safety. Further studies will also be dealt in the future on the evaluation of the Ecodrive program during real-world application alongside built environment factors (i.e., traffic characteristics, road characteristics, vehicle characteristics, driving characteristics, travel characteristics) and policy implications for developing countries to advance the Ecodrive program.

ACKNOWLEDGEMENT

This study would like to acknowledge the office of ECCJ and IBS for their generous support in this academic research. To them, we would like to express our deep gratitude.

APPENDIX A

Training day Diagnostic Data (Before-Training and After-Training)

		Fuel Efficiency (km/L)		Distance (km)		Travel Time (sec)	
Driver	Training Date	Before	After	Before	After	Before	After
D1	11/13/2010	8.95	9.77	3.17	3.12	581	658
D2	11/13/2010	8.38	9.73	3.12	3.11	585	544
D3	11/13/2010	8.05	8.39	3.16	3.15	722	791
D4	11/13/2010	7.07	7.68	3.04	3.01	671	727
D5	11/20/2010	8.63	8.03	3.12	2.78	623	669
D6	11/20/2010	7.18	8.21	3.15	3.14	638	805
D7	11/27/2010	5.26	6.08	3.08	3.06	606	678
D8	11/27/2010	7.82	8.59	3.12	3.10	568	690
D9	12/4/2010	8.70	9.16	3.09	3.15	875	836
D10	12/11/2010	9.93	11.61	3.20	3.21	611	554
D11	2/5/2011	7.65	8.94	3.05	3.04	658	654
D12	2/5/2011	6.72	7.99	3.06	3.00	634	767
D13	2/5/2011	5.95	7.20	3.08	3.03	556	674
D14	2/12/2011	6.13	6.69	3.06	3.04	635	602
D15	2/12/2011	4.57	6.60	3.06	3.03	536	651
D16	2/19/2011	6.56	7.17	3.05	3.05	610	674
D17	2/19/2011	6.21	6.93	3.07	3.05	621	660
D18	2/19/2011	6.09	6.72	3.06	3.05	574	614
D19	3/12/2011	4.61	5.95	3.08	3.08	663	705
D20	3/12/2011	6.45	7.28	3.04	3.02	659	702
D21	3/12/2011	6.46	6.81	3.06	3.06	673	674
D22	3/12/2011	6.46	6.79	3.02	3.07	610	681
D23	3/19/2011	6.29	7.10	3.05	3.06	647	697
D24	3/26/2011	7.97	8.29	3.03	3.03	603	670
D25	3/26/2011	6.83	8.67	3.05	3.06	648	636
D26	3/26/2011	6.37	7.49	3.06	3.04	541	538
D27	3/26/2011	6.15	7.33	3.06	3.06	544	593
D28	12/4/2013	10.02	11.51	3.12	3.15	744	681
D29	4/9/2013	7.03	7.86	3.07	3.03	684	682
D30	4/9/2013	6.88	8.01	3.18	3.18	663	657

REFERENCES

Abuzo, A. and Muromachi, Y. (2011), The Effect of Ecodrive Program on Driving Behavior and Fuel Economy of Passenger Cars in Tokyo, *Journal of the Eastern Asia Society for Transportation Studies*, Vol.8, pp. 858-871.

Agency for Natural Resources and Energy (ANRE) and Ministry of Economy, Trade and Industry(METI), Japanese Eco-driving Initiative, Available online January 15, 2013. http://www.internationaltransportforum.org/Proceedings/ecodriving/1-04Japan.pdf

Asian Development Bank, ADB (2008) Green Transport: Resource Optimization in the Road Sector in PRC, Handbook: Awareness of Climate Change and Eco2-Transport, Draft Report, November 2008. http://www.adb.org/Documents/Reports/Consultant/39150-PRC/39150-06-PRC-TACR.pdf

Barth, M., and Boriboonsomsin, K. (2009) Energy and Emissions Impacts of a Freeway-Based Dynamic Eco-Driving System, *Transport Research Part D: Transport and Environment*, Article in Press, Corrected Proof, doi:10.1016/j.trd.2009.01.004, Available online 5 March 2009.

Berry, I.M. (2010), The Effects of Driving Style and Vehicle Performance on the Real-World Fuel Consumption of U.S. Light-Duty Vehicles, Department of Mechanical Engineering and the Engineering Systems Division, Massachusetts Institute of technology (MIT) Thesis Paper. http://web.mit.edu/sloan-auto-lab/.../IreneBerry_Thesis_February2010.pdf

Commission Internationale des Examens de Conduite Automobile, CIECA (2007), Internal Project on "Eco-Driving" in Category B Driver Training & Driving Test, Eco-driving Project Final Report.
http://www.ecodrive.org/fileadmin/dam/ecodrive/Downloads/CIECA_Eco-driving_project_final_report_EN.pdf

Decicco, J., and Ross, M., 1996, Recent Advances in Automative Technology and the Cost Effectiveness of Fuel Economy Improvement, Transportation Research Board Part D (2), 79-76.

Deutsche Gessellsschaft Fur Technische Zusammenarbeit, GTZ (2005), Sustainable Transport: A Sourcebook for Policy Makers in Developing Cities Module 4f: Ecodriving.
http://www2.gtz.de/dokumente/bib/05-0524.pdf

De Vlieger, I., De Keukeleere, D., and Kretzschmar, J.G. (2000), Environmental Effects of Driving Behavior and Congestion Related to Passenger Cars, *Atmospheric Environment 34*, Pp. 4649-4655.

Ericsson, E. (2001), Independent Driving Pattern Factors and their Influence on Fuel-Use and Exhaust Emission Factors, *Transportation Research* Part D 14, pp. 325–345.

Ericsson, E., Larsson, H., and Brundell-Freij, K. (2006), Optimizing Route Choice for Lowest Fuel Consumption- Potential Effects of a New Driver Support Tool, *Transportation Research*, Part C 14, pp. 369–383.

European Conference of Ministers of Transport, ECMT (2005), Technology and Policies to Improve Vehicle In-Use Fuel Economy: Making Cars more Fuel Efficient, OECD, IEA and ECMT Publication Service, France, ISBN 92-821-0343-9, pp.33-35.

European Environmental Agency, EEA (2008), Success stories within the road transport sector on reducing greenhouse gas emission and producing ancillary benefits- Technical Report, ISSN 1725-2237 http://www.eea.europa.eu/publications/technical_report_2008_2

Evans, L., 1979, Driver Behaviour Effects on Fuel Consumption in Urban Driving, Human Factors 21 (4), 389-398.

Fujikawa, T., and Taniguchi, M. (2002), Effects of Ordinary Users' Driving Conditions on Automobile Fuel Consumption, *Proceedings of the Society of Automotive Engineers of Japan (JSAE) Annual Congress*, Vol. 100-02, pp. 5-8.

Henning, W. (2008), Ford Eco-driving: Best Practice Training and Evaluation, Presented at the ECODRIVEN Conference, Prague.

Hooker, J.N., 1988, Optimal Driving for Single-Vehicle Fuel Economy, Transportation Research, Part A (22A(3)), 183-201.

Hornung, D., Stiefel, A., Stampfli, M., and von Hebenstreit, B. (2000), Evaluation of the Eco-Drive Courses, in Response to a Commission from the Federal Office of Energy (German), Bern (BBL No. 905.527 d).

Hornung, D., Röthlisberger, and T., M. Stampfli, M. (2001), Evaluation of the Eco-Drive, Simulator Courses, in Response to a Commission from the Quality Alliance Eco-Drive, and the Swiss Federal Office of Energy (BFE), in German, Bern 2001.

Hornung, D., Röthlisberger, T., M. Stampfli, M. (2003), Evaluation of the Effectiveness of Simulator Demonstration Driving: In Response to a Commission from Quality Alliance Eco-Drive, and the Swiss Federal Office of Energy (BFE) (in German), Bern 2003 (BBL Nr. 805.548 d).

Igarashi, T., Yagi, Y., Tamura, S., Masaki, K. (2006), Effects of EcoDrive Using "DriveManager", *Proceedings of the Society of Automotive Engineers of Japan (JSAE) Annual Congress,*Vol.1, No.1, pp.110-114.

Intelligent Energy Europe, IEE (2008), European Campaign On improving DRIVing behaviour, ENergy-efficiency and traffic safety (ECODRIVEN), Final Progress Report (FR), EIE/05/007/SI2.419394 http://www.fiabrussels.com/download/projects/ecodriven/final_pr_ecodriven_230309.pdf

Japan Automobile Research Institute (JARI) (2012) Eco-driving, 1st Asia Automobile Institute Summit, Accessed: January 15, 2013, http:// www.jari.jp/.../AAI_Summit_09-JARI.pdf

Katayama, H., Taniguchi M. (2005), A Study on Practical Training System for Energy Conservational Drives, *Proceedings of the Society of Automotive Engineers of Japan (JSAE)***,**Vol. 80-05, pp. 20.

Katayama, H., Taniguchi, M. (2005), A Study on Ordinary Driver's Senses about "Idling-Stop", *Proceedings of the Society of Automotive Engineers of Japan (JSAE) Annual Congress*, Vol.98-05, pp.7-8.

Katayama, H., Taniguchi, M. (2006), Studies on Idling Stop Approach along with Traffic Lights as Science and Technology for Society, *Proceedings of the Society of Automotive Engineers of Japan (JSAE) Annual Congress*, Vol. 112-06, pp. 7-10.

Matsuki, Y. (2006), The Relationship between Driving Behavior and Fuel Consumption, Institute of Electronics Information and Communication Engineers (IEICE), Technical Report, *Proceedings of the Society of Automotive Engineers of Japan (JSAE)* Annual Congress, Vol.106, No.266, pp.1-6.

Miyasaka, T.,Taniguchi, M., and Sambuichi, H. (2005), Potentiality of Effects by Fuel Conservation Driving in Automatic Transmission Car, *Proceedings of the Society of Automotive Engineers of Japan (JSAE)***,** Vol.80-05, pp. 13-16.

Morimitsu, N., Taniguchi, and M., Sambuichi, H. (2005), Eco-Drive Promotion Activities in Europe, *Proceedings of the Society of Automotive Engineers of Japan (JSAE),* Vol. 80-05, pp. 9-12.

Nader, J., 1991, Measurement of the Impact of Driving Technique on Fuel Consumption: Preliminary Results, roads and Transportation, Technical Note TN-172, 1-6.

Onoda, T. (2009), IEA Policie- G8 Recommendations and an Afterwards", *Energy Policy,* Vol. 37, No. 10, pp. 3822-3831.

Pandian, S., Gokhale, S., and Ghoshal, A.K.(2009), Evaluating, Effects of Traffic and Vehicle, Characteristics on Vehicular Emissions near Traffic Intersections**,** *Transportation Research* Part D 14, pp. 180-196.

Rafael, M., Sanchez, M., Muchino, V., Cervantes, J., and Lozano, A., 2006, Impact of Drving Styles on Exhaust Emissions and Fuel Economy from a Heavy-Duty Truck: Laboratory Tests, *International Journal of Heavy Vehicle Systems*, Vol. 13 No. 1/2, pp. 56-73.

Sah, J. S., Chung, N. H., and Sunwoo, M. H., (2003), Experimental Analysis of Driving Patterns and Fuel Economy for Passenger Cars in Seoul, *International Journal of Automotive Technology,* Vol. 4, No. 2, pp. 101-108.

Saboohi,Y., and Farzaneh, H. (2005), Model for Developing an Eco-driving Strategy of a Passenger Vehicle Based on Fuel Consumption, *Applied Energy***,** Vol. 6, Issue 10, pp. 1925-1932.

Swedish National Road Administration Vagverket (2000), Impact of EcoDriving on Emissions and Fuel Consumption http://publikationswebbutik.vv.se/upload/2000/1999_165E_impact_of_ecodriving_on_emissionsand_fuel_consumption.pdf

Taniguchi, M., Kasai, J., and Sambuichi, H. (2006), A Study on the Fuel Consumption for Driving at Vehicle Starting Under Energy Saving Drives, *Proceedings of the Society of Automotive Engineers of Japan (JSAE)***,** Vol.26-06.

Taniguchi M., and Miyasaka T. (2005), A Study on Practical Energy Saving Drives under Traffic Condition, *Proceedings of the Society of Automotive Engineers of Japan (JSAE),*Vol. .80-05, pp. 21-24.

Taniguchi M., and Mori, K. (2006), The Influence of Idling Stops on Traffic at the Intersection, *Proceedings of the Society of Automotive Engineers of Japan (JSAE)* Annual Congress, Vol. 112-06, pp. 5-6.

Taniguchi, M., and Sato, F. (2003), The Effect of Idling Stop at Red Light for Fuel Saving from the data of the Field Test, *Proceedings of the Society of Automotive Engineers of Japan (JSAE)* Annual Congress, Vol. 4-03 pp. 9-12.

Treatise Project: Ecodriving (Smart, Efficient Driving Techniques**),** Senter Novem, Utrecht for the EC Treatise Project, Sept.2005. http://www.transportlearning.net/docs/Eco_Drive.pdf

Ukita M., and Shirota H. (2003), Study on the Effect of Eco-Driving by Equipping with Fuel Consumption Meter, *Proceedings of Annual Meeting of Environmental Systems Research***,** Vol. 31, pp. 413-419.

Van Mierlo, J., Maggetto, G., van de Burgwal, E., and Gense, R. (2004), Driving Style and Traffic Measures Influence on Vehicle Emissions and Fuel Consumption, *Proceedings of the Institution of Mechanical Engineers, Journal of Automobile Engineering***,** Part D, Vol. 218.

Wilbers, P. (1999), The New Driving Force: A New Approach to Promote Energy-Efficient Purchasing and Driving Behavior, Proceedings of Ecodrive Conference, Graz, Austria 900916-990917.

Zarkadoula, M., Zoidis, G., and Tritopoulou, E. (2007), Training Urban Bus Drivers to Promote Smart Driving : A note on a Greek Eco-driving Pilot Program, *Transportation Research Board Part D*, Vol. 12, pp 449-452.