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DOCTORAL DISSERTATION

EFFECTIVENESS OF ECODRIVING PROGRAM ON FUEL ECONOMY IN DEVELOPING COUNTRY REAL-WORLD APPLICATION

開発途上国におけるエコドライブプログラムの 実走行燃費改善効果に関する研究

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EFFECTIVENESS OF ECODRIVING PROGRAM ON FUEL ECONOMY IN DEVELOPING COUNTRY REAL-WORLD APPLICATION

by

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ABSTRACT

Because of the depleting reserves of fossil fuels and the concern on global warming and climate change due to increasing CO2 emissions, some developed and developing countries have made future plans for reducing CO2 emissions from transportation. While the introduction of hybrid and electric cars and provision of less carbon-intensive public transportation are common policy measures in these plans, the measures of Ecodriving or Ecodrive, are also suggested because the penetration of new cars takes time and the provision of public transportation might not be so effective in small or medium-sized cities.

In real-world application of Ecodriving, on-road fuel consumption and emission values are influenced by driving patterns which are in turn directly influenced by external factors such as: traffic characteristics, road characteristics, vehicle characteristics, driver's characteristics, trip characteristics and other possible variables. To capture all this factors will require intensive investigation of outcome before and after Ecodriving program. Thus, this study limited itself to investigate the outcome of Ecodriving program based on driver's characteristics and road characteristic. Specially, it focused on the similarities and differences observed from the results of the Ecodriving programs in developing (Manila) and developed (Tokyo) countries.

The general intent of this study was to develop and assess Ecodriving program for developing country application vis-à-vis developed country application in real-world as well as pre-defined test route settings. The general objective of this study was to promote and demonstrate Ecodriving program in developing country settings. To achieve this objective, the study specifically:

- evaluated the vehicle parameters on real-time and real-world driving operation;
- quantified and evaluate drivers' performance and fuel economy; and
- formulated program guidelines for policy recommendations.

First, this study was able to demonstrate that Ecodriving program significantly affected the overall fuel economy during the Ecodriving training day suggesting that drivers could adopt well the Ecodriving techniques in developing country as well as developed country settings. However, the results in terms of the drivers' driving operation (i.e., acceleration, cruising, and deceleration) or modes, the Ecodriving program needed to be improved to further advance the application of Ecodriving program in developing countries.

With respect to the driver's psychological aspects, it was found that rough driving influenced the absolute fuel economy in Tokyo at 10% level of significance. If it is possible to know the psychological and non-psychological characteristics of the participants of the Ecodriving program in advance, it might be able to improve the program by incorporating those characteristics. However, significant characteristics of the participants in Manila drivers were not found fully.

Second, this study also focused on the effectiveness of Ecodriving program on the driver's driving style in real-world driving condition. The effect of the Ecodriving program before and after Ecodriving training in the case of the Manila drivers was investigated in relation to fuel economy, fuel consumption, engine speed and speed values during the acceleration, cruising and deceleration modes. The study was able to demonstrate that Ecodriving program significantly affected the outcome of the cruising and deceleration modes of the drivers' driving style in real-world driving operation. However, the starting acceleration mode of the driving operations was not significant.

Moreover, the results of idling-stop and gentle acceleration techniques of the Ecodriving program using both training and real-world data in the case of the Manila as well as Tokyo drivers further revealed that even as there were improvements in real-world driving, the results among some drivers were not significant, and that the relationship between the fuel economy during the Ecodriving training and that in the real-world was not necessarily related. Therefore, the Ecodriving program needed to examine how the guidelines for idling-stop and gentle acceleration could be improved or enhanced to further advance the real-world driving operation in developing as well as developed country applications.

In relation to the relationship between improvements in real-world driving and the characteristics of the drivers in Manila and Tokyo, it was found that female drivers practiced idling-stop better than male drivers, while male drivers practiced gentle start better than the females. Aside from gender, other socio-economic variables were found to affect the adoption of idling-stop and gentle acceleration in real-world driving.

Third, the discussion on the recommended modifications of Ecodriving program in developing country settings was conducted. For cruising and deceleration of Ecodriving program, the inclusion of cruising and deceleration into the program was considered to be reasonable even in developing country settings. The application of gentle acceleration of Ecodriving technique could be included if the drivers were not badly affected by peak hour congestion, and the implementation was eased by newer models with automatic transmission. In relation to the idling-stop technique, while the introduction of the idling-stop guideline needed carefulness, it might be too much to exclude it from the program.

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Ad majorem Dei gloriam

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CHAPTER 1

BACKGROUND AND STUDY OBJECTIVES

1.1 Background

Awareness of the environment and the need for sustainable development is a growing apprehension in both developed and developing countries. Today's global environment is defined by population growth, urban sprawl and increased motorization.

Consequently, the International Energy Agency (IEA) reports that major source of CO_2 emissions comes from the transport sector. In particular, the rising motorization in developed and developing countries created environmental and transport issues such as traffic congestion, vehicular pollution, car dependency, ageing vehicle, increasing fuel cost etc., which has greatly challenged transportation policies. Road transport has become a major source of CO_2 emissions that creates adverse effect on the environment alongside the issues on noise, congestion, local air pollution, and road accidents.

Today, much attention is focused on the reduction of fuel consumption of road transport, because of the depleting reserves of fossil fuels and the concern on global warming and climate change due to increasing CO_2 emissions. Some developed and developing countries have made future plans for reducing CO_2 emissions from transportation. While the introduction of hybrid and electric cars and provision of less carbon-intensive public transportation are common policy measures in these plans, the measures for improving fuel economy by reducing traffic congestion and promoting an efficient driving style, called as Ecodriving or Ecodrive, are also suggested because the penetration of new cars takes time and the provision of public transportation might not be so effective in small or medium-sized cities.

1.2 Ecodriving Background

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 environment. Ecodriving is the attitude of driving in an environmentally-conscious and energy-efficient manner.

In general, Ecodriving programs are directed to change a driver's driving behavior through a generally improved driving operation and practical driving advisory. The basic operational technique characterizing Ecodriving includes:

- efficient speed application (starting, acceleration, and cruising),
- switching-off the engine (e.g., during signal stop, parking etc.),
- appropriate choice of gear (manual transmission),
- appropriate control on acceleration and deceleration, and
- efficient coasting or gliding, anticipation of traffic condition.

Along with this characteristic, practical advisories are also recommended which include:

- regular vehicle maintenance (e.g. engine, tires, air conditioner, etc.),
- minimizing mass and improving aerodynamics,
- anticipating traffic flow and signals,
- avoiding sudden starts and stops,
- driving at or below the speed limit,
- maintaining an even driving pace,
- appropriate choice of fuel type (i.e. octane level) and engine oil,
- wise usage of in-vehicle electronics (i.e., stereo, air conditioner, etc.), and
- employment of on-board computers and navigational systems (e.g., cruise control, GPS, trip computers, revolution counter, etc.).

The application of Ecodriving is particularly effective for intra-urban car trips because of several signals and other stop-and-go occasions in urban areas.

Ecodriving benefit is not only limited to lower emissions of CO_2 (Ukita and Shirota, 2003) and potential cost-savings on fuel (Miyasaka, 2005). Research studies (CIECA, 2007) also revealed that Ecodriving benefit further includes:

- narrowing the gap between real-world and test/drive cycle estimates of fuel consumption and emission,

- reduction of local air pollutants,
- reduction of noise,
- enhanced traffic safety,
- reduced drivers stress (from speeding and overtaking),
- improved driving comfort,
- positive effects on vehicle wear and tear or maintenance (e.g. brakes, tires),
- reduced costs (fuel, safety, repair and maintenance),
- improved service (increase in timely delivery) and
- improved trip time.

1.3 Ecodriving Program in Developing Country Real-World Application

Compilations of related studies on Ecodriving have shown the technical and practical approach to Ecodriving guidelines. Intensive Ecodriving promotions and initiatives in Europe and Japan have shown that the Ecodriving program waved great benefits that were evident in the training and reviews of the participating drivers. However, these studies also revealed the extensiveness of the program and initiatives that were very limited only to developed countries if not a handful few pilot initiatives in developing country application.

Moreover, reviews of Ecodriving evaluation were limited only to two groups of training-day methodologies: (1) the evaluation of Ecodriving along predefined "real-world" test route serving as training day driving environment (Taniguchi 2002-2006; van der Moort et al. 2001, De Vlieger et al. 2000, Rafael et al. 2006) and (2) the evaluation of Ecodriving using simulators or virtual-world driving test routes (van der Moort, et al., 2001; Ericsson, et al., 2006). The first methodology involved Ecodriving evaluations conducted along a predefined test route that represented the real-world driving condition. The candidate drivers were also initially informed and advised to drive along the assigned routes that simulated the "real-world" driving environment. Information such as origin and destination, the traffic environment, and the road geometry were already indicated for the drivers and driving instructors were usually present during the test drive. Drivers were required to drive the route twice: for the normal driving (or pretest) application and for the Ecodriving (or posttest) application. This type of evaluation and methodology was also adopted for Ecodriving training using driving simulators that simulated driver's driving operation in a "static" and virtual road environment. Training day evaluations of Ecodriving as usually found to be subjective because predefined routes and virtual environment already isolated the inherent constraints and the risks involved in real-world driving applications. These static conditions allow the drivers a degree of confidence in driving the posttest of the training and thereof the results of the evaluation, which might be deemed biased.

In contrast, real-world driving applications were usually random and dynamic situations of driving. Thus, the Ecodriving applications in real-world driving environments were found to be also dynamic. In this case, drivers' daily driving operations were evaluated according to two categories: the normal driving (pretest) and the Ecodriving (posttest) application. In this study, the daily traces of drivers' routes were investigated alongside their driving operations. The driving operations during pretest and posttest were further investigated to check if the Ecodriving guidelines were adopted after the Ecodriving training. Moreover, while past studies (Shuitchi, et al., 2010; Kenji and Maasaki, 2007; Tatsusugu and Taizo, 2009) either focused on the entire or some part (i.e., idling-stop) of the Ecodriving program, and on the relevant equipment for helping drivers to adapt themselves to Ecodriving styles, more recent evaluations were now focused on the effectiveness of Ecodriving in urban areas where traffic congestion prevailed and Ecodriving styles might not always be applicable within dynamic traffic conditions (Hideki, et al, 2010; Kenji and Hiroshi, 2010; Satoshi, et al., 2010).

It is also vital to consider the big difference between develop and developing countries when considering Ecodriving program and its promotion. Ecodriving program in developed countries includes the greater part of Europe, North America (i.e., USA and Canada), and some parts of Asia (i.e., Japan). These programs were developed with strong legislative cooperation between country-to-country promotions and initiatives that went side by side with government support and private support from various organizations (e.g., car industries). There were also initiatives or pilot programs conducted in developing countries which were tied to the program of developed countries through cooperation of international funding agencies (e.g.., ADB, GTZ etc.). However, these promotions were not strongly supported by government legislation and were usually voluntary commitment of the participants with short-lived impact. The foundation of the Ecodriving programs in developed countries took years of research and development. These were highly established and built upon strong basis in terms of the application, the advisories, guidelines and the techniques. It would also take time to initiate these programs in developing countries considering application, the advisories, guidelines and the techniques that should be viable in local settings. Developed and developing countries have strong commitment for environmental efforts where the Ecodriving promotion is aligned with CO_2 reduction (i.e., Kyoto protocol) and fuel economy. However, in developing countries, economic conditions limit its capacity. With limited resource and capability, most developing countries' priority was directed to economic growth. Ecodriving program promotions in developed and developing countries were also affected by behavioral and cultural acceptance of the participants. Interpretation of the application, the advisories, guidelines and the techniques affect driver's response to adherence to the program specially when compromised with local traffic and road conditions. Driver's behavioral tendencies with adherence to road policies were contrasting in both developed and developing countries. Road policies maybe stringent but in most cases of developing countries drivers have higher propensity to violate when institutional policies and commitment were weak e.g., driver's trainings, driving licenses, penalties and subsidies.

The conceptual framework in Figure 1.1 highlights that there is a gap between the Ecodriving promotion in developed and developing country applications. The factors that make up this difference include: vehicle, traffic, road, system and environment. Drivers driving factors are also different and more so because the driving orientation or culture, and behavior of the drivers in these environment contribute to the greater variability of the outcomes.

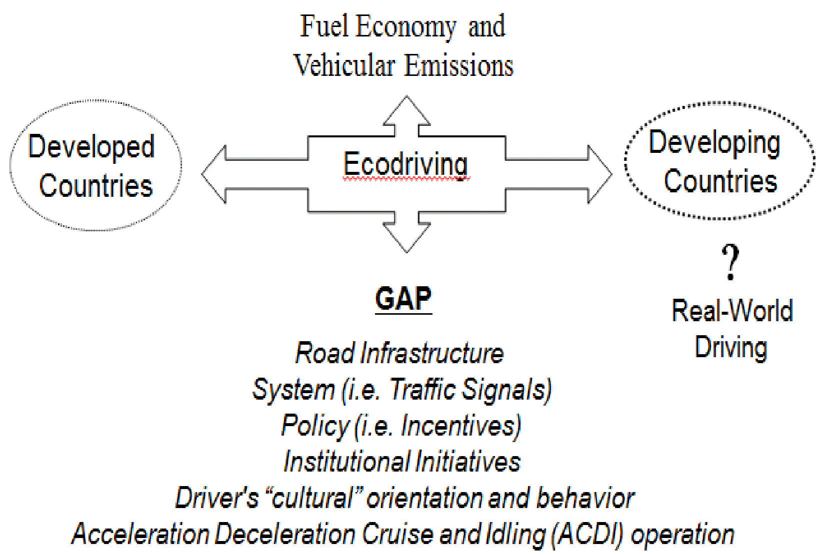

Figure 1.1 Ecodriving concept

As most Ecodriving programs are geared towards trainings and application that are applied in static or predefined driving routes and environment, the application in real-world driving is an issue that should be addressed as well an opportunity for further research. Since, the gap between static and dynamic applications may have significant effect on the program and promotion of the guidelines. There may be also significant difference in the results of the savings and benefits of Ecodriving in static environment against the results in dynamic and real-world environment. These prevailing issues also apply to Ecodriving evaluations of drivers driving outcomes in virtual environments, such as driving simulators. This further highlights the gap between the three applications of Ecodriving evaluations: static environment, virtual-world and real-world. The more realistic approach would have been to evaluate Ecodriving results in a more dynamic and real-world applications. And, since there are limited studies in this application, this becomes one of the motivations of this study.

In terms of program applications, most Ecodriving programs are highly established in developed country settings such as those in Europe and Japan, However, Ecodriving programs, guidelines and applications in real-world developing country application were very limited. Only one study by the Deutsche Gessellsschaft Fur Technische Zusammenarbeit (GTZ, 2005) revealed significant results of the European Ecodriving program for pilot country applications in Argentina, Chile and Indonesia. This study was an attempt to transfer the technology of

European Ecodriving program in developing country settings for bus drivers in static driving environment. Still, these pilot programs did not address the actual driving settings in a real-world developing country environment fully. The evaluation of Ecodriving program viability in developing country application and in real-world or dynamic environment or routes is necessary.

1.4 Study Objectives

In real-world application of Ecodriving, on-road fuel consumption and emission values are influenced by driving patterns which are in turn directly influenced by external factors such as: traffic characteristics, road characteristics, vehicle characteristics, driver's characteristics, trip characteristics and other possible variables. To capture all this factors will require intensive investigation of outcome before and after Ecodriving program. Thus, this study limits itself to investigate the outcome of Ecodriving program based on driver's characteristics and road characteristic. Specially, it focuses on the similarities and differences observed from the results of the Ecodriving programs in developing (Manila) and developed (Tokyo) countries.

This study would attempt to develop and assess Ecodriving program for developing country application vis-à-vis developed country application in real-world as well as pre-defined test route settings. The general objective of this study is to promote and demonstrate Ecodriving program in developing country settings. To achieve this objective, the study would specifically:

1. evaluate the vehicle parameters on real-time and real-world driving operation;
2. quantify and evaluate drivers' performance and fuel economy; and
3. formulate program guidelines for policy recommendations.

In order to address each objective, the study would focus on: the adopted Japanese Ecodriving guideline for the training; the assessment of drivers' driving operation during training and real-world application; and the formulation of the Ecodriving guidelines for developing country application. The study would be a pretest-posttest evaluation of the Ecodriving intervention. The methodology would involve three phases: input, process and output. For the input, the vehicle is equipped with on-board-diagnostic (OBD) equipment and drivers' driving operation is monitored through the vehicle parameters that serve as drivers' driving data. The Drivers' driving operation is monitored for two weeks, the first week for pretest data collection and the second week for posttest data collection. For the data processing, drivers' driving data along each driver's fixed (i.e., training data) and random route (i.e., real-world data) during training-day and the real-world driving operation, respectively, are assessed for pretest-posttest (i.e., before and after Ecodriving training) evaluation of drivers' improvement (e.g., fuel consumption, speed, acceleration etc.). The output is the assessment of drivers' improvement and the effectiveness of the Ecodriving which would then be used for improving and/or modifying Ecodriving guidelines for developing country application.

The first objective is addressed by evaluating the outcome of the vehicle parameters of the driver during their daily trips. This represents variable origin-destination or random trip route of their real-world driving operation which is presented in Chapter 5. The second objective is addressed by evaluating the outcome of drivers' driving characteristics and improvement (i.e., change in vehicle operations) during training day (pretest and posttest results) and real-world (pretest and posttest results) application. Assuming that, after the training each driver learned Ecodriving techniques, the second objective is presented in Chapter 4 and Chapter 5. Finally, the last objective is addressed in Chapter 6 and 7. The discussion of Chapter 6 details the outcome of drivers' driving characteristics, performance and fuel economy improvements from Chapter 4 and Chapter 5 evaluation. And, in Chapter 7 will discuss which Ecodriving guidelines should be adopted, retained, or modified for future policy recommendations of the Ecodriving program for developing country application.

1.5 Significance of the Study

Ecodriving application is greatly beneficial to drivers; however, the benefits are not limited to fuel economy but also emission, safety and the transport environment. Therefore, this study might be very significant to the following group and recipient:

- Professional licensed drivers; passenger, bus, and truck drivers of company fleets
- Private companies: fleet employers or managers
- Public transport companies

- Young or novice drivers
- Partner (promotion) network
- Maintenance personnel and managers
- Driving schools
- Driving instructors
- General public (i.e., practical parents and public awareness)

Ecodriving applications and programs are highly established applications in developed countries such as in Europe, Japan and the United States. There are however very few Ecodriving applications in developing countries. This study therefore addresses to explore Ecodriving application in developing country settings. Moreover, most Ecodriving researches are limited to evaluation of fuel economy improvement in a static driving environment or along test routes that are predefined to simulate real-world scenarios. These Ecodriving evaluations are also short-term application. Therefore, this study also explores the evaluation of Ecodriving in real-world application.

This study is therefore significant in its application as it explores to evaluate the two significant areas: real-world and developing country application of the Ecodriving program. The output of this study also further demonstrates if the Ecodriving guidelines would be feasible for developing countries application.

1.6 Scope and Limitations

The study primarily adopts the Japanese Ecodriving guidelines as promoted by the Energy Conservation Center of Japan and the ReCoo program. This study thereof, evaluates the outcome of the Ecodriving in Tokyo and uses the output as baseline for the guideline. On this basis, the guideline is then applied in Manila. The Manila study and investigation in turn serve as baseline reference in developing guidelines suitable for developing country environment, particularly in Asia. This study investigates the effectiveness of Ecodriving program of two groups of drivers: Manila and Tokyo. It explores both predefined test (training) and real-world driving characteristics of drivers' driving operation and fuel economy improvement. For the predefined test, the investigation also includes the investigation of operational, psychological and non-psychological attributes and parameters that affects the overall improvement. However, the parameters not included are real-world driving trip datalog and therefore the investigation is limited in terms of the evaluation of real-world drivers' trip characteristics, road characteristics, and traffic evaluation. The study focuses on the evaluation of real-world vehicle operation and fuel economy.

1.7 Structure of the Study

The following chapters of this study outline the evaluation of Ecodriving in real-world developing country application.

Chapter one presents the general background on the current issues of the transport environment and the introduction of Ecodriving. It also presents the background of Ecodriving programs and applications, and the gaps that set the direction of the study and motivation. It also outlines the general objectives, significance, scope and limitations, and definitions of terms of the study.

Chapter two presents related research reviews on Ecodriving programs (i.e., Europe, Japan etc.), initiatives of various countries and the promotion of Ecodriving in various agencies. It also presents the reviews of Ecodriving benefits, as well as the practical and technical advisories of Ecodriving guidelines. These reviews are significant in presenting the need to explore real-world developing country Ecodriving application.

Chapter three presents the general methodology of the study that tackles the approach of setting, collecting, handling and analyzing the data which comprise three areas of concern in the study: the questionnaire, the training diagnostic report and the real-world data collection. This chapter presents to include: the research design, research instruments (survey questionnaires, on-board-diagnostics, GPS and Fuel gauge, and GIS mapping), data collection process (questionnaire data collection, real-world data collection, and training-day data collection etc.), the characteristic of the data, the setting of the study (i.e., driver, vehicle, equipment and study area) and the analyses.

Chapter four highlights the investigation of the effectiveness of Ecodriving and the influencing factors on driver's driving behavior and characteristics. The Chapter elaborates in detail the Ecodriving training application on candidate Tokyo and Manila drivers. The Chapter details the results of drivers' driving operation and fuel economy before and after the Ecodriving program. It also addresses the influence of the non-psychological and psychological factors of the drivers on the results of Ecodriving program in developed and developing countries.

Chapter five presents the investigation of the effectiveness of Ecodriving in real-world driving in developed and developing country settings. This Chapter elaborates in detail the four operations of driving: acceleration, cruising, deceleration, and idling modes and the corresponding evaluation of the improvements on the fuel economy. This Chapter also explores to discuss if there is connection between the Ecodriving training day results, as well as socio-economic characteristics of the drivers, and the real-world Ecodriving results on the fuel economy improvements of the drivers.

Chapter six presents the Ecodriving programs initiatives, strategies, and guidelines used in the study as well as the proposed guidelines for developing country settings.

Finally, the last Chapter seven summarizes the results of the study and the conclusions of the evaluation of the effectiveness of Ecodriving in real-world developing country application. This Chapter also discusses further study directions for Ecodriving promotion.

1.8 Definitions of Terms

This section itemizes the various terms or terminologies adopted throughout the content of this study. The definitions, herein, are prescribed according to its usage.

Acceleration

Acceleration is the rate of increase of speed or the rate of change of velocity.

Addictive Driving

The 'addicted driving' means psychological characteristics of a driver feels enjoyment during driving.

Cruising

Cruising is to travel at a constant speed or at a speed providing maximum operating efficiency for a sustained period.

Idling

Idle or idling is to cause (a motor, for example) to stop or stand still; or the condition wherein vehicle engine is running while vehicle is actually stationary.

Idling-Stop

Idling-stop is to switch-off the engine when vehicle is idle to cut the engine fuel supply.

Carbon Dioxide (CO_2)

Carbon Dioxide is a colorless, odorless and non-combustible greenhouse-gas, formed when any fuel containing carbon is burned.

Deceleration

The act of decelerating or decreasing the speed**;** quantified as the rate of decrease in velocity.

Driving Characteristics

Specific driving operations such as acceleration, deceleration, cruising, and idling describe the driving characteristic and operation.

Drive Cycles

A driving cycle is a series of data points representing the speed of a vehicle versus time. It is composed of a unique profile of stops, starts, constant speed cruises, accelerations and decelerations and is typically characterized by an overall time-weighted average speed.

Driving Modes

The driving mode is defined by four specific driving operations that include acceleration (A), cruising(C), deceleration (D), and idling (I) or what is called ACDI.

Driving Operations

Driving is the controlled operation and movement of a land vehicle, such as a car, truck or bus.

Dynamic Routes

Dynamic routes are not initially set or defined routes; real-world driving routes.

Ecodriving

Ecodriving or Ecodrive is a driving technique designed to improve fuel economy. It is the attitude of driving in an environmentally-conscious (emission reduction) and energy-efficient manner (reduced fuel consumption).

Energy Efficiency

Energy efficiency is efficient energy use; to reduce the amount of energy required to provide products and services.

Fuel Consumption Rate

Fuel consumption rate is the ratio of the number of miles traveled to the number of gallons of gasoline burned

Fuel Gauge

A fuel gauge (or gas gauge) is an instrument used to indicate the level of fuel contained in a tank.

Fuel Economy

Fuel economy is the energy efficiency of a particular vehicle, and is given as a ratio of distance travelled per unit of fuel consumed. Fuel economy is expressed in miles per gallon (mpg) and in kilometres per litre (km/L).

Gentle Driving

The ‘gentle driving’ means the psychological characteristics of a driver who tends to drive in non- aggressive and non-hurried manner.

Global Positioning Systems (GPS)

Global Positioning System is a satellite navigation system used to determine ground position and velocity (location, speed, and direction).

Indecisive Driving

The ‘indecisive driving’ means psychological characteristics of a driver who is slow in driving decisions.

Intra-Urban Street Network

Movement from within or coming from within the urban street network

Irritated Driving

The ‘irritated driving’ means a psychological characteristic of a driver who tends to be irritated by other drivers.

Non-Psychological Characteristics

Characteristics that are not related to personal attributes such as gender, age, income level, etc.

On-Board Diagnostics (OBD)

On-board diagnostics, or OBD, is an automotive term referring to a vehicle's self-diagnostic and reporting capability. OBD systems give the vehicle owner or repair technician access to the status of the various vehicle sub-systems.

Practical Advisories

Practical advisories are driving advisories more appropriately directed at driving habits and behavior of drivers which are not related to driving operations. This includes practical advisories on ergonomics, vehicle maintenance and repairs, etc. This serves as the non-operational guidelines in the Ecodriving training.

Pre-Defined Routes or Static Routes

Static routes are set route; path with specific direction, origin and destination.

Psychological Characteristics

Psychological characteristics are defined in terms of personal attributes; aggressiveness, gentle, irritated etc. that characterize the driving.

Real-World Driving

Driving in the real or actual experience, or in a dynamic road environment

Rough Driving

The 'rough driving' means psychological characteristics of a driver who tends to drive in less gentle manner.

Stop-and-Go

Characterized by periodically enforced stops, as caused by heavy traffic or traffic signals; stop-and-go traffic.

Sustainable Development

Sustainable development refers to a mode of human development in which resource use aims to meet human needs while ensuring the sustainability of natural systems and the environment, so that these needs can be met not only in the present, but also for generations to come.

Sustainable Transport

Sustainable transport refers to the broad subject of transport that is or approaches being sustainable. Transportation sustainability is largely being measured by transportation system effectiveness and efficiency as well as the environmental impacts of the system.

Technical Advisories

Technical advisories are driving advisories more appropriately directed to address drivers' driving operations (i.e., acceleration, deceleration, cruising and idling). This serves as the operational guidelines in the Ecodriving training.

Traffic Characteristics

Specific parameters such as traffic speed, travel time, volume and density, etc. that characterize the traffic which are fundamental for planning, design and operation of roads and motorways (highways) and transport facilities.

Trip Characteristics

Specific trip parameters such as travel time, trip frequency, trip distance, etc. that describe the trip from an origin to a destination

Vehicle Characteristics

Specific parameters such as engine model, size, weight, cylinder size, engine power etc. that characterize the vehicle

Vehicle Navigational Systems

An automotive navigation system is a satellite navigation system designed for use in automobiles. It typically uses a GPS navigation device to acquire position data to locate the user on a road in the unit's map database. Using the road database, the unit can give directions to other locations along roads also in its database.

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CHAPTER 2

REVIEW OF RELATED STUDIES

2.1 Driving Behavior, Operation and Fuel Consumption

Mitigating emissions and minimizing fuel consumption are the primary concern of transportation environment particularly when considering the adverse impact of motorization. As customary, emission rates and fuel consumption values are measured on standardized test-cycle or drive cycle in controlled condition which serves as the basis for emission standards, still the estimation of emission loads in "real-world driving" conditions remains a challenge. The gap between estimates of real and controlled condition exists (i.e. shortfall). In "real-world driving," the conditions typically revolve on factors such as road characteristics, vehicle and driving operation, drivers' behavior etc.

In this study, driving operation is classified and measured according to specific driving modes, namely: acceleration, deceleration, cruising and idling. Energy efficiency is measured in terms of fuel economy and fuel efficiency. Engine fuel efficiency relates to the fraction of the energy content of the fuel used to move the vehicle while fuel economy is fuel efficiency relationship between distance traveled by an automobile and the amount of fuel consumed.

Improving fuel economy in driving a car is critical, environmental, and economic issues (Matsuki, 2006). Research and product design of auto manufacturers for fuel-efficient vehicles were (i.e. hybrid vehicles) aimed to reduce fuel consumption and cost (Morimitsu, 2005). Carbon-neutral alternative fuels (Barth and Boriboonsomsin, 2009) were also considered for reduction in CO_2 emissions. However, in spite of these technology options, additional consumption of fuel in an intense traffic condition is inevitable (Saboohi and Farzaneh, 2005), thus compounding the problem. Various strategies (Barth and Boriboonsomsin, 2009) were then considered: reducing the congestion, improving the traffic flow, reducing excessive vehicle speeds etc. were explored.

According to the result of TREATISE project (2005), modern fuel injection engines (petrol and diesel) produce high torque values at lower engine power (rpm). This study suggested that efficient engine operation should be between engine speed of 2000rpm-3000rpm and at torque values between 150Nm-250Nm. This range of values (i.e. engine speed and torque combination) was found to be the most fuel-efficient and was the basis of the Ecodriving strategy. It is then found that even if one's driving condition is exposed to the surrounding condition of a vehicle, other factors and constraints (Saboohi and Farzaneh, 2005; Rafael-Morales and Cervantes-de Gortar, 2002; Af Wahlberg, 2007) of excess fuel consumption may be avoided if an optimal driving strategy (i.e. engine speed and torque) is adopted. Ecodriving is defined as economical, ecological, and safe driving strategy that is aimed to reduce fuel consumption, greenhouse gas emissions, and accidents (Zarkadoula et. al., 2007).

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. This was supported by the study of De Vlieger *et al*. (2000) where adverse driving behavior (e.g. aggressive driving) and city driving conditions increased the fuel consumption by 20% - 45%. Therefore, increasing engine speed (i.e. RPM), speed fluctuations, and erratic accelerations produced higher fuel consumption values.

2.2 Ecodriving Program

Ecodriving or Ecodrive programs originated as methods of economical driving in Finland and Sweden. These programs encouraged widespread European Union Ecodriving initiatives (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 programs were primarily centered on the diffusion of the Ecodriving technique among drivers (novice drivers, professional drivers and fleet owners) especially with respect to the integration of the technique within the education (technology, culture, and legislation) of novice drivers. In Asia, Japan has become a leading country in promoting Ecodriving (ANRE and METI, 2007; JARI, 2012) following 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. Japan Ecodriving program slightly deviates from the European counterparts since Japanese car fleet is mostly automatic type (Automatic Transmission) of vehicle compared to manual transmission type which is predominant in Europe. The Japan Ecodriving guideline in Figure 2.1 illustrates the focus of its advisory which particularly addresses the operation of the driving modes: acceleration, deceleration, cruising and idling. This guideline specifically highlights “to accelerate gently up to 20kph within 5 seconds after starting”, “to reduce desired target speed by 5kph to save energy” and “to apply idling-stop or switching-off the engine if the vehicle is idle for more than 5 seconds.”

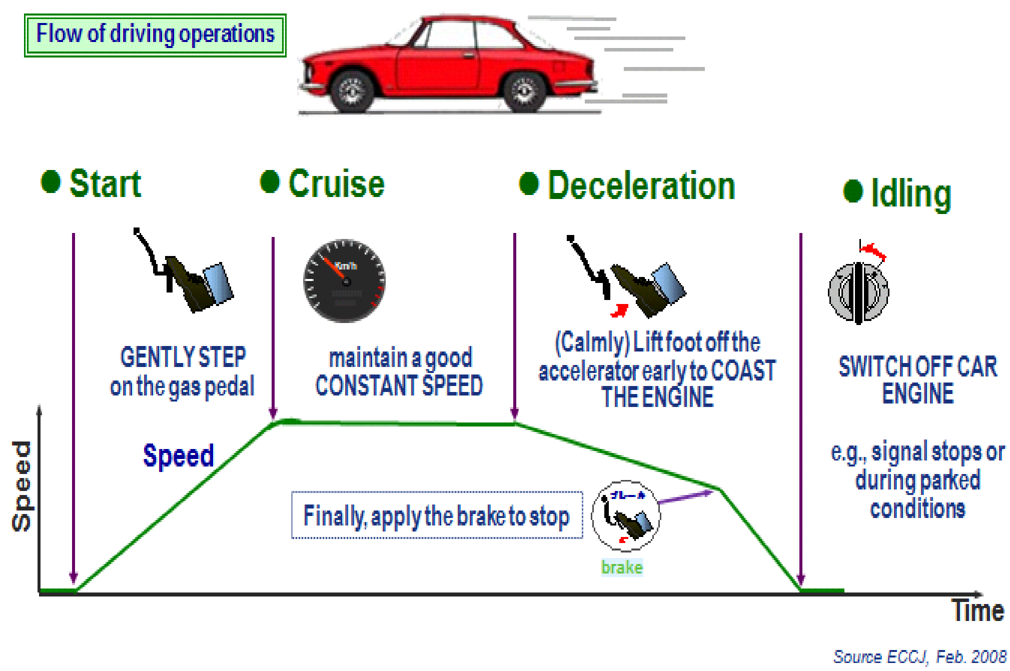

Figure 2.1 Japan Ecodriving program

Ecodriving program was also initiated in developing countries, particularly Asia and Latin America under the Gessellsschaft 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, Nicaraguaand Indonesia. The summary of program initiatives and development of Ecodriving programs in various countries for the last 18 years since 1995 was summarized in Table 2.1.

Table 2.1 Ecodriving country and program initiative

COUNTRY	PROGRAM/ INITIATIVE
Argentina*	Deutshe Gesellsschaft Fur Technische Zusammenarbeit (GTZ). Location: Buenos Aires area (1999) and Mendoza area(2003)
Chile*	GTZ: Pilot Initiative. Location: Santiago de Chile area
Costa Rica*	GTZ: Pilot Initiative. Location: San Jose area
Indonesia*	GTZ: Pilot Initiative. Location: Jakarta and Subaraya area
France	Regional Campaign RATP
Japan	Ecodrive 10/ Idling Stop Study on Buses at Cape Soya, Hokkaido and Cape Sata, Kagoshima Prefecture/ Smart Eco-drive contest in Tokyo(2004)
Austria	Spritspar-initiative/ NIGG Bus Company(2000)
Netherlands	Het Nieuwe Rijden/ Car Panel Consumentenbond (2002) Logistics Companies (1995-2003)
Greece	Center for Renewable Energy Sources of Greece, Organization of Urban Transportation in Athens, and the Thermo-bus Company (2008)
Switzerland	Eco-driving Quality Alliance/ Swissenergy: Eco-Drive® Courses/ Swiss Federal Office for Energy in (2000) Canon Company
Finland	Motiva: Ecodriving Networt (2008)
Scotland	Top Four Tips and Best of the rest
Poland	Ecodrive Europe
United Kingdom	Smarter Driving ("Act on CO_2" Campaign)/ Drivers Standards Agency (2004)
United States	USA Ecodrive
Germany	Hamburger Wasserwerke (2003) Frankfurt Motor Show (2007)
Spain	Real Catalonia Automobile Club (2003)
Belgium	Eco-driving, National Campaign/ Bond Beter Leefmilieu (BBL) Campagnes and Tire Profile Centre (2008)
Sweden	Energy (2000)
Czech Republic	A-Class Driver, Golden Rules of Ecodriving

*Note: * Pilot Ecodrive initiatives in developing country application*

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 the technique within the novice drivers' education (technology, culture, and legislation). The Ecodriving promotion strategies include: common knowledge base, synchronization of existing activities (common evaluations), integration into different policy fields (e.g., road safety, climate protection), and integration into legislation (e.g. driving education, common standards). These programs (CIECA, 2007; Treatise, 2005; Vagverket, 1999;

GTZ, 2008) were also grouped according to various collaboration efforts from local level and through implementing expert groups. Local level groups include fuel suppliers, car dealers, municipalities, driving schools, tire service stations, touring club shops, and other local actors. The expert groups include car manufacturers (e.g., Ford Europe), fuel suppliers (e.g., Shell), association of touring clubs (e.g., FIA), tyre manufacturers and suppliers (e.g., Profile International), road safety council (e.g., DVR, Germany), association of car manufacturers and importers (e.g., ACEA), associations responsible for licensing drivers (e.g., CIECA), association of driving schools (e.g. EFA), and experts from various stakeholders. These were also of the same approach adopted in Japan, under the Energy Conservation Center (ECCJ) and ReCoo Programs among other local endeavors that promote the Ecodriving information. And, as global demand for fuel increased along with the increasing price of fuel, the United States joined the band-wagon of promoting the Ecodriving program.

Already, the World Energy Outlook of 2007 indicated that 60% of world oil demand came from the transport sector, where 80% was attributed to road transport which accounted to 25% of carbon dioxide emissions. Moreover, as the world demand for fuel (IEA) was highly dependent on global macroeconomic conditions; increased oil price created negative impact on global economic growth. This also prompted the automobile manufacturers and industries to consider eco-friendly product design and ergonomics; in-vehicle technologies (i.e., navigation systems, driving-assistance systems etc.); and marketing strategies (i.e., training programs) in line with Ecodriving promotion. Because of this, more recent Ecodriving programs and 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. The Ecodriving timeline in Figure 2.2 of Abuzo and Muromachi (2011) revealed that consistent with increased worldwide motorization and increased global demand for petroleum, the Ecodriving program which started in 1995 became a global trend. At present, Ecodriving programs are focused mainly on marketing further the techniques and trainings while also on developing the Ecodriving related technologies (e.g., simulators, on-board electronic driving systems, etc.).

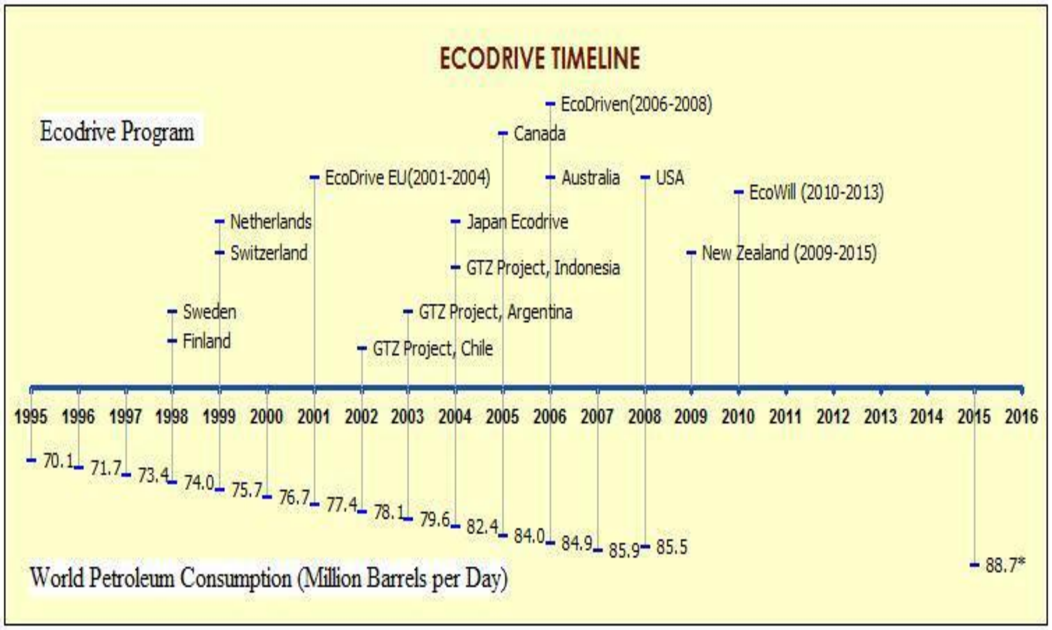

Figure 2.2 The Ecodriving timeline (1995-2015)

However, the bigger challenge with the Ecodriving was the promotion of long term program application and its sustainability, the integration of the program into local policy, and the development of Ecodriving guidelines that were suitable to the local settings. Unlike developed country programs, Ecodriving programs in developing countries face greater difficulty against its promotion. Developing country issues include: inadequate road infrastructure and traffic system, existence of ageing in-use vehicle and modified vehicle, rampant vehicle overloading, heavily congested roads with mixed modes of transport, inadequate traffic management, poor policy implementation, and inadequate program funding and promotion. In addition, the driver's behavior such as the aggressiveness in driving in a highly congested road with poor road infrastructure and poor traffic condition is prevalent, while driving practices such as warming-up of the engine and sudden starts and stops are also extensive. These factors of driver's characteristics include the fact that socio-economic condition of these countries also influences their driving practice (such as vehicle maintenance and overloading). Thus, there is a significant difference in Ecodriving application between developed and developing countries. Now, the more challenging area of the Ecodriving program would be focused on the technology transfer of the program for developing country application, particularly, if it can demonstrate its viability and applicability for developing country environment.

2.3 Ecodriving Technical and Practical Advisories

Ecodriving guidelines are technical advisories directed at addressing driving operations such as acceleration, deceleration, cruising and idling. These advisories serve as operational guidelines in Ecodriving training. Studies on driving patterns (Decicco and Ross, 1996; Ericsson, 2001; El-Shawarby et. al., 2005) revealed that road network and traffic conditions influenced driving behavior. These studies corroborate the technical aspect of Ecodriving programs, which specifically address driving operations, primarily those that focus on the resulting fuel economy, Ecodriving techniques, and the influence of driving operations or driving mode (i.e., acceleration, cruising, deceleration and idling). European Ecodriving according to programs (GTZ, 2005; CIECA, 2007; ECMT, 2005) and studies (GTZ, 2005; Zarkadoula, 2007) involves maintaining an efficient driving speed and engine speed application; switching-off the engine while stopped at signals, parking, loading and unloading, etc.; appropriate choice of gear by transmission type; and efficient coasting and application of brakes when decelerating. On the other hand, Japan Ecodriving program (ANRE and METI, 2007; JARI, 2012) focuses its guidelines on the correct operation of driving modes: acceleration, deceleration, cruising and idling. Studies (Ukita and Shirota, 2003; Taniguchi and Sato, 2003; Kasai, *et al.,* 2005; Taniguchi and Miyasaka, 2005; Miyasaka, *et al.* 2005; Katayama and Taniguchi, 2005 and 2006; Taniguchi and Mori, 2006, Matsuki, 2006; Taniguchi *et al*., 2006; Abuzo and Muromachi, 2011) revealed that strategic reduction of fuel consumption required curbing of the driving modes by applying the Ecodriving guideline, namely: gentle starting acceleration, idling-stop and application of speed control for cruising and deceleration modes.

Aside from the technical advisories, Ecodriving guidelines also involve practical advisories. Practical advisories are driving advisories more appropriately directed to curb driving habits and behavior of drivers which are not related to driving operations (i.e. technical and mechanical). These advisories include practical advice directed to better driving practices that would enhance the performance of the vehicle and the outcome of the fuel economy. Studies (Wilbers, 1999; Hornung, *et al.,* 2000, 2001 and 2003; Fujikawa and Taniguchi, 2002; Rafael-Morales and Cervantes-de Gortar, 2002; Ukita and Shirota, 2003; Saboohi and Farzaneh, 2005; Matsuki, 2006; Iagarashi *et al.*, 2006; Barth and Boriboonsomsin, 2009; IEE, 2008) encouraged

Ecodriving advisories which included: to improve maintenance practice, to improve aerodynamics, to anticipate traffic condition, to avoid overloading vehicle capacity, to choose appropriate fuel and engine oil, to regulate unnecessary use of in-vehicle electronics, and to employ on-board computers and navigational systems (e.g., simulators, driving systems, cruise control, GPS, rev counter, etc.) in aid of driving.

The collated Ecodriving programs in Table 2.2 and Table 2.3 itemized the Ecodriving programs by country and highlighted the Ecodriving techniques and advisories according to four specific driving modes, namely: acceleration, cruising, deceleration and idling. These Ecodriving programs accounted a total of sixteen (Zarkadoula, 2007) countries across Europe (El-Sharwarby, et. al., 2005), Japan, Canada and the United States.

Table 2.2 Ecodriving techniques and advisories by acceleration and cruising modes

Driving Modes	Driving Techniques and Advisories	Country
Acceleration	▪ Drive for 30sec to circulate oil in the engine to warm -up. Avoid sudden acceleration; adopt light foot acceleration.	▪ United States
	▪ Warm-up on the go: driving gently and allow your transmission, steering, and engine all warm up at once. Accelerate smoothly and shift to higher gear.	▪ Canada
	▪ Swift to higher gear at lower engine speeds	▪ Scotland, Belgium, Poland, Norway, Switzerland, Spain, Iceland, Greece, and Netherlands
	▪ Prudently shift to higher gear and control engine speed less than 3000rpm	▪ Sweden
	▪ Drive-off to warm -up engine. Check engine speed: 2,500rpm (petrol) and 2000rpm (diesel).	▪ United Kingdom, Austria, Germany, France
	▪ Do not warm up the engine; drive off immediately after starting. Drive with low revs and avoid "jackrabbit" start.	▪ Austria
	▪ Avoid hasty starts. Follow the "20km/hr within 5secs after starting" rule then change to higher gear if possible.	▪ Japan
Cruise	▪ Efficient driving speed and engine speed (rpm) application.	▪ France
	▪ Comply with speed limit; drive smoothly and fluidly.	▪ Austria, UK, Czech Republic, and Scotland
	▪ Drive evenly and in the flow of traffic; "mitschwimmen"	▪ Germany
	▪ Drive at constant speed, using higher possible gear.	▪ Sweden, Greece, Scotland, Belgium, Austria, Greece, Netherlands, and Poland
	▪ On highways, keep steady speeds.	▪ Canada
	▪ Use steady speeds. Use cruise control selectively on hilly roads.	▪ United States
	▪ Drive at low speeds according to traffic conditions; reduce desired target speed by 5kph to save energy.	▪ Japan

Table 2.3 Ecodriving techniques and advisories by deceleration and idling modes

Driving Modes	Driving Techniques and Advisories	Country
Deceleration	▪ Maintain safe distances and avoid sudden braking and accelerating.	▪ France, Austria, Canada, Iceland Switzerland, Spain, and Norway
	▪ Rather than last minute braking, decelerate smoothly by easing off the throttle as early as possible.	▪ Scotland, Czech Republic, Austria, Netherlands, Poland, and Germany
	▪ Release the gas pedal smoothly. Brake on the engine; modern engines will conclude automatically the fuel supply when accelerator is released.	▪ Belgium
	▪ Keep on rolling in traffic, anticipate stops and coast as much as possible; brake smoothly, especially around corners. Avoid tailgating.	▪ United States
	▪ When slowing down or driving downhill, remain in gear but take foot off the accelerator early to reduce fuel flow in the engine; avoid heavy braking.	▪ United Kingdom
	▪ Use engine braking when decelerating whenever possible.	▪ Japan
Idling	▪ Switch-off the engine (e.g., during signal stop, parking, loading and unloading etc.) ; turn off the engine if stationary.	▪ Sweden, Germany, Greece, Scotland, Spain, Norway, Iceland, and Poland
	▪ Switch-off the engine when vehicle is idle. Switching off the engine or stopping and restarting a car use less fuel than leaving the engine running for more than 20 seconds.	▪ France and Austria
	▪ Switch-off when idle; modern cars use virtually no extra fuel when they are re -started without pressing the accelerator.	▪ United Kingdom
	▪ Switch-off engine; 10secs of idli ng uses more fuel than restarting the engine.	▪ Canada
	▪ Avoid idling.	▪ United States
	▪ Apply idling-stop (witching off the engine) if vehicle stop or idling time is greater than 5secs; short -time stopping of the engine this way is effective in saving energy.	▪ Japan

2.4 Ecodriving Benefits and Issues

The successful results of Ecodriving program in developed countries such as 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. Potential benefits of Ecodriving were not only limited to CO_2 and fuel economy. Ecodriving programs that included 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 included: 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 of 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).

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. It also stressed that Ecodriving success would depend on the driving lecture and skill-transfer of the driving technique. However, these studies were extensively limited to only two groups of methodology: (1) the evaluation of Ecodriving in static or pre-defined test routes (Taniguchi 2003-2006, Nader 1991, Hooker 1988, van der Moort et al. 2001, Rafel 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, and, Ericsson, et al., 2006). There were very limited studies of real-world Ecodriving evaluation. Moreover, there were no existing Ecodriving programs for developing country settings.

Advisories such as those presented in the simulation study of Barth and Boriboonsomsin (2009) encouraged the use of real-time traffic sensing and telematics technology. This technology offered dynamic driving advice to drivers and showed savings and lower CO_2 emissions without a significant increase in travel time. However, even as significant benefits of adopting Ecodriving have been shown, there were also issues and constraints. The study of Degraeuwe and Beusen (2013) revealed that attendance at an Ecodriving training course significantly reduced fuel consumption values; however, some constraints that influenced long-term applications could be attributed to ambient temperatures. The study of Symmons et al. (2008) on heavy vehicle drivers likewise showed reduced fuel consumption, gear changes, and braking application after the drivers underwent Ecodrive training; however, there were also issues that were raised concerning road safety implications. The studies of Beusen et al. (2009) and Strömberg and Karlsson (2013) found that increased fuel savings, and decreased deceleration and speed values were attained among drivers who underwent Ecodriving training; however, the drivers had difficulty in maintaining its application over the long term and usually fell back to their original driving habits. The study of Delhomme et al. (2013) on adopting eco-friendly driving behavior revealed that controlling engine speed and shifting to a higher gear to optimize fuel efficiency were perceived attitudes that were difficult to adopt for most young and middle-aged drivers. The study of Hallihan et al. (2011) on the effects of hybrid interfaces (i.e., in vehicle technologies) to facilitate on Ecodriving behaviors revealed that it reduced excessive acceleration and hard braking among the drivers; however, the promising results were constrained to younger drivers in the study who were more ecologically sensitized. While, the study of Martin, et al. (2012) on Ecodriving education using the internet (i.e., static and web-based information), revealed that respondents within the experimental group had significantly changed their maintenance practice and altered some of their driving practice; however, before and after evaluation revealed that some drivers did not modify their behavior (i.e., made no change and were actually worsened).

2.5 Ecodriving Challenges in Developing Country and Real-World Application

The bigger challenge with the Ecodriving was the promotion of long term program application and its sustainability, the integration of the program into local policy, and development of Ecodriving guidelines that were suitable to the local settings. Unlike developed country programs, Ecodriving programs in developing countries face greater difficulty against its promotion. Developing country issues include: inadequate road infrastructures and traffic system, existence of ageing in-use vehicle and modified vehicle, rampant vehicle overloading, heavily congested roads with mixed modes of transport, inadequate traffic management, poor policy implementation, and inadequate program funding and promotion. In addition, the driver's behavior such as the aggressiveness in driving in a highly congested road with poor road infrastructure and poor traffic condition was prevalent, while driving practices such as warming-up of the engine and sudden starts and stops were also extensive. This factor of driver's characteristics includes the fact that socio-economic condition of these countries also influences their driving practice (such as vehicle maintenance and overloading).

Reports from Deutsche Gessellsschaft Fur Technische Zusammenarbeit (GTZ) study revealed significant results of pilot Ecodriving evaluation in Argentina, Chile and Indonesia (Tsuchida, 2005). However, there were no defined Ecodriving program and guideline set for local settings. Therefore, the more challenging area of the Ecodriving program would be focused on the technology transfer of the program for developing country application, particularly, in Ecodriving guidelines for local settings.

Considering the above preceding studies and challenges in developing countries, this study investigates the effectiveness of Ecodriving programs on fuel economy in developing (Manila) and developed (Tokyo) countries. Because the study followed a Japanese Ecodriving program and only English translation was available for the program, Manila was selected as a developing country case where the program in English was applicable. According to statistics, population, GDP per capita and passenger cars per 1000 people are 9.4 million, 2,200 USD, and 82 in Manila, and 32.3 million, 45,400 USD, and 307 in Tokyo Metropolitan areas. While the motorization in Tokyo was relatively stable, the growth in GDP per capita and passenger cars was on-going in Manila where the driver's behavior in developing countries above was typically found. The study specially focused on the driver's characteristics including psychological aspects among other factors influencing the outcome of the Ecodriving programs.

2.6 Conclusions

This Chapter presents related studies on the relationship among driving behavior, operation and fuel consumption, Ecodriving program initiatives in the world, Ecodriving technical and practical advisories, as well as Ecodriving benefits and issues. These reviews are significant in understanding that there is a need to explore real-world and developing country Ecodriving application since there are very few studies that explore this area of research.

Furthermore, the reviews presented in this Chapter serve as vital information for the methodology and guidelines of this study. The next Chapters elaborate further the direction of Ecodriving in real-world developing country application.

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CHAPTER 3

STUDY METHODOLOGY

3.1 Study Design

The study design (Figure 3.1) incorporates two main areas of concern that validate the final program and guideline of Ecodriving in developing country application. These two areas are: (1) driver setting and equipment setting, and (2) vehicle setting and the program setting.

The first area is represented by the primary data collected in the study. This included the real-world driving data, the training-day data and the questionnaire data. The real-world and training data necessitated calibration and instrumentation prior to the conduct of the data collection. Its survey also represented pretest and posttest data collection of the study during driving condition of the drivers. The raw data of the real-world and training-day were processed, mapped, evaluated and analyzed.

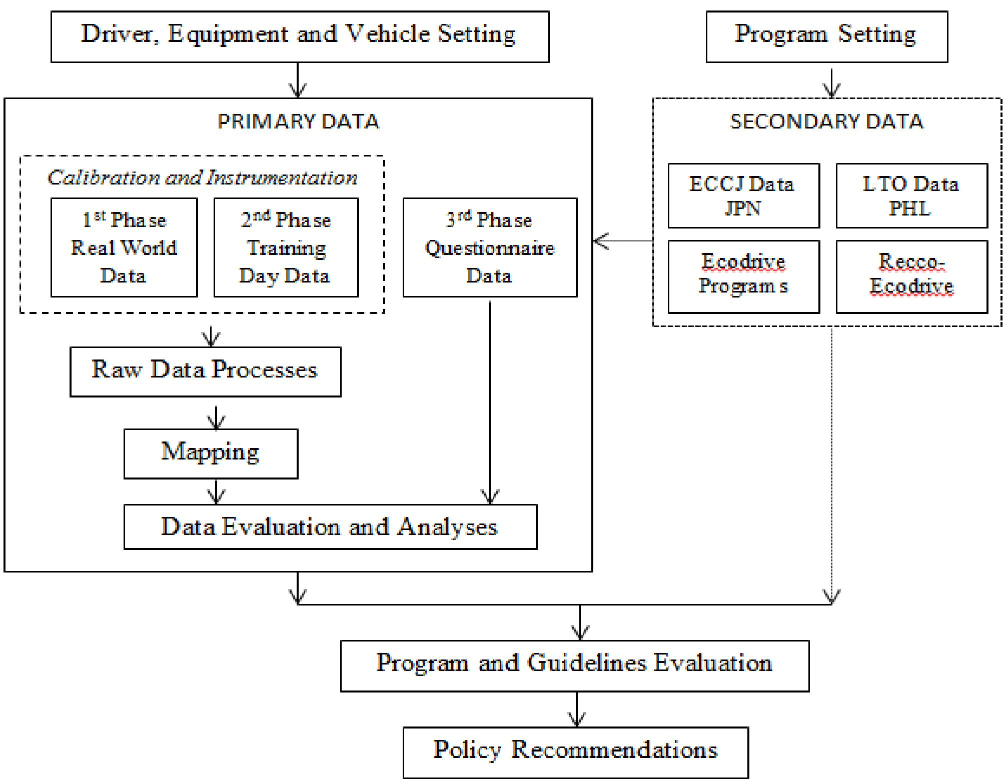


Figure 3.1 Ecodriving study design

On the other hand, the questionnaires were designed to measure the driving behavior of the candidate drivers. As part of the primary data, each candidate driver was asked to answer two sets questionnaires. Therefore, the process was administered twice; as a pretest (before the Ecodriving training day) and posttest (after the Ecodriving training day) evaluations of the program. The questionnaires were also evaluated and analyzed alongside the driving data.

With the primary and secondary data in place, the first objective is to evaluate the outcome of the vehicle parameters of the driver during their real-world driving operation. The second objective is to evaluate the outcome of drivers' driving characteristics and improvement during the training day (pretest and posttest results) and real-world (pretest and posttest results) driving application. And, the last objective is to evaluate the outcome drivers' driving characteristics, performance and fuel economy improvements for policy recommendations of the modified Ecodriving program for developing country application.

3.1.1 Driver, Equipment and Vehicle Settings

The driver, equipment and the vehicle are the main factors in setting the primary data collection of the study.

The driver. The promotions of the Ecodriving training were handled by invitation. Invitations were distributed in-campus universities alongside social-network referrals of interested drivers who were communicated through emails. There were two groups of drivers identified in the study, the Tokyo drivers and the Manila drivers. Furthermore, since the target numbers of drivers per group were set only for thirty (30) participants, the final listings of candidate drivers were then trimmed down. The preset criterion for the selection of the candidates was then to include only those drivers with vehicles compatible to the instrumentation requirements of the study. The candidate drivers were then given an orientation on the schedules, survey instruments and their responsibilities as participants of the study. The informed drivers were subject to a two-week survey for both pretest and posttest evaluations of the program.

The equipment. Two sets of monitoring equipment were installed in the test vehicles of the candidate drivers: the Global Position System (GPS) and the fuel gauge. The fuel gauge equipment from the Energy Conservation Center of Japan (ECCJ) was employed to monitor driving operation alongside the fuel values. This was installed as a monitoring system to the vehicle system through the On-Board Diagnostic (OBD) ports. The fuel gauge collects instantaneous data parameters per 0.10 second which include speed, distance, fuel consumption, engine velocity and acceleration. The Global Positioning System (GPS) from the center of Institute of Behavioral Sciences (IBS) was also employed to monitor the movements and locations (precision: +/- 6.44m) of the tested vehicles. Instantaneous values of GPS location such as latitude, longitude and altitude per 0.10 second were collected from the trace of the driver's trip data. The fuel gauge equipment was also preset and calibrated according to the vehicle make, engine size and model (see ANNEX C) of each driver's car prior to data collection. Each driver's data logs from the fuel gauge and GPS readings were then collected, lumped, cleaned and filtered from noise and finally logged into the drivers' database. They were in *.csv and *.dat file formats which were then translated into an *.xls and *txt file formats and logged in the drivers' database for data processing. These data were used for the evaluation of driver's driving operation, route mapping and statistical analysis.

The vehicle. The vehicles of the candidate drivers were the primary criterion for their participation in the program. Thereof, only Japanese cars that passed vehicle specification requirements for the monitoring equipment of the study were considered. Further testing and vehicle-instrument calibration were also done prior to the survey to confirm vehicle and instrument compatibility. The vehicle was equipped with the GPS and fuel gauge. The equipment were connected or attached through the car's On-Board Diagnostic (OBD) ports. Especially, the vehicle with compatible OBD-II port is prerequisite of the fuel gauge for collecting instantaneous data parameters per 0.10 second. After the vehicle passed the initial prequalification, drivers were then subject to an initial driving test to check if the data logging of GPS and fuel gauge equipment were working properly. During real-world data collection, the drivers owning vehicles (i.e., specific brand and model was indicated in the list of ANNEX C) with compatible OBDs that passed the calibration test became candidates of the study. For the data collection during training day, only one type of a vehicle was used as control. In Manila for the driver's test car a Toyota Vios model was used and in Tokyo a Toyota Vitz model was used.

These compatibility requirements were necessary for the fuel gauge equipment that had to be set according to the specification of the vehicle prior to all data collection.

3.1.2 Ecodriving Program Setting

The program setting of the study included secondary data from four important sources, namely: the Energy Conservation Center of Japan (ECCJ), the Land Transportation Office (LTO) of Manila, collection of European and Japanese Ecodriving Programs.

From the office Energy Conservation Center of Japan, the proponent of this study was able to undergo trainings and apprenticeship in learning the Japan Ecodriving programs and initiatives including the methodology of Ecodriving training that was shared for the purpose of the research in Manila and Tokyo. The Office also granted the permission for the use of fuel gauge for the data collection in Manila and Tokyo, including the permission of using the Ecodriving Diagnostic software for the drivers' test drives. In the Philippines, the Land Transportation, the Department of Transportation and Communication (DOTC) and the National Center for Transportation Studies (NCTS), the University of the Philippines Diliman were also consulted regarding the models of passenger cars currently in the market for the instrumentation and compatibility or the OBD criterion of the study. The outcome of this investigation also served as the basis for the selection of the instrumented vehicle used during the training day in Manila.

The Ecodriving programs collated in this study were all referred from the Ecodriving program guidelines of Japan since the bulk of imported car in the Philippines were made from Japanese car models. The European Ecodriving information was also considered for the guidelines.

3.2 Study Setting

Two sets of drivers group were considered for data collection, namely, the group from Japan and the Philippines, particularly in the capital cities of Tokyo and Manila.

3.2.1 Tokyo Setting

Thirty (30) Japanese drivers were selected for the Ecodriving study in Tokyo. Each driver was first instructed to drive at least for three (3) days (i.e., pretest or normal driving). They were then asked to report to the office of the ECCJ for the Ecodriving training. After the training day, the drivers were then again monitored for another three (3) days of driving. This monitoring is presumed to be the posttest or Ecodriving driving.

During the training day, the drivers were also subject to two sets of test driving: (1) normal driving and (2) Ecodriving. In between the two test drives, drivers were introduced to the Ecodriving guideline. The survey route during this training day for the Japanese candidate drivers was around the downtown Tokyo Hachoobori area (Figure 3.2). During the training day, the candidate drivers were required to drive the test car around this test route twice for the normal test drive and the Ecodriving test drive. This Tokyo test route had a length of 2.8 km passing through four major intersections with about twelve intersection signals around the street network of downtown Chuo Ward section. This was also 2-way 4-lane road with typical traffic conditions and was selected to simulate city-driving condition.

3.2.2 Manila Setting

Thirty (30) Filipino drivers were also selected for the Ecodriving study in Manila. Each driver was again instructed to drive at least for three (3) days (i.e., pretest or normal driving). They were then asked to report to the office of the National Center for Transportation Study (NCTS) for the Ecodriving training. After the training day, the drivers were then again monitored for another three (3) days of driving for the posttest or Ecodriving application.

Figure 3.2 Tokyo training route

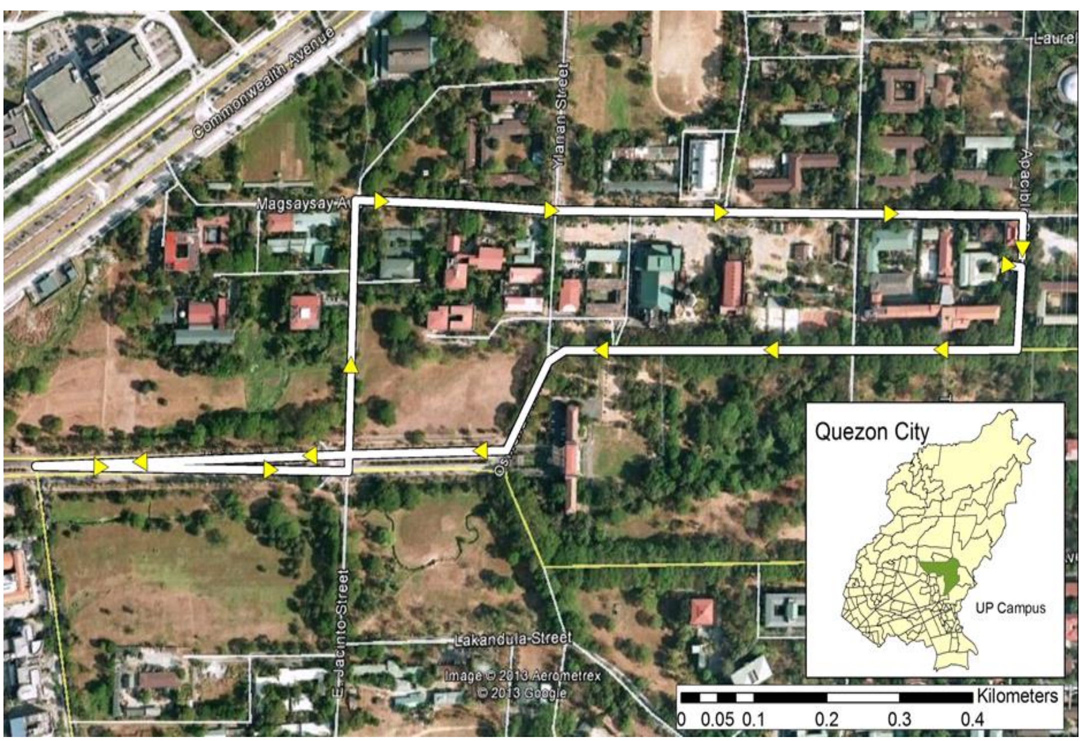


Figure 3.3 Manila training route

Similar to the methodology of training Tokyo drivers, during the training day, the drivers were also subject to two sets of test driving: (1) normal driving and (2) Ecodriving. The survey route for the Filipino candidate drivers was around the University of the Philippines, Diliman campus area (Figure 3.3). The drivers were also asked to drive the test car around this route twice for the normal and the Ecodriving test drives. The Manila test route had a length of 3.1 km passing through one signalized intersection and four minor intersections. This 2-way, 4-lane road was again selected to simulate a typical city-driving condition. The route had a traffic signal intersection and hypothetical stopping points that served as stopping points for the evaluation of idling and idling-stop application as well as the evaluation for gentle acceleration.

3.3 Study Instruments

The instruments of this study include: the drivers' questionnaire, on-board diagnostics equipment, the training day diagnostic report and the Japan Ecodriving guideline.

3.3.1 Research Questionnaire

The research questionnaire was designed for the pretest (Questionnaire A) and posttest (Questionnaire B) evaluation of drivers' driving behavior before and after the Ecodriving training day. The pretest questionnaire was administered after the drivers finished their three (3) day real-world normal driving while the posttest questionnaire was administered after they finished the Ecodriving training and the three (3) day real-world Ecodriving driving.

In particular, this questionnaire included nine (9) questions related to drivers' personal and driving profile, vehicle profile and finally fifty-five (55) questions related to their behavior and perception when driving. The questionnaire also included a section for drivers' comment and recommendation for the Ecodriving program. The questionnaires were also translated in English (Annex A) and Japanese (Annex B) for the candidate drivers.

3.3.2 Vehicle On-Board Diagnostic

The vehicle's on-board diagnostics (OBD) included the GPS and fuel gauge equipment. The equipment were fitted and calibrated according to the model of the car, the brand and the specification for compatibility of the OBD. The car OBD performed only as a monitoring system during the conduct of the survey and so drivers were assured that it would not in any way create problems with the vehicle system. Figure 3.4 shows the photo profile that indicates monitoring equipment connected through the OBD of the vehicles.

3.3.3 Ecodriving Diagnostic Report

The driver training included the test drives of each candidate driver. The results of the normal driving and Ecodriving test drives were reflected to the drivers after the Ecodriving training sessions. The diagnostic report (sample in ANNEX C) reflected the performance of the driver particularly on fuel efficiency, energy savings and the acceleration, cruising, deceleration, and idling, or the ACDI operation of his/her driving style. Each of the Ecodriving candidates received the diagnostic report of his/her driving. This report detailed his/her performance before and after the Ecodriving training by the ACDI modes. This report also detailed the change in the driver's driving operation through the change in the ACDI modes before and after learning the Ecodriving guidelines in the training. Figure 3.5 shows the profile of diagnostic report summary of the drivers during training evaluation of this study.

3.3.4 Ecodriving Training Guidelines

The Japan Ecodriving training was based from the Recoo-ECCJ training program. The general guideline for the Ecodriving, particularly in relation to the acceleration, deceleration, cruising and idling or in the ACDI modes, was used in the training of the Manila and Tokyo drivers. Figure 3.6 illustrates the general concept of the Ecodriving training based on the four important driving operations of the ACDI modes alongside the speed- time parameters. The acceleration mode is specifically indicated as starting acceleration before the start of the trip or the starting acceleration at traffic signal stop. The guideline indicates (1) to avoid hasty starts, (2) to accelerate gently to 20 kph within 5 seconds after starting and (3) to change to higher gear if possible. The cruising mode advisory indicates (1) to drive at low speed according to traffic conditions and (2) to reduce desired target speed by 5 kph to save energy. Deceleration mode advisory is to use engine braking when decelerating whenever possible. And, for idling mode the advisory specifically indicates to apply idling-stop or switching-off the engine if the vehicle is idle for more than 5 seconds.

3.3.5 GPS and GIS Mapping

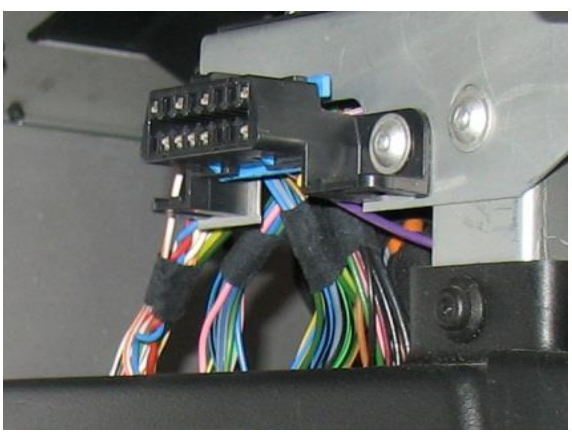
The data from the real-world driving and training day contained two sets of simultaneous data from the GPS and fuel gauge. Both equipment lumped instantaneous dataset that created the database of the candidate drivers. For the GPS data, GIS mapping was a tool in evaluating the drivers driving routes. In handling the training day data, the pretest and posttest GPS and fuel gauge data were matched as the GPS routes were similar for the pretest and posttest driving condition. The mapping of the GPS data clearly indicated the same route per driver as the test route was static or pre-defined. Therefore, only the conditions and results of the fuel gauge were reviewed and evaluated.

Fuel Gauge on the dashboard

Training test car

Fuel gauge monitoring screen

Magnetic GPS sensor



On-board diagnostic post

Figure 3.4 Ecodriving monitoring equipment

	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	
	FE	**FE'**	**FC**	**FC'**	**DST**	**DST'**	**T**	**T'**	**SFC**	**SFC'**	**S**	**S'**	**NS**	**NS'**	**% changed**
Candidates	Km/L	Km/L	cc	cc	km	km	sec	sec	cc/sec	cc/sec	sec	sec	stops	stops	(savings)
DRIVER1	8.95	9.77	354.33	319.76	3.17	3.12	581	658	0.26	0.1	128	118.5	4	3	9.2
DRIVER2	8.38	9.73	373.04	319.71	3.12	3.11	585	544	0.31	0.32	78	76	4	3	16.1
DRIVER3	8.05	8.39	392.57	375.7	3.16	3.15	722	791	0.08	0.2	175	165.5	6	9	4.3
DRIVER4	7.07	7.68	430.42	392.36	3.04	3.01	671	727	0.35	0.12	161	190	7	4	8.7
DRIVER5	8.63	8.03	361.36	346.25	3.12	2.78	623	669	0.28	0.09	101.5	200	4	3	-6.9
DRIVER6	7.18	8.21	439.04	382.92	3.15	3.14	638	805	0.26	0.12	156.5	247.5	4	5	14.3
DRIVER7	5.26	6.08	585.8	502.99	3.08	3.06	606	678	0.5	0.16	127	165	6	5	15.7
DRIVER8	7.82	8.59	399.24	360.22	3.12	3.1	568	690	0.39	0.18	124	170.5	5	7	9.9
DRIVER9	8.7	9.16	354.69	343.78	3.09	3.15	875	836	0.28	0.15	282.5	286	9	8	5.3
DRIVER10	9.93	11.61	321.92	276.71	3.2	3.21	611	554	0.27	0.11	150	115.5	5	3	16.9
DRIVER11	7.65	8.94	398.2	340.31	3.05	3.04	658	654	0.29	0.11	89.5	142.5	4	5	16.9
DRIVER12	6.72	7.99	455.73	375.42	3.06	3.00	634	767	0.31	0.17	123	227	6	5	19.0
DRIVER13	5.95	7.2	517.61	421.21	3.08	3.03	556	674	0.34	0.22	112.5	153.5	7	7	21.0
DRIVER14	6.13	6.69	498.66	454.5	3.06	3.04	635	602	0.4	0.16	163	129.5	4	5	9.1
DRIVER15	4.57	6.6	670.05	459.39	3.06	3.03	536	651	0.44	0.18	111	137	5	4	44.4
DRIVER16	6.56	7.17	456.06	426.25	3.05	3.05	610	674	0.41	0.09	77.5	176	6	4	9.1
DRIVER17	6.21	6.93	494.53	440.6	3.07	3.05	621	660	0.42	0.08	126	189.5	6	5	11.6
DRIVER18	6.09	6.72	502.26	454.57	3.06	3.05	574	614	0.39	0.13	97.5	152	7	6	10.4
DRIVER19	4.61	5.95	667.01	517.64	3.08	3.08	663	705	0.42	0.11	169.5	179.5	9	5	29
DRIVER20	6.45	7.28	471.87	414.86	3.04	3.02	659	702	0.37	0.14	138	186.5	7	4	12.9
DRIVER21	6.48	6.81	473.4	449.82	3.06	3.06	673	674	0.35	0.18	173	175.5	8	6	5.4
DRIVER22	6.46	6.79	467.36	452.31	3.02	3.07	610	681	0.31	0.08	116	191	5	4	5.2
DRIVER23	6.29	7.1	485.43	430.89	3.05	3.06	647	607	0.34	0.18	136.5	184.5	6	6	12.9
DRIVER24	7.97	8.29	379.86	365.45	3.03	3.03	603	670	0.26	0.16	78	146	3	5	4.1
DRIVER25	6.83	8.67	446.07	353.21	3.05	3.06	648	636	0.31	0.12	159.5	153.5	6	4	26.9
DRIVER26	6.37	7.49	480.74	405.54	3.06	3.04	541	538	0.33	0.18	92.5	111.5	6	4	17.5
DRIVER27	6.15	7.33	497.24	417.16	3.06	3.06	544	593	0.35	0.13	85.5	117.5	5	5	19
DRIVER28	7.06	8.17	436.09	375.84	3.08	3.07	691	661	0.3	0.18	135	128	5	5	15.7
DRIVER29	7.03	7.86	436.47	385.11	3.07	3.03	684	682	0.3	0.23	151.5	164.5	7	4	11.8
DRIVER30	6.88	8.01	461.79	397.37	3.18	3.18	663	657	0.37	0.17	144.5	140	8	5	16.3
	FE	Fuel Economy			**DST**	Distance		**SFC**	Specific Fuel Consumption				**NS**	Number of Stops	
	FC	Fuel Consumption			**T**	Time		**ST**	Stops Time				**% changed**	Fuel Savings	

Figure 3.5 Training diagnostic data summary log

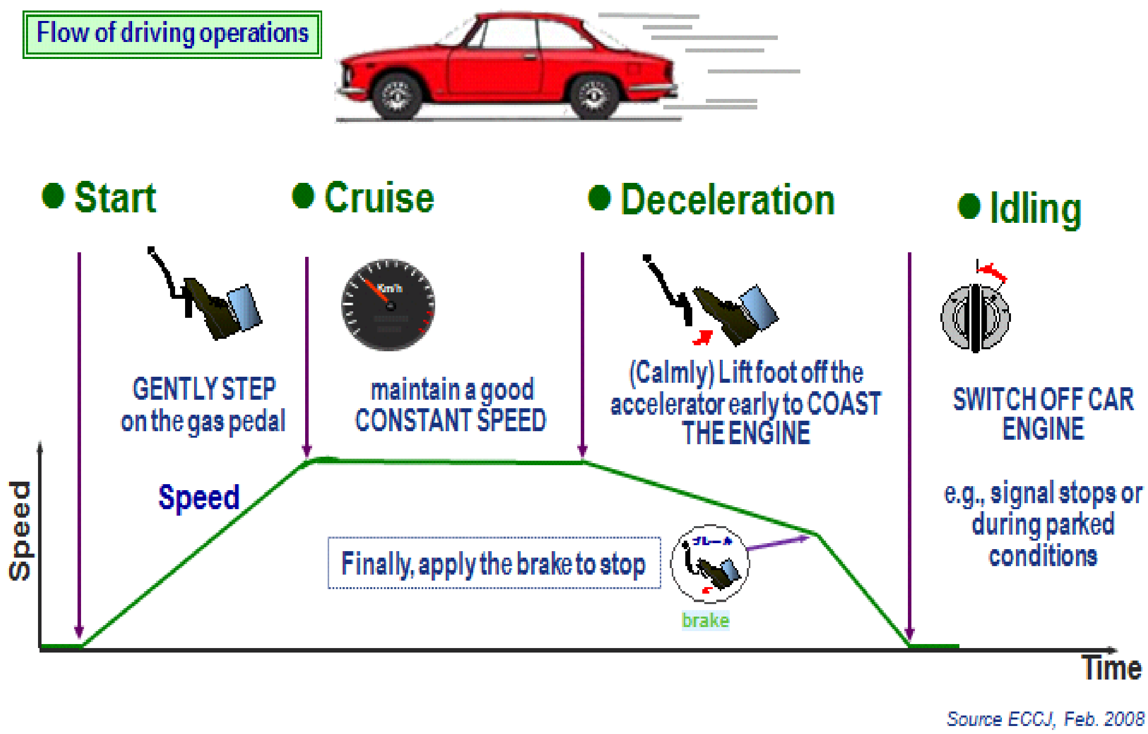


Figure 3.6 Japan Ecodriving program guideline

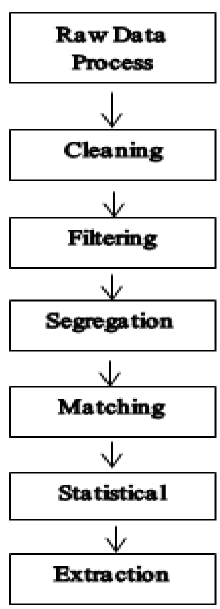


Figure 3.7 Real-world data processing

However, this is not the case for the real-world driving data of the driver. In handling the real-world data, the candidate driver selected random routes and on daily basis their routes were uniquely defined by their origin to destination choice, time of driving and the purpose of the trip. Thus, the pretest and posttest evaluations of each driver's routes were directed to filtering, and partly matching similar routes for the comparison of the normal and Ecodriving data of the fuel gauge. This was an intensive process (Figure 3.7) of evaluating the drivers' routes during normal (pretest) condition and the Ecodriving (posttest) condition. Figure 3.8 represents a sample normal driving trace of one candidate driver while Figure 3.9 represents corresponding pair of an Ecodriving trace, and Figure 3.10 shows the matched traces of both GPS data for the analysis.

Figure 3.8 Typical path of Manila normal driving route of one candidate driver

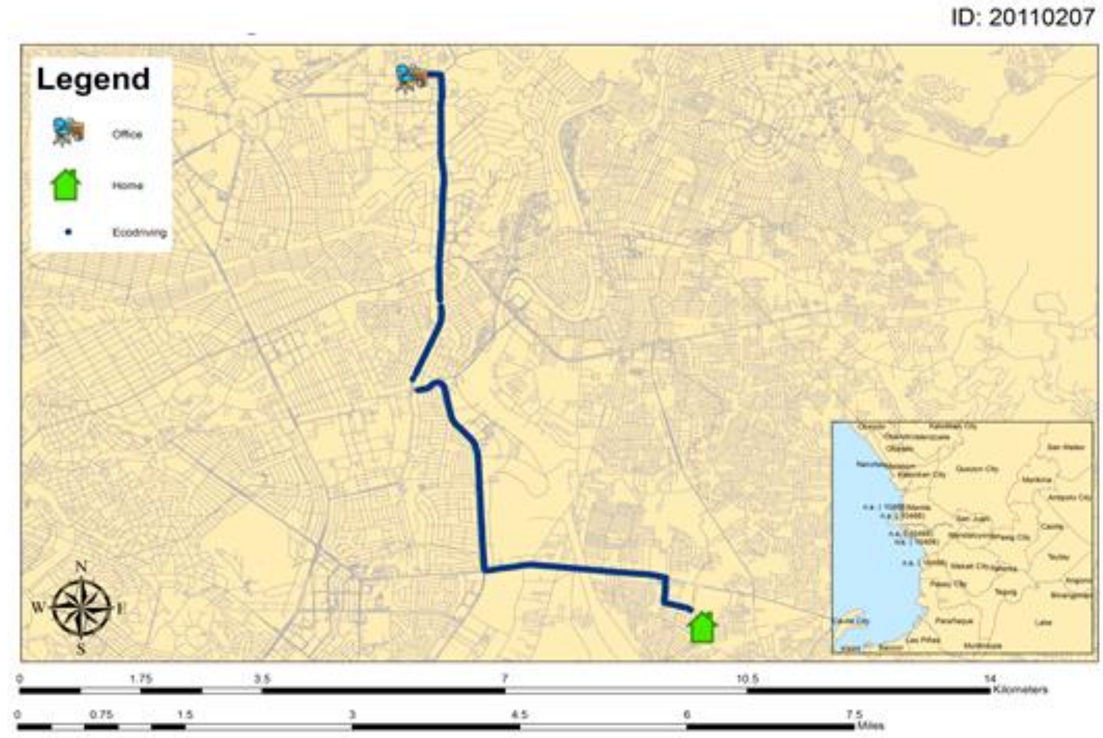


Figure 3.9 Typical path of Manila Ecodriving route of one candidate driver

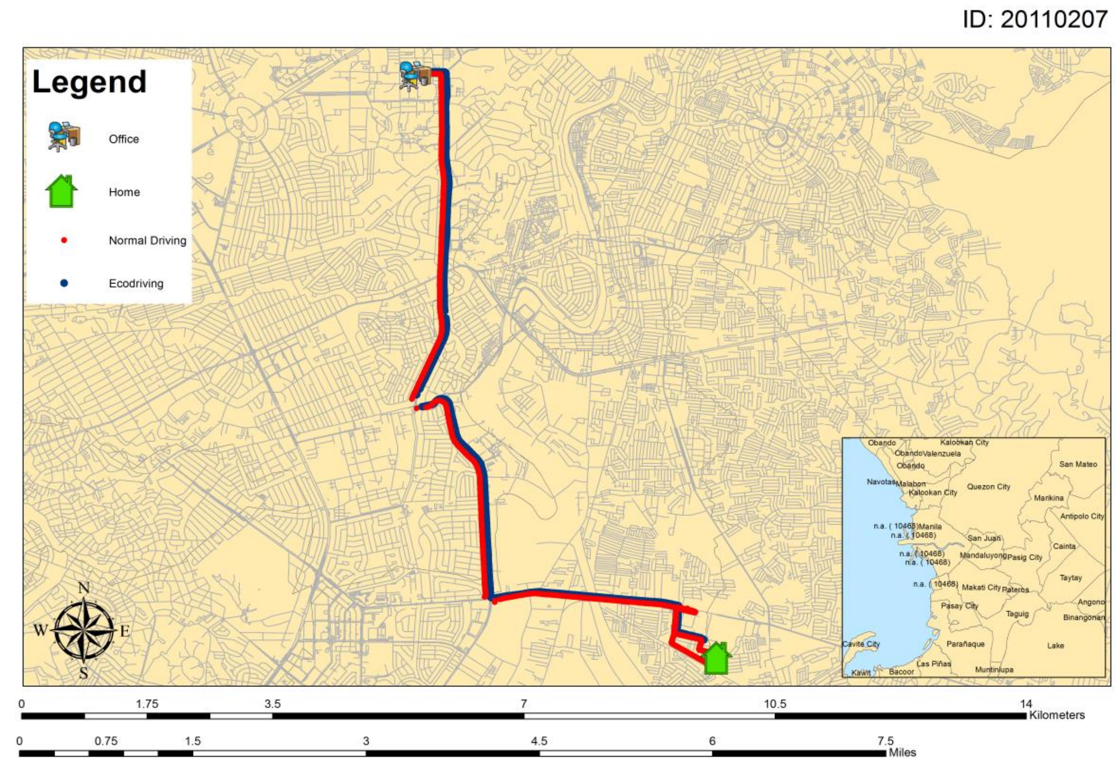


Figure 3.10 Typical path matching (origin to destination GPS traces)

3.4 Data and Data Collection Process

After vehicle and equipment calibration, the next stage is data collection. Data collection is divided into the steps for three datasets, namely: the training-day data, real-world data and questionnaire data. The training-day and real-world data were empirical data from actual driving while the questionnaire data was behavioral and perception type of data.

3.4.1 Questionnaire Data

To test the effect of Ecodriving training on drivers' driving behavior, a pretest-posttest questionnaire was given to the driver. The questionnaire was translated both in English and Japanese languages. Its content and the methodology of administering the process were the same. The questionnaires included information on drivers' profile, trip and driving characteristics, and driving perceptions. The pretest questionnaires were administered before the Ecodriving training while the posttest questionnaires were administered on the last day of the real-world trip data collection**.** The driver's questionnaire data was designed to test the effect of Ecodriving training on drivers' driving behavior. Therefore, in the pretest questionnaire, questions were asked to check on the psychological/non-psychological characteristics of each driver.

The questions on non-psychological characteristics included gender, age, household members, driving experience, profession, education, frequency of driving, purpose of driving, annual distance (kilometers) of driving, running cost allocation of driving (by myself or company), and household income. There were also questions pertaining to non-psychological characteristics such as use of accessories (e.g. air-conditioner and DVD/CD player) and frequency of maintenance check-up. The questions on psychological characteristics included fifty-five sentences such as "I tend to change lanes often." Each driver was requested to answer these questions by choosing one from the five scales "1: not like me at all" to "5: very much like me." The questions were classified into five categories with each category used to measure a psychological construct such as "rough driving," "irritated driving," "indecisive driving," "anti-law abiding driving," and "addicted driving."

3.4.2 Training-Day Setup and Data Collection

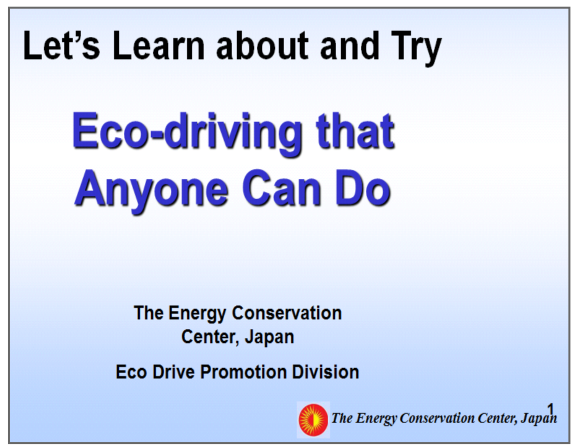
While the Ecodriving training of Tokyo drivers were handled by Japanese Ecodriving trainers of the Energy Conservation Center of Japan (ECCJ), the Ecodriving training of Manila drivers were handled by Filipino proficient trainers trained by the Ecodriving expert from the office of ECCJ. Figure 3.11 shows the training day session photos with the trainers, candidate drivers and the test vehicle used in the study. On the Ecodriving training day, the drivers were given specific driving orientation, Ecodriving 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.

A pretest (before) and posttest (after) evaluation of drivers' driving operation and fuel economy was designed to assess if the Ecodriving as intervention affected improvements on drivers' driving operation and fuel economy. The orientation session introduced the normal driving operations of drivers and its corresponding effects on fuel consumption and emission values. Next, Ecodriving 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, drivers were asked (1) to drive in the normal way and (2) to drive applying what they learned in Ecodriving orientation. 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 diagnostic report elaborated in detail the normal driving and Ecodriving performance of the driver during the test drives. It particularly highlighted the drivers' improvement in terms of the driving modes (i.e., acceleration, cruising, deceleration and idling), fuel consumption and fuel economy.

Expert's training session

Trainer's training review session

Driver's driving with evaluation



Ecodrive training program

Drivers driving test

Figure 3.11 Ecodrive training and test drive pictures for Manila normal and Ecodriving routes of one candidate driver

3.4.3 Real-World Setup and Data Collection

To test the effects of Ecodriving training, a pretest-posttest study with intervention or treatment was used. In this case the intervention was the Ecodriving training program and two rounds of data collection were conducted: (1) real-world normal driving dataset and (2) real-world Ecodriving dataset. Similar to the evaluation during training day, a pretest (before) and posttest (after) evaluation of drivers' driving operation and fuel economy was designed to assess if the Ecodriving (as intervention) affected improvements on drivers' driving operation and fuel economy. The first round of this dataset was collected as pretest real-world normal driving dataset which were collected at least for three days before the Ecodriving training day. After the Ecodriving training day, the second round of data collection resumed, and drivers were again subjected to three-day 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. And so, the outcome of drivers' driving operation in the posttest dataset would reveal the change and effect of Ecodriving training. In the real-world driving, various parameters might influence the driving style of the drivers. The driving routes of each driver varied, the time and condition of driving varied, and the purposes of the trip varied. Thereof, road, traffic, vehicle type, climate, driver's age, gender and other environmental and behavioral factors were assumed to affect one's driving style. These factors might influence the outcome of one's driving operations. However, if the drivers would be driving their vehicles in an efficient manner -*ceteris paribus*- the resulting vehicle performance would also be found different.

3.4.4 GPS and Fuel Gauge Data Evaluation

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 evaluations 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 Ecodriving training, the Ecodriving operational techniques were intensively taught and were supposed to contribute to reducing fuel consumptions considerably. Figure 3.12 and Figure 3.13 show the data logs of fuel gauge and GPS outputs.

FUEL	ACC Open	ACC	DST	Unused	Unused	ACC	SPD	TRVL DST	FC	RPM	INJ PULSE	RAW ACC	Year	Month	Day	Time	Amount	Sec	SHFT POS	BRAKE	EQ of EU R	GPS測位情報	総走行距離	総燃料消費量											
0.266	17.6	0	0	0	0	0	0	0	0	874	3.712	0	2010	3	6	8	55	6	0	0	0	0	0	0	3/6/2010	8:55:06	0	0	32767	1007	1130	0	0	1	0
0.266	17.6	0	0	0	0	0	0	0	0	885	3.712	0	2010	3	6	8	55	6	0	0	0	0	0	0	3/6/2010	8:55:06	0	0	32767	1007	1130	0	0	2	0
0.266	17.6	0	0	0	0	0	0	0	0	885	3.712	0	2010	3	6	8	55	6	0	0	0	0	0	0	3/6/2010	8:55:06	0	0	32767	1007	1130	0	0	3	0
0.266	17.6	0	0	0	0	0	0	0	0	881	3.712	0	2010	3	6	8	55	7	0	0	0	0	0	0	3/6/2010	8:55:07	0	0	32767	1007	1130	0	0	4	0
0.266	17.6	0	0	0	0	0	0	0	0	874	3.712	0	2010	3	6	8	55	7	0	0	0	0	0	0	3/6/2010	8:55:07	0	0	32767	1007	1130	0	0	5	0
0.266	17.6	0	0	0	0	0	0	0	0	876	3.712	0	2010	3	6	8	55	7	0	0	0	0	0	0	3/6/2010	8:55:07	0	0	32767	1007	1130	0	0	6	0
0.266	17.6	0	0	0	0	0	0	0	0	876	3.712	0	2010	3	6	8	55	7	0	0	0	0	0	0	3/6/2010	8:55:07	0	0	32767	1007	1130	0	0	7	0
0.266	17.6	0	0	0	0	0	0	0	0	874	3.712	0	2010	3	6	8	55	7	0	0	0	0	0	0	3/6/2010	8:55:07	0	0	32767	1007	1130	0	0	8	0
0.266	17.6	0	0	0	0	0	0	0	0	874	3.712	0	2010	3	6	8	55	7	0	0	0	0	0	0	3/6/2010	8:55:07	0	0	32767	1007	1130	0	0	9	0
0.266	17.6	0	0	0	0	0	0	0	0	881	3.712	0	2010	3	6	8	55	7	0	0	0	0	0	0	3/6/2010	8:55:07	0	0	32767	1007	1130	0	0	10	0
0.266	17.6	0	0	0	0	0	0	0	0	882	3.712	0	2010	3	6	8	55	7	0	0	0	0	0	0	3/6/2010	8:55:07	0	0	32767	1007	1130	0	0	11	0
0.256	17.6	0	0	0	0	0	0	0	0	881	3.584	0	2010	3	6	8	55	7	0	0	0	0	0	0	3/6/2010	8:55:07	0	0	32767	1007	1130	0	0	12	0
0.256	17.6	0	0	0	0	0	0	0	0	881	3.584	0	2010	3	6	8	55	7	0	0	0	0	0	0	3/6/2010	8:55:07	0	0	32767	1007	1130	0	0	13	0
0.256	17.6	0	0	0	0	0	0	0	0	865	3.584	0	2010	3	6	8	55	8	0	0	0	0	0	0	3/6/2010	8:55:08	0	0	32767	1007	1130	0	0	14	0
0.266	17.6	0	0	0	0	0	0	0	0	860	3.712	0	2010	3	6	8	55	8	0	0	0	0	0	0	3/6/2010	8:55:08	0	0	32767	1007	1130	0	0	15	0
0.266	17.6	0	0	0	0	0	0	0	0	864	3.712	0	2010	3	6	8	55	8	0	0	0	0	0	0	3/6/2010	8:55:08	0	0	32767	1007	1130	0	0	16	0
0.266	17.6	0	0	0	0	0	0	0	0	865	3.712	0	2010	3	6	8	55	8	0	0	0	0	0	0	3/6/2010	8:55:08	0	0	32767	1007	1130	0	0	17	0
0.266	17.6	0	0	0	0	0	0	0	0	867	3.712	0	2010	3	6	8	55	8	0	0	0	0	0	0	3/6/2010	8:55:08	0	0	32767	1007	1130	0	0	18	0
0.266	17.6	0	0	0	0	0	0	0	0	871	3.712	0	2010	3	6	8	55	8	0	0	0	0	0	0	3/6/2010	8:55:08	0	0	32767	1007	1130	0	0	19	0
0.266	17.6	0	0	0	0	0	0	0	0	872	3.712	0	2010	3	6	8	55	8	0	0	0	0	0	0	3/6/2010	8:55:08	0	0	32767	1007	1130	0	0	20	0
0.266	17.6	0	0	0	0	0	0	0	0	865	3.712	0	2010	3	6	8	55	8	0	0	0	0	0	0	3/6/2010	8:55:08	0	0	32767	1007	1130	0	0	21	0
0.266	17.6	0	0	0	0	0	0	0	0	857	3.712	0	2010	3	6	8	55	8	0	0	0	0	0	0	3/6/2010	8:55:08	0	0	32767	1007	1130	0	0	22	0
0.266	18	0	0	0	0	0	0	0	0	857	3.712	0	2010	3	6	8	55	8	0	0	0	0	0	0	3/6/2010	8:55:08	0	0	32767	1007	1130	0	0	23	0
0.266	18.4	0	0	0	0	0	0	0	0	868	3.712	0	2010	3	6	8	55	9	0	0	0	0	0	0	3/6/2010	8:55:09	0	0	32767	1007	1130	0	0	24	0
0.092	18.8	0	0	0	0	0	0	0	0	879	1.536	0	2010	3	6	8	55	9	0	0	0	0	0	0	3/6/2010	8:55:09	0	0	32767	1007	1130	0	0	25	0
0.282	19.2	0	0	0	0	0	0	0	0	911	3.712	0	2010	3	6	8	55	9	0	0	0	0	0	0	3/6/2010	8:55:09	0	0	32767	1007	1130	0	0	26	0
0.325	20.3	0	0	0	0	0	0	0	0	948	4.224	0	2010	3	6	8	55	9	0	0	0	0	0	0	3/6/2010	8:55:09	0	0	32767	1007	1130	0	0	27	0
0.343	21.1	0	0	0	0	0	0	0	0	997	4.224	0	2010	3	6	8	55	9	0	0	0	0	0	0	3/6/2010	8:55:09	0	0	32767	1007	1130	0	0	28	0
0.583	22.3	0	0	0	0	0	0	0	0	1111	6.016	0	2010	3	6	8	55	9	0	0	0	0	0	0	3/6/2010	8:55:09	0	0	32767	1007	1130	0	0	29	0
0.621	22.7	0	0	0	0	0	0	0	0	1244	5.888	0	2010	3	6	8	55	9	0	0	0	0	0	0	3/6/2010	8:55:09	0	0	32767	1007	1130	0	0	30	0
0.764	23.5	0	0	0	0	0	0	0	0	1383	6.4	0	2010	3	6	8	55	9	0	0	0	0	0	0	3/6/2010	8:55:09	0	0	32767	1007	1130	0	0	31	0
0.885	23.9	0	0	0	0	0	0	0	0	1507	6.656	0	2010	3	6	8	55	9	0	0	0	0	0	0	3/6/2010	8:55:09	0	0	32767	1007	1130	0	0	32	0
0.983	24.3	0	0	0	0	0	0	0	0	1612	6.912	0	2010	3	6	8	55	9	0	0	0	0	0	0	3/6/2010	8:55:09	0	0	32767	1007	1130	0	0	33	0
0.994	24.7	0	0	0	0	0	0	0	0	1679	6.784	0	2010	3	6	8	55	10	0	0	0	0	0	0	3/6/2010	8:55:10	0	0	32767	1007	1130	0	0	34	0

Figure 3.12 Fuel gauge data log (sample)

Date	Time	Latitude	Longitude	Nxspd	Pyspd	Nyspd	Prspd	Nrspd	DGPS
7/29/2010	18:08:31	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:32	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:33	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:34	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:35	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:36	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:37	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:38	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:39	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:40	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:41	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:42	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:43	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:44	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:45	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:46	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:47	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:48	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:49	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:50	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:51	35.648825	139.379085	1	1	1	1	1	0
7/29/2010	18:08:52	35.6489918	139.37904	1	1	1	1	1	0
7/29/2010	18:08:53	35.6489934	139.379036	1	1	1	1	1	0
7/29/2010	18:08:54	35.6489884	139.379021	1	1	1	1	1	0
7/29/2010	18:08:55	35.6489818	139.379	1	1	1	1	1	0
7/30/2010	8:03:12	35.6489684	139.378978	1	2	2	2	1	0
7/30/2010	8:03:13	35.6489434	139.378955	2	2	2	2	2	0
7/30/2010	8:03:14	35.6489134	139.378923	2	2	2	2	2	0
7/30/2010	8:03:15	35.6488834	139.378883	2	2	2	2	2	0
7/30/2010	8:03:16	35.6488484	139.378831	2	2	2	2	2	0
7/30/2010	8:03:17	35.64881	139.378778	2	2	2	2	2	0
7/30/2010	8:03:18	35.6487684	139.378716	2	2	2	2	2	0
7/30/2010	8:03:19	35.6487234	139.378651	2	2	2	2	2	0
7/30/2010	8:03:20	35.6486784	139.378581	2	2	2	2	2	0
7/30/2010	8:03:21	35.6486284	139.378515	2	2	2	2	2	0
7/30/2010	8:03:22	35.6485834	139.378446	2	2	2	2	2	0
7/30/2010	8:03:23	35.6485401	139.378376	2	2	2	2	2	0
7/30/2010	8:03:24	35.648495	139.37831	2	2	2	2	2	0
7/30/2010	8:03:25	35.6484517	139.378245	2	2	2	2	2	0
7/30/2010	8:03:26	35.6484084	139.378185	2	2	2	2	2	0
7/30/2010	8:03:27	35.6483718	139.378135	2	2	2	2	2	0
7/30/2010	8:03:28	35.6483434	139.378091	2	2	2	2	2	0
7/30/2010	8:03:29	35.6483251	139.378065	2	2	2	2	2	0
7/30/2010	8:03:30	35.6483168	139.378053	2	2	2	2	2	0

Figure 3.13 GPS data log (sample)

CHAPTER 4

EFFECTIVENESS OF ECODRIVING PROGRAM IN DEVELOPING COUNTRY SETTINGS

4.1 Background

In recent years global warming issues have greatly challenged environmental policies. In urban areas, one of the major contributors to global warming is transportation. Rising motorization in developed and developing countries created transportation issues such as traffic congestion, vehicular pollution, car dependency, ageing transport and infrastructure, and increasing fuel cost which are among others that concern cities worldwide. In particular, emissions of carbon dioxide (CO_2) and other vehicular pollutants created adverse impact on the global and local environment.

Some developed and developing countries have made future plans for reducing CO_2 emissions from transportation (Matsuhashi, 2007). While the introduction of hybrid and electric cars and provision of less carbon-intensive public transportation are common policy measures in these plans, the measures for improving fuel economy by reducing traffic congestion and promoting an efficient driving style are also suggested because the penetration of new cars takes time and the provision of public transportation might not be so effective in small or medium-sized cities (Yonezawa and Matsuhanshi, 2009; Uchida, et al., 2009). The economical and efficient driving style or what this study introduce in concept as Ecodriving is primarily a driving technique designed to improve fuel economy, reduce CO_2 emissions and mitigate the adverse impacts of road transport on its surrounding environment (Taniguchi and Miyasaka, 2005). It is the attitude of driving in an environmentally-conscious and energy-saving manner.

In terms of program applications, most Ecodriving programs are highly established in developed country settings such as those in Europe and Japan. However, Ecodriving programs, guidelines and applications in developing country were very limited. In application of Ecodriving, on-road fuel consumption and emission values are influenced by driving patterns which are in turn directly influenced by external factors such as traffic characteristics, road characteristics, vehicle characteristics, driver's characteristics, trip characteristics and other possible variables. The effectiveness of Ecodriving program may well be different in developing country from developed country settings because of these factors in developing countries.

This chapter thereof initiates to evaluate the effectiveness of Ecodriving program in developing country application as well as to confirm it in developed country application. First, the chapter investigates the effectiveness of Ecodriving program during training day by assessing the driving data obtained from the training day before and after the Ecodriving program in Tokyo and Manila. Second, it details the discussion on the results of the program by studying the distribution of improvement of fuel economy in terms of acceleration, cruising, deceleration and idling. Lastly, the chapter focuses on the driving behavior of drivers that defines their driving characteristics. It especially focuses on the driver's characteristics including the non-psychological and the psychological factors that affect or influence the outcome of Ecodriving program in Manila and Tokyo.

4.2 Methodology

4.2.1 Ecodriving Training Data Collection and Evaluation

The study evaluated thirty drivers in Manila and thirty drivers in Tokyo who were invited to participate in the study. The initial number of applicants was narrowed down to include only those owning Japanese passenger cars (model year 2000-2009) with compatible on-board diagnostics (OBDs) for the fuel meter (or gauge) and the global positioning system (GPS) equipment. The vehicles were equipped with the GPS and fuel meter to monitor driving operations, movement and location. The GPS equipment from the Institute of Behavioral Sciences (IBS) tracks latitude, longitude and altitude every 0.10 second. The fuel meter equipment from the Energy Conservation Center of Japan (ECCJ) collects vehicle parameters every 0.10 second while the vehicle is being driven. The equipment was fitted to the OBD port of each vehicle and preset according to the vehicle model and engine size. The fuel meter data collected included velocity, distance, fuel consumption, engine velocity and acceleration. Prior to data collection, both the GPS and fuel meter equipment were calibrated, checked and pretested for accuracy in Tokyo and Manila.

Data collection in this study was conducted in 2010 to 2011. To test the effect of the Ecodriving program on the drivers, a pretest-posttest study after intervention or treatment was used. In this case the intervention is the Ecodriving training. The Ecodriving training of drivers in Tokyo and Manila was handled by the ECCJ according to the ECCJ Ecodriving program. In the case of Manila, a Japanese Ecodriving expert trained four drivers from the National Center of Transportation Studies (NCTS) in the University of the Philippines. These four drivers then served as trainers for the Manila test drivers. The training in Manila and Tokyo were scheduled on Saturday mornings in order to minimize the effect of traffic congestion on the training. During the Ecodriving training day, the test drivers underwent driving orientation, Ecodriving training, a driving test, and driving evaluation. A short orientation session detailed the normal driving operations of drivers and its corresponding effects on fuel consumption values. Ecodriving was then introduced alongside driving operation techniques. The drivers were then given two driving tests: a normal driving test and an Ecodriving test. The same route and test car were used for both tests, and the route was carefully selected from a road network that represented city driving conditions (speed limits: 40 kph) in downtown areas. The results of the normal driving and the Ecodriving test drives were fed back to the drivers after the Ecodriving training sessions. Each driver was given a diagnostic report that reflected their performance in terms of fuel efficiency and energy savings. This report also detailed the change in the driver's driving operation through the change in acceleration, cruising, deceleration, and idling modes before and after learning the Ecodriving guidelines during training.

On the training day, the Tokyo test drivers reported to the office of the ECCJ for Ecodriving training. The survey route selected for use on the training day for the Tokyo test drivers was around the downtown Tokyo Hatchobori area. During the training day, the test drivers were required to drive a test car around this test route twice: once for the normal test drive and once for the Ecodriving test drive. The Tokyo test route had a length of 2.8 km, and passed through four major intersections with about 12 intersection signals around the street network of the downtown Chuo Ward section. The route was a 2-way, 4-lane road with typical traffic conditions and was selected to represent standard city-driving conditions.

On the training day, the Manila test drivers reported to the office of the NCTS in the University of the Philippines. Similar to the methodology of training Tokyo drivers, during the training day, the drivers were asked to perform two test drives: (1) normal driving and (2) Ecodriving. The drivers were asked to drive a test car around a test route twice: once for the normal test drive and once for the Ecodriving test drive. The Manila test route had a length of 3.1 km around the university campus area, and passed through one intersection with signals and four minor intersections. A 2-way, 4-lane road was again selected to simulate typical city-driving conditions. The route had a traffic signal intersection and hypothetical stopping points that served as stopping points for the evaluation of idling and idling-stop application as well as the evaluation for gentle acceleration.

Data on the drivers were logged via vehicle monitoring equipment (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 was specifically focused on the driving operations that were described in the driving modes that included gentle acceleration during a green signal or a “go” at intersections, 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 (while stopping at a signal, parking, etc.). These driving modes were evaluated because during the Ecodriving training, Ecodriving operational techniques were taught and were supposed to contribute to reducing fuel consumptions considerably. Since the study adopted a pretest and posttest study design with intervention, a paired t test was employed to compare the means of two values (i.e., normal driving and Ecodriving) of the fuel parameters, or equivalently to identify whether the average of the differences (of the values for each case) differed from zero (0).

4.2.2 Driver’s Questionnaire Data Collection and Evaluation

The thirty candidate drivers each in Manila and Tokyo were subject to questionnaire evaluation. The questionnaire was used to test the effect of Ecodriving training on driving behavior, thereof, pretest-posttest questionnaires were given to the drivers. The questionnaires included information on drivers’ profile, trip and driving characteristics and driving perceptions. The pretest questionnaires were administered before the Ecodriving training while the posttest questionnaires were administered on the last day of the trip data collection.

In the pretest questionnaire, questions were asked to check on the psychological/non-psychological characteristics of each driver. The questions on non-psychological characteristics included gender, age, household members, driving experience, profession, education, frequency of driving, purpose of driving, annual kilometers of driving, running cost allocation of driving (by yourself or company), and household income. There were also questions related to the use of accessories (for example, air-conditioner and DVD/CD player) and frequency of maintenance check-up. The questions on psychological characteristics included fifty-five sentences such as 'You often switch lanes.' Each driver was requested to answer these questions by choosing one from five scales "1: not like me at all" to "5: very much like me." The questions were classified into five categories with each category used to measure psychological construct such as 'rough driving,' 'irritated driving,' 'indecisive driving,' 'anti-law-abiding driving,' and 'addicted driving.' Discussion on how measurements were calculated will follow later.

In order to make a measurement for each psychological construct, there were six to twelve sentences that were carefully prepared to best describe the situations in relation to each psychological characteristic. After excluding the questions with missing data, answers were calculated using Cronbach's alpha index for each psychological characteristic and questions that did not contribute to the improvement of the index was excluded. Finally a few sentence questions for each psychological characteristic were chosen. Measurements were then made by summing up the answers to every question corresponding to each characteristic. In order to investigate the effect of Ecodriving training program among the candidate drivers in Manila and Tokyo, special focus was made on the psychological characteristics of the drivers. We selected two objective variables that would be regressed by explanatory variables including psychological characteristics: absolute fuel economy (km/l) and improvement after the program. The absolute fuel economy was obtained from normal driving on the test route during Ecodriving training that indicated before-training fuel economy of each candidate driver in terms of kilometer per liter value (km/l). The improvement after the program was obtained by dividing after-training fuel economy with before-training fuel economy (i.e. after-km/l divided by before-km/l). For explanatory variables, psychological/non-psychological variables with missing data were excluded.

4.3 Results and Discussions

4.3.1 The Characteristic of the Data

The summary of driver's profile and driving attitude for both Manila and Tokyo drivers is shown in Table 4.1. The data revealed that in terms of the driver's gender, both samples had more male candidate drivers than female candidate drivers. Comparing the driver's age, the driver group in Manila (89%) had more adult (30yrs. old and above) drivers than in Tokyo (56%). However, there were prevalent numbers of the drivers above the age of 60 in Tokyo group, which attributed to the fact that Japan comprised older population. The data also revealed their job status. There were more workers in Manila than in Tokyo. The household income level of the entire family among the Japanese drivers was greater than the Manila drivers. This confirmed the economic difference between two subject cities. Their weekly activities seemed to indicate car dependency since the data showed high proportion of the drivers driving at least 3-4 times a week. Because the data in Tokyo revealed higher proportion of non-leisure trips than in Manila, and Manila group indicated higher proportion of household size, higher proportion of driving with passengers was found in Manila than Tokyo.

Table 4.1 Drivers profile

	gender	age	job	household income	frequency of driving	Passenger
Drivers Group	Female, Male	<30yrs, >30yrs	Working, Non-Working	<$1M, >$1M	At least 3-4days/wk	With, Without
Tokyo Group	70%, 30%	44%, 56%	63%, 37%	81%, 19%	85%, 15%	48%, 52%
Manila Group	63%, 37%	11%, 89%	85%, 15%	56%, 44%	85%, 15%	56%, 44%

4.3.2 Outcome of the Ecodriving Training

During the Ecodriving training, the drivers were taught of the Ecodriving techniques. The application of this technique was tested through its normal driving and Ecodriving result of each candidate driver. The data collected were then evaluated through a diagnostic report. The diagnostic report compared the normal (pretest) driving and Ecodriving (posttest) operations and the parameters of the candidate drivers. This report revealed the driving operation referred from four different modes namely: acceleration, cruising, deceleration, and idling. These four modes related to the outcome of five driving parameters, namely: fuel economy (km/l), fuel consumption (cc), traveled distance (km), travel time (sec), fuel consumption rate during idling (cc/sec) and stopping time (sec).

A paired t test was employed to compare the means of two values (i.e., normal driving and Ecodriving) of the fuel parameters or equivalently to identify whether the average of the differences (of the values for each case) differed from zero (0). In calculating the t statistics for each group (i.e., Tokyo and Manila), the difference between normal driving and Ecodriving values were computed, and then the average difference and the standard deviation (SD) of the difference were also computed in order to finally compute the t value.

Table 4.2 is the summary of thirty Manila drivers' pretest diagnostic report. This report detailed the vehicle parameters that included fuel economy, fuel consumption, travel distance, travel time, fuel consumption rate during idling, stopping time and the number of stops incurred during normal test drive (pretest) of the drivers. Table 4.3 shows the summary of the posttest diagnostic report of the Manila drivers. This report detailed the vehicle parameters that included the same indices incurred during Ecodriving test drive (posttest) of the drivers.

Table 4.4 is the summary of the pretest diagnostic report of twenty-seven Tokyo drivers. This report detailed the vehicle parameters that included fuel economy, fuel consumption, travel distance, travel time, fuel consumption rate during idling, stopping time and the number of stops incurred during normal test drive (pretest) of the drivers. Table 4.5 also shows the summary of the posttest diagnostic report of the Tokyo drivers. This report detailed the vehicle parameters that included the same indices incurred during Ecodriving test drive (posttest) of the drivers.

Figure 4.1 shows the distribution profile of the fuel economy (km/l) improvements of the Manila driver group. All of the drivers gained fuel economy improvement after the Ecodriving training.

This profile revealed that 73% of the drivers gained improvement between range of 1.1-1.19 (40%) and 1.2-1.29 (33%).

Figure 4.2 shows the distribution profile of the fuel consumption rate during idling (cc/sec) improvements of the Manila driver group after the Ecodriving training. This profile revealed that more than 74% of the drivers gained improvement between range of 1.0-1.99 (34%) and 2.0-2.99 (40%). Out of the thirty drivers only one driver did poor performance after the training.

Table 4.2 Summary of Manila drivers' pretest diagnostic report

Driver Candidate N=30	Fuel Economy km/l	Fuel Consumption cc	Distance km	Travel Time sec	Consumption Rate cc/sec	Acceleration Rate m2/s2/km	Stopping Time sec	Number of Stops N
D1	8.95	354.33	3.17	581	0.26	460.86	128.00	4
D2	8.38	373.04	3.12	585	0.31	505.72	78.00	4
D3	8.05	392.57	3.16	722	0.08	493.16	175.00	6
D4	7.07	430.42	3.04	671	0.35	369.22	161.00	7
D5	8.63	361.36	3.12	623	0.28	456.22	101.50	4
D6	7.18	439.04	3.15	638	0.26	579.52	156.50	4
D7	5.26	585.80	3.08	606	0.50	493.98	127.00	6
D8	7.82	399.24	3.12	568	0.39	550.03	124.00	5
D9	8.70	354.69	3.09	875	0.28	398.92	282.50	9
D10	9.93	321.92	3.20	611	0.27	472.94	150.00	5
D11	7.65	398.20	3.05	658	0.29	285.94	89.50	4
D12	6.72	455.73	3.06	634	0.31	454.08	123.00	6
D13	5.95	517.61	3.08	556	0.34	715.41	112.50	7
D14	6.13	498.66	3.06	635	0.40	365.22	163.00	4
D15	4.57	670.05	3.06	536	0.44	679.10	111.00	5
D16	6.56	456.06	3.05	610	0.41	417.42	77.50	6
D17	6.21	494.53	3.07	621	0.42	431.83	126.00	6
D18	6.09	502.26	3.06	574	0.39	407.82	97.50	7
D19	4.61	667.01	3.08	663	0.42	680.67	169.50	9
D20	6.45	471.87	3.04	659	0.37	480.50	138.00	7
D21	6.48	473.40	3.06	673	0.35	314.93	173.00	8
D22	6.46	467.36	3.02	610	0.31	476.77	116.00	5
D23	6.29	485.43	3.05	647	0.34	459.09	136.50	6
D24	7.97	379.86	3.03	603	0.26	252.15	78.00	3
D25	6.83	446.07	3.05	648	0.31	399.11	159.50	6
D26	6.37	480.74	3.06	541	0.33	482.52	92.50	6
D27	6.15	497.24	3.06	544	0.35	519.63	85.50	5
D28	7.06	436.09	3.08	691	0.30	363.84	135.00	5
D29	7.03	436.47	3.07	684	0.30	361.50	151.50	7
D30	6.88	461.79	3.18	663	0.37	283.18	144.50	8

Table 4.3 Summary of Manila drivers' posttest diagnostic report

Driver Candidate N=30	Fuel Economy km/l	Fuel Consumption cc	Distance km	Travel Time sec	Consumption Rate cc/sec	Acceleration Rate m2/s2/km	Stopping Time sec	Number of Stops stops
D1	9.77	319.76	3.12	658	0.10	364.70	118.50	3
D2	9.73	319.71	3.11	544	0.32	396.24	76.00	3
D3	8.39	375.70	3.15	791	0.20	469.47	165.50	9
D4	7.68	392.36	3.01	727	0.12	336.12	190.00	4
D5	8.03	346.25	2.78	669	0.09	421.52	200.00	3
D6	8.21	382.92	3.14	805	0.12	389.98	247.50	5
D7	6.08	502.99	3.06	678	0.16	413.44	165.00	5
D8	8.59	360.22	3.10	690	0.18	321.02	170.50	7
D9	9.16	343.78	3.15	836	0.15	434.04	286.00	8
D10	11.61	276.71	3.21	554	0.11	436.91	115.50	3
D11	8.94	340.31	3.04	654	0.11	354.97	142.50	5
D12	7.99	375.42	3.00	767	0.17	324.97	227.00	5
D13	7.20	421.21	3.03	674	0.22	420.37	153.50	7
D14	6.69	454.50	3.04	602	0.16	415.69	129.50	5
D15	6.60	459.39	3.03	651	0.18	419.44	137.00	4
D16	7.17	426.25	3.05	674	0.09	433.44	176.00	4
D17	6.93	440.60	3.05	660	0.08	386.86	189.50	5
D18	6.72	454.57	3.05	614	0.13	479.45	152.00	6
D19	5.95	517.64	3.08	705	0.11	471.67	179.50	5
D20	7.28	414.86	3.02	702	0.14	411.35	186.50	4
D21	6.81	449.82	3.06	674	0.18	406.73	175.50	6
D22	6.79	452.31	3.07	681	0.08	481.38	191.00	4
D23	7.10	430.89	3.06	607	0.18	484.69	184.50	6
D24	8.29	365.45	3.03	670	0.16	297.19	146.00	5
D25	8.67	353.21	3.06	636	0.12	309.69	153.50	4
D26	7.49	405.54	3.04	538	0.18	459.10	111.50	4
D27	7.33	417.16	3.06	593	0.13	438.70	117.50	5
D28	8.17	375.84	3.07	661	0.18	275.68	128.00	5
D29	7.86	385.11	3.03	682	0.23	321.88	164.50	4
D30	8.01	397.37	3.18	657	0.17	192.49	140.00	5

Table 4.4 Summary of Tokyo drivers' pretest diagnostic report

Driver Candidate N=27	Fuel Economy km/l	Fuel Consumption cc	Distance km	Travel Time sec	Consumption Rate cc/sec	Acceleration Rate m2/s2/km	Stopping Time sec	Number of Stops N
D1	9.76	276.22	2.70	689	0.21	420.70	275.50	11
D2	8.87	308.47	2.74	651	0.20	516.46	311.50	9
D3	8.62	314.51	2.71	677	0.17	582.98	284.50	12
D4	8.02	337.64	2.71	764	0.15	661.10	394.00	12
D5	9.77	274.44	2.68	641	0.16	450.81	283.00	10
D6	9.88	275.76	2.72	516	0.17	628.45	171.50	7
D7	8.05	334.34	2.69	805	0.18	551.33	410.00	14
D8	10.10	269.41	2.72	612	0.16	387.03	245.00	9
D9	8.19	331.52	2.72	667	0.23	476.15	282.00	17
D10	9.19	291.44	2.68	652	0.21	413.27	287.00	12
D11	10.37	258.76	2.68	621	0.19	415.69	249.00	7
D12	8.82	305.37	2.69	759	0.18	547.60	391.00	10
D13	10.30	260.32	2.68	440	0.20	480.54	170.50	5
D14	8.44	318.96	2.69	680	0.19	638.25	321.00	11
D15	8.96	301.70	2.70	669	0.19	577.59	300.50	12
D16	10.13	265.92	2.69	625	0.17	383.16	217.00	10
D17	10.30	261.91	2.70	650	0.16	483.62	224.00	9
D18	8.74	305.21	2.67	514	0.19	556.43	202.50	8
D19	8.31	325.10	2.70	632	0.19	734.73	277.50	11
D20	8.09	336.72	2.73	684	0.19	658.47	310.00	13
D21	10.54	256.76	2.71	663	0.18	473.44	254.50	12
D22	8.82	308.58	2.72	630	0.19	523.18	277.50	10
D23	6.29	433.58	2.73	661	0.19	825.41	300.50	11
D24	8.65	311.15	2.69	677	0.18	591.66	290.00	11
D25	9.30	292.28	2.72	680	0.18	435.50	278.50	12
D26	8.69	314.93	2.74	673	0.18	558.98	315.00	10
D27	9.47	286.97	2.72	624	0.17	592.43	291.00	7

Table 4.5 Summary of Tokyo drivers' posttest diagnostic report

Driver Candidate N=27	Fuel Economy km/l	Fuel Consumption cc	Distance km	Travel Time sec	Consumption Rate cc/sec	Acceleration Rate $m^2/s^2/km$	Stopping Time sec	Number of Stops stops	Fuel Savings %
D1	9.75	276.17	2.69	682	0.15	406.36	298.50	14	-0.10
D2	10.66	255.90	2.73	661	0.14	507.24	246.50	10	20.10
D3	9.70	278.55	2.70	803	0.09	437.68	357.00	14	12.60
D4	11.34	236.58	2.68	775	0.04	429.13	344.50	11	41.40
D5	10.58	254.66	2.69	645	0.10	490.85	254.50	11	8.20
D6	10.11	265.65	2.68	640	0.10	483.78	241.50	10	2..3
D7	9.59	285.60	2.74	816	0.10	412.05	345.00	16	19.10
D8	11.19	241.87	2.71	754	0.06	450.82	344.50	9	10.80
D9	10.13	269.37	2.73	843	0.09	394.31	419.50	12	23.60
D10	11.19	238.79	2.67	653	0.12	498.28	250.00	10	21.70
D11	11.32	237.34	2.69	688	0.14	459.10	253.50	10	9.20
D12	10.93	247.90	2.71	613	0.11	362.64	217.00	10	23.90
D13	10.69	254.32	2.72	694	0.09	489.21	304.50	11	3.80
D14	10.02	266.47	2.67	664	0.12	505.78	285.50	12	18.80
D15	10.52	256.24	2.70	650	0.11	449.46	246.00	9	17.50
D16	10.29	262.16	2.70	660	0.10	582.55	250.50	10	1.50
D17	11.22	239.18	2.68	651	0.08	368.20	259.50	10	9.00
D18	9.86	273.83	2.70	682	0.08	504.02	311.00	11	12.90
D19	9.71	277.36	2.69	682	0.12	539.07	290.00	11	16.90
D20	9.50	286.26	2.72	683	0.11	485.11	259.00	12	17.40
D21	11.28	239.36	2.70	688	0.08	371.23	256.00	13	7.00
D22	10.42	263.08	2.74	665	0.08	391.39	264.50	11	18.10
D23	9.91	276.30	2.74	647	0.09	478.35	238.00	14	57.40
D24	10.26	260.88	2.68	673	0.09	348.66	274.00	12	18.70
D25	11.30	237.88	2.69	702	0.09	290.26	268.00	10	21.60
D26	10.30	265.32	2.73	643	0.08	439.14	280.50	9	18.50
D27	10.11	265.50	2.68	691	0.09	408.05	269.00	11	6.80

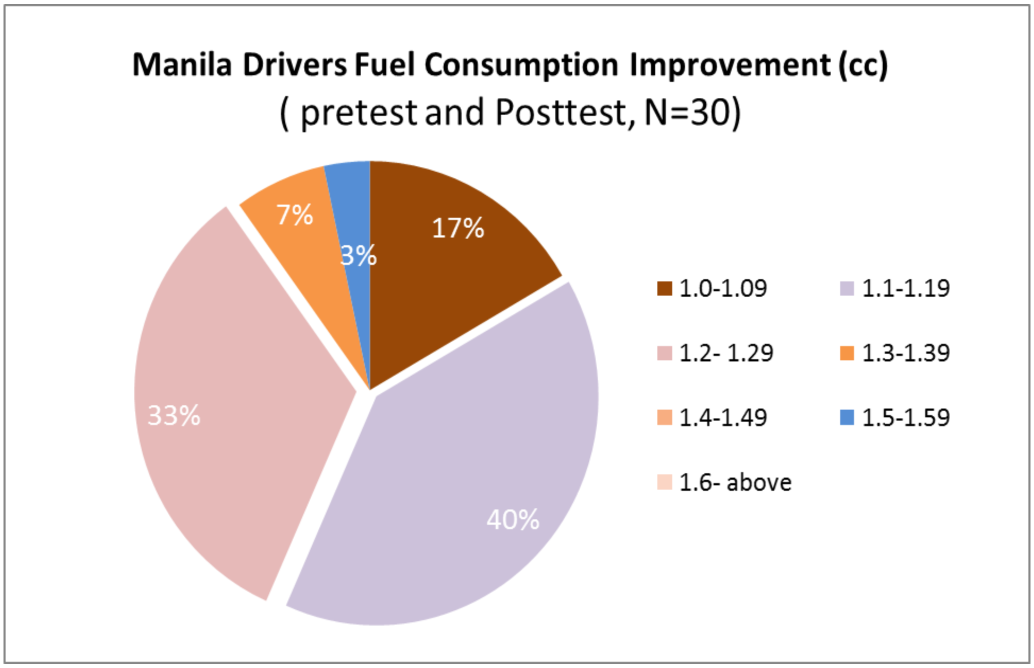


Figure 4.1 Fuel consumption improvement profiles of Manila drivers

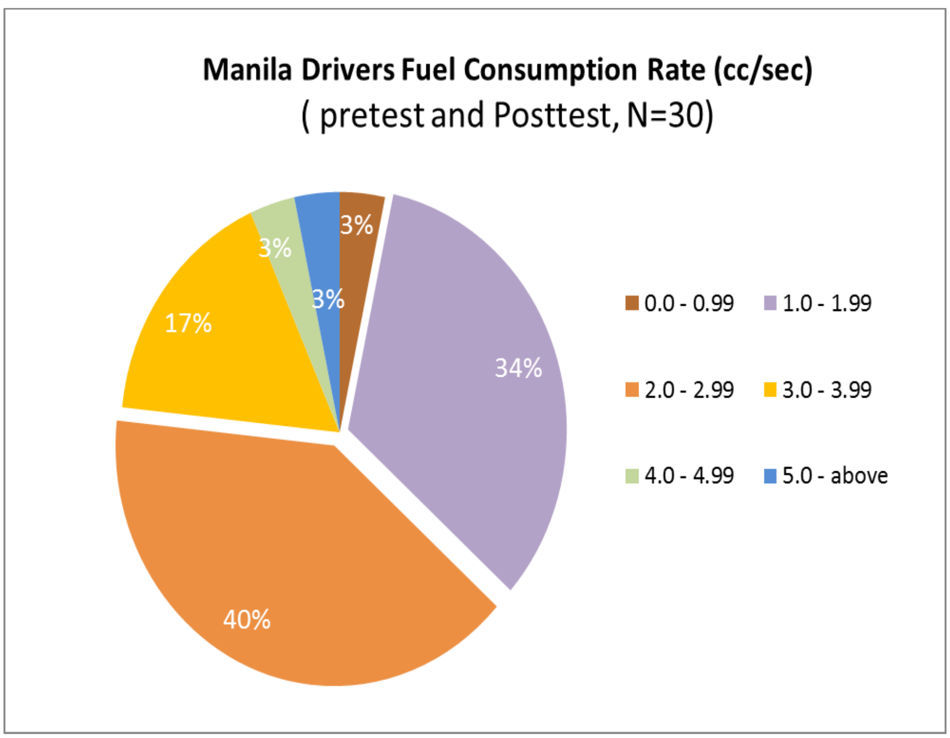


Figure 4.2 Fuel consumption rate improvement profiles of Manila drivers

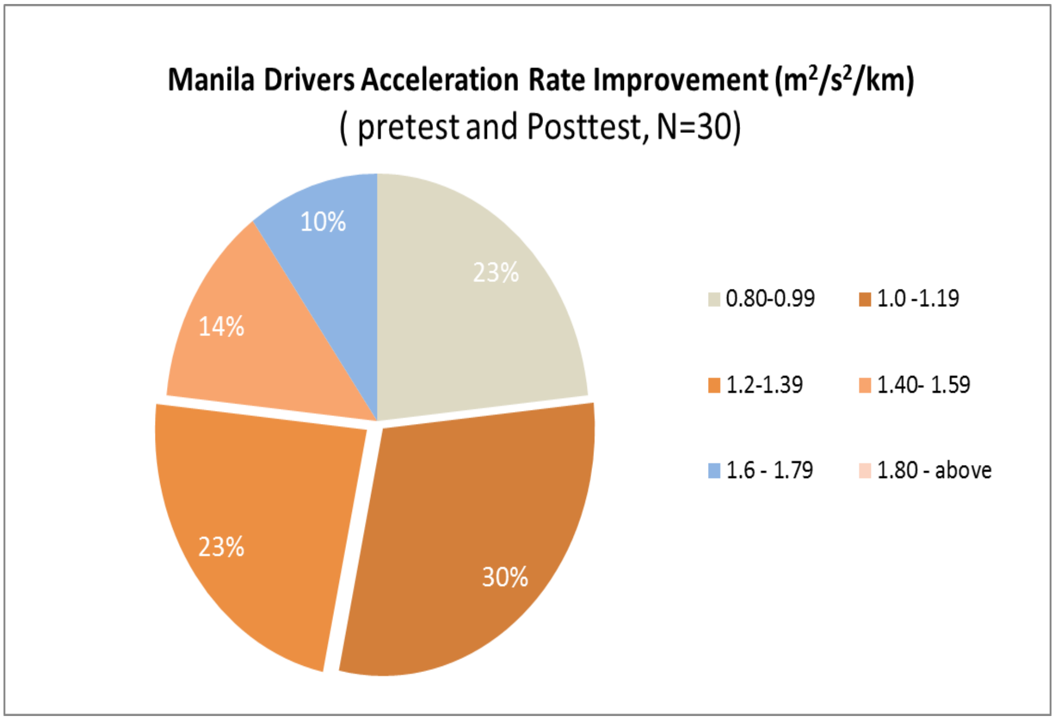


Figure 4.3 Acceleration rate improvement profiles of Manila drivers

Figure 4.3 shows the distribution profile of the acceleration rate ($m^2/s^2/km$) improvements of the Manila driver group after the Ecodriving training. This result revealed that 23% of the drivers (7 persons) did not gain fuel economy improvement after the Ecodriving training during acceleration. The driver's acceleration rate only ranged between 0.80 and 0.99. However, more than 75% were able to reduce their acceleration rate after the Ecodriving training; this is an indicator of the drivers' effort to practice gentle starting acceleration.

Figure 4.4 shows the distribution profile of the fuel economy (km/l) improvements of the Tokyo driver group after the Ecodriving training. All of the drivers gained fuel economy improvement after the Ecodriving training. This profile revealed that more than 77% of the drivers gained improvement between range of 1.1-1.19 (29%) and 1.2-1.29 (48%).

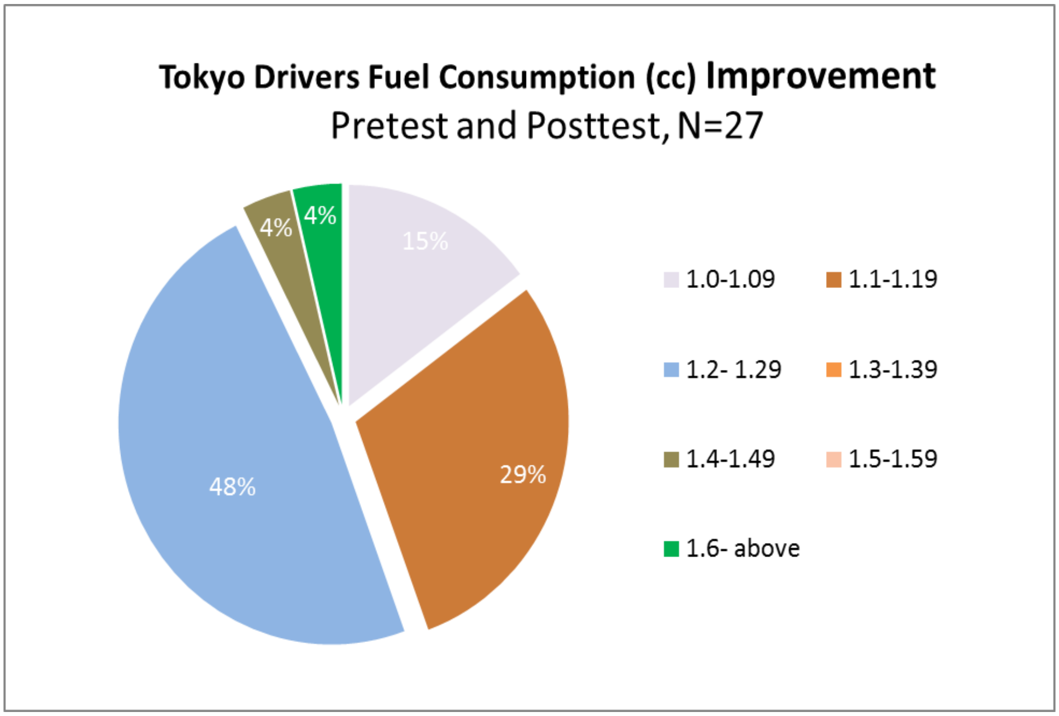


Figure 4.4 Fuel consumption improvement profiles of Tokyo drivers

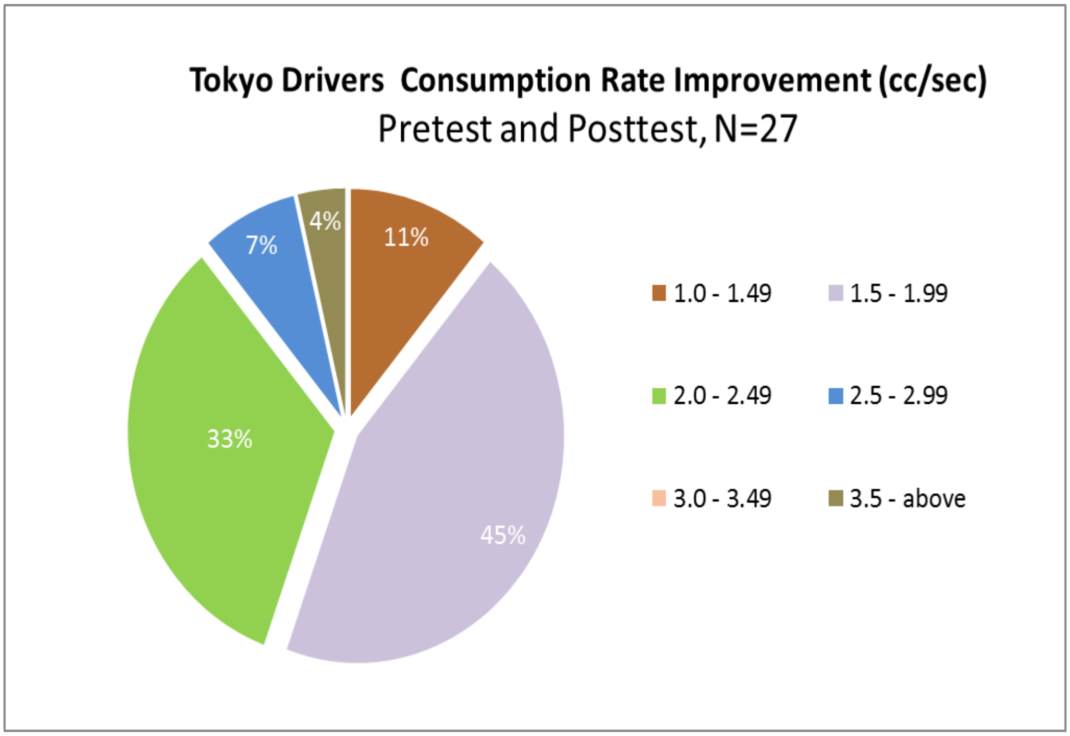


Figure 4.5 Fuel consumption rate improvement profiles of Tokyo drivers

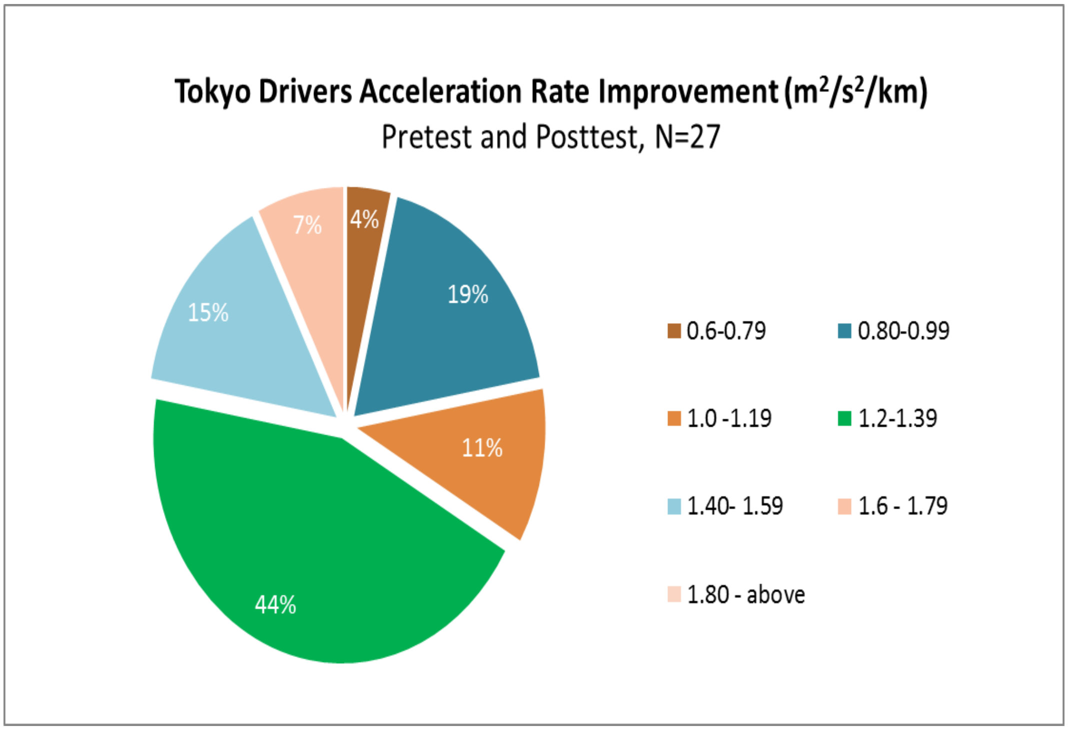


Figure 4.6 Acceleration rate improvement profiles of Tokyo drivers

Figure 4.5 shows the distribution profile of the fuel consumption rate during idling (cc/sec) improvements of the Tokyo driver group after the Ecodriving training. This profile revealed that more than 78% of the drivers gained improvement between range of 1.5-1.99 (45%) and 2.0-2.49 (33%).

Figure 4.6 shows the distribution profile of the acceleration rate ($m^2/s^2/km$) improvements of the Tokyo driver group after the Ecodriving training. This result revealed that 23% of the drivers (6 persons) did not gain fuel economy improvement after the Ecodriving training during acceleration. The driver's acceleration rate ranged between 0.60 and 0.99. However, more than 75% were able to reduce their acceleration rate after the Ecodriving training; this is an indicator of the drivers' effort to practice gentle starting acceleration.

Table 4.6 summarized the outcome of the Ecodriving training. It revealed that there was a general improvement in the driver's manner of driving. For both Tokyo and Manila candidate drivers, the average fuel economy before training was significantly less than that of after training which would imply that fuel savings were achieved after the drivers were trained with Ecodriving techniques. The average fuel consumption before training was also significantly greater than that of after training. This corresponded with the fuel economy improvement among the drivers. There was no significant difference in the average distance traveled. The average fuel consumption rate during idling before training was significantly greater than that of after training. This means that lesser fuel was consumed after training, indicating further that fuel savings during idling was achieved by simply applying the idling-stop technique in both cases.

However, while the average time traveled before training was significantly shorter than that of after training in Manila, this was not the case in Tokyo. The mean stopping time before training was also significantly lower than that of after training in Manila case. From the observation, Manila drivers could have longer stopping time after training due to their slow adaptation and application of idling-stop technique. The technique involved switching the ignition off during signal stop and switching the engine on again to accessory position as the traffic signal turned green.

Table 4.6 Normal driving and Ecodriving statistics

Vehicle Parameters	Tokyo Drivers Statistics			Manila Drivers Statistics		
	Mean	SD	P-value	Mean	SD	P-value
Fuel Economy Before – Fuel Economy After (km/l)	-1.378	0.843	0.000**	- 0.894	0.525	0.000**
Fuel Consumption Before – Fuel Consumption After (cc)	42.424	31.875	0.000**	58.366	41.366	0.000**
Distance Traveled Before – Distance Traveled After (km)	0.003	0.022	0.551	0.021	0.065	0.084
Travel Time Before – Travel Time After (sec)	-40.444	80.732	0.015**	- 37.467	58.615	0.002**
Fuel Consumption Rate on Idling Before – Fuel Consumption Rate on Idling After (cc/sec)	0.086	0.020	0.000**	0.181	0.097	0.000**
Acceleration Rate Before – Acceleration Rate After ($m^2/s^2/km$)	95.639	117.546	0.000**	61.403	99.393	0.002**
Stopping Time Before – Stopping Time After (sec)	- 0.519	70.186	0.970	- 31.883	38.863	0.000**
Number of Stops Before – Number Stops After	- 0.778	2.326	0.094	0.867	1.655	0.008**

Driving parameters were calculated as before minus after (before – after); ** : significant P-value at 5% level; SD: Standard Deviation.

4.3.3 Detailed Analysis on the Case of Manila Drivers

This section details the results of the training day for the Manila drivers. The analysis includes the evaluation of the training day results in terms of the drivers' driving operation (i.e., acceleration, cruising, and deceleration) or modes. Statistical evaluation of the driving parameters was investigated using paired sample t-test (at 5% significance level) on each of the driving modes. This part of the analysis attempted to reveal which driving operation or mode the drivers were able to follow effectively the Ecodriving technique that was extensively discussed and coached during the training session.

The driver's driving behavior during the training day was assessed by comparing the speed, engine power, fuel economy, and fuel consumption against the driving operation before and after the Ecodriving training. The summary of the comparison is presented in Table 4.7.

Table 4.7 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 20 kph mark at the first 5 seconds 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 decreased speed and engine power at 95% confidence interval ($p<0.05$). However, for this mode or during this operation, the fuel consumption rate was 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 4.7 revealed that there was a significant decrease in the engine power and fuel economy parameters at 95% confidence interval ($p<0.05$) among the thirty drivers. This would imply that drivers were able to lower their engine RPM values as they decelerated, which enabled them to optimize their vehicle performance as reflected in the increased fuel efficiency at this mode.

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 cruising mode revealed that there was a significant decrease in the engine power (RPM) at 95% confidence interval ($p<0.05$). Moreover, the drivers were able to lower the fuel consumption rate, the fuel economy and the speed values; however these values were not significant. In this mode, it would be safe to assume that the drivers attempted to apply the Ecodriving technique.

For acceleration mode 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 acceleration mode revealed that there was a significant decrease in the engine power (RPM) at 95% confidence interval ($p<0.05$). The drivers managed to reduce the fuel consumption rate and speed values at this mode, but they were not fuel efficient, and furthermore, the overall result of these parameters was not significant.

4.3.4 Ecodriving and Drivers' Psychological and Non-Psychological Characteristics

The pretest questionnaire of the drivers was evaluated in terms of the psychological/non-psychological characteristics of each driver. The questions on non-psychological characteristics included gender, age, and other items. A part of these items were summarized in Table 4.8. Based on preceding study results, five psychological constructs that indicated psychological characteristics of drivers were selected and grouped as follows: 'rough driving,' 'irritated driving,' 'indecisive driving,' 'anti-law-abiding driving,' and 'addicted driving.' The 'rough driving' means psychological characteristics of a driver who tends to drive in less gentle manner, while the 'irritated driving' characteristic means that a driver tends to be irritated by other drivers. The ‘indecisive driving,’ ‘anti-law-abiding driving’ and ‘addicted driving’ mean psychological characteristics of a driver who is slow in driving decisions, pays less attention to traffic law and feels enjoyment during driving.

In order to measure each psychological construct, there were six to twelve items that were carefully prepared to best describe the situations in relation to each psychological construct. After excluding the questions with missing data, Cronbach’s alpha index for each psychological construct was calculated and the questions that did not contribute to the improvement of the index were excluded. Finally, relevant questions for each psychological construct were chosen. The measurements were then made by summing up the answers to every question corresponding to each construct.

Table 4.4 showed the selected questions and Cronbach’s alpha indices for the measurements of five psychological constructs. For ‘rough driving’ and ‘anti-law-abiding driving,’ this study chose different questions between Tokyo and Manila cases because this study could not attain satisfactory values for Cronbach’s alpha especially for ‘anti-law-abiding’ in Manila case.

Table 4.8 Selected sentences and Cronbach’s alpha indices for the measurements of five psychological constructs

constructs	examples of questions (5 scales from '1: not like me at all' to '5: very much like me')	Cronbach's alpha (the number of questions) Tokyo	Manila
rough driving*	I tend to change lanes often.	0.82	0.71
	I just casually change lanes	(2)	(3)
irritated driving	I don't feel good if my pace is interrupted.	0.81	0.81
	Bad drivers should let others go on first.	(2)	(2)
indecisive driving	I tend to drive "pretty" awkwardly.	0.89	0.92
	I think I drive indecisively and am poor at driving in a timely manner.	(6)	(6)
anti-law-abiding driving*	The reason it's hard to obey traffic rules is because there's a problem with the rules themselves.	0.91	0.63
	I don't know why they set speed "sensors" at places where people can't help driving fast.	(2)	(3)
addicted driving	Driving is so fun.	0.84	0.70
	Driving gives me something to live for.	(3)	(3)

Note: * means use of different questions between Tokyo and Manila analyses

In order to investigate the effect of Ecodriving training program among the candidate drivers in Tokyo and Manila, special focus was made on the psychological characteristics of the drivers. Two objective variables were regressed, namely, the fuel economy (km/l) and the improvement after the program (training). The fuel economy was obtained from normal driving fuel economy, and the Ecodriving fuel economy improvement value taken from before and after the Ecodriving program of each candidate driver. The improvement after the program was obtained by dividing after-training fuel economy with before-training fuel economy (i.e. after-km/l divided by before-km/l). For explanatory variables, psychological/non-psychological variables with missing data were excluded.

The study initially attempted to identify if there were "good drivers" among the group because then the Ecodriving training intervention would only further or enhance the fuel economy results of these driver. The good drivers' driving characteristic would have to yield better fuel economy values compared to the average drivers even before the Ecodriving intervention was introduced. Thereof, the two objective variables were used, namely: absolute fuel economy and the improvement to obtain this outcome. However, as it is shown later, since the initial result did not reveal significant "good drivers," the regression analysis was directed to identify a common characteristic among the drivers by considering the drivers' psychological characteristics and non-psychological factors.

The results were indicated in Table 4.9. For the Tokyo group, the case of the absolute fuel economy at R-square=0.610 revealed that the drivers with rough driving behavior had very significant effect on fuel economy compared to other drivers with different psychological characteristics. For non-psychological characteristics the results revealed that only frequency of vehicle maintenance was very significant. Overall, both rough driving and poor vehicle maintenance characteristics caused to lower the overall fuel economy. The case of the improvement after the program at R-square=0.55 revealed that two non-psychological characteristics namely: frequency of driving and frequency of vehicle maintenance were very significant. Driver's frequency of driving (1: higher, 5: lower) reduced the improvement value after the program while frequency of vehicle maintenance (1: higher, 5: lower) increased the improvement value after the program. In other words, the drivers with higher frequency of driving and lower frequency of vehicle maintenance were effectively motivated by the program.

Table 4.9 Regression results of absolute fuel economy (km/l) and improvement after the program

LEFT:Tokyo, RIGHT:Manila	abs. fuel economy		improve. after program		abs. fuel economy		improve. after program	
	cofficient	t_value	cofficient	t_value	cofficient	t_value	cofficient	t_value
constant	12.692	5.395	0.798	2.542	5.745	2.653	1.518	9.055
rough driving	-0.384	-1.813	0.045	1.599	-0.157	-0.425	-0.009	-0.304
irritated driving	-0.351	-1.496	0.049	1.567	0.502	1.339	0.018	0.617
indecisive driving	0.094	0.306	-0.011	-0.280	0.517	1.392	-0.047	-1.637
anti-law-abiding driving	0.075	0.319	-0.019	-0.624	-0.056	-0.113	-0.021	-0.554
addicted driving	0.222	0.896	0.016	0.491	-0.289	-0.924	-0.015	-0.599
gender (male:1, female:2)	-0.255	-0.512	-0.088	-1.320	0.119	0.195	-0.057	-1.197
age	-0.016	-0.661	0.001	0.431	0.456	1.565	-0.017	-0.751
frequency of driving (1:higher, 5:lower)	0.321	1.098	-0.064	-1.652	-0.431	-1.248	-0.022	-0.835
car occupancy	0.010	0.023	0.017	0.281	-0.313	-0.526	-0.009	-0.197
running cost shouldered by myself	-0.055	-0.104	-0.058	-0.822	-1.172	-1.983	0.052	1.141
frequency of maintenance check-up (1:higher, 5:lower)	-0.660	-2.523	0.084	2.395	0.144	0.568	-0.025	-1.274
household income	0.000	0.163	0.000	0.351	0.000	-0.150	0.000	0.412
Number of samples		27		27		30		30
R-square		0.610		0.554		0.440		0.407

For the Manila case, R-square values for both absolute fuel economy and improvement of the program were less than satisfactory level. While psychological characteristics of indecisive driving influenced improvement after the program negatively, non-psychological variable of "running cost shouldered by myself" also influenced absolute fuel economy negatively. The latter might be counter-intuitive; however, this might reflect that Manila candidate major driving purpose was leisure. Furthermore, the drivers' feedback also indicated that some items in the questionnaire were not applicable for the Manila settings (i.e., traffic environment and drivers' behavior) and that there were also questions that were not clear (i.e., Japanese to English translation of the questions). Therefore, the poor regression outcomes of the questions in the analysis of the Manila drivers could also be a reflection of these issues.

4.4 Conclusions

In this study, fuel economy and the effectiveness of Ecodriving programs in developing (Manila) as well as developed (Tokyo) countries were investigated. It especially focused on the driver's characteristics including psychological aspects among other factors influencing fuel economy and the outcome of Ecodriving programs. First, it was demonstrated that the Ecodriving program was effective in urban areas in developing countries such as Manila. Second, common psychological measurements were developed and they were applicable to both Tokyo and Manila drivers.

The study was able to demonstrate that Ecodriving program significantly affected the overall fuel economy during the training day suggesting that the driver could adopt well the Ecodriving techniques in developing country as well as developed country settings. However, the results in terms of the driver's driving operation (i.e., acceleration, cruising, and deceleration) or modes, the Ecodriving program needs to be improved to further advance the application of Ecodriving program in developing countries.

With respect to the driver's psychological aspects, it was found that rough driving influenced the absolute fuel economy in Tokyo at 10% level of significance. If it is possible to know the psychological and non-psychological characteristics of the participants of the Ecodriving program in advance, it might be able to improve the program by incorporating those characteristics.

CHAPTER 5

EFFECTIVENESS OF ECODRIVING IN REAL-WORLD APPLICATION

5.1 Background

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 are in turn, influenced by external factors such as traffic characteristics, road characteristics, vehicle characteristics, driving characteristics, travel characteristics, and other variables. Nevertheless, if drivers are driving their vehicles in an efficient manner -*ceteris paribus*- the resulting vehicle performance is optimized.

The studies on Ecodriving investigation in real-world application particularly those that address specific driving modes (i.e., acceleration, cruising, deceleration and idling) are very limited. More specifically, those that examined which specific driving mode "before and after" the ecodriving program significantly affected the fuel economy and vehicle performance have not been conducted sufficiently.

Thereof, this chapter investigates the outcome of Ecodriving program and its effect on fuel economy. It particularly examines the effect of the ecodriving program in real-world driving; the vehicle performance (i.e. speed, engine power, fuel efficiency etc.); and the four elements of the driving modes or driving operations, namely: acceleration, cruising, deceleration, and idling.

5.2 Methodology

5.2.1 Instrumentation

Thirty candidate drivers and vehicles equipped with on-board data-logging equipment were considered in the study. Invitation letters for drivers interested to join the research and survey were distributed among the universities in Manila and Tokyo and also sent through emails. The list was then trimmed down to include drivers with vehicles compatible to instrumentation requirements of the study. The vehicles with compatible On-Board Diagnostic (OBD) ports are prerequisite for data collection. Thereof, only Japanese cars that passed vehicle specification requirements for the monitoring equipment of the study were considered. The fuel gauge 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 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 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 the driver's trip data. Each driver's data logs from the fuel gauge and GPS readings were collected, lumped, processed, cleaned and filtered from noise and finally logged into the drivers' database. This data was used for the evaluation of the driver's driving operation, route mapping and statistical analysis in real-world application.

5.2.2 Calibration

Prior to actual data collection, there was an initial pre-testing evaluation for compatibility of monitoring instruments and vehicle. This involved vehicle-instrument calibration. When selected vehicle passed the initial prequalification stage, the drivers were then required to take an initial driving test to check if the data loggings of GPS and fuel gauge equipment were successful. The drivers owning vehicle that passed the calibration test became candidate drivers for the Ecodriving training program.

5.2.3 Data Collection

This study focused on the data collection of two real-world datasets: (1) driving dataset before and (2) driving dataset after the Ecodriving training program of the drivers. A total of thirty Manila and Tokyo drivers were candidates for the Ecodriving training program. With permission each driver's car was tested for calibration and equipped with the GPS and fuel gauge equipment for at least two weeks.

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

5.2.4 Data Evaluation

The drivers' data were logged through vehicle monitoring equipment (i.e., GPS and fuelmeter). Global Positioning System (GPS) data included latitude, longitude and altitude while Fuelmeter data parameters included fuel consumption, speed, acceleration, engine velocity and distance. The data collected from both equipment were in *.csv and *.dat file formats which were then translated into an *.xls and *txt files formats and logged in the drivers' database for data processing. 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 Ecodriving training program.

5.3 Results and Discussions

First, the statistical evaluation (paired t-test at 5 % significance level) of the data specifically focused on the driving operation in relation to the Manila drivers which was 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, and gentle acceleration during the signal green or "go" at intersections. These driving modes were evaluated because during the Ecodriving training, the

Ecodriving operational techniques were intensively taught and were supposed to contribute to reducing fuel consumptions considerably.

The second part of the statistical analysis focused on two specific evaluations in relation to the Manila as well as the Tokyo drivers, namely: gentle acceleration and idling-stop application of the Ecodriving guideline. The evaluation used Welch's test of unequal variance at 5% significance level for each driver's case with his/her occasions for gentle acceleration and idling-stop applications. Two index values were considered in this analysis: for idling the index was the fuel consumption value during idling (cc/sec) and for gentle acceleration the index was the fuel consumption (cc) at the end of the 20 m distance from initial acceleration after a sufficient time of stopping.

The second part of the statistical analysis also focused on the relationship between the improvement in terms of fuel economy after the Ecodriving training program, and the characteristics of the drivers in Manila and Tokyo including the improvement observed during the Ecodriving training. The results might be useful for modifying the Ecodriving program according to the characteristics of the drivers especially in developing country settings.

5.3.1 Analysis on the Driving Operation of the Manila Drivers

The first round (three days) and second round (three days) of collecting the drivers' real-world driving data from the GPS and fuel gauge were examined for the real-world driving characteristics of the Manila and Tokyo drivers. The GPS data were plotted on GIS road network map. By matching the location (i.e., GIS data) with fuel gauge data, dataset was built containing the 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 data were selected objectively by tracing overlapping data of the GPS route and comparing these traces according to the normal driving and Ecodriving criteria. For the evaluation of the idling and acceleration modes, the intersection points were used as control positions for assessment of the gentle starting acceleration and idling-stop. Therefore, the intersection data were filtered and isolated from the raw data of GPS and fuel gauge traces. For idling, two evaluation criteria were set for assessment of the vehicle parameters: (1) for idling criteria (i.e., speed=0 and distance=0) against idling-stop criteria (i.e., fuel consumption=0, speed=0 and distance=0) and (2) for acceleration criteria (i.e., 10 second evaluation of acceleration values) against gentle acceleration (i.e., 10 second evaluation of acceleration with less than 20 kph without decreased speed). For deceleration mode, the traffic intersection was used as reference point for evaluation. The preset criteria were that utmost a tracing the last 10 seconds prior to full stop at the traffic signal best represented the deceleration operation of the drivers. Finally, the cruising mode was isolated from the data traces of the GPS and fuel gauge of the drivers' operation that were retained after filtering the deceleration traces, the starting acceleration traces and the idling traces. The vehicle operation modes considered in this evaluation included: the starting acceleration at the beginning of the trip, cruising, deceleration (mostly due to traffic signals), and acceleration at the traffic signal green or "go." The final dataset was reduced to the dataset containing twelve drivers with matched routes and with ample duration of trips for the analysis.

This section examined which 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 the driver's daily trip before and after the Ecodriving training day were examined. The driver's 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 the driver's driving operation: starting acceleration (beginning of the trip), cruising, 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 5.1.

Table 5.1 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 the Ecodriving technique for starting acceleration, the results in Table 5.1 revealed that Ecodriving had no significant effect on the drivers' starting acceleration in real-world condition. The fuel consumption value decreased and the engine speed (RPM) also decreased, however, these values were not significant at 95 % confidence interval. Furthermore, the speed value also increased after Ecodriving training but this value was not significant either. This could imply that the drivers were not able to apply the Ecodriving technique on this mode due to some factors in the real-world driving environment. Moreover, feedback from some of the drivers revealed that apparently when in a hurry, expecting rush hours of traffic, and when the trip purpose was very important, and etc., this part of the driving operation was compromised.

In terms of deceleration mode, the results revealed that there was a significant effect of the Ecodriving program on the drivers' driving behavior. This was revealed in the decrease in the values of fuel consumption, engine power and fuel economy parameters at 95 % confidence interval ($p<0.05$) among the twelve drivers. The speed increased in value but this was not significant. This result suggested that the 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).

For cruising mode, there was a significant effect of the Ecodriving technique on this phase of the drivers' driving operation. These were revealed in the significant decrease of the fuel consumption and fuel economy values after the Ecodriving training at 95% confidence interval ($p<0.05$). There were increased values in the speed and RPM values after the Ecodriving training but these values were not significant. In combining these results, the drivers were assumed to drive efficiently in the real-world driving condition. Moreover, this could suggest that during the cruising mode, the drivers were attempting to improve their speed and RPM values to drive according to the speed of the traffic flow as the Ecodriving training program did specifically direct to drive at a “good constant speed by operating the accelerator in accordance to the surrounding traffic flow.”

Lastly the evaluation of the acceleration mode at signal stop was conducted. This part of the mode is operated when the vehicle stands still to stop at the red light, and then begins to start gaining acceleration as the signal turns green. This mode revealed that there were some improvements in the fuel economy, fuel consumption and engine RPM values before and after the Ecodriving training program, however, these values were not significant. Only the value of speed was found to be significantly reduced. Again, the results indicated that this mode needed to be addressed in the Ecodriving promotion in a better way.

5.3.2 Real-World Evaluation on Idling-Stop and Gentle Acceleration

In real-world scenarios, drivers usually stop or stall their vehicles for various reasons. Most of the time, these stops are characterized as (1) stops at intersection traffic signals, (2) parking in hazard signal for short emergency stop, and (3) stops at destinations. These types of stops are called idling. Idling events are characterized by speed, distance and fuel consumption parameters. Idling state has zero speed, zero distance, but fuel consumption is not always equal to zero since the engine is not switched off but is set on stand-by mode. Therefore, prolonged idling mode consumes fuel. The opposite of this concept is idling-stop. Ecodriving program promotes that when vehicle is standing still (i.e. speed and distance are zero), the engine should be switched off to reduce fuel consumption when idling. Idling and idling-stop concepts were highlighted in the Ecodriving training program. The candidate drivers were recommended during the training session to adopt the technique in real-world driving.

Since the candidate drivers had their cars equipped with the calibrated GPS and fuel gadgets before and after the Ecodriving program, it was possible to capture the real-world driving data for idling evaluation. Out of the thirty Manila and Tokyo candidate drivers, twenty drivers' dataset each was successfully obtained, which enabled to compare the driving performance before and after the program sufficiently, particularly for idling and idling-stop evaluation. The datasets were taken from both GPS and fuel gauge data. By indicating GPS data on GIS road network map and by matching the location with fuel data, the dataset containing the information on fuel consumption during stopping and the stopping time which were mostly due to intersection signals of each driver was built. The data on the stopping were used for investigating the practice of idling-stop. The result of the analysis on the effectiveness of the Ecodriving program in terms of idling criteria by the number of the drivers assumed to adopt the practice is shown in Table 5.2.

In terms of idling-stop, after the Ecodriving program, four out of the twenty Tokyo drivers demonstrated reduction in fuel consumption significantly with 5 percent of significance in the real-world (Abuzo, et al, 2012), whereas, six out of twenty Manila drivers were also able demonstrate significant fuel reduction at 5 percent significance in real-world. However, there were two Japanese drivers and three Manila drivers whose performance worsened after the program. Most drivers were successful in reducing fuel consumption after the program in terms of idling-stop occasions, however, the differences were mostly not statistically significant.

Table 5.2 The effectiveness of the Ecodriving program and the Idling-Stop technique

5% Significance	Idling-Stop Tokyo	Idling-Stop Manila
Improved	4	6
Worsened	2	3
Unchanged	14	11
Sample Size, N	N=20	N=20

Again, by indicating GPS data on GIS road network map and by matching the location with fuel consumption data, the dataset containing the information on fuel consumption during stopping and the acceleration after the stopping was built. The acceleration pattern after the stopping for each driver was filtered and separately data logged. The data on the acceleration was used for studying the practice of gentle start. This section especially focused on the efficient speed application or 'gentle start' because this operational technique was intensively taught in the Ecodriving program, and it was supposed to contribute to reducing fuel consumptions considerably. The result of the analysis on the effectiveness of the Ecodriving program in terms of gentle acceleration criteria is shown in Table 5.3.

Table 5.3 The effectiveness of the Ecodriving program and the gentle start acceleration technique

5% Significance	Gentle Acceleration Tokyo	Gentle Acceleration Manila
Improved	7	8
Worsened	0	1
Unchanged	13	6
Sample Size, N	N=20	N=15

In term of gentle start, seven Tokyo drivers (Abuzo, et al, 2012) and eight Manila drivers indicated 5 percent significant fuel reduction during real-world application. Most drivers were successful in reducing fuel consumption after the program in terms of gentle start occasions; however, the differences were mostly not statistically significant.

Next, we classified the drivers into the group with large difference, medium difference and small difference according to the difference (improvement) of fuel consumption before and after the Ecodriving program. Each group consisted of six to eight drivers in both Tokyo and Manila cases. Then the relationship between the fuel economy improvement during the Ecodriving training program and the three groups was studied and indicated in Table 5.4 and Table 5.5. In the analysis of idling-stop, for both Manila and Tokyo drivers, some of the group with small difference indicated the largest improvement. Therefore, the result of the Ecodriving program was not necessarily related with the real-world practice of Ecodriving.

Again, similar to the method of handling idling-stop, the drivers were classified into the group with large difference, medium difference and small difference according to the difference (improvement) of fuel consumption before and after the Ecodriving program. Then the relationship between the fuel economy improvement during the Ecodriving training program and the three group's results of the gentle acceleration criteria was investigated and indicated in Table 5.4 and Table 5.5. In this evaluation, in the case of Manila and Tokyo drivers, the group with small difference in the gentle acceleration criteria (during real-world application) had values with largest improvement during training, Therefore, in the evaluation of gentle acceleration criteria, the result of the Ecodriving program during training was again not necessarily related with the real-world practice of Ecodriving.

Table 5.4 Comparison of training and real-world fuel economy improvements during idling and acceleration modes of Manila drivers

	Fuel Economy Improvement (Pretest and Posttest Ratio)			Scale of Improvement			
n	Training (A)	Real-world Acceleration (B)	Real-world Idling (C.)	A	B	C	Remarks
1	1.110	0.940		oo	o		regress
2	1.170	2.471	1.503	oo	ooo	ooo	improve
3	1.100	0.541	0.756	o	o	o	maintain
4	1.040	0.973		o	o		maintain
5	1.110	1.042	1.017	oo	oo	oo	maintain
6	1.030	0.760		o	o		maintain
7	1.160	0.977	1.128	oo	o	oo	vary
8	1.100	1.103	1.269	o	oo	ooo	improve
9	1.460	1.542	0.827	ooo	ooo	o	vary
10	1.070	0.971		o	o		maintain
11	1.103	1.008	0.840	o	oo	o	vary
12	1.291	0.978	1.252	ooo	o	oo	regress
13	1.140	1.119	0.990	oo	ooo	o	vary
14	1.051	1.360	1.449	o	ooo	ooo	improve
15	1.260	0.935	1.158	ooo	o	oo	regress
16	1.190	1.104		ooo	oo		regress
17	1.192	1.072	1.192	ooo	oo	oo	regress
18	1.157	0.926	5.525	oo	o	ooo	vary
19	1.130	1.023	1.155	oo	oo	oo	maintain
20	1.164	1.220	1.125	oo	ooo	o	vary

Scale: o low improvement oo medium improvement ooo large improvement

Table 5.5 Comparison of training and real-world fuel economy improvements during idling and acceleration modes of Tokyo drivers

	Fuel Economy Improvement (Pretest and Posttest Ratio)			Scale of Improvement			
n	Training (A)	Real-world Acceleration (B)	Real-world Idling (C.)	A	B	C	Remarks
1	1.00	0.946	3.143	o	oo	ooo	improve
2	1.21	0.954	1.366	ooo	oo	ooo	vary
3	1.13	0.902	0.777	oo	o	o	regress
4	1.43	0.858	0.372	ooo	o	o	regree
5	1.08	0.621	0.655	o	o	o	maintain
6	1.17	1.015	1.496	oo	ooo	ooo	improve
7	1.11	0.833	0.777	oo	o	o	regress
8	1.22	0.981	1.176	ooo	ooo	oo	vary
9	1.23	0.834	3.753	ooo	o	ooo	vary
10	1.02	0.954	1.076	o	oo	oo	improve
11	1.20	1.090	0.953	ooo	ooo	oo	vary
12	1.18	0.914	0.986	oo	oo	oo	maintain
13	1.01	0.926	0.626	o	oo	o	vary
14	1.11	0.973	1.037	oo	ooo	oo	vary
15	1.17	0.772	0.677	oo	o	o	regress
16	1.18	0.778	0.837	oo	o	o	regress
17	1.17	0.867	1.215	oo	o	ooo	vary
18	1.57	0.912	1.143	ooo	oo	oo	regress
19	1.23	1.021	0.829	ooo	ooo	o	vary
20	1.08	1.086	1.062	o	ooo	ooo	improve

Scale: o low improvement oo medium improvement ooo large improvement

Further analysis was conducted to assess the relationship between the drivers' fuel economy improvements by mode (i.e., idling and acceleration) and the drivers' characteristics (e.g., gender, income etc.). Therefore, Chi-test evaluation was employed and the results in Table 5.6 summarized this item.

In the analysis of idling-stop with respect to the gender of the drivers, the Tokyo group of drivers with large difference tended to include many female drivers and the group with small difference tended to include many male drivers. Also, the Manila group of drivers with large difference tended to include many female drivers and the group with small difference tended to include many male drivers. Both group revealed consistent performance that female drivers adopted the idling-stop technique better than male drivers. In relation to the drivers' characteristics, it was found that car usage (i.e., daily, weekly etc.) affected the adoption of idling stop in real-world driving especially in the Manila group; however, Tokyo drivers characteristics revealed no significant results.

In the analysis of gentle acceleration with respect to the gender of the drivers, the Tokyo group of drivers with large difference tended to include many male drivers and the group with small difference tended to include many female drivers. This was also true for the Manila group of drivers with large difference tended to include many male drivers and the group with small difference tended to include many female drivers. This result revealed that male drivers could adopt the gentle acceleration technique better than female drivers. In relation to drivers' characteristics that affected the adoption of gentle acceleration in real-world driving operation; for Manila group, it was found that experience of driving or the age of driver's license (5%) and number of in-vehicle accessories (10%) were significant; as for Tokyo group, the driver's income level and vehicle engine displacement were significant (10%) characteristics.

Table 5.6 Manila drivers' real-world trip characters

Drivers Characteristics (Attributes)	5% Sig. Improvements by Mode				10% Sig. Improvements by Mode			
	Idling		Acceleration		Idling		Acceleration	
	Manila	Tokyo	Manila	Tokyo	Manila	Tokyo	Manila	Tokyo
1. Gender	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
2. Age	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
3. Household Size	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
4. License Age	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	***	n.s.
5. Job Type	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
6. Acadamic Level	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
7. Car Usuage	***	n.s.	n.s.	n.s.	***	n.s.	n.s.	n.s.
8. Purpose of Driving	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
9. Passenger	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
10. Car Ownership	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
11. Income Level	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	***
12. Engine Displacement Size	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	***
13. Transmission Type	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
14. Car Condition	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
15. In-Vehicle Accesorories	n.s.	n.s.	***	n.s.	n.s.	n.s.	***	n.s.
16. Maintenance	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

***significant ; n.s. not significant.

5.4 Manila Drivers Real-World Trip Characteristics

Real-world traffic conditions and the effect of Ecodriving drivers' driving style on other drivers in the traffic stream were not included in this study. However, the results of the real-world cruising and deceleration modes are largely attributed to the speed and movement of other vehicles in the traffic stream as well as the condition of the traffic at the time the trip is made. It is also interesting to note that there might be behavioral changes in the drivers' driving characteristics in terms of trip distance, the duration of stops and number of stops in real-world driving application after the Ecodriving training program.

The driver's real-world driving operation in terms of average distance per trip and the number of trips were compared before (i.e., normal driving) and after (i.e., Ecodriving) the Ecodriving training program. These characteristics were evaluated to check if there were changes in the drivers' trip characteristics after the Ecodriving information was introduced to the drivers; particularly, if the changes might be attributed to the drivers' driving consciousness and environmental awareness. The trip data of each driver's real-world driving operation was divided between weekday and weekend.

The result of the drivers' weekday trip evaluation in Table 5.7 revealed that fourteen (70%) of the drivers reduced average distance (i.e., kilometer) per trip after Ecodriving training. This same scenario was also found in Table 5.8 among the eight (57%) drivers' average distance per trip characteristics during weekends; only six (43%) drivers increased distance values. Moreover, two of the drivers retained their values of average travel distance per trip before and after the Ecodriving program while four of the drivers had no comparable results since they either traveled or did not travel on weekends. This decreased distance (compared to normal driving) value per trip could be attributed to the driver's driving consciousness and awareness of reducing fuel consumption per trip (i.e., taking short trips and avoiding unnecessary trips).

In terms of the number of trips per week, the results in Table 5.7 revealed that real-world weekday number of trips of the drivers decreased among ten drivers (56%) after Ecodriving training program while eight (44%) of the drivers increased their number of trips; only two drivers retained their number of trips. As for weekend evaluation, Table 5.8 revealed that eleven of the drivers increased number of stops; one driver decreased the value; four drivers retained their number of trips; and four had no revealing outcome of the average distance (i.e., with or without weekend trips) before and after the program.

Table 5.7 Manila drivers' weekday trip characteristics

	WEEKDAY TRIP CHARACTERISTIC			
	AVERAGE DISTANCE PER TRIP		**Number of Trips**	
DRIVER	km/trip, PRETEST	km/trip , POSTTEST	Number, Pretest	Number, Posttest
D1	3.37	5.38	17	10
D2	5.07	2.33	16	32
D3	5.55	4.67	4	4
D4	5.07	6.49	24	18
D5	10.40	7.59	15	19
D6	20.34	7.45	1	8
D7	7.31	8.02	15	13
D8	7.88	5.08	21	25
D9	23.53	13.42	12	8
D10	5.17	1.70	17	5
D11	17.17	18.49	13	5
D12	10.53	10.04	16	16
D13	5.44	7.70	10	20
D14	7.18	5.27	37	40
D15	8.08	6.81	15	13
D16	17.57	12.20	5	7
D17	11.96	5.68	14	5
D18	40.80	11.80	5	11
D19	2.53	4.79	26	9
D20	9.47	5.17	31	18

Table 5.8 Manila drivers' weekend trip characteristics

	WEEKEND TRIP CHARACTERISTIC			
	AVERAGE DISTANCE PER TRIP		Number of Trips	
DRIVER	km/trip, PRETEST	km/trip , POSTTEST	Number, Pretest	Number, Posttest
D1	2.62	5.85	1	2
D2	0.00	0.00	0	0
D3	17.64	7.29	1	3
D4	3.69	5.39	10	3
D5	10.65	10.28	1	7
D6	0.00	0.00	0	0
D7	9.07	10.57	1	3
D8	9.10	7.73	2	4
D9	15.20	5.00	2	2
D10	3.54	3.02	1	4
D11	3.09	12.23	2	3
D12	8.77	8.27	4	4
D13	5.56	0.00	3	0
D14	3.18	2.81	3	5
D15	5.71	0.00	4	0
D16	0.00	33.50	0	6
D17	0.00	5.68	0	5
D18	12.10	17.50	5	6
D19	1.64	2.75	2	5
D20	10.98	3.08	3	9

The driver's real-world driving operation in terms of stop duration and the number of stops were compared before and after the Ecodriving training program. Again, the characteristics were evaluated to check if there were changes in the drivers' trip characteristics after the Ecodriving information was introduced to the drivers which might be attributed to driving consciousness and environmental awareness. The trip data of each driver's real-world driving operation was divided between weekday and weekend trip. The examination of the duration of stop was taken at the traffic signal locations.

The result of the drivers' weekday trip evaluation in Table 5.9 revealed that thirteen (65%) of the drivers had an increased average duration of the stop after Ecodriving training. This longer (compared to normal driving) duration of stop could be attributed to the driver's application of the idling-stop technique at the traffic signal locations. The weekend trip characteristic, however, revealed that only five drivers had an increased duration of stop while eight drivers had a decreased duration of stop; two had no changes; and five drivers had no comparative results since the drivers' either did or did not travel during weekends.

Table 5.9 Manila drivers' average duration of stop

	AVERAGE DURATION OF STOP			
	Weekday Stop		Weekend Stop	
DRIVER	sec/stop, PRETEST	sec/stop, POSTTEST	sec/stop, PRETEST	sec/stop, POSTTEST
D1	29	17	14	22
D2	36	40	29	25
D3	70	43	34	16
D4	30	55	29	29
D5	31	39	47	37
D6	52	42	0	0
D7	28	40	52	31
D8	27	31	21	19
D9	37	53	34	57
D10	85	17	52	14
D11	37	44	38	36
D12	34	56	23	39
D13	41	52	54	0
D14	27	32	0	30
D15	25	24	38	0
D16	58	50	0	49
D17	37	43	0	35
D18	41	38	27	67
D19	35	61	29	25
D20	48	67	24	26

Table 5.10 Manila driver's total number of stop

	TOTAL NUMBER OF STOP			
	Weekday Stop		Weekend Stop	
DRIVER	total stops, PRETEST	total stop, POSTTEST	total stops, PRETEST	total stop, POSTTEST
D1	35	18	1	5
D2	75	24	9	17
D3	21	24	14	8
D4	56	88	6	22
D5	85	100	15	56
D6	17	45	0	0
D7	159	57	9	13
D8	98	48	17	18
D9	41	23	4	6
D10	139	5	7	18
D11	75	31	8	29
D12	104	77	8	2
D13	45	102	8	0
D14	109	78	0	8
D15	47	43	9	0
D16	32	33	0	37
D17	172	33	0	59
D18	116	21	47	10
D19	65	13	3	10
D20	77	35	9	12

Again, the trip data of each driver's real-world driving operation was divided between weekday and weekend trip. The examination of the number of stops was taken at the traffic signal locations. The result of the drivers' weekday trip evaluation in Table 5.10 revealed that fourteen (70%) of the drivers decreased total number of the stops after Ecodriving training. This reduced number of stops could be attributed to the driver's avoidance of stops particularly at the traffic signal locations (i.e., re-routing trips and taking shorter trips). The weekend trip characteristic, however, revealed that only eleven drivers increased total number of stops while only three drivers decreased; one did not change; and five drivers with no comparative results (either did or did not travel on weekends).

5.5 Real-World Fuel Economy Model

An interim prediction of the real-world fuel economy was generated for Manila and Tokyo drivers using linear regression to assess which of the predictor variables affected the outcome of the drivers' improvement (i.e., before and after fuel economy ratio) particularly in modeling the outcomes of real-world fuel economy improvements during idling and acceleration modes of Manila and Tokyo drivers. The model explored fourteen predictor variables (i.e., training and drivers' characteristics) that were considered for linear regression analysis of real-world fuel economy improvements (i.e., dependent variable) of the drivers. The matrix summaries of the drivers' real-world, training day and characteristics parameters are presented in Table 5.11 and Table 5.12 for the Manila drivers and Table 5.13 and Table 5.14 for the Tokyo drivers. These summaries are the basis of the regression analysis for Tokyo and Manila drivers' acceleration and idling real-world fuel economy evaluations.

Manila drivers' real-world acceleration (dependent variable) regression model (R^2=0.967) according to Eq. (1) revealed that maintenance practice was a significant predictor. This means that drivers characteristic of regular monthly maintenance (RMM) practice significantly increased and contributed to the real-world fuel economy improvement of the drivers. As for real-world idling (dependent variable), the regression results at R=0.590 in Eq. (2) revealed that Ecodriving results during training (TFE) was a significant predictor, meaning that the result of drivers' Ecodriving fuel economy significantly affected and contributed to the real-world fuel economy improvement of the drivers.

$$Y = 1.119 + 4.406RMM \quad (1)$$

$$Y = 0.275 + 5.398TFE \quad (2)$$

On the other hand, Tokyo drivers' real-world acceleration regression results at R=0.268 revealed that only vehicle engine displacement size (DSE) ranging between 1800cc-2000cc would increase the real-world fuel economy improvement, however, the model prediction was low and this was initially suspected to be attributed to the low sample size used for model building. As for real-world idling, regression (R=0.605) revealed that "normal driving fuel economy" and "car ownership" were significant predictor variables. The drivers' normal fuel economy during training (TNFE) and "car owned by family" (COF) were predictor variables that significantly (i.e., decreases) affected the outcome of the real-world fuel economy improvement of the drivers.

$$Y = 1.035 + 0.158DSE \quad (3)$$

$$Y = 5.786 - 24.991TNFE - 0.457COF \quad (4)$$

Table 5.11 Manila drivers' idling mode: drivers' improvements and characteristics

Driver	Training Day		Real-World		Drivers Characteristics											
	1	2	1	2	1	2	3	4	5	6	7	8	9	10	11	12
D1	0.260	0.100	0.236	0.251	1	3	1	1	2,4	2	5	2	2	1	1,5	3
D2	0.310	0.320	0.312	0.126	2	5	2	1	3	1	2	3	2	1	1,3	3
D3	0.350	0.120	0.222	0.411	1	3	1	1	3	1	3	2	2	1	1,3,5	4
D4	0.280	0.090	0.564	0.580	2	3	1	1	1	1	3	2	1	2	1,5	4
D5	0.390	0.180	0.415	0.398	1	5	2	1	1	1	4	3	1	1	1,3,5	3
D6	0.280	0.150	0.238	0.313	2	4	1	1	3	1	5	2	1	1	1,3,5	1
D7	0.270	0.110	0.400	0.410	1	3	2	1	3,4	3	2	3	1	1	1,4	3
D8	0.400	0.160	0.448	0.406	1	3	2	2	6	4	4	2	1	1	1	1
D9	0.440	0.180	0.239	0.155	1	2	1	1	1	1	3	3	2	1	1,3,5	3
D10	0.410	0.090	0.382	0.394	1	3	2	1	3,5	3	1	4	1	1	1,5	2
D11	0.390	0.130	0.265	0.263	1	3	2	1	1,4	1	2	4	1	2	1,3,4,5	3
D12	0.420	0.110	0.399	0.408	2	3	1	1	3,4,5	1	5	2	1	1	1,3,5	3
D13	0.370	0.140	0.214	0.191	2	3	1	1	1	1	3	2	2	1	1,3,5	3
D14	0.350	0.180	0.352	0.259	1	5	3	3	1	1	5	3	1	1	1,5	3
D15	0.310	0.120	0.274	0.293	1	4	3	1	3,4,5	3	7	3	1	1	1,5	4
D16	0.330	0.180	0.494	0.447	2	4	2	2	1	1	5	2	2	1	1,3,5	3
D17	0.350	0.130	0.265	0.247	1	3	2	1	3	4	1	2	2	1	1,5	1
D18	0.300	0.180	0.155	0.167	1	5	4	1	2	1	3	3	2	1	1,5	2
D19	0.300	0.230	0.391	0.383	1	2	2	1	3	2	3	2	2	1	1,5	5
D20	0.370	0.170	0.449	0.368	1	2	1	2	1,5	1	7	3	1	1	1,5	4

Where:
Training Data: idling fuel consumption during training-day, cc/sec (1: before; 2: after)
Real-World Data: idling fuel consumption during real-world, cc/sec (1: before; 2: after)
Drivers Personal Information:
1 Gender (1: male; 2: female)
2 Age (1: 20 and below; 2: 20-29; 3: 30-39; 4: 40-49; 5: 50-59; 6: 60-69; 7: 70 and above)
3 License Age (1: <20; 2: <20; 3: <30; 4: <40; 5: <50)
4 Car Usage (1: daily; 2: 3-4 times per week; 3:1-2 times per week; 4: 1-2 times per month; 5: 1 times per month)
5 Purpose (1: commuting; 2: school; 3: business; 4: shop; 5: leisure; 6: others)
6 Ownership (1: self; 2: family; 3: company; 4: others)
7 Income (1: <50000; 2: <100,000; 3: <500,000; 4 :< 1,000,000; 5: <5,000,000; 6: <10,000,000; 7:<100,000,000)
8 Engine Displacement (1: <1000; 2: 1000<1500; 3: 1500<2000; 4: 2000<2500; 5: 2500<3000; 6: 3000<3500)
9 Transmission Type (1: auto; 2: manual; 3: others)
10 Car Type (1: new; 2: used)
11 Accessories (1: air conditioning; 2: car navigation; 3: DVDs and CDs; 4: TV; 5: radio; 6: others)
12 Maintenance (1: >1 week; 2: 1 month; 3: 6 months; 4: 1 year; 5: < 1 year)

The initial evaluation of the models revealed good prediction for Manila drivers' real-world fuel economy; however, some of the models particularly for Tokyo drivers' group lacked the strength of prediction. This was already suspected to be due to limited sample size used for model building. Moreover, the step-wise approach of regression modeling also reduced the model to one or two significant predictor variables but more predictor variables could have been significant for the model if the sample size were larger. Nevertheless, this initial approach of modeling real-world fuel economy revealed promising approach to prediction and could be considered as basis for future exploration of model prediction.

Table 5.12 Manila drivers' acceleration mode: drivers' improvements and characteristics

Driver	Training Day			Real-World			Drivers Characteristics											
	1	2		1	2		1	2	3	4	5	6	7	8	9	10	11	12
D1	505.72	396.24	1.2763	8.119	5.401	1.503	2	5	2	1	3	1	2	3	2	1	1,3	3
D2	369.22	336.12	1.09848	5.293	7.003	0.756	1	3	1	1	3	1	3	2	2	1	1,3,5	4
D3	550.03	321.02	1.71338	9.397	9.239	1.017	1	5	2	1	1	1	4	3	1	1	1,3,5	3
D4	472.94	436.91	1.08247	10.386	9.209	1.128	1	3	2	1	3,4	3	2	3	1	1	1,4	3
D5	365.22	415.69	0.87859	12.584	9.917	1.269	1	3	2	2	6	4	4	2	1	1	1	1
D6	679.1	419.44	1.61906	6.239	7.541	0.827	1	2	1	1	1	1	3	3	2	1	1,3,5	3
D7	407.82	479.45	0.8506	5.864	6.979	0.840	1	3	2	1	1,4	1	2	4	1	2	1,3,4,5	3
D8	680.67	471.67	1.44311	13.027	10.403	1.252	2	3	1	1	3,4,5	1	5	2	1	1	1,3,5	3
D9	480.5	411.35	1.16811	5.481	5.535	0.990	2	3	1	1	1	1	3	2	2	1	1,3,5	3
D10	314.93	406.73	0.7743	10.264	7.086	1.449	1	5	3	3	1	1	5	3	1	1	1,5	3
D11	399.11	309.69	1.28874	10.800	9.325	1.158	1	4	3	1	3,4,5	3	7	3	1	1	1,5	4
D12	519.63	438.7	1.18448	7.700	6.461	1.192	1	3	2	1	3	4	1	2	2	1	1,5	1
D13	363.84	275.68	1.31979	5.229	0.947	5.525	1	5	4	1	2	1	3	3	2	1	1,5	2
D14	361.5	321.88	1.12309	8.495	7.353	1.155	1	2	2	1	3	2	3	2	2	1	1,5	5
D15	283.18	192.49	1.47114	11.150	9.911	1.125	1	2	1	2	1,5	1	7	3	1	1	1,5	4

Where:

Training Data: idling fuel consumption during training-day, cc/sec (1: before; 2: after)
Real-World Data: idling fuel consumption during real-world, cc/sec (1: before; 2: after)
Drivers Personal Information:
1 Gender (1: male; 2: female)
2 Age (1: 20 and below; 2: 20-29; 3: 30-39; 4: 40-49; 5: 50-59; 6: 60-69; 7: 70 and above)
3 License Age (1: <20; 2: <20; 3: <30; 4: <40; 5: <50)
4 Car Usage (1: daily; 2: 3-4 times per week; 3:1-2 times per week; 4: 1-2 times per month; 5: 1 times per month)
5 Purpose (1: commuting; 2: school; 3: business; 4: shop; 5: leisure; 6: others)
6 Ownership (1: self; 2: family; 3: company; 4: others)
7 Income (1: <50000; 2: <100,000; 3: <500,000; 4 :< 1,000,000; 5: <5,000,000; 6: <10,000,000; 7:<100,000,000)
8 Engine Displacement (1: <1000; 2: 1000<1500; 3: 1500<2000; 4: 2000<2500; 5: 2500<3000; 6: 3000<3500)
9 Transmission Type (1: auto; 2: manual; 3: others)
10 Car Type (1: new; 2: used)
11 Accessories (1: air conditioning; 2: car navigation; 3: DVDs and CDs; 4: TV; 5: radio; 6: others)
12 Maintenance (1: >1 week; 2: 1 month; 3: 6 months; 4: 1 year; 5: < 1 year)

Table 5.13 Tokyo drivers' idling mode: drivers' improvements and characteristics

Driver	Training Day		Real-World		Drivers Characteristics											
	1	2	1	2	1	2	3	4	5	6	7	8	9	10	11	12
D1	0.21	0.15	0.025	0.080	2	5	3	1	1	1	7	3	1	1	1,2,3,5	3
D2	0.20	0.14	0.335	0.457	1	3	2	1	1,3,4,5	1	6	3	3	1	2,4,5	3
D3	0.17	0.09	0.201	0.157	1	6	5	2	1	1	6	4	3	1	3,5	4
D4	0.15	0.04	0.126	0.047	1	4	3	1	1	3	7	3	1	1	1,3	3
D5	0.16	0.10	0.025	0.017	1	4	3	1	1	1	6	3	1	1	2	3
D6	0.18	0.10	0.197	0.294	2	5	3	2	4,5,6	2	6	2	1	1	1,3,5	3
D7	0.16	0.06	0.129	0.100	1	2	1	1	2	2	6	2	1	1	1,2,3	3
D8	0.21	0.12	0.283	0.333	1	4	4	1	1	1	6	4	1	1	1,2,3	3
D9	0.18	0.11	0.228	0.857	1	2	1	2	2,4	2	6	3	1	1	1,5	5
D10	0.20	0.09	0.270	0.291	1	2	1	3	5	1	4	4	2	2	3	3
D11	0.19	0.12	0.242	0.230	1	2	1	1	2	1	4	6	1	2	1,2,3	3
D12	0.19	0.11	0.188	0.185	1	2	1	2	4	1	5	4	1	1	1,3	3
D13	0.17	0.10	0.589	0.369	1	3	2	3	4,5	1	6	6	1	2	1,5	4
D14	0.19	0.08	0.192	0.199	1	2	1	1	1	1	5	3	1	1	1,3	3
D15	0.19	0.12	0.405	0.275	2	2	2	3	4	2	6		1	1	1,2,3,5	5
D16	0.19	0.11	0.191	0.160	2	4	3	2	1	1	7	3	1	1	1,5	4
D17	0,19	0.08	0.233	0.283	1	2	1	1	1	1	5	3	1	1	1,2	3
D18	0.19	0.09	0.095	0.108	1	4	3	2	4	1	6	3	1	1	1,2,3,4	5
D19	0.18	0.09	0.365	0.303	1	3	2	1	1,3,4,5	3	6	4	2	1	1,2,3,4,5	2
D20	0.17	0.09	0.204	0.217	1	2	1	3	4	2	6	4	1	1	1,2,3,5	3

Where:

Training Data: idling fuel consumption during training-day, cc/sec (1: before; 2: after)
Real-World Data: idling fuel consumption during real-world, cc/sec (1: before; 2: after)
Drivers Personal Information:
1 Gender (1: male; 2: female)
2 Age (1: 20 and below; 2: 20-29; 3: 30-39; 4: 40-49; 5: 50-59; 6: 60-69; 7: 70 and above)
3 License Age (1: <20; 2: <20; 3: <30; 4: <40; 5: <50)
4 Car Usage (1: daily; 2: 3-4 times per week; 3:1-2 times per week; 4: 1-2 times per month; 5: 1 times per month)
5 Purpose (1: commuting; 2: school; 3: business; 4: shop; 5: leisure; 6: others)
6 Ownership (1: self; 2: family; 3: company; 4: others)
7 Income (1: <50000; 2: <100,000; 3: <500,000; 4 :< 1,000,000; 5: <5,000,000; 6: <10,000,000; 7:<100,000,000)
8 Engine Displacement (1: <1000; 2: 1000<1500; 3: 1500<2000; 4: 2000<2500; 5: 2500<3000; 6: 3000<3500)
9 Transmission Type (1: auto; 2: manual; 3: others)
10 Car Type (1: new; 2: used)
11 Accessories (1: air conditioning; 2: car navigation; 3: DVDs and CDs; 4: TV; 5: radio; 6: others)
12 Maintenance (1: >1 week; 2: 1 month; 3: 6 months; 4: 1 year; 5: < 1 year)

Table 5.14 Tokyo drivers' acceleration mode: drivers' improvements and characteristics

Driver	Training Day		Real-World		Drivers Characteristics											
	1	2	1	2	1	2	3	4	5	6	7	8	9	10	11	12
D1	420.70	406.36	4.232	4.003	2	5	3	1	1	1	7	3	1	1	1,2,3,5	3
D2	516.46	507.24	7.379	7.036	1	3	2	1	1,3,4,5	1	6	3	3	1	2,4,5	3
D3	582.98	437.68	6.592	5.942	1	6	5	2	1	1	6	4	3	1	3,5	4
D4	661.10	429.13	5.969	5.124	1	4	3	1	1	3	7	3	1	1	1,3	3
D5	450.81	490.85	5.188	3.224	1	4	3	1	1	1	6	3	1	1	2	3
D6	551.33	412.05	5.100	5.179	2	5	3	2	4,5,6	2	6	2	1	1	1,3,5	3
D7	387.03	450.82	4.622	3.849	1	2	1	1	2	2	6	2	1	1	1,2,3	3
D8	413.27	498.28	7.194	7.060	1	4	4	1	1	1	6	4	1	1	1,2,3	3
D9	547.60	362.64	7.169	5.979	1	2	1	2	2,4	2	6	3	1	1	1,5	5
D10	480.54	489.21	5.626	5.369	1	2	1	3	5	1	4	4	2	2	3	3
D11	638.25	505.78	5.097	5.554	1	2	1	1	2	1	4	6	1	2	1,2,3	3
D12	577.59	449.46	6.008	5.491	1	2	1	2	4	1	5	4	1	1	1,3	3
D13	383.16	582.55	12.263	11.360	1	3	2	3	4,5	1	6	6	1	2	1,5	4
D14	556.43	504.02	5.337	5.194	1	2	1	1	1	1	5	3	1	1	1,3	3
D15	734.73	539.07	8.101	6.252	2	2	2	3	4	2	6		1	1	1,2,3,5	5
D16	658.47	485.11	7.407	5.763	2	4	3	2	1	1	7	3	1	1	1,5	4
D17	523.18	391.39	4.753	4.123	1	2	1	1	1	1	5	3	1	1	1,2	3
D18	825.41	478.35	2.417	2.204	1	4	3	2	4	1	6	3	1	1	1,2,3,4	5
D19	435.50	290.26	6.186	6.317	1	3	2	1	1,3,4,5	3	6	4	2	1	1,2,3,4,5	2
D20	592.43	408.05	6.723	7.301	1	2	1	3	4	2	6	4	1	1	1,2,3,5	3

Where:

Training Data: idling fuel consumption during training-day, cc/sec (1: before; 2: after)
Real-World Data: idling fuel consumption during real-world, cc/sec (1: before; 2: after)
Drivers Personal Information:
1 Gender (1: male; 2: female)
2 Age (1: 20 and below; 2: 20-29; 3: 30-39; 4: 40-49; 5: 50-59; 6: 60-69; 7: 70 and above)
3 License Age (1: <20; 2: <20; 3: <30; 4: <40; 5: <50)
4 Car Usage (1: daily; 2: 3-4 times per week; 3:1-2 times per week; 4: 1-2 times per month; 5: 1 times per month)
5 Purpose (1: commuting; 2: school; 3: business; 4: shop; 5: leisure; 6: others)
6 Ownership (1: self; 2: family; 3: company; 4: others)
7 Income (1: <50000; 2: <100,000; 3: <500,000; 4 :< 1,000,000; 5: <5,000,000; 6: <10,000,000; 7:<100,000,000)
8 Engine Displacement (1: <1000; 2: 1000<1500; 3: 1500<2000; 4: 2000<2500; 5: 2500<3000; 6: 3000<3500)
9 Transmission Type (1: auto; 2: manual; 3: others)
10 Car Type (1: new; 2: used)
11 Accessories (1: air conditioning; 2: car navigation; 3: DVDs and CDs; 4: TV; 5: radio; 6: others)
12 Maintenance (1: >1 week; 2: 1 month; 3: 6 months; 4: 1 year; 5: < 1 year)

5.6 Conclusions

The study focused on the effectiveness of Ecodriving program on the driver's driving style in real-world driving condition. First, the effect of the Ecodriving program before and after Ecodriving training program in the case of the Manila drivers was investigated in relation to fuel economy, fuel consumption, engine speed and speed values during the acceleration, cruising, and deceleration modes. The study was able to demonstrate that Ecodriving program significantly affected the outcome of the cruising and deceleration modes of drivers' driving style in real-world driving operation. However, the starting acceleration mode of the driving operations was not significant.

Moreover, the results of idling-stop and gentle acceleration techniques of the Ecodriving program using both training and real-world data in the case of the Manila as well as Tokyo drivers further revealed that even as there were improvements in real-world driving, the results among some drivers were not significant, and that the relationship between the fuel economy during the Ecodriving training and that in the real-world was not necessarily related. Therefore, Ecodriving program needs to examine how the guidelines for idling-stop and gentle acceleration could be improved or enhanced to further advance the real-world driving operation in developing as well as developed country applications.

In relation to the relationship between improvements in real-world driving and the characteristics of the drivers in Manila and Tokyo, it was found that female drivers practiced idling-stop better than male drivers, while male drivers practiced gentle start better than the females. The initial evaluation of real-world fuel economy model also revealed that training-day results and the drivers' characteristics affected the drivers' improvement after Ecodriving, and these models can be explored further for future model prediction.

CHAPTER 6

RECOMMENDED MODIFICATIONS OF ECODRIVING PROGRAM FOR DEVELOPING COUNTRY APPLICATION

6.1 Discussions on the Results of the Previous Chapters

The previous Chapters presented the results of the Ecodriving guidelines in three areas of undertaking: the driving behavior (i.e. non-psychological and psychological), the training and the real-world driving evaluations.

The training day evaluation in Chapter 4 reflected that most drivers improved on the driving performance when they followed and applied the guidelines and techniques of the Ecodriving program. The outcome of drivers' improvements in the fuel economy and the driving operation on the training day showed very significant results when the drivers were motivated and encouraged to apply the technique, and were able to appreciate firsthand via diagnostic results of their improvement of driving. However, the effectiveness of the Ecodriving program in this case may solely be attributed to specific application of the guidelines and adherence to follow the technique during the test drives of the training day. The results during the training may not be reflective of the real-world Ecodriving application of the drivers. Success of the training results may also be attributed to the predefined route during the test drive. The conditioning of the driver to drive along this predefined route may be too ideal to reflect the actual scenario of driving. Controlled conditions of driving during test drive only might encourage the promotion of Ecodriving on short term application, but this may not be reflective of driver's attitude for long term Ecodriving application. Drivers could forget the technique and go back to their old habits and way of driving. The greater challenge of successful Ecodriving programs would then greatly depend on driver's decisiveness and prudence in adopting the Ecodriving way of driving for long term.

The results of Chapter 5 revealed the outcome of the drivers' driving operation in real-world application after the Ecodriving training day. This Chapter revealed that the driver's driving operation yield very significant results in the application of Ecodriving technique on two specific modes: cruising and deceleration. These results were primarily attributed to the drivers' awareness to apply steady speed (i.e., when cruising) and slowing down gently (i.e., when decelerating) in real-time traffic situation. However, the idling-stop and gentle acceleration techniques were not used significantly among the drivers. Therefore further evaluation of these two modes was addressed by isolating the acceleration and idling traces of each driver along their stops at traffic signal location using GPS data. The vehicle parameters (such speed, fuel consumption values, distance, time and engine speed values) were evaluated and the drivers with significant results were filtered from the general group and further evaluated in terms of high, low and medium improvements during idling and acceleration at intersection signal stop scenarios. This data revealed that the applications of idling-stop were generally practiced by female group of the drivers (for both Manila and Tokyo cases) and the applications of gentle acceleration were favorably practiced by male drivers (again for both Manila and Tokyo cases). However, as previously indicated, the training outcomes among the drivers were not related with the outcomes of their real-world applications. Therefore, Ecodriving training results were not reflective of the outcome of the drivers' Ecodriving in real-world. Furthermore, the observation of the data of Ecodriving such as idling-stop and gentle acceleration revealed that some drivers choose to apply the technique only at specific portions of the trip. There were specific locations of traffic intersections where the drivers chose to ignore the techniques. In real-world Ecodriving applications, the drivers may desire to apply the technique not in the entire trip but only along the specific locations. This may be one tendency among the drivers in developing countries when they are presented with congestion issues or queues at intersection stops etc., and their adherence to Ecodriving is compromised.

6.2 Evaluation of the Ecodriving Program for Developing Country Application

The Ecodriving program evaluation of Tokyo and Manila in this study was made possible by the generous support of the Energy Conservation Center of Japan (ECCJ) and the Institute of Behavioral Sciences (IBS). The Ecodriving evaluations conducted in this study were also made possible by presetting compatible vehicle instrumentations (i.e., OBDs, fuel gauge and GPS) for Japanese car models. Moreover, the Japan Ecodriving guideline was adopted and highly considered over the Ecodriving guidelines in Europe since most car fleet in the Philippines and other Asian markets were Japanese car models. Combining the results in Chapters 4 and Chapter 5, this section reviews in detail the Ecodriving guidelines and recommended modifications of the Japan Ecodriving program which are built from the result of the experimental evaluation of the Manila drivers that represent the drivers in developing country settings. The modified Ecodriving program would be recommended for future applications of Ecodriving program in developing country settings, by operation modes namely: acceleration, cruising, deceleration and idling.

6.2.1Acceleration

Ecodriving recommendation advises that at the start of acceleration, one should start the drive by gently accelerating and speeding without necessarily warming up the engine. By pressing the accelerator pedal little more gently compared to a normal start-up, fuel consumption can be significantly reduced by around 10%. This recommendation is known as gentle acceleration. In the gentle acceleration mode, the guideline indicates to reach a gradual and smooth acceleration up to 20 kph in the first 5 seconds without any deceleration.

The operational method in adopting the gentle acceleration technique indicates that drivers should:

1. Move the foot from the brake pedal to the accelerator in one clean sweep, lightly stepping on the accelerator pedal and gently pressing the pedal inch by inch or by fraction;
2. As the speed increases, slowly increase the pressure on the pedal.
3. To avoid over-acceleration, release the pedal pressure a little when approaching the target speed.
4. It is also recommended to check the engine speed (i.e., RPM) since Ecodriving promotes that during gentle acceleration stage the engine RPM should not reach beyond 1800 RPM.

According the results of this study, the drivers were easily assumed to conduct gentle acceleration; however, in real-world application, when the drivers were in haste, the gentle acceleration technique was compromised. This kind of case was most often observed when drivers were in a rush to avoid peak hour congestion and traffic, which might be typically found in most developing countries. On the other hand, it is also worthy to note that, drivers behave better in adopting gentle acceleration technique at intersection stops. In real-world application, some drivers applied the gentle acceleration technique independent of the idling-stop technique at intersection stops, and even randomly applied the technique at some intersections. The technique independent of the idling-stop technique can be easily adopted by experienced drivers with newer models and automatic transmission rather than manual transmission types. Thus, in the modification of the Ecodriving program for developing countries, the application of gentle acceleration of Ecodriving technique could be included if the drivers were not badly affected by peak hour congestion, and the implementation would be eased (more) by newer models with automatic transmission.

6.2.2 Cruising and Deceleration

The Ecodriving guidelines for the cruising mode are generally aimed to maintain steady speed when driving. The cruising practical advisory indicates that the driver should drive with a little speed adjustment by "5 kph lower" than the actual speed limit. It also indicates that the driver should maintain a distance margin of at least two cars in order to anticipate the flow of traffic. Otherwise, short distance margin may affect the changes in speed between cars and become erratic with accompanied speed fluctuations. By controlling speed changes, fuel consumptions can be reduced by 3.4 %. Also, when driving in constant speed, the Ecodriving cruising guideline advises using higher gear as it results to lower fuel consumption. Cruising practical advisory also indicates that the driver should anticipate the traffic flow while driving at constant speed.

The operational method in adopting the steady cruising technique indicates that the driver should:

1. Anticipate the traffic ahead. Instead of using the brakes, ease pressure on the accelerator pedal when slowing down.
2. When changing speed, use the accelerator pedal to modify the speed gently.
3. By making minor adjustments on the accelerator pressure, set appropriate distance or allowance with the car in front so one can control ones speed.

In relation to deceleration, Ecodriving advises to decelerate by easing pressure on the accelerator pedal slowly. When the accelerator pedal is released while a car is moving, the vehicle keeps moving due to inertia, enabling the vehicle to move with less fuel consumption. Thus, when one needs to stop, the accelerator pedal should be released early and the driver decelerates the car using the engine brake. By releasing the accelerator pedal early, fuel consumption can be reduced by 2.1%.

The operational method in adopting the Ecodriving deceleration technique also indicates that the driver should release the accelerator pedal (moving due to inertia 200 m) at 60 kph, reducing speed gradually to 40 kph until the vehicle starts to slow down and stops.

For the recommended modifications for cruising and deceleration of Ecodriving program in developing country, as revealed in the results of the Ecodriving application in real-world, the cruising and deceleration techniques of the Ecodriving guidelines would be suitable for developing country application. It would be safe to say that candidate drivers could easily adapt the technique when the conditions of the traffic were favorable. While for intra-city driving, observable stop-and-go conditions of traffic as well as delay and congestion might preset the challenge of the technique, long distance trips and trips in sub-urban or rural areas with less traffic signal stops would also be favorable for the application. One concern might be that their travel times were sacrificed, however, the inclusion of cruising and deceleration into the program is considered to be reasonable even in developing country settings.

6.2.3 Idling

Ecodriving promotes the application of idling-stop. Ecodriving guideline for idling-stop operation indicates that when the vehicle is stopped due to traffic signals, minor hazards, or when parking, the driver should switched off the engine; particularly when the stop time duration extends for more than 5 seconds, because the idle vehicle would still consume fuel when the engine is not switched-off. Fuel savings during idling-stop are more felt overtime when more frequently experienced at the traffic signal stops.

In terms of the idling-stop guideline of the Ecodriving program for developing country application, it was found that this guideline might not be favorable in developing country settings considering the following comments and feedback among the candidate drivers:

1. Developing countries prevalently have second-hand and older vehicle fleet in the market which may not favorable to the idling-stop technique;
2. Battery maintenance problem and cost issues when idling-stop would be frequently adopted or when applied on vehicles with low maintenance might cause problems;

3. Climate and in-vehicle temperature condition would be an issue; drivers would not follow the Ecodriving guidelines when they have to regularly adjust the in-vehicle air-conditioning system and the heater.
4. Some drivers felt that the guidelines would be cumbersome to maneuver particularly when the idling-stop technique would be applied at traffic intersections with long queues and congestion problem.

Therefore the idling-stop technique may not be an applicable guideline in some developing country settings. However, even in the case of Manila study, about 30% of the drivers were assumed to implement the guideline. While the introduction of the idling-stop guideline needs caution, it might be too much to exclude it from the program.

6.2.4 Modified Guidelines for Developing Country Ecodriving Program

The summary of Ecodriving guidelines in Table 6.1 presents the recommended modifications of Ecodriving program for developing country application. The inclusion of cruising and deceleration into the program is considered to be reasonable even in developing country settings as revealed in the Manila drivers' evaluation. The application of gentle acceleration of Ecodriving technique could be included if the drivers are not badly affected by traffic conditions such as peak hour congestion etc. and the implementation would be more favorable and eased by the influx of newer models of car fleet with automatic transmission. In relation to the idling-stop technique, while the introduction of the idling-stop guideline needs caution; prudent switching off the engine when the conditions of the traffic and the vehicle are applicable would still be part of the recommendations for the guidelines.

Table 6.1 Ecodriving program for developing country application

Driving Mode	Ecodriving Guidelines	Advisory
Acceleration (A) “Gentle starting acceleration”	Slowly accelerate to 20 kph within 5 seconds at low engine speed (1500RPM-1800 RPM)	Slowly press the accelerator pedal; smoothly and slowly increase pedal pressure to increase speed; and warm-up the engine while moving the vehicle in this manner.
Cruise (C) “Constant and steady cruising”	Maintain constant and steady speed: lower by 5 kph of the actual road speed limit at higher gear	Prudently maintain front-clearance or margin of two cars; gently adjust the pressure on the accelerator pedal when changing speed; and anticipate traffic condition by driving along (with) the flow of the traffic stream.
Deceleration (D) ‘Gentle deceleration”	Gently release pressure on the accelerator pedal to slow down by engine braking (when applicable) before stepping on the brake pedal	Slowly ease on the accelerator pedal; allow vehicle to engine brake; and gently depress the brake pedal to stop.
Idling (I) “Prudent idling-stop”	Prudently switch-off engine when vehicle is idle	When favorable traffic conditions and vehicle (i.e. battery, engine, safety etc.) conditions allow, apply idling-stop. Caution: *Avoid idling-stop when vehicle stands along a steep road slope.*

6.3 Conclusions

This chapter reviewed the evaluation of the Ecodriving technique and programs in three areas of undertaking (behavior, training and real-world) for the investigation of the effectiveness of Ecodriving for developing country application. The results revealed that Ecodriving guideline was effective in curbing driving attitudes during training as revealed in their improvement after undergoing Ecodriving program. However, there were prevailing factors that affected the actual real-world results of applying the Ecodriving techniques. The factors were primarily attributed to actual environment and behavior of the drivers in real-world environment which somehow compromised the Ecodriving application in some modes or techniques.

For the recommended modifications for cruising and deceleration of Ecodriving program in developing country, the inclusion of cruising and deceleration into the program was considered to be reasonable even in developing country settings. The application of gentle acceleration of Ecodriving technique could be included if the drivers were not badly affected by peak hour congestion, and the implementation was eased by newer models with automatic transmission. In relation to the idling-stop technique, while the introduction of the idling-stop guideline needed carefulness, it might be too much to exclude it from the program.

CHAPTER 7

CONCLUSIONS AND FURTHER STUDIES

7.1 Conclusions

Because of the depleting reserves of fossil fuels and the concern on global warming and climate change due to increasing CO_2 emissions, some developed and developing countries have made future plans for reducing CO_2 emissions from transportation. While the introduction of hybrid and electric cars and provision of less carbon-intensive public transportation are common policy measures in these plans, the measures of Ecodriving or Ecodrive, are also suggested because the penetration of new cars takes time and the provision of public transportation might not be so effective in small or medium-sized cities.

In real-world application of Ecodriving, on-road fuel consumption and emission values are influenced by driving patterns which are in turn directly influenced by external factors such as: traffic characteristics, road characteristics, vehicle characteristics, driver's characteristics, trip characteristics and other possible variables. To capture all this factors will require intensive investigation of outcome before and after Ecodriving program. Thus, this study limited itself to investigate the outcome of Ecodriving program based on driver's characteristics and road characteristic. Specially, it focused on the similarities and differences observed from the results of the Ecodriving programs in developing (Manila) and developed (Tokyo) countries.

The general intent of this study was to develop and assess Ecodriving program for developing country application vis-à-vis developed country application in real-world as well as pre-defined test route settings. The general objective of this study was to promote and demonstrate Ecodriving program in developing country settings. To achieve this objective, the study specifically:

1. evaluated the vehicle parameters on real-time and real-world driving operation;
2. quantified and evaluate drivers' performance and fuel economy; and
3. formulated program guidelines for policy recommendations.

First, this study was able to demonstrate that Ecodriving program significantly affected the overall fuel economy during the Ecodriving training day suggesting that drivers could adopt well the

Ecodriving techniques in developing country as well as developed country settings. However, the results in terms of the drivers' driving operation (i.e., acceleration, cruising, and deceleration) or modes, the Ecodriving program needed to be improved to further advance the application of Ecodriving program in developing countries.

With respect to the driver's psychological aspects, it was found that rough driving influenced the absolute fuel economy in Tokyo at 10% level of significance. If it is possible to know the psychological and non-psychological characteristics of the participants of the Ecodriving program in advance, it might be able to improve the program by incorporating those characteristics. However, significant characteristics of the participants in Manila drivers were not found fully.

Second, this study also focused on the effectiveness of Ecodriving program on the driver's driving style in real-world driving condition. The effect of the Ecodriving program before and after Ecodriving training in the case of the Manila drivers was investigated in relation to fuel economy, fuel consumption, engine speed and speed values during the acceleration, cruising and deceleration modes. The study was able to demonstrate that Ecodriving program significantly affected the outcome of the cruising and deceleration modes of the drivers' driving style in real-world driving operation. However, the starting acceleration mode of the driving operations was not significant.

Moreover, the results of idling-stop and gentle acceleration techniques of the Ecodriving program using both training and real-world data in the case of the Manila as well as Tokyo drivers further revealed that even as there were improvements in real-world driving, the results among some drivers were not significant, and that the relationship between the fuel economy during the Ecodriving training and that in the real-world was not necessarily related. Therefore, the Ecodriving program needed to examine how the guidelines for idling-stop and gentle acceleration could be improved or enhanced to further advance the real-world driving operation in developing as well as developed country applications.

In relation to the relationship between improvements in real-world driving and the characteristics of the drivers in Manila and Tokyo, it was found that female drivers practiced idling-stop better than male drivers, while male drivers practiced gentle start better than the females. Aside from gender, other socio-economic variables were found to affect the adoption of idling-stop and gentle acceleration in real-world driving.

Third, the discussion on the recommended modifications of Ecodriving program in developing country settings was conducted.

For cruising and deceleration of Ecodriving program, the inclusion of cruising and deceleration into the program was considered to be reasonable even in developing country settings. The application of gentle acceleration of Ecodriving technique could be included if the drivers were not badly affected by peak hour congestion, and the implementation was eased by newer models with automatic transmission. In relation to the idling-stop technique, while the introduction of the idling-stop guideline needed carefulness, it might be too much to exclude it from the program.

7.2 Further Studies

Since most developing countries have different transportation environment, it is recommended to conduct initiatives that will investigate the applicability of the guidelines for the local or regional application, particularly, by looking at the factors that may constrain its application such as road environment and cultural adoptability by the driver. It is also appropriate to encourage trainings of the driver in a more focused group orientation so as to ensure the success of demonstrating the effectiveness of Ecodriving program.

This study also needs to investigate further the real-world Ecodriving in relations to factors that extends to road characteristics and vehicle characteristics. Particularly, in terms of road characteristics, developing countries have variable road environment, and in terms of vehicle characteristics, most developing countries have mixed modes of transport as well as variable vehicle models. It would also be important to consider the effect of Ecodring program on the driver's driving behavior after training. Particularly, traffic characteristics (i.e., peak, non-peak, congestion level, etc.), trip characterization (i.e., travel distance, trip purpose, trip time, etc.), road characteristics (i.e., road slopes, number of lanes, etc.) and the effect of the Ecodriving- trained driver's driving style on other drivers' driving style in the traffic stream. It is also worthy to explore the advantage and disadvantage of Ecodriving guidelines in relation to idling and acceleration as well as external effects such as delay and congestion that preset the challenge of the Ecodriving programs in real-world developing country application.

Annex A

Drivers Pretest Questionnaire

(English Format)

DRIVER'S QUESTIONNAIRE (A)

Paper No: ____________ Date: ________________________

This questionnaire is part of an academic research project at Tokyo Institute of Technology. This will only serve to understand driver's characteristics and behavior. Your answers are highly valuable and will help advance information on driving research. It will only about five (5) minutes to complete the questionnaire. All information will be held confidential and will serve only for purpose of academic research. Thank you very much for your kind cooperation.

Tokyo Institute of Technology

(A) Driving Information. Please answer the following questions about your driving habits. Encircle the appropriate number that describes what is "most like you".

	Not like Me at all	Not Like Me	Neither	Like Me	Very much like Me
1 Bad drivers should let others go on first	1	2	3	4	5
2 I use engine brakes on downhill slopes	1	2	3	4	5
3 I practice switching-off the engine (idling stop) when stopping (signal light) or parking	1	2	3	4	5
4 Driving is so fun	1	2	3	4	5
5 I get very tired, even after driving a little	1	2	3	4	5
6 There are times when I can't decide and don't know what to do	1	2	3	4	5
7 I get flustered when someone gives me the right of way	1	2	3	4	5
8 I sometimes get distracted when others are in the car and don't drive normally	1	2	3	4	5
9 I'm not good at backing into a parking space	1	2	3	4	5

10 I tend to drive "pretty" awkwardly	1 • • • • 2 • • • • 3 • • • • 4 • • • • 5
11 I think I drive indecisively and am poor at driving in a timely manner	1 • • • • 2 • • • • 3 • • • • 4 • • • • 5
12 I always have a strong desire to drive fast	1 • • • • 2 • • • • 3 • • • • 4 • • • • 5

	Not like Me at all	Not Like Me	Neither	Like Me	Very much like Me
13 People observe and say I drive aggressively	1	2	3	4	5
14 I get irritated when a pedestrian crosses the road slowly	1	2	3	4	5
15 In a traffic jam, if someone cuts in from the side, I feel that I've been robbed of space	1	2	3	4	5
16 I pay attention to my driving by lessening my acceleration and deceleration	1	2	3	4	5
17 I often check the air pressure in my tires	1	2	3	4	5
18 Driving gives me something to live for	1	2	3	4	5
19 When I get upset at work or studying, I feel like driving	1	2	3	4	5
20 I sometimes park illegally on the street	1	2	3	4	5
21 If it doesn't cause an accident, a small violation can be overlooked	1	2	3	4	5
22 Driving at the speed limit causes traffic jams and is rather an annoyance	1	2	3	4	5
23 Getting caught for disobeying traffic rules is bad luck	1	2	3	4	5
24 I like the feeling of accelerating when I start to drive	1	2	3	4	5

25 I take notice on the cars around me after I turn

the steering the wheel 1 • • • • 2 • • • • 3 • • • • 4 • • • • 5

26 I something can't get the timing for changing lanes right 1 • • • • 2 • • • • 3 • • • • 4 • • • • 5

27 When waiting to turn left, I cannot sometimes get the "right timing" right. 1 • • • • 2 • • • • 3 • • • • 4 • • • • 5

28 When I'm heading to a traffic jam, I sometimes enter a minor bypass (or side) road 1 • • • • 2 • • • • 3 • • • • 4 • • • • 5

29 I can always turn left quickly so I don't have to wait at the traffic light 1 • • • • 2 • • • • 3 • • • • 4 • • • • 5

30 I drive with things in the car that I don't need 1 • • • • 2 • • • • 3 • • • • 4 • • • • 5

31 When merging in traffic, I sometimes don't know whether to go or stop 1 • • • • 2 • • • • 3 • • • • 4 • • • • 5

	Not like Me at all	Not Like Me	Neither	Like Me	Very much like Me
32 I sometimes get mad at the driving of others	1	2	3	4	5
33 I get irritated if I have to stop at the traffic light often	1	2	3	4	5
34 It can't be helped if I drive a little over the speed limit	1	2	3	4	5
35 I accelerate if there is no one in front of me	1	2	3	4	5
36 I try to start gently	1	2	3	4	5
37 I am often concerned about the condition of the battery	1	2	3	4	5
38 Sometimes I go for a drive for no reason at all	1	2	3	4	5
39 When I buy a car, I buy one that I can boast	1	2	3	4	5
40 (For those with automatic transmission) I try to use over drive	1	2	3	4	5
41 (For those with manuals) I try to use high gear	1	2	3	4	5

42 I make it a rule to check the car before I start driving 1・・・・2・・・・3・・・・4・・・・5

43 I always fill the tank full (at the gas station) 1・・・・2・・・・3・・・・4・・・・5

44 I tend to change lanes often 1・・・・2・・・・3・・・・4・・・・5

45 I just casually change lanes 1・・・・2・・・・3・・・・4・・・・5

46 I get irritated when someone is slow getting out or off the car in front of me (ex. school zone) 1・・・・2・・・・3・・・・4・・・・5

47 I get mad if someone honks their horn at me from behind 1・・・・2・・・・3・・・・4・・・・5

48 I think it's unfair that, though many drivers disobey the rules, only some drivers are caught 1・・・・2・・・・3・・・・4・・・・5

49 I don't feel good if my pace is interrupted 1・・・・2・・・・3・・・・4・・・・5

50 I tend to have no confidence in my driving 1・・・・2・・・・3・・・・4・・・・5

51 I often check the road traffic information 1・・・・2・・・・3・・・・4・・・・5

52 I tend not to use the air conditioner in summer or rainy season 1・・・・2・・・・3・・・・4・・・・5

53 I take off as soon as I start the engine 1・・・・2・・・・3・・・・4・・・・5

54 The reason it's hard to obey traffic rules is because there is a problem with the rules themselves 1・・・・2・・・・3・・・・4・・・・5

55 I don't know why they set speed "sensors" at places where people can't help driving fast 1・・・・2・・・・3・・・・4・・・・5

(B) Kindly save this are for your any possible comments and recommendation on Ecodrive training.

Annex B

Drivers Posttest Questionnaire

(English Format)

DRIVER'S QUESTIONNAIRE (B)

Paper No: ____________ Date: ________________________

This questionnaire is part of an academic research project at Tokyo Institute of Technology. This will only serve to understand driver's characteristics and behavior. Your answers are highly valuable and will help advance information on driving research. It will only about five (5) minutes to complete the questionnaire. All information will be held confidential and will serve only for purpose of academic research. Thank you very much for your kind cooperation.

(A) Vehicle information. Please fill in the space provided or encircle (O) your answer among the given choices.

1. What type (brand and model) of car do you drive? (______________________________)
2. What is its engine displacement? (________________ cc)
3. What is its engine transmission type?
(Automatic Manual CVT Others_______________________________)
4. What type of fuel does it run?
(Gasoline Diesel Others _____________________________________)
5. Who owns the car?
(Self-owned Family Company Others_______________)
6. What year was the car purchased? (______________________)
Upon purchase, the car is: (NEW or OLD)
If OLD, when was your car first registered? (_________________)
7. What is the Odometer reading of your car? (________________km)
8. What car accessory do you often use? (Can be multiple answers)
(Air Condition Car Navigation System DVD/CD Player

Car TV Radio Others____________________)

9. How often do you do maintenance check-up?

(More than once a week At least once a month At least once every six months

At least once a year Not at all, only when necessary)

(B) Driving Information. Please answer the following questions about your driving habits. Encircle the appropriate number that describes what is "most like you".

	Not like Me at all	Not Like Me	Neither	Like Me	Very much like Me
1. I tend to change lanes often	1	2	3	4	5
2. I just casually change lanes	1	2	3	4	5
3. I get irritated when someone is slow getting out or off the car in front of me (ex. school zone)	1	2	3	4	5
4. I get mad if someone honks their horn at me from behind	1	2	3	4	5
5. I don't feel good if my pace is interrupted	1	2	3	4	5
6. I tend to have no confidence in my driving	1	2	3	4	5
7. I think it's unfair that, though many drivers disobey the rules, only some drivers are caught	1	2	3	4	5
8. The reason it's hard to obey traffic rules is because there is a problem with the rules themselves	1	2	3	4	5
9. I don't know why they set speed "sensors" at places where people can't help driving fast	1	2	3	4	5
10. I often check the road traffic information	1	2	3	4	5
11. I tend not to use the air conditioner in summer or rainy season	1	2	3	4	5
12. I take off as soon as I start the engine	1	2	3	4	5

13. I always fill the tank full (at the gas station)	1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
14. I'm not good at backing into a parking space	1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
15. I tend to drive "pretty" awkwardly	1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
16. I think I drive indecisively and am poor at driving in a timely manner	1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
17. I always have a strong desire to drive fast	1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
18. People observe and say I drive aggressively	1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
19. I get irritated when a pedestrian crosses the road slowly	1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
20. In a traffic jam, if someone cuts in from the side, I feel that I've been robbed of space	1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

	Not like Me at all	Not Like Me	Neither	Like Me	Very much like Me
21. Bad drivers should let others go on first	1	2	3	4	5
22. I get very tired, even after driving a little	1	2	3	4	5
23. There are times when I can't decide and don't know what to do	1	2	3	4	5
24. I get flustered when someone gives me the right of way	1	2	3	4	5
25. I sometimes get distracted when others are in the car and don't drive normally	1	2	3	4	5
26. I pay attention to my driving by lessening my acceleration and deceleration	1	2	3	4	5
27. I often check the air pressure in my tires	1	2	3	4	5
28. I use engine brakes on downhill slopes	1	2	3	4	5
29. I practice switching-off the engine (idling stop) when stopping (signal light) or parking	1	2	3	4	5
30. Driving is so fun	1	2	3	4	5
31. Driving gives me something to live for	1	2	3	4	5

32. When I get upset at work or studying, I feel like driving 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
33. I take notice on the cars around me after I turn the steering the wheel 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
34. I something can't get the timing for changing lanes right 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
35. When waiting to turn left, I cannot sometimes get the "right timing" right. 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
36. When merging in traffic, I sometimes don't know whether to go or stop 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
37. I sometimes get mad at the driving of others 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
38. I get irritated if I have to stop at the traffic light often 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
39. It can't be helped if I drive a little over the speed limit 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
40. I accelerate if there is no one in front of me 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

	Not like Me at all	Not Like Me	Neither	Like Me	Very much like Me

41. When I'm heading to a traffic jam, I sometimes enter a minor bypass (or side) road 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
42. I can always turn left quickly so I don't have to wait at the traffic light 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
43. I drive with things in the car that I don't need 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
44. I try to start gently 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
45. (For those with automatic transmission) I try to use over drive 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5
46. (For those with manuals) I try to use high gear 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

47. I am often concerned about the condition of the battery 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

48. I make it a rule to check the car before I start driving 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

49. I sometimes park illegally on the street 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

50. If it doesn't cause an accident, a small violation can be overlooked 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

51. Driving at the speed limit causes traffic jams and is rather an annoyance 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

52. Getting caught for disobeying traffic rules is bad luck 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

53. I like the feeling of accelerating when I start to drive 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

54. Sometimes I go for a drive for no reason at all 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

55. When I buy a car, I buy one that I can boast 1 · · · · 2 · · · · 3 · · · · 4 · · · · 5

(C) Personal information.

1. Gender: (Female Male)
2. Age: (-19 20-29 30-29 40-49 50-59 60-69 70- years old)
3. How many members are in your household including yourself? (member/s)
4. How many years have you been driving since your first license? (year/s)
5. Have you ever participated in an Ecodriving Program? (Yes No)
6. Line or type of work:
Office/Business (full time) Part-time job Student Housewife/husband
Independent Business Unemployed Others: ________________________

7. Academic attainment:
(Elementary Graduate High School Graduate 2-year College Graduate
Vocational/Technical School College Graduate)
8. Frequency of driving your car:
(Every day Three to four times a week Once or twice a week
Once or twice a month Less than once a month)
9. Purpose of driving:
(Commuting School Business Shopping Leisure Others)
10. Car occupancy: (Yes, with passenger No, without passenger)
11. Distance traveled per year by yourself:
(0-500km 500-1000km 1000-2500km
2500-5000km 5000-10000km 10000km-)
12. Car insurance: (Yes, has insurance No, without insurance)
13. Cost of fuel: (Paid by myself Paid by my family Paid by company Others)
14. Household annual income level:
(below 500 USD 500-1,000 USD 1,000-5,000 USD 5,000-10,000 USD
10,000-50,000 USD 50,000-100,000 USD 100,000 USD-)

Annex C

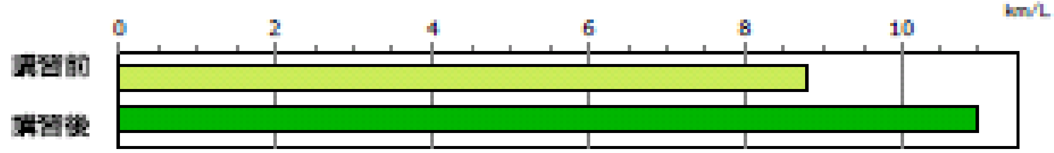
Ecodriving Diagnostic Report

(Japanese Format)

エコドライブ講習　診断書

受講者氏名	谷口　正明　様	実施日時	2010/03/06	受講者 No	007
教官名	谷口　正明	実施場所	八丁堀		

リッターあたりの走行距離（燃費）の比較



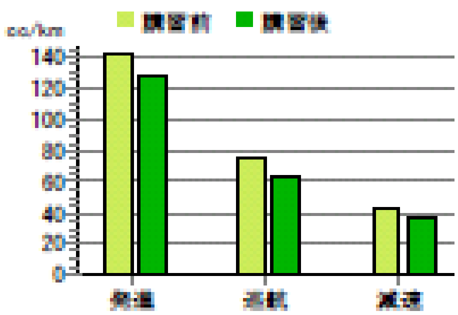
講習後のあなたの燃費は 24.7 % 改善しました

走行データの比較

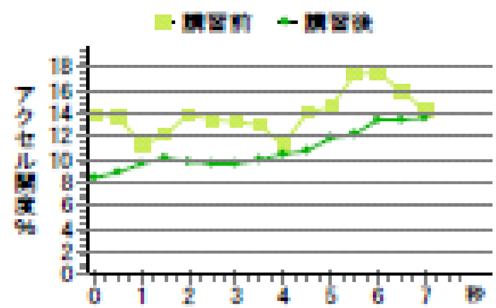
	講習前	講習後
燃費(km/L)	8.81	10.98
燃料消費量(cc)	304.67	245.72
走行距離(km)	2.68	2.70
走行時間(sec)	628	670

	講習前	講習後
停止時燃料消費率(cc/sec)	0.22	0.11
巡航時速度変動率(m²/s²/km)	458.88	401.90
停止時間(sec)	277.50	291.50
停止回数(回)	10	10

走行パターン別の燃料消費量



発進時のアクセル開度



CO_2削減効果

今回の講習で習得したエコドライブを実践し、1年間に1万kmを走行した場合、CO_2削減量は以下の通りです。

10000km ÷ (講習前燃費 8.81 km／ℓ) − 10000km ÷ (講習後燃費 10.98 km／ℓ) = 224.33 ℓ

ガソリン1ℓで2.32kgのCO_2が発生しますので、1年間の削減量は 224.33 ℓ×2.32kg = 520.44 kg となります。

杉の木1本の年間CO_2吸収量は約14kgですので、520.44 kg÷14kg = 37.2 本 を植えたことと同じ効果があります。

講評

Annex D

Car Models for OBD Compatibility

(Japanese Format)

燃費マネージャー(FCM-2000)
係数一覧
http://www.techtom.co.jp/FCM coe.html

ご注意: 下表は弊社にて実車で算出された、もしくは報告いただいた近似値ですのであくまで目安として下さい。
参考に同一車種で3セットまで掲載予定です。
掲載係数はFCM-2000シリーズで共通です。(ダイハツを除く)
参考までに算出を行った機種を表記しております。
個々の車両によって算出数字に違いがありますので、必ず取付車両で補正作業を行うことをおすすめします。

The Toyota International Standard connector type

Model	Vehicle type	Engine	Type	DST	FUEL	Type	DST	FUEL	type	DST	Fuel
RAV4	Veh Type	2AZ-FE	W	999	2940						
Vits(1.0L)	SCP10	1SZ-FE	T2	1001	1643	T2	1000	1461			
VitsRS(1.3L)	NCP10	2NZ-FE	T2	1003	1812						
VitsRS(1.5L)	NCP13	1NZ-FE	T2	985	1597						
Vits(1.0L)	KSP90	1KR-FE	W	1007	1130						
1st L edition	NCP65	1NZ-FE	T2	1000	1698						
Will Vi	NCP19	2NZ-FE	W	993	1828						
Will VS	ZZE128	2ZZ-GE	T2	1000	3425						
Aruhuado AS	ANH10W	2AZ-FE	A2	988	2920						
Aruhuado MZ 4WD	MNH15W	1MZ-FE	A2	1000	3120						
Aruhuado MZ	MNH10W	1MZ-FE	T2	997	2997						
aruhuado haiburitsudo (high breed)	ATH10W	2AZ-FXE	T2	1002	2610						
ipusamu 240i/u (Ipsum)	ACM21W	2AZ-FE	T2	1000	2800	T2	1000	2822	W	1036	2950
vuerotsusa VR25 (Verossa)	JZX110	1JZ-GTE	T2	1035	5150						
esuteima G (Estima)	MCR30W	1MZ-FE	T2	1000	2750						
esuteima aerasu	MCR30W	1MZ-FE	A2	999	2682						
esuteima aerasu	GSR50W	2GR-FE	W	1001	5326						
esuteima aerasu	ACR30W	2AZ-FE	T2	1002	2686						
karoraakushio	NZE141	1NZ-FE	W	1006	1760						
karoraakushio X 4WD	NZE144	1NZ-FE	W	1000	1603						
karorahuiruda S(Corolla High Road)	ZZE122	1ZZ-FE	T2	997	2429						
karorarankusu (corolla)	ZZE123	2ZZ-GE	T2	1003	3422	T2	1001	2765			
The Crown estate	JZS173W	1JZ-GTE	T2	1016	8891						
The Crown royal extra	GS171	1G-FE	W	1032	2539						
Grand high ace	VCH10W	5VZ-FE	T2	1002	2860						
kuresutaruran	JZX100	1JZ-GE	T2	1034	3378						
shienta 1.5X 8 (Sentra)	NCP80W	1NZ-FE	T2	1035	1600						
Shienta X Limited	NCP80W	1NZ-FE	T2	1030	1410						
Town Ace Noah	SR50G	3S-FE	T2	1004	1765						
chieisaabante four	GX105	1G-FE	T2	1026	2440						
High Ace van Super ーGL	TRH200V	1TR-FE	W	1000	2781						
patsuso GF package	QNC10	K3-VE	W	1486	3181						
Pre-mortar	NHW10	1NZ-FXE	T2	1000	1800						
Pre-mortar	NHW20	1NZ-FXE	W	1011	1671	W	1017	1444			
Mark 2	GX110	1G-FE	T2	1038	2470						
Mark 2 Kouriso	MCV21W	2MZ-FE	T2	999	2590						
rakuteisu S package	NCP100	1NZ-FE	W	1002	1667						
rakuteisu S package	NCP105	1NZ-FE	W	1002	1727						
Land cruiser 100	UZJ100W	2UZ-FE	T2	1013	4221						

The Toyota old type connector type (T1)

車種	車両型式	エンジン	距離	燃料	距離	燃料	距離	燃料			
serika GT-FOUR	ST205	3S-GTE	1344	7127							
supura RZ	JZA80	2JZ-GTE	1344	7058							
RAV4 touring limited	SXA1xW	3S-FE	1343	4807							
karen ZS	ST206	3S-GE	1342	4467							
Mark 2	GX90	1G-FE	1353	6019							
The Corolla SE limited	AE104	4A-FE	1346	1952							

The NISSAN International Standard connector type

車種	車両型式	エンジン	機種	距離	燃料	機種	距離	燃料	機種	距離	燃料
Wing load 1.8X (Wing load 1.8X)	WHNY11	QG18DE	N2	1021	1561						
ekusutoreiru	T30	QR20DE	N2	1061	1415	N2	1003	1415			
otsutei	H92W	3G83	W	996	540						
Caravan Silk Road VX	QE25	KA24DE	N2	1012	1450						
Cube 15RX	Z11	HR15DE	N2	1055	1349	W	1055	1353			
Grolier	Y34	VQ30DET	N2	1021	2187						
Sunny	FB15	QG15DE	N2	1048	1449						
Seaming machine LX	GF50	VK45DD	N2	1010	2617						
Skyline	V35	VQ25DD	N2	1025	2000						
sutejia] 250RX	M35	VQ25DD	N2	1026	1881						
sutejia 300RX	HM35	VQ30DD	N2	1023	2068						
Serena	PC24	QR20DE	N2	1039	1376	N2	1017	1405			
Serena	PC24	SR20DE	N2	1028	1446						
Teida	C11	HR15DE	A2	1056	1504						
NOTE Rider	E11	HR15DE	A2	1064	1522						
March	AK12	CR12DE	N2	1100	1490						
March	BK12	CR14DE	N2	1090	1502	N2	1097	1471	N2	1074	1372
murano 250XL	Z50	QR25DE	A2	1030	1410						
rahuesuta 20S	B30	MR20DE	A2	1058	1400						
rahuesutahaiueisuta	B30	MR20DE	A2	1055	1695						

HONDA International Standard connector type

車種	車両型式	エンジン	機種	距離	燃料	機種	距離	燃料	機種	距離	燃料
CR-V	RD5	K20A	H2	1030	1862						
S2000	AP1	F20C	H2	998	2106						
Accord Europe R	CL1	H22A	H2	992	2058						
integurataipu R	DC5	K20A	H2	1015	2061						
edeitsukusu 20X	BE3	K20A	A2	1029	1666						
edeitsukusu 20X 4WD	BE4	K20A	A2	1043	1688						
edeitsukusu 24S	BE8	K24A	W	1015	1668						
Odyssy	RA6	F23A	H2	1031	1878	H2	1041	1767			
Odyssy	RA7	F23A	H2	1018	1816	H2	1022	1766			
Odyssy absolute	RA8	J30A	H2	1020	2650						
shibitsuku Type-R	FD2	KA20	W	991	2166						
shibitsukuhuerio	ES3	D17A	H2	1000	1315						
Step wagon	RF4	K20A	H2	1021	1787						
Step wagon 24Z	RG3	K24A	A2	1045	1672						
Stream	RN1	D17A	H2	1001	1321						
Stream	RN3	K20A	H2	1008	1761	H2	1007	1839	H2	1008	1732
Spike	GK1	L15A	H2	1006	1310						
Fitting	GD1	L13A	H2	1101	1172						
Fitting	GD3	L15A	H2	1016	1320						

The Subaru International Standard connector type

車種	車両型式	エンジン	機種	距離	燃料	機種	距離	燃料	機種	距離	燃料
レガシィ B4 RSK	BE5	EJ20	S2	998	2638						
レガシィ B4 RS25	BE5	EJ25	S2	999	2881						
レガシィ GTB	BH5	EJ20	S2	999	3040	S2	999	3058			
レガシィ TS-R	BH5	EJ20	S2	1000	2040						
レガシィ 250T-B	BH9	EJ25	S2	999	2647						
レガシィ 250S	BH9	EJ25	S2	999	2836						
インプレッサWRX STi	GDB	EJ20	S2	1000	3090						
インプレッサ S-GT	GH8	EJ20	W	1000	3490						
フォレスター	SG5	EJ20	S2	997	2925	A2	998	2875	A2	999	3000
クロススポーツ2.0T											
フォレスターXT	SG5	EJ20	A2	1001	2560	A2	1000	2568			

[mitsubishi] International Standard connector type

車種	車両型式	エンジン	機種	距離	燃料	機種	距離	燃料	機種	距離	燃料
eKアクティブV	H81W	3G83	A2	1003	556						
eKワゴン M	H82W	3G83	A2	1005	580						
エアトレック	CU2W	4G64	A2	1002	8006						
グランディス スポーツ	NA4W	4G69	A2	1004	2100						
ミニカ トッポBJ R	H41A	4A30	A2	1006	1016	A2	1004	984			
ランサー エボ8	CT9A	4G63	A2	1002	3703						
ランサー エボ9	CT9A	4G63	A2	1003	3470						
ランサーセディアワゴン	CS5W	4G93	A2	1004	7576						

Matsuda International Standard connector type

車種	車両型式	エンジン	機種	距離	燃料	機種	距離	燃料	機種	距離	燃料
MPV 23T	LY3P	L3-VDT	W	999	16070	W	958	15951			
MPV エアロリミックス	LW3W	L3-DE	W	1066	3949	W	1026	4029			
アクセラ 15F	BK5P	ZY-VE	W	1001	5429						
デミオ SPORT	DY5W	ZY-VE	W	1002	4384						
プレマシー 20S	CREW	LF-VE	W	1000	4243						
マツダスピードアクセラ	BK-3P	L3-VDT	W	1000	16202						

The Daihatsu International Standard connector type

車種	車両型式	エンジン	機種	距離	燃料	機種	距離	燃料	機種	距離	燃料
コペン	L880	JB-DET	D2	1014	1136						
ソニカ RS Limited	L405S	KF-DET	W	1001	1728						
ハイゼット クルーズターボ	S330V	EF-DET	W	1531	2508						
ハイゼット デッキバンG	S330W	EF-VE	W	1490	2016						
マックス RS	L962S	JB-DET	D2	1015	1112	D2	1015	1131			
ミラ カスタムX	L275S	KF-VE	W	1002	1347						
ムーヴ	L912S	JB-DET	D2	1008	1117						
ムーヴ	L160S	EF-DET	D2	1015	1339						
ムーヴ	L912S	JB-DET	D2	1008	1117						
ムーヴ	L150S	EF-VE	D2	1015	1112	D2	1016	1132			
ムーヴ カスタム	L152S	JB-DET	W	1549	2685						

※.Wより設定される係数の値が異なっていますのでご注意ください

*. Because value of the factor w hich is set differs from W, please note

Sea bass International Standard connector type

車種	車両型式	エンジン	機種	距離	燃料	機種	距離	燃料	機種	距離	燃料
アルト	HA23S	K6A	A2	1003	778						
ワゴンR FX	MH21S	K6A	A2	1010	797						
ワゴンR N-1	MC22S	K6A	A2	1003	824						
ワゴンR RR-Di	MH21S	K6A	A2	1003	3507						
シボレークルーズ	HR52S	M13A	A2	1003	1185						
ジムニー ワイルドウィンド	JB23W	K6A	W	997	1077						