Towards Sustainable Transportation through Introduction of Eco-Drive Management System for Vehicle Fuel Efficiency

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Abstract: Sustainable transport development is a key factor for supporting economic development and growth, and facilitating the exchange of goods. However, rapidly increasing emissions of carbon dioxide from the transport sector, particularly in urban areas, is a major challenge to sustainable development in developing countries. In order to reduce CO_2 emission of automobiles, promotion of ecodriving is considered being effective. Ecodriving is a well-established, affordable and simple behavioral change intervention, which could reduce fuel consumption between 5 to 25% according to different situations. In this paper, Eco-drive Management System (EMS) was first introduced through a case study in Vietnam. The findings may help to realize the effectiveness of eco-drive toward sustainable transportation in Vietnam as well as to promote the countermeasures for the global warming issue. In addition, some major issues have been discussed for further studies of ecodriving and for introduction of fuel efficient vehicles.

Keywords: GHG emissions, Sustainable transportation, Fuel efficiency, Fuel consumption, Eco-drive management system, Vietnam.

1. INTRODUCTION

Sustainable transport development is a key factor for supporting economic development and growth, and facilitating the exchange of goods. At the same time, transport industry and vehicle are major emitters of gaseous and particulate pollution in urban areas which have serious health effects, including respiratory and cardiovascular diseases. The transport sector remains one of the main sources of CO_2 emissions from 10 – 25% in most countries (EEA, 2008; Timilsina and Shrestha, 2009). Ecodriving is a well-established, affordable and simple behavioural change intervention, which could reduce fuel consumption between 10 to 20% (Barth and Boriboonsomsin, 2009). Ecodriving attempts to change drivers' behaviour through advice such as driving more smoothly by anticipating changes in the traffic, shifting gear sooner, operating the vehicle within an optimum range of engine revolutions or with operating speed range, avoiding jerky braking/acceleration and avoiding traffic congestion. Many countries have promoted ecodriving in "Green Transport" as a key element of national strategies to reduce CO_2 emissions (ECODRIVEN, 2009; JAPE, 2012) towards sustainable development.

Ecodriving strategies can be classified more specifically. Driver training and advice can be called static ecodriving with limited feedback. Next, ecodriving based on instantaneous vehicle performance display fuel economy in real-time, with a growing number of such devices used in vehicles today. Finally, dynamic ecodriving adds to instantaneous

performance with real-time advice or feedback, such as speed management suggestions based on roadway geometries or congestion. CE-CERT (2011) has recently conducted dynamic ecodriving studies on highways and arterials and found significant reductions in fuel use (13% reduction on highways, 12% reduction on arterials) and CO_2 emissions (12% on highways, 14% on arterials), while maintaining similar travel times. However, ecodriving research in Vietnam has never been studies so far.

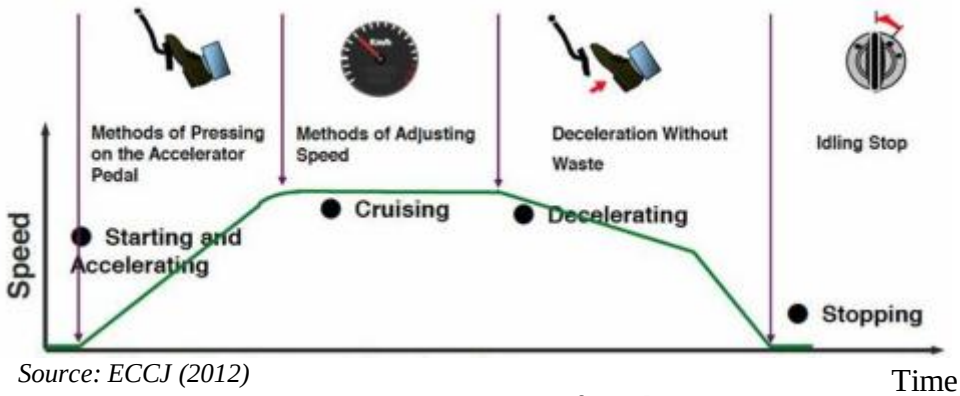
Given the merit of ecodriving towards sustainable transportation, the objective of this paper is to introduce Eco-drive Management System (EMS) in order to reduce vehicle fuel consumption as well CO_2 emission through a case study in Vietnam. In the following sections, eco-driving along with EMS is first presented, then overview of transport situation and CO_2 emission from transport sector in Vietnam, which is followed by a case study demonstrating the introduction of EMS in Vietnam. Taxi vehicles are employed in the study with different traffic situations in center and suburban areas of Hanoi city.

2. ECO-DRIVE MANAGEMENT SYSTEM

2.1 Overview of Ecodriving

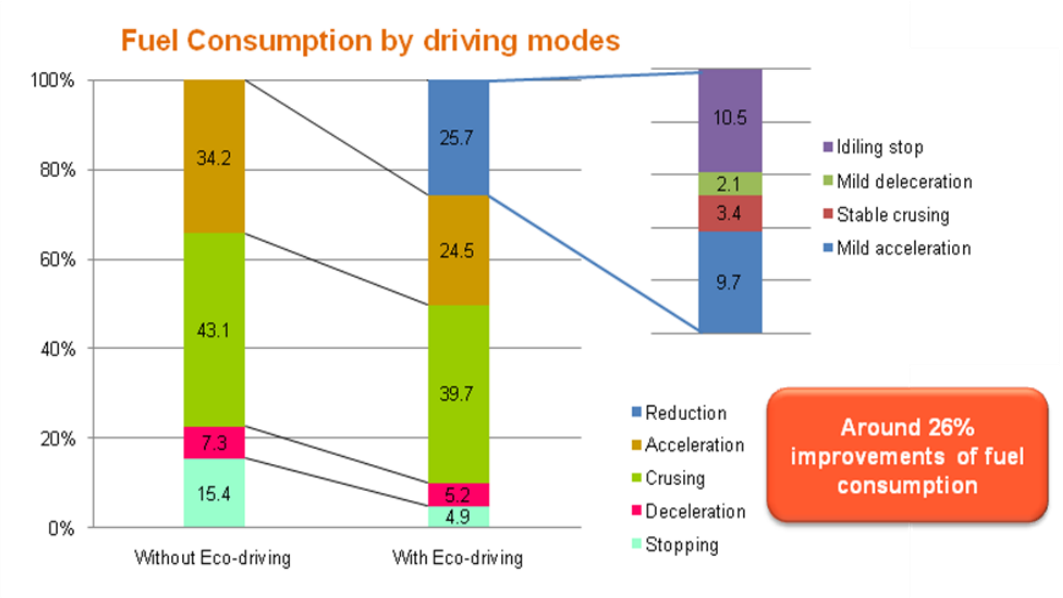
Ecodriving consists of changing driving behavior to maximize the fuel economy of existing cars and trucks while minimizing carbon emissions. It is a modified way of driving that is best suited for modern engine technology, taking into account various driving conditions. Ecodriving research and programs can take on many forms, ranging from providing basic advice such as anticipating changes in traffic, smoother acceleration and braking, and proper vehicle maintenance, all the way to receiving real-time information on how to drive in current traffic conditions, or what route to take. Ecodriving offers numerous benefits, including greenhouse gas (GHG) emissions reductions, fuel cost savings, as well as greater safety and comfort. Fuel reduction through applying ecodriving can be obtained up to 20 or 25% in most studies (Rakotonirainy et al., 2012; ECCJ, 2012). Figures 1 and 2 present driving patterns a long with the benefit of ecodriving according to driving patterns in different stages below.

1. When starting and accelerating: accelerate taking around 5 seconds to reach 20km/h then conduct further acceleration smoothly.
2. When driving: drive while watching in front and maintain a wide space from the car in front to prevent changes in speed.
3. When decelerating and stopping: remove your foot from the accelerator early and endeavour to drive stably.
4. When stopped: engage neutral gear and use the side brake. If possible, eliminate idling by stopping the engine.



Source: ECCJ (2012)

Figure 1. Driving patterns of ecodriving



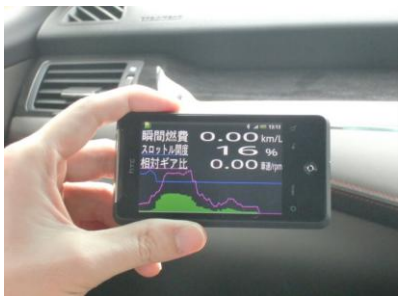
Source: ECCJ (2012)

Figure 2. Effects of ecodriving according to driving patterns

2.2 Eco-drive Management System

Eco-drive management system (EMS) is used for evaluating effectiveness of ecodriving and for dynamic ecodriving to display instantaneous performance with real-time advice or feedback. EMS application on smart-phone are used to collect and display the fuel consumption (FC) and other drive situation data (DSD) in real time. Using popular smart-phone as the EMS device offers inexpensive and effective eco-drive to vehicle users in developing countries. The On Board Diagnosis II (OBD2) (as a Bluetooth device) is installed in a connecter in the car. The data scanned in the connecter are transmitted to smart-phone by Bluetooth (wireless). Smart-phone used in EMS is an application of Android smart-phone with a EMS software developed by ISHIDA R&D. The EMS device help driver to practice eco-drive by in real time displaying the drive situation and notice for sudden acceleration or braking by alarm sound, including instantaneous fuel consumption, average fuel consumption, acceleration, GPS location, Eco-drive diagnosis point. The total of 55 types of data will be displayed and collected through EMS as shown in Figure 3.

a) OBD2 scanner



b) EMS device (Smartphone)

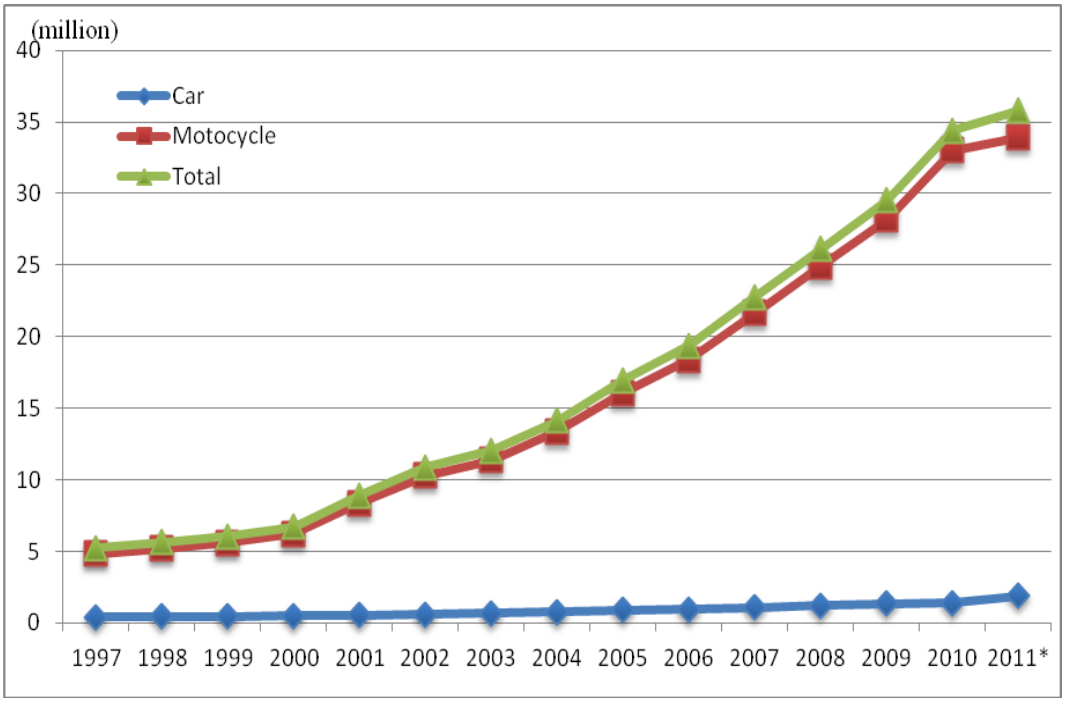
c) FC and DSD performance

Figure 3. Outline of EMS device

3. VEHICLE TREND AND TRANSPORT CARBON EMISSION IN VIETNAM

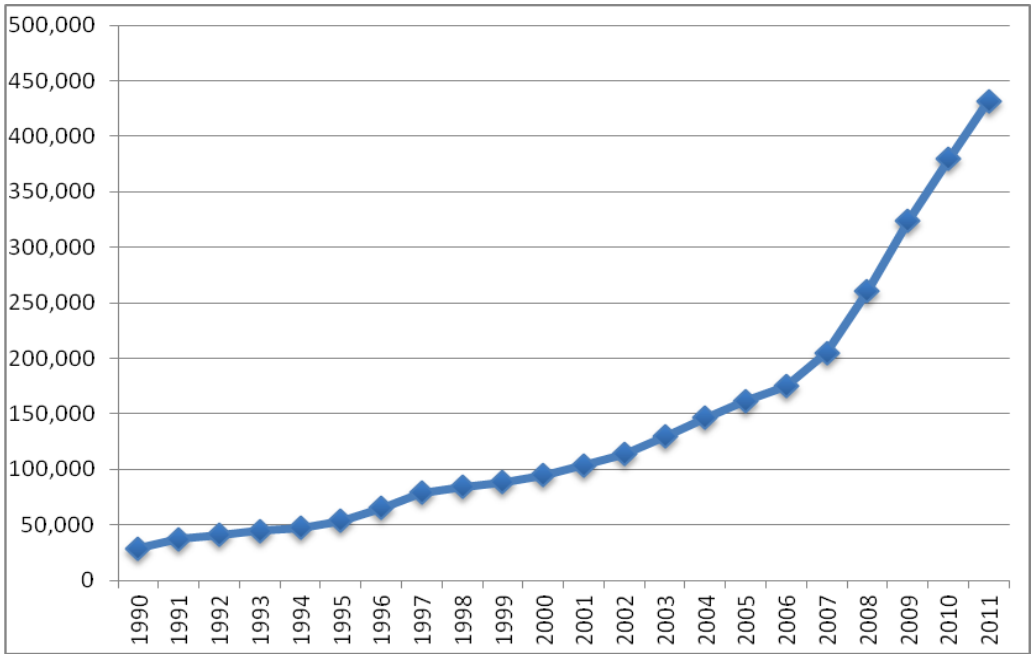
3.1 Vehicle Registration in Vietnam

Vietnam is one of the countries which is using motorcycle as a primary vehicle. The number of registered motorcycle has significantly increased within 10 years. According to statistics by Ministry of Transportation (MOT) from 2005-2011, the number of motorcycle is increased up to 2.05 times as shown in Figures 4. In the end of 2010, newly-registered cars account for 4% of registered vehicles, newly-registered motorcycles account for 96%. However, the number of car registration significantly increased in major cities such as Hanoi and HCMC during recent years. Before the year of 2006, a number of registered cars in Hanoi slowly increases, but from 2007 to present registered cars are rapidly increasing because the price of car gets closer to people's affordability, even though total various tax is accounted for more than 200%. The fast growth of registered car in Hanoi is shown in Figures 5. Hanoi is one of the two cities (i.e., Hanoi and HCM cities) in Vietnam with the largest number of registered car, to the end of 2010, the number of registered car is 380,000 cars accounting for 1/6 of cars in nationwide.



Source: The National Safety Traffic Committee, 2009; Ministry of Transportation, 2012.

Figure 4. Vehicle registration number in Vietnam

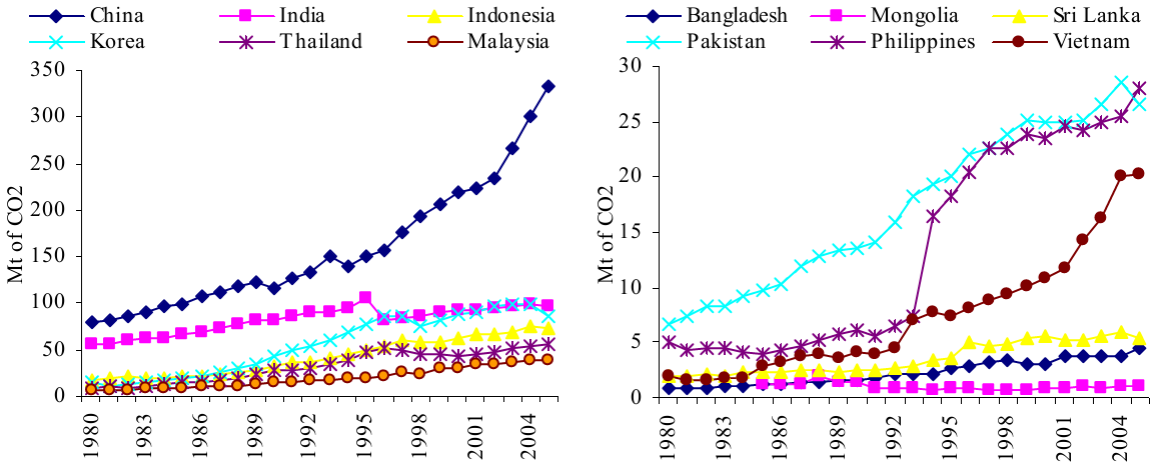


Source: Hanoi Traffic Police, 2011

Figure 5. Number of registered car in Hanoi

3.2 Carbon Emissions from Transport Sector in Vietnam

Rapidly increasing emissions of carbon dioxide from the transport sector, particularly in urban areas, is a major challenge to sustainable development in developing countries. The World Bank (Timilsina and Shrestha, 2009) has analyzed the CO_2 emissions growth of transport sector in selected developing Asian countries during 1980–2005. Figure 6 shows the trend of transport sector CO_2 emissions of selected countries in Asia. The transport sector remains one of the main sources of CO_2 emissions in most countries in Asia, while rising incomes a long with higher levels of car ownership (Webster et al, 1986a,b) and greater trip rates/distances (Schäfer, 2000) has resulted significant increase of CO_2 emissions in transport sector in these countries.



Source: IEA (2007)

Figure 6. Trend of transport sector CO_2 remissions in Asia

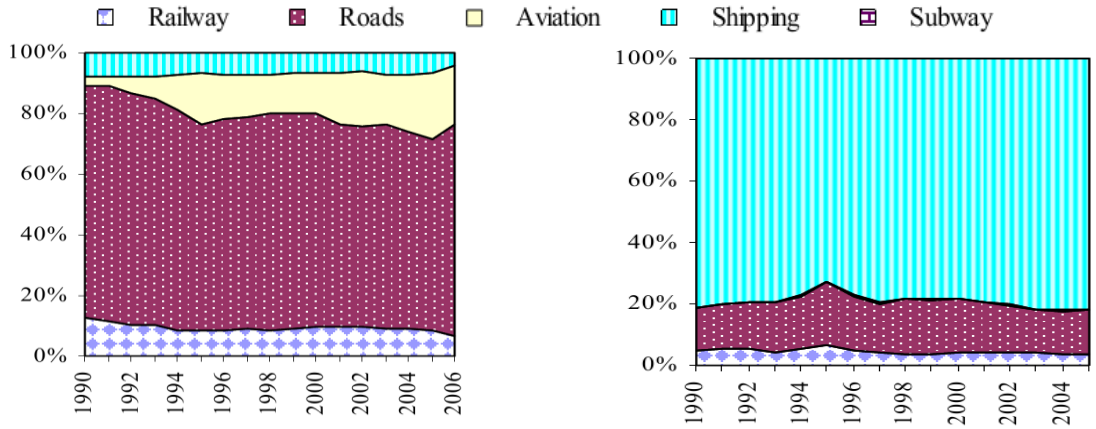
National CO_2 emissions in Vietnam have increased from 14 million tons in 1980 to 80 million tons in 2005, while the transport sector's share of those emissions has almost doubled

from 14% to 25% as indicated in Table 1. In 2005, looking at different transportation modes, road transport accounted for the bulk of CO_2 emissions with 91.95%; other modes were air (2.5%), water (4.8%), and rail (0.8%) as illustrated in Figure 7. Therefore, any attempt to address climate change in Asia must pay attention to transport sector emissions, especially for road transport.

Table 1. CO_2 emission mix by sector

Country	1980					2005				
	Total (Mt of CO_2)	Power (%)	Indus-try (%)	Trans-port (%)	Other (%)	Total (Mt of CO_2)	Power (%)	Indus-try (%)	Trans-port (%)	Other (%)
Bangladesh	7	21	41	14	24	36	35	29	12	24
China	1,403	20	51	6	23	5,060	48	37	7	9
India	292	26	39	19	16	1,147	52	30	8	10
Indonesia	69	10	39	26	26	341	28	39	22	11
Korea	122	20	32	12	37	449	35	31	19	15
Malaysia	23	32	34	28	6	138	33	35	28	3
Mongolia[#]	12	48	25	11	16	10	70	8	12	10
Pakistan	26	16	37	25	22	118	30	37	22	11
Philippines	32	27	39	15	18	76	37	19	37	7
Sri Lanka	4	8	22	55	16	12	28	16	45	11
Thailand	34	33	23	28	16	214	30	37	26	7
Vietnam	14	24	36	14	26	80	24	37	25	14

Source: IEA (2007)



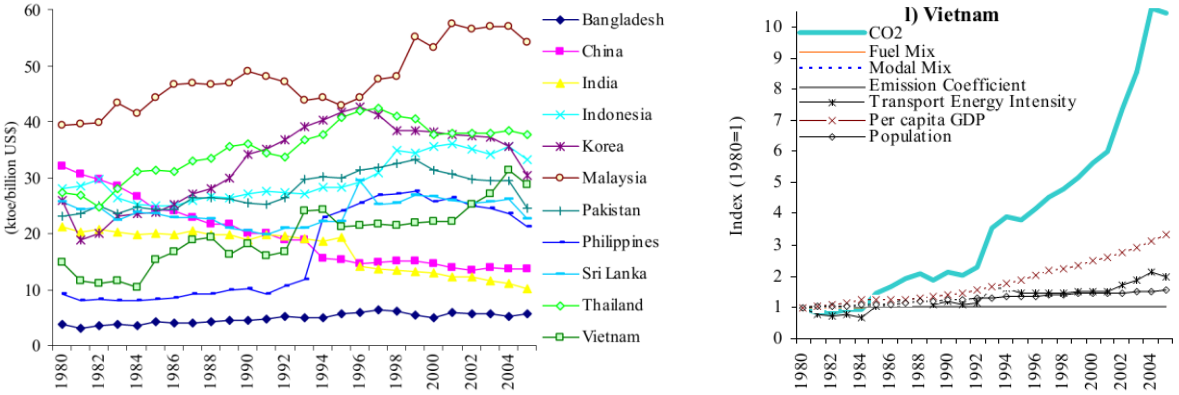
a) Modal mix for passenger transport b) Modal mix for freight transport

Source: IEA (2007)

Figure 7. Modal mix for passenger and freight transport in Vietnam

The analysis splits the annual emissions growth into components representing economic development; population growth; shifts in transportation modes; and changes in fuel mix, emission coefficients, and transportation energy intensity (which is the ratio of total fuel consumption for transportation in an economy to its gross domestic product). The World Bank study finds that of the six factors considered, three—economic development, population growth, and transportation energy intensity—are responsible for driving up transport sector CO_2 emissions in Vietnam. Transportation energy efficiency is the ratio of total fuel consumption for transportation in an economy to its gross domestic product. This value has slowly started to decline in Vietnam starting in about 1996, i.e., fuel consumption for transportation has declined per unit of economic output. However, of the 11 countries in southeast Asia for which data are presented, Vietnam has the second highest transportation energy inefficiency, trailing only Malaysia (Figure 8a). In effect, the high inefficiency of fuel

consumption relative to economic output in Vietnam contributes to its rapid growth in CO_2 emissions from the transport sector as clearly presented in Figure 8b.



a) Transportation energy intensity in selected Asian countries (1980-2005)

b) Transport sector CO_2 emissions growth and driving factors in Vietnam

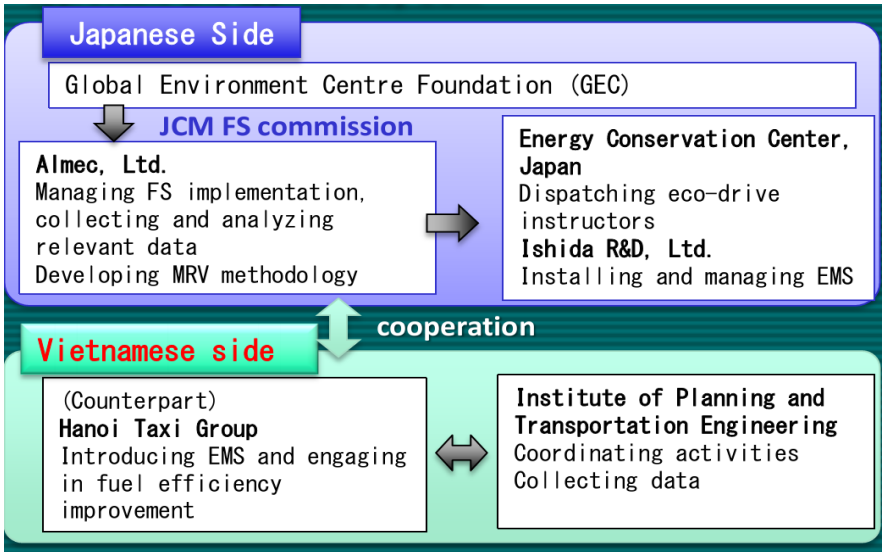
Source: IEA (2007)

Figure 8. Transportation energy intensity and transport sector CO_2 emissions growth

4. CASE STUDY

4.1 General Information

Road transport has been recently developed rapidly due to the economic development in Vietnam. As a result, emissions of carbon dioxide from the road transport causes a major challenge to sustainable development for the country. Realizing this problem, ecodriving employed EMS has been considered as an advanced low-carbon technology through a the Bilateral Offset Credit Mechanism (BOCM) in order to achieve reduction of GHG emissions. Japan Global Environment Centre Foundation (GEC, 2012) has firstly introduced a project of improvement vehicle fuel efficiency through application of EMS for taxies in Hanoi. The implementing procedure for the project is shown in Figure 9. The case study of this paper is to employ main input data and result from GEC's project for its analysis and discussion as in following sections.



Source: GEC, 2012

Figure 9. Organizational chart for project implementation

4.2 Study Routes

Two routes, in city centre and suburban areas, will be used for training and field observation of ecodriving study as illustrated in Figure 10. Table 2 shows different traffic situations in these two areas in terms of average travel speed and average fuel efficiency which was collected and analysed by using EMS device with GPS driving trace.

Table 2. Average travel speed and average fuel efficiency

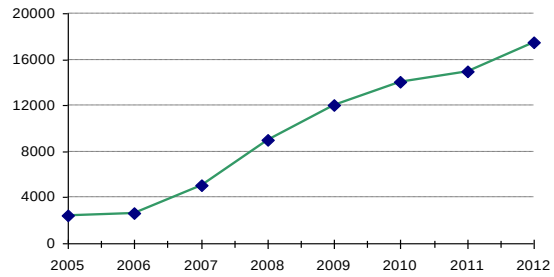
Item	Unit	Centre	Suburban
Traffic situation	-	Congested	Uncongested
Average travel speed	km/h	15.6	29.2
Average fuel efficiency	litter/100km	6.7	5.2

Centre area (4km) Suburban area (4km)

Figure 10.Routes of the case study

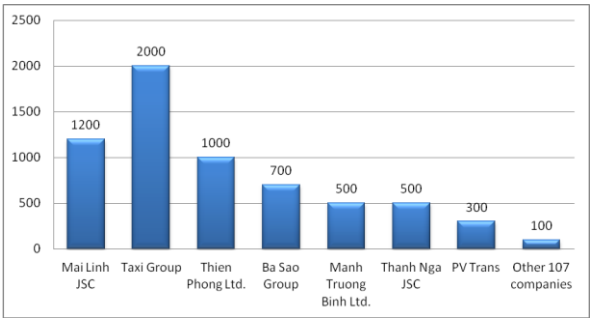
4.2 Selected Vehicle Type

Taxi operators have been rapidly increased with accelerating urbanization and motorization in big cities such as Hanoi and HCMC due the lack of adequate public transport means. Figure 11 illustrates the increasing trend of taxi number in Hanoi city in recent years. The number of taxi slowly increases in Hanoi from 2,000 cabs in 2003 to 2,600 cabs in 2006 equivalent to 200 cars per year in average. However, up to November 2007, the number of taxi was significantly doubled from 5,000 cabs to 9,000 cabs in 2008. In a short time from the end of 2009 to April 2010, the number of taxi cabs increases sharply from 12,000 up to 14,000. The growth rate is still maintained until now, the number of taxi cabs in Hanoi is 15,000 in March 2011 and 17,500 in April 2012. Figure 12 shows the list of taxi brands and taxi businesses in Hanoi, total of 114 registered companies, and the average number of taxi cabs in each taxi company. Taxi Group is presented as a biggest company with a larger number of taxi cabs, responsible for about 63% of total taxi cabs operating in Hanoi city. Given the fact, the study select Taxi Group for the case study with the vehicle of 4-seat Toyota Vios as the most popular vehicle in Hanoi's taxi operators.



Source: ALMEC-IPTE (2012)

Figure 11. Growth of registered taxi in Hanoi



Source: ALMEC-IPTE (2012)

Figure 12. Number of cabs in each company

4.3 Analysis Procedure

The procedure for the study will be the following stages: (1) collection and analysis of the taxi operation data before the EMS introduction; (2) collection and analysis of the taxi operation data after installing EMS devices into studied cabs; (3) carrying out Eco-Drive Training Program based on the Japanese know-how; (5) implementing eco-drive in practice and collecting fuel consumption as well carbon emission; and (6) estimating for vehicle fuel efficiency and carbon emission reduction. Figure 13 shows the procedure of the eco-drive study.

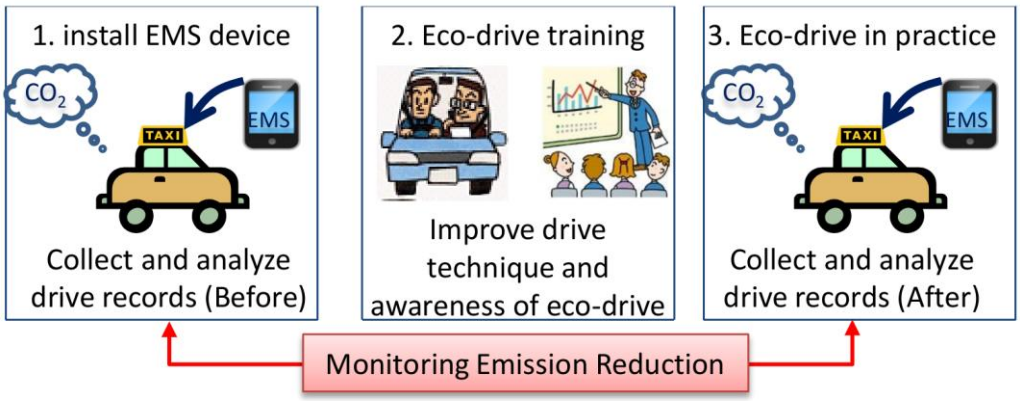


Figure 13. Procedure of the eco-drive study

5. ANALYSIS RESULTS AND DISCUSSIONS

5.1 Analysis Results

A designated course was cruised twice by taxi drivers, once in the normal manner (without project activity) and once in the eco drive mode. Number of participants is 6 and 16 for city center and suburban areas, respectively. The driving experience in city center is more than suburban area (due to the difficult driving in congested traffic in Hanoi center) which is 5.4 and 4.5 years in average respectively. The driving performance was recorded for comparative analysis as example illustrated in Figure 14. In the suburban course, cruising was without interruptions of traffic congestion while in inner city course the cruising was in traffic congestion mixed with other automobiles and motor cycles. After collecting data and carrying out analysis, average fuel reductions are obtained about 6.0% and 2.0% in suburban and inner city courses, respectively. Figure 15 shows the comparative data analysis of fuel consumption in the normal and eco-drive modes (GEC, 2012).

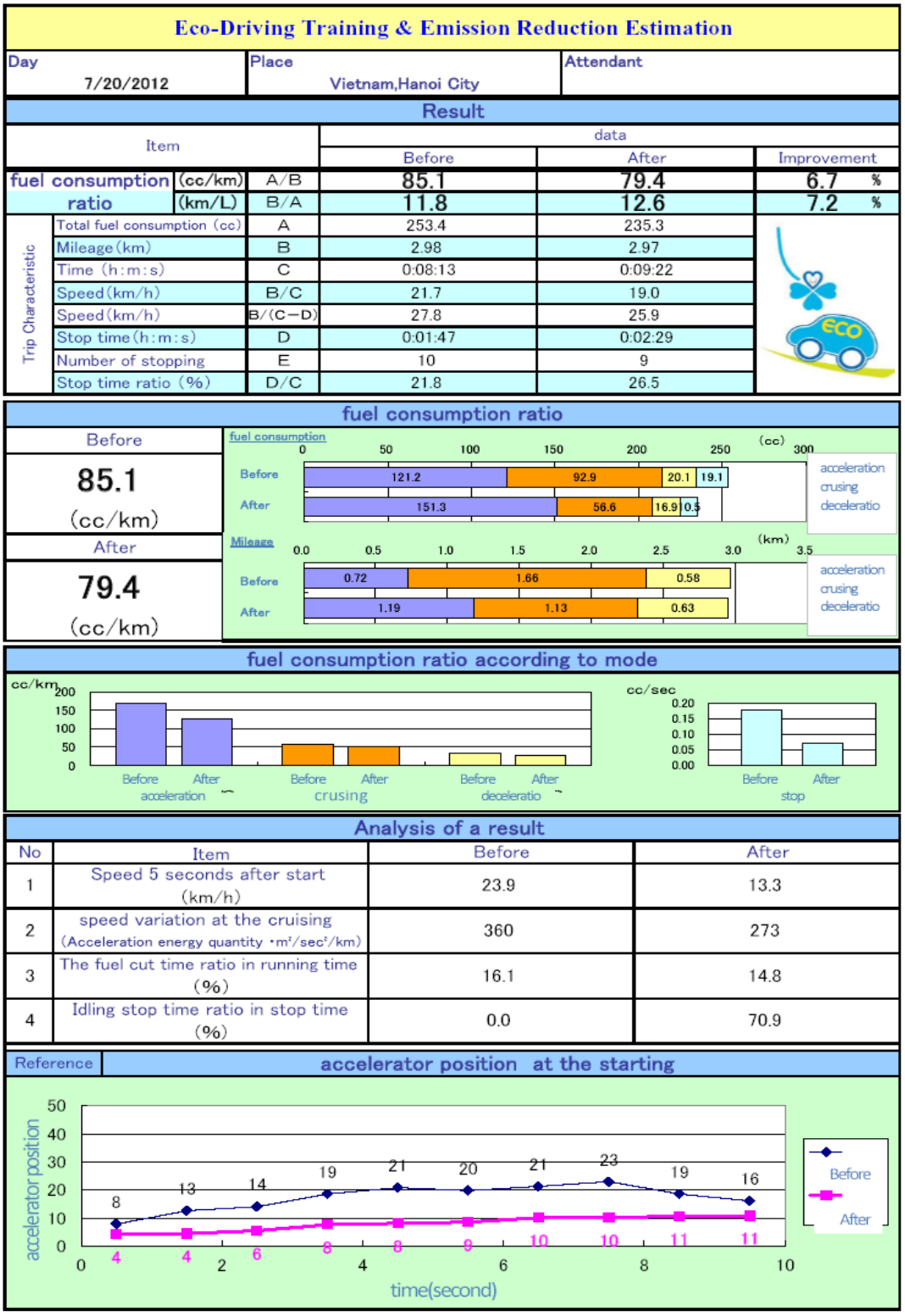


Figure 14. Comparative analysis record before and after applying eco-drive mode

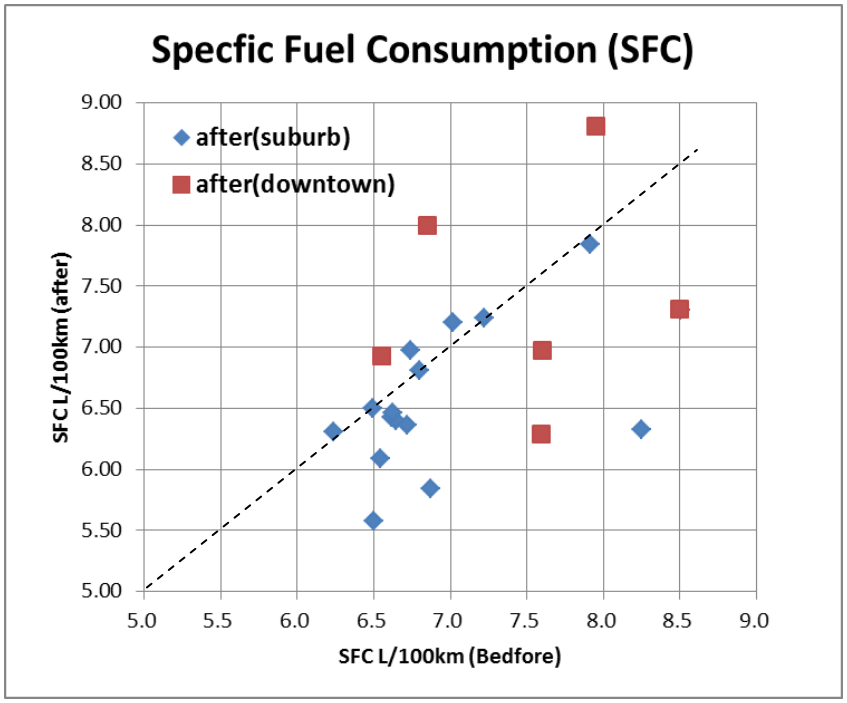


Figure 15. Fuel consumption analysis before and after applying eco-drive mode

5.2 Discussion of Eco-drive Issues

The aggregated average fuel reduction obtained in the study is not high as expected as well in comparison with other studies (e.g. ECODRIVEN, 2009; MRPI, 2011; Rakotonirainy et al., 2012; ECCJ, 2012). Furthermore, there is a significantly difference between city center and suburban areas. Main reasons have been primarily observed from the study, i.e. traffic situation, driving environment such as an inference of traffic flow by motorcycles, personal motivation, driver experience, vehicle quality. In the following, some major remained issues for further consideration are overviewed:

- When driving in a crowded urban area, it can be difficult to maintain a steady speed (e.g. keeping rolling in traffic) with a high gear, and safety should be prioritized by adopting a low speed although it is not fuel efficient. This matter is one of reasons that ecodriving is not so effective in city center of Hanoi where traffic is heavily congested.
- An experienced driver may understand easily that the best compromise depends on the situation, but it should be noted that driving habits learned by experience could also hard to change. Therefore, during a short time of training in this study, it is difficult for experienced drivers to change their habits and follow ecodriving technique exactly.
- Most drivers had an immediate fuel consumption improvement that was stable over time but some tended to fall back into their original driving style. Eco-driving style is difficult to turn into driving habit as it is dependent to the driving situation such as traffic, environment and personal motivations (Dogan et al., 2011). It points out that training is one of important ways to constantly improve driver skills related to ecodriving technique. In Vietnam, ecodriving as a new introduction and its guideline should be added into instruction of driving license.

- Time saving is an issue when considering eco-driving (Dogan et al., 2011). CE-CERT (2011) has recently conducted dynamic ecodriving studies on highways and arterials and found significant reductions in fuel use, while maintaining similar travel times. However, further studies need for differently cultural, technical, and educational barriers inhibiting the adoption of eco-driving practices in order to promote ecodriving.
- Open research questions and challenges include providing drivers with dynamic traffic information through limited infrastructure, incentivizing manufacturers to install ecodriving feedback devices into automobiles, and further analyzing driver behavior and distraction. Ecological Driving Assistance Systems (EDAS) and Intelligent Speed Adaptation (ISA) will become a standard part of future driving assistance systems. The heterogeneity of vehicles, the complexity of the driving task and variability of driving style will require simple advices through the use of aggregated indicators to safety and ecology.

5. CONCLUSIONS

The study has implemented the eco-drive training program and thereby established the procedure from the preparation of the curriculum and the text to the implementation of training in Vietnam. The study has ascertained the positive effect of the eco drive activities on vehicle fuel efficiency improvement. The findings have shown that the average fuel reduction are about 6.0% and 2.0% in suburban and inner city courses, respectively. Although the reduction results are not so high, it shows a potential for introducing ecodriving as a friendly environmental technique to road transport system towards GHG improvement. Furthermore, the study carried out in a short time and limited areas as well not considering various factors effecting the eco-drive measure. Therefore, it need to further study to find the effective measure of introducing eco-drive into Vietnam according to its different traffic situations, driving environment, personal motivation, driver experience, vehicle quality and types (including trucks and buses). Other issues need to be simultaneously considered along with ecodriving such as safety, travel time, relationship between fuel consumption and emission that gaining optimal benefits. Continuous actions should be put on ecodriving on both training, practice and operating management strategies in Vietnam to achieve a goal of CO_2 reducion as well sustainable transportation, as referring to Japanese experience when its 2010 goal of reducing CO_2 emissions by 31 million tons below 2001 levels by encouraging drivers to use their vehicles more efficiently through Eco-driving (Transport America, 2010). Given merits of available advanced technologies, fuel efficient vehicles such as hybrid cars proposes a promising alternative which integrated safety and ecology driving assistance, i.e. Ecological Driving Assistance Systems (EDAS) and Intelligent Speed Adaptation (ISA).

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