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Assessment of Greenhouse Gas Emission Reduction Measures in Transportation Sector of Malaysia

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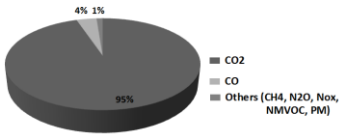
Graphical abstract



Abstract

Malaysia has committed to reduce its greenhouse gas (GHG) emissions by up to 40% by the year 2020. The fact that transport sector of Malaysia shares a big portion of national GHG emissions; its role is paramount. The present study reviews the current state of GHG emission, the major technical and policy measures that can be adopted, and the measures that have been initiated in Malaysia for GHG emission reduction in transportation sector. Data related to road vehicles and GHG emission from road transportation are collected from open source databases and analyzed to reveal the present trends and possible future changes in GHG emission due to government initiatives. The result shows deceleration of GHG emission from transportation sector of Malaysia in recent years. However, the study reveals that the present measures may not be enough to reduce GHG emission up to the set target. Malaysia needs more prudent strategies for climate-friendly development of transportation to achieve sustainability goals. The study also examines the potential of Malaysia to reduce GHG and the measures that that can be initiated to streamline the effort towards GHG emission reduction are discussed.

Keywords: Road transportation; greenhouse gas; emission reduction; mitigation; climate change

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1.0 INTRODUCTION

The transportation sector is greatly contributing to the socio-economic development worldwide with inherent environmental impacts [1, 2]. The conflicts are ever increasing between the goals of fulfilling mobility needs and improving quality of environment. The transport sector is responsible for the emission of more than a quarter of carbon dioxide (CO2) world-wide, as well as considerable shares of methane (CH4), and nitrous oxide (N2O) emissions, and is thereby one of the largest single contributors to global greenhouse gas (GHG) emissions.[2] Unbounded emissions of greenhouse gases to atmosphere warmed the planet to levels that have never been experienced in the history of human civilization [3]. Climate change due to global warming could have far-reaching and unpredictable environmental, social, and economic consequences [3]. Therefore, the reduction of greenhouse gas emissions has become a primary focus of environmental programs in countries around the world. Though the developed countries are traditionally the main emitters of greenhouse gases, some developing country's emissions are now believed to have surpassed developed country emissions due to huge development activities in recent decades [4]. Emerging economies such as China and India are now considered as the major greenhouse gases emitter in the world [5, 6]. Owing to the above fact, Bali declaration emphasized the joint efforts by both developed and developing countries to take measures against climate change [7].

Malaysia is second largest per capita greenhouse gas emitter among the group of ASEAN countries [8]. Although, Malaysia shares only 0.3% of global GHG emission [6], the major concern lies in the ever increasing trend of GHG emission. When many developed countries have successfully reduced the GHG emission, Malaysia continues to increase its emission level. Figure 1 draws a comparative through the time series of GHG emission by Malaysia and a few developed countries of Europe. The figure indicates that Malaysia has already surpassed many developed countries in terms of GHG emission [9]. As a result of which the country is facing an increasing domestic and international pressure to decelerate its greenhouse gas emission.

Malaysian is a signatory of many international accords for greenhouse gas emission reduction including Montreal protocol of 1987, Kyoto protocol of 1992, Copenhagen accord of 2009 and Cancun agreements of 2010 [10]. The Cancun agreements provided a framework for all major developed and developing countries to formally anchor their 2020 greenhouse gas targets in a parallel manner [11]. Malaysia has also declared to reduce its greenhouse gas emissions by up to 40% by the year 2020 as comparable with 2005 levels to implement the Cancun agreements and the Bali declaration of joint efforts of emission reduction by both developed and developing countries [12].

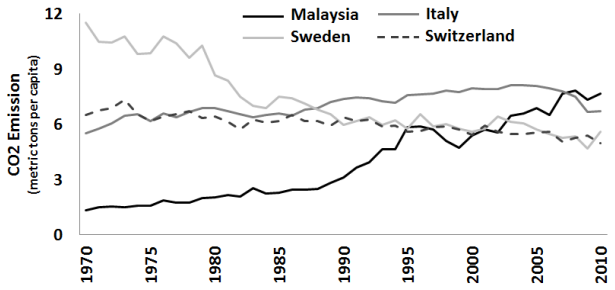


Figure 1 Comparison of CO2 emissions in recent years by Malaysia with few developed countries [18]

The transport sector is an important component of the economy impacting on development and the welfare of Malaysian population. The rapid development of transport sector has contributed a lot to the gross development of socio-economy and people's livelihood of Malaysia [2]. However, the present reality is that the transport sector will be among the first that have to address the fulfillment of the goals of GHG emission reduction. Some concerns are raised by stakeholders that the GHG reduction efforts will affect the growth in transportation sector which in turn will have negative impacts on national economy and people's livelihoods. Therefore, Malaysia needs to take prudent strategies for climate-friendly development of transportation to fulfill national aspirations for sustainability. Studies are needed to review, analyze and formulation of the policy options in Malaysian context. Few studies have been carried out in recent years in this regard [2, 13-16]. However, studies are still in their infancy and many relevant issues are ignored. Thus, more analyses in terms of policy initiatives are needed to identify the most effective and applicable measures.

An attempt has been taken in the present study to examine the current situation of GHG emission reduction in transportation sector of Malaysia. The initiatives taken in Malaysia in this regard are reviewed in detail. The underlying potential of Malaysia in this regard is discussed. Finally, this study concludes by providing recommendations that are necessary to streamline the Malaysian efforts of GHG emission reduction from transportation sector.

2.0 DATA AND METHODS

Data related to vehicle registration, vehicle ownership, CO2 emission from transport and other sectors, other greenhouse gases emission for different sectors, natural gas vehicles, fuel mixing, percentage of fuel consumptions, etc. are collected from open source databases of various international organization including Carbon Dioxide Information Analysis Center [17], the world bank [18], Trading Economics [19] and Index Mundi [20] as well as other published sources such as published journal articles, annual reports, newsletters, booklets and online databases of various organizations responsible for transportation management, planning and development in Malaysia such as, Road Transport Department Malaysia, Ministry of Transport Malaysia, Land Public Transport Commission of Malaysia, Dewan Bandaraya Kuala Lumpur (DBKL), National Land Transport Master Plan (SPAD), Malaysia's Public Transport Forum, Iskandar Malaysia, etc. The data are presented graphically to show the changes in GHG emission and other parameters.

Greenhouse gas includes carbon dioxide (CO2), carbon monoxide (CO) and other gasses like CH_4, N_2O, NO_x, etc. Like most of the other countries of the world, CO2 is the principle GHG in Malaysia. Shares of different gases to total GHG emission in Malaysia is shown in Figure 2. Carbon dioxide (CO2) emissions amounted to about 95% of the total greenhouse gas emissions in Malaysia. Therefore, reduction of CO2 emissions can play a pivotal role in combating the greenhouse effect and global warming. The present study concentrates only on CO2 emission reduction related measures.

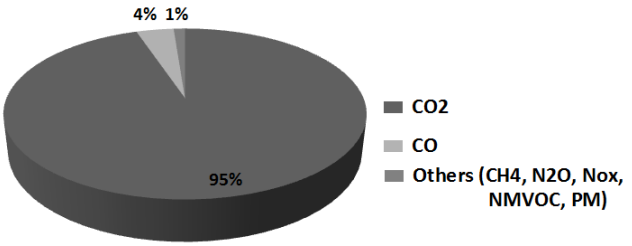


Figure 2 Shares of different constituents of GHG in Malaysia [20]

Possible changes in CO2 emission due to the technical measures adopted in Malaysia are deciphered through analysis of information gathered from above mentioned sources. In some cases, published data are re-analyzed to understand the changes. For example, the published data of CO2 emission from transport sector of Malaysia are re-analyzed using non-linear regression method to reveal the changing pattern of CO2 emission with time. For this purpose, the data are modeled by a function which is a non-linear combination of the model parameters. Successive approximation method is used in the present study to fit the non-linear function.

A short review is also carried out to summarize the present state in GHG emission and the measures taken to reduce GHG emission in Malaysia. Relevant studies in the recent years in this regard are identified and thoroughly reviewed to understand both the direct and indirect impacts of government initiatives on GHG emission reduction. The measures adopted to reduce GHG emission from transport sector of Malaysia are discussed and their impacts on CO2 emission are revealed through the analysis of gathered data.

3.0 BRIEF OVERVIEW OF GHG EMISSION IN MALAYSIA

The per capita GHG emission in Malaysia is 5.9 million tons which is three times more than the levels recorded for the whole Southeast Asia [9]. In terms of total GHG emission, Malaysia's position is also high among the other developing Southeast Asian countries. Although the total emission for Malaysia is only about 40% of Indonesia and 64% of Thailand, the per capita emission of Malaysia is about 3.5 and 1.6 times of the values of Indonesia and Thailand, respectively. Total emission of GHG in Malaysia was about 180 million metric tons in the year 2012. Energy generation, transport, Industry, residential building and agriculture are the major sectors contributing to GHG in the country. The Energy generation contributes about 54.9% of the total emissions followed by the transport, which accounted for 22.9%. The Industry shares about 17.4% of total GHG emission ranks third which is followed by residential buildings and other sectors.[18-20] Time series of CO2 emission by different sectors is shown in Figure 3. It can be noticed that transport sector superseded industry in term of CO2 emission in recent years.

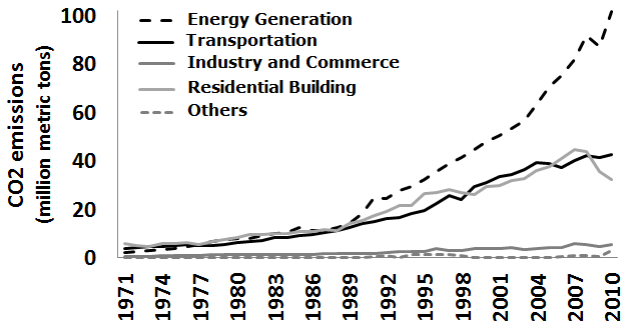


Figure 3 Trends in CO2 emission by different sectors of Malaysia during 1971-2010 [19]

4.0 GHG EMISSION FROM TRANSPORT

Malaysia is undergoing rapid development in fulfilling the aspiration of achieving a developed nation status by year 2020. The aspiration towards economic competitiveness and well-being has led to rapid urbanization and increase the need for an effective and efficient public transportation system [2]. The government promoted the transportation sector to support economic development. Tremendous growth in economy, rapid urbanization and rising incomes caused exponential increase in the demand for passenger transport services in the country. Consequently, motorization in Malaysia has increased by five-fold over the past three decades. Figure 4 shows the number of vehicles registered in Malaysia over the last two and half decades. The figure shows that the total number of vehicles in the country has increased from about 5 million in 1991 to 19 million in 2009.

The public transportation system in Malaysia is still not developed enough. Hence, the private transport flourished rapidly with growing economic ability [21]. Motor cars and motor cycles together share about 92% of the total vehicles in the country in 2009 [14]. On the other hand, public transportation modes in Malaysia have only 1% share in the total registered vehicles. The share of public transport in cities has continuously declined from 34% in 1985 to 20% in 1997 and is now closer to 10–12%. Poor public transportation system and high demand of mobility caused rapid increase of cars compared to population growth. The time series of car ownership in Malaysia is shown in Figure 5. The figure shows rapid increase of car ownership in Malaysia. Approximately three people had one vehicle in 1995 which reduced to 1.4 people in 2010.

The consumption of both petrol and diesel has been increasing rapidly with growing motorization and increasing dependence on private modes. At present, transportation sector consumes about 36% of the national energy [22]. Consequently, it has appeared as a major emitter of CO2. It is also responsible for other gases causing air pollution.

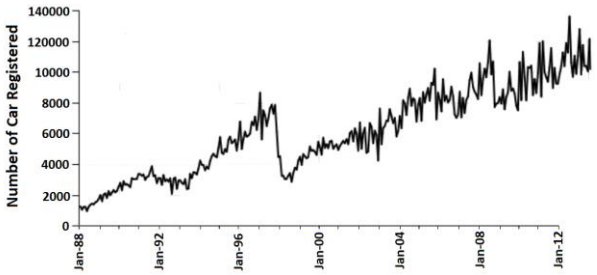


Figure 4 Monthly data of number of vehicles registration in Malaysia in last 25 years [20]

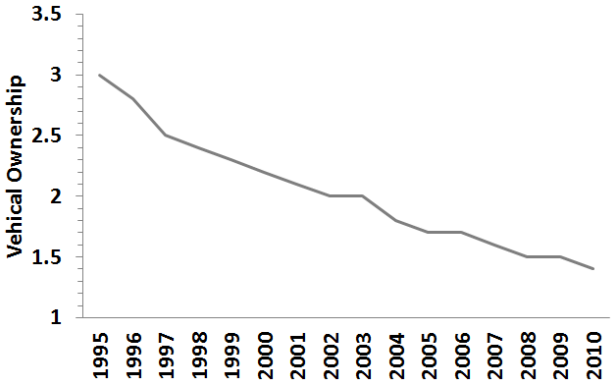


Figure 5 Changes in car ownership in Malaysia over the time period 1995-2010 [19]

Transport sector of Malaysia produced 42.43 million metric tons CO2 which shares 22.9% of total CO2 emission in Malaysia. Increased number of registered motor vehicles is expected in years to come which will certainly increase the emission further. Growth of CO2 emission from transport sector of Malaysia is shown in Figure 6. It can be seen that CO2 emission has increased from about 15 million metric tons in early nineties to 42.43 million metric tons in 2012. As per calculation, transport sector needs to reduce CO2 by 9.17 million metric tons in order to reduce 40% emission by the year 2020.

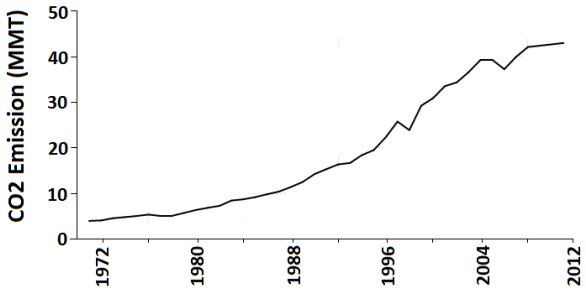


Figure 6 Trends in transportation CO2 emission in Malaysia during 1971-2010 [19]

Shares of different transport modes to total CO2 emissions from transportation sector are shown in Figure 7. The road transportation has the major share (85.2%) of total GHG emission from transportation. This follows the aviation, shipping and other small sectors. Therefore, the major reduction of CO2 emission should be achieved in road transportation.

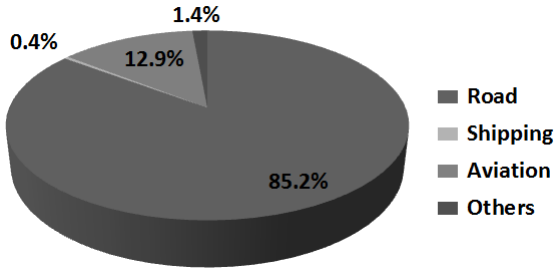


Figure 7 Shares of different transport modes to total CO2 emissions [17]

Contribution of different road vehicles in CO2 emission is shown in Figure 8. Cars are the major emitter of CO2 which stake about 59% of total emission from road transportation. This is followed by motor cycles which contribute about 11% to total emission. This indicates that private transportation is the major sources of CO2 emission from road transportation. It has already been mentioned that the country experienced unprecedented growth of private cars in last two decades. It has been projected that it will boom further in the coming years. Therefore, the major challenge of GHG reduction in transportation sector of Malaysia is to control emissions from private vehicles.

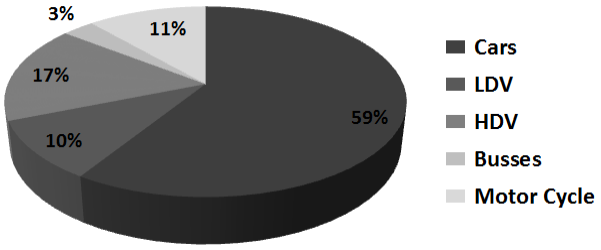


Figure 8 Contributions of different road vehicles in CO2 emission [16]

■5.0 GHG EMISSION REDUCTION STRATEGIES

A useful conceptual tool for reduction of GHG emission at country and regional levels is the avoid-shift-improve approach.[23] Avoidance of traffic is intended through reducing the need to travel. Similarly shifting to more energy efficient modes or routes is necessary. Continuous improvement using innovative technologies that are more energy efficient will be required. Based on this concept dozens of strategies have been proposed, evaluated and implemented in relation of CO2 emission reduction from transportation [24-26]. Many of the strategies are related to each other and have different time scale. A brief overview of few widely accepted strategies is given below.

Introduce low-carbon fuels–Strategies related to this group focus on using alternative fuels that have lower carbon content such as ethanol, biodiesel, natural gas, liquefied petroleum gas, synthetic fuels, electricity etc. to reduce GHG emissions from vehicles [26-27].

Increase vehicle fuel efficiency–The objective of this group of strategies is to improve vehicle fuel efficiency through advancement of technologies related to vehicle engine, transmission, materials, aerodynamics, etc. It is expected that less fuel for travel will reduce GHG emissions [26, 28].

Improve transportation system efficiency–These strategies focus GHG emission reduction by reducing the vehicle travel time by improvement of traffic system through various innovative forms of traffic management [24, 29].

Reduce carbon-intensive travel activity–The major focus of strategies belong to this group is to increase vehicle occupancy, eliminate the need for trips and actions that reduce GHG emissions associated with personal travel [26].

Introduce carbon tax–The objective of these strategies is to recover the cost incurred due to harmful effect of GHG emission and thereby influencing consumers to reduce GHC emission [30].

Encourage modal shift–This group of strategies is based on improving travel efficiency by shifting travel to more efficient modes, such as passenger vehicle to bus or train [25].

Planning efficient transportation–This group of strategies focus on integration of transportation and land use planning to reduce travel distances and reduce GHG emission [28].

Road charges and tolls–The focus of these strategies are to increase travel cost by introducing road charges and tools to reduce unnecessary or unimportant travels [30].

■6.0 INITIATIVES IN RELATION TO TRANSPORTATION-GHG EMISSION REDUCTION IN MALAYSIA

Malaysia has taken a short term roadmap for the reduction of emissions up to 40% by 2020 compared with 2005 levels. The roadmap identified three key sectors in achieving the target reduction namely, energy efficiency, renewable energy and solid waste management. The plan is to reduce about nine million tons of carbon dioxide annually by improving energy efficiency especially in transportation, another 11 million tons in the energy sector and 25 million tons reduction from the solid waste management sector by the year 2020. Number of initiatives in this line has been taken to improve energy efficiency and reduce GHG emission from transportation sector of Malaysia. The concept of integrating land use and transportation planning has been incorporated in planning of new settlements. Measures are taken to shift passengers from private vehicles to public transportation in urban areas. More public transportation such as MRT, LRT, trains and busses have been implemented and further planned in Kuala Lumpur and many other cities for this purpose. Initiatives also exist to improve vehicle standards, and encouragement of using energy efficient vehicles and diversification of fuels to cut CO2 emissions. Strict emission testing system has been introduced by Ministry of Transport Malaysia and Department of Environment Malaysia for vehicles. The measures are discussed below in brief.

6.1 Increasing Share of Public and Non-motorized Modes in Urban Areas

The government has taken initiatives to increase the use of public transportation. National Land Public Transportation Master Plan 2012 is designed to improve the standard of public transportation at the main population centers of Malaysia in order to increase the share of public transportation by 25% in 2020 [31]. Other initiatives such as increasing the accessibility and communication of the overall percentage of the population residing within 400 meters of the public transportation route from 63% to 75%, refurbishment of bus stoppages, introduction of new bus service, extension of rail routes, etc. have been taken to attract more people to use public transportation.

6.2 Planning Efficient Transportation

In planning of transportation system of newly developing urban areas, concept of green transport has been adopted. For example, the urban transportation blueprint of Iskandar Development Region (IDR) proposed smart development of both transit and landuse which is known as Transit Oriented Development (TOD) in order to enable the policy makers to plan for future development in a more sustainable manner. The strategies include reduction of auto dependency by reducing the road-based per capita travel and car ownership, and increase public modes ridership by using push and pull factors such as reliable transit services, development of compact and self-sustained growth centers among many others [32].

6.3 Diversification of Fuel

The government promoted natural gas vehicles (NGV) with incentives and legislation, and encouraged vehicle owners to use natural gas. The import duty and sales tax on NGV conversion kit are exempted. Besides those measures, gradual reduction of fuel subsidies and the price hikes on petrol and diesel led to a drastic increase in the number of new NGV in Malaysia. The increase of natural gas vehicles in Malaysia over the time period 2000-2009 is shown in Figure 9. The number of NGV increased to 42 thousand vehicles in 2009 as compared to less than 5 thousands in 2000 [33]. Furthermore, the government has planned to use bio-fuel for vehicles involving 5% of palm methyl ester blended with 95% diesel under the B5 program. Use of biodiesel is encouraged in National Bio-fuel Policy of 2006.

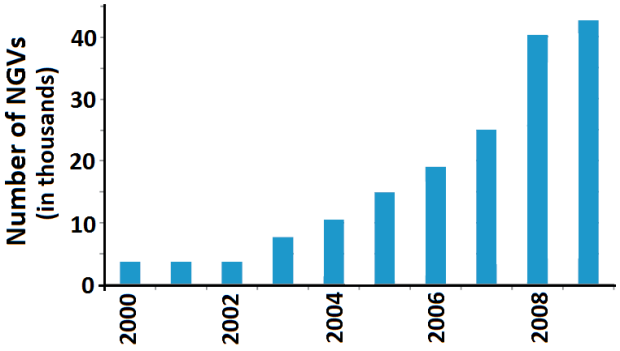


Figure 9 Increase of natural gas vehicles in Malaysia [33]

6.4 Increase Vehicle Fuel Efficiency

With the technological advances, vehicle fuel efficiency has increased worldwide. Malaysia is not out of this trend. However, vehicle fuel efficiency at national level depends on various direct and indirect measures including reducing fuel subsidies, increasing fuel price, encouraging alternative fuels, etc. Changes in vehicle fuel efficiency in Malaysia in recent years are shown in Figure 10. It can be seen from the figure that vehicle fuel efficiency has increased drastically in recent years. This may be due to technological advances at global scale as well as various measures taken at national level. It can be anticipated that gradual reduction of fuel subsidies and the price hikes on petrol and diesel has promoted fuel economy in new automobiles and discourage driving by owners of new and used vehicles alike.

Increased fuel efficiency has reduced fuel use and consequently, reduced average CO2 emission per vehicle. The trend in percentage of fuel combustion in transport sector of Malaysia is shown in Figure 11. The figure clearly shows that increasing vehicle fuel efficiency has decreased fuel combustion and reduces CO2 emission from vehicles.

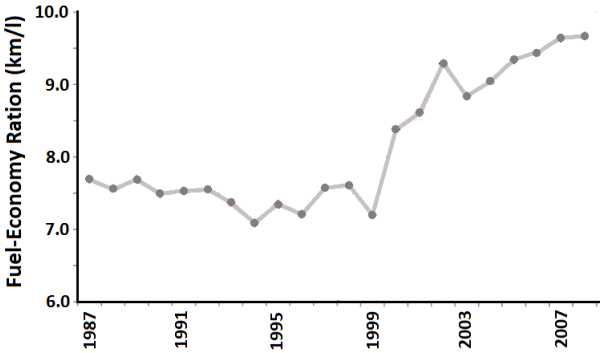


Figure 10 Increasing trend in fuel-economy ratio in Malaysia [34]

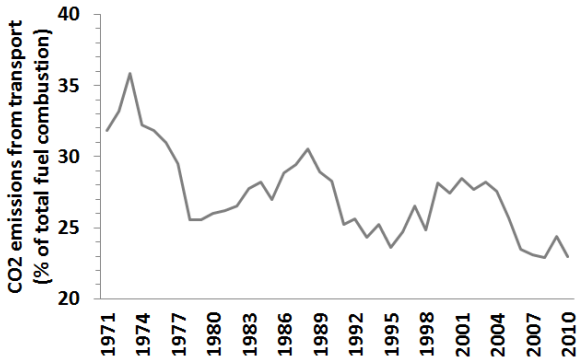


Figure 11 Decreasing trend in percentage of fuel combustion from transport sector of Malaysia [15]

■7.0 EVALUATION OF PROGRESS IN CO2 REDUCTION

To understand the overall progress in CO2 emission reduction in Malaysia in response to government initiatives, the CO2 emission time series data is divided into two periods, namely, pre-Asian financial crisis and post-Asian financial crisis. The Asian financial crisis in 1997 reduced car registration drastically in 1997 and consequently reduced CO2 emission in the years 1997-1998. This is clearly visible in Figures 4 and 6. Therefore, to remove the effects of financial constraints on CO2 emission, the trend over the data between 1999 and 2010 is analyzed.

It is well known that environmental phenomena follows Kuznet curve [34]. The Environmental Kuznets Curve (EKC) hypothesis postulates an inverted-U-shaped relationship between different pollutants and policy measures, i.e., environmental pressure increases up to a certain level; after that, it decreases. An EKC actually reveals how technically specified measures changes environmental quality of a country [34]. The CO2 emission data of Malaysia after Asian financial crisis is fitted with non-linear curve to show how emission reduction measures have affected the transportation-related CO2 emissions in Malaysia. The fitted curve is shown in Figure 12. It can be seen that increasing trend of transportation CO2 emission has decelerated in recent years. The upper part of the curve is still not flat, but it can be anticipated that it is going toward a saturation level.

EKC depends on many factors and therefore, with limited amount of data, it is not possible to project the present state of transportation CO2 emission of Malaysia in EKC. It is also not

possible to predict when CO2 emission trend will start to decrease. However, from the present trend it is very clear that CO2 emission will not enter to a decreasing trend with in next few years. This indicates that Malaysia will not able to reduce CO2 emission by 40% in 2020 compared to the level of 2005. More effective but prudent measures are required to achieve the goal.

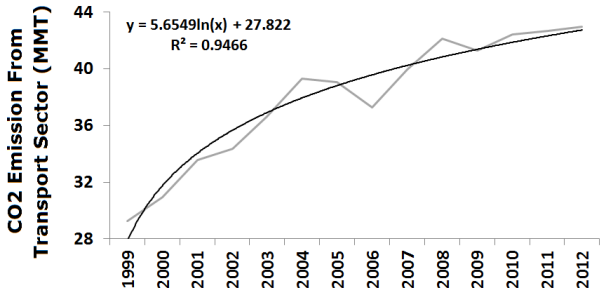


Figure 12 Best fitted non-linear regression curve shows decelerated trend in CO2 emission from transport sector of Malaysia in post-Asian financial crisis period

8.0 MALAYSIAN POTENTIAL IN CO2 REDUCTION

A comprehensive strategy to diversify the fuel basket for the transport sector and adopt fuels like natural gas, electricity and biodiesel on a large scale can reduce greenhouse gas emission significantly. Malaysia has plenty of natural gas available for automotive use and thus, it bears a good potential to convert road vehicles to NGV in order to reduce CO2 emission. Natural gas can be a clean alternative to other automobile fuel in order to reduce GHG emission. It has been reported that emission like unburned HC, CO, O2 and CO2 can be significantly lowered by using natural gas [36]. A number study indicates that the CNG is a better choice as automobile fuel than the gasoline both economically and environmentally [37-39].

Malaysia is the largest palm oil producer and exporter in the world and therefore, has potential to become pioneer palm biodiesel producer. Biodiesel is the renewable energy derived from the reaction of vegetable oils or lipids as well as alcohol and has great potential to serve as an alternative to petro-diesel fuel in compression ignition engine [15]. Biodiesel can reduce CO2 and CO emissions from 62% to 36%. It has been reported that Palm oil can reduce GHG emission by 36%. The GHG emission reduction capacity of Palm oil can be improved to 62% by processing Palm oil with methane capture.[40] Therefore, Malaysia has good prospect to introduce bio-fuel as a major fuel for road transportation and reduce CO2 and other GHG emissions.

Malaysia has high potential to develop public transportation systems in terms of their capacity, coverage and quality. Malaysia showed its potential to develop a proper transportation system in Putrajaya, the administrative headquarters of Malaysia. Improved public transportation can reduce the use of personalized motor vehicles and hence help to cut CO2 emission from transportation sector substantially.

9.0 OPTIONS FOR ACCELERATING CO2 REDUCTION IN MALAYSIA

Numerous measures have been proposed to reduce GHG emission from transport sector [24-30]. It is required to review those measures to identify the suitable options for Malaysia. Based on the review of existing literature, different measures implemented in developed countries to reduce GHG emission from transport sector and considering the potentiality of Malaysia in this regard, present study proposed few options that can be adopted to streamlining the ongoing measures.

9.1 Energy Efficient Road-based Mobility

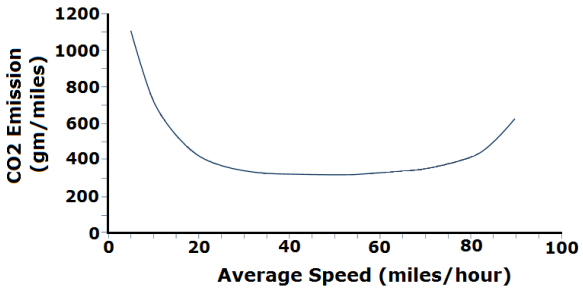
Malaysia can target developing mandatory fuel efficiency norms, stringent emission standards and strict inspection and maintenance regimes to encourage energy efficient and less polluting movement of road based modes. More intra-urban public transportation projects need to be undertaken in order to encourage a shift from personal to mass modes of transportation. This can be done by improving public transportation systems in terms of their capacity, coverage and quality. In addition to improve public transport and discourage the use of personal motor vehicles, government should target encouraging use of non-motorized greener modes of travel in cities.

9.2 Traffic Management to Reduce Congestions

Traffic congestion is a major problem in road transportation of Malaysia. Obviously, it has a significant role to CO2 emission from road transportation of Malaysia. The fuel consumption of vehicular traffic and associated CO2 emissions on a given road section depends strongly on the velocity profiles of the vehicles. A typical relation between CO2 emission and vehicle speed adapted from Barth and Boriboonsomsin [41] is shown in Figure 13. Analysis of data shows that if vehicle velocity reduces from 40 mile/h to 15 mile/h due to traffic congestion, the fuel consumption and CO2 emission can be increased up to 80% [42]. Therefore, Malaysia needs to adopt congestion mitigation strategies to increase traffic speeds and reduce CO2 emissions.

9.3 Eco-driving

A number of studies have summarized that fuel consumption and CO2 emission also depends on the nature of driving such as accelerating and decelerating [41, 43]. Public awareness should be grown on the benefit of smooth driving. Eco-driving can be made mandatory part of driver's training. Roads development and maintenance are also required to facilitate to reduce the number



and intensity of acceleration and deceleration events.

Figure 13 Relation between vehicle speed and CO2 emission [41]

9.4 More Diversification of Fuel

As Malaysia is the largest palm oil producer, it has high potential to generate bio-fuel. It is necessary to adopt effective measures to diversify fuel such as bio-fuel, natural gas, etc. by giving incentives for their promotion. Figure 14 shows how mixing of

bio-fuel with diesel can reduce CO2 emission. As fuel combustion is the major source of CO2 emission from road vehicle, fuel diversification can reduce emission very effectively. Efforts to implement the National Bio-fuel Policy (2006) are therefore, necessary.

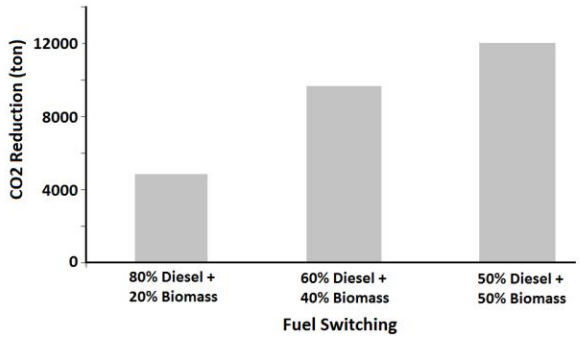


Figure 14 Impact of fuel-mixing on CO2 emission [38]

10.0 CONCLUSION

Transportation is the backbone of economic development of any nation. Efficient mobility enhances productivity and encourages economic activity; thereby increase national production and competitiveness. At the same time, transport has fundamental impacts on both built-up and natural environment. The issue of GHG emission from transportation has become a major concern across the world in the context of climate change. Malaysia like many other developed and developing countries has taken initiatives to reduce GHG emission from transportation sector. Present study reveals that CO2 emission which is the major constituent of GHG has decelerated in Malaysia in recent years. This obviously gives an indication that implementation of government green environment policy has impacted positively and effectively on CO2 emission. However, the analysis of data reveals that it is very unlikely that Malaysia will able to reduce CO2 emission from transport sector by 9.17 million metric tons per year by the year 2020 to fulfill its commitment. Malaysia has good potential to reduce CO2 emission by diversification of fuel and developing public transportation systems. Measures including diversification of fuels used in road vehicles, development of public transportation systems, improvement in the efficiency of road movement, growing public awareness on eco-driving can be adopted to develop climate-friendly transportation system as well as to fulfill the national aspirations for sustainability.

Reduction of CO2 emissions especially from transportation is a very broad and disputed issue. Numerous technical and non-technical measures have been proposed, evaluated and implemented in this regard is various geographical regions. The present study discussed only few widely used measures and their applicability in Malaysia. Further studies can be carried out in future to identify more suitable but effective options for CO2 emission reduction from transportation sector in Malaysia.

Mostly qualitative analysis of data is conducted in the present study as the trends were obvious in the graphical presentation. However, more rigorous analysis of data can be assimilated and analyzed to understand the major causes of recent deceleration of GHG emissions from transportation sector of Malaysia. As a result of which adaptation measures that are based on such studies would be more effective and comprehensive.

More data related to CO2 emissions need to be collected and fitted with environmental Kuznet curve to understand the present status of CO2 emission in Malaysia reliably. The analysis can also be used as the basis of possible future changes.

Interactions between different technical and non-technical measures with CO2 emission are non-linear and often complex. Sophistical modeling tools system dynamics and various soft computing techniques can be employed for reliable simulation of CO2 emissions.

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