International Journal of Engineering & Technology, 7 (4.35) (2018) 823-829

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Factors Influencing CO_2 Emissions and Strategies for Emissions Reduction in Malaysian Transportation Sector

Mustapa, S.I.,[1]*, Bekhet, H.A.[2]

[1]*Institute of Energy and Policy Research, Universiti Tenaga Nasional*
[2] *College of Graduate Studies, Universiti Tenaga Nasional*
**Corresponding author E-mail: indati@uniten.edu.my*

Abstract

The rapid urbanisation and economic growth has led to unprecedented increase in CO_2 emissions, which led to a vital global issue due partly to the rise in demand from the transport sector. In the years ahead, the transport services demand is likely to increase further, which lead to intensification in CO_2 emissions as well. The transportation sector in Malaysia contributes for about 28% of total CO_2 emissions, of which 85% of it goes to road transportation mode. This has led to a great interest in how the CO_2 emissions in this sector can effectively be reduced. Using a multiple regression model and datasets from 1990 to 2015, this study aimed to examine factors that influence the CO_2 emissions in Malaysia. Key factors of CO_2 emissions, i.e., fuel consumption (FC), distance travel (DT), fuel efficiency (FE), and fuel price (FP) were investigated for the road transport sector. The findings demonstrated that the impact of factors on CO_2 emissions were varies in each technology vehicles. These findings not only contributes to enhancing the current literature, but also provide insights for policy maker in Malaysia to design policy instruments for road transport sector.

Keywords: *CO_2 emissions, road transport, transport sector.*

1. Introduction

With rapid growth of economy and increasing population, Malaysia's transport sector has experienced intense development since 1990. The transportation is an important sector that significantly contributes to the socio-economic development. Passenger demand in Malaysia has increased by an annual 6.5% from 164 bpkm in 1990 to 793 bpkm in 2015, and freight demand increased from 36 btkm to 178 btkm, at 6.6% for the same period. Like many other countries around the world, the total transport demand is expected to increase in the further in the future [1].

The increasing economic growth, rapid urbanization and rising incomes had caused tremendous pressures on energy demand and CO_2 emissions [2]. In 2015, the share of energy consumption was recorded at 46.7 million tons of energy, consuming about 37% for transport sector, of which 85% (19 million tons) largely derived from road transportation modes [3],[4]. The population of motor vehicles also increased by 7.3% annually from 1990 to reach 26 million in 2015, with motorcycles and motorcars together contributing for 91% of total vehicles [5]. The insufficient public transportation system has also abetted the increasing of private vehicles in the country. In 2015, Malaysia's public transportation (i.e., bus and taxi) contributes almost 1% share of the total registered vehicles.

The transport sector remained as the prevalent CO_2 emitters after power generation. Over the years, the CO_2 emissions in the Malaysia's energy sector has increased. In 2015, a total of 220 million tons was emitted from the energy sector [6]. Power generation, transportation, industries and other sectors contributed 46%, 22%, 19% and 13% of the total CO_2 emissions with 6.4%, 4.4%, 3.6% and 13.9% annual growth increases, in the respective sectors. The CO_2 emissions in the transportation sector has superseded the industries sector in recent years [3]. Currently, road transportation accounts for the largest share with 85.2% of CO_2 emissions from the total transportation sector, followed by aviation, maritime, and rail sector. Private vehicles such as motorcars and motorcycles, represents about 70% of the total road transportation sector [7]. This sector depends mostly on fossil-fuels, particularly petrol (66%) and diesel (32%). And natural gas (2%) consist a marginal share [8]. Its heavy reliance on fossil-fuels is worrisome because it relates to energy security and environmental issues [9],[10].

The global CO_2 emissions have increased about 1.7% annually from 20.9 billion tons in 1990 to 32.3 billion tons in 2015 [6]. The world energy consumption in the transportation sector has projected to increase by 43% to reach 3260 million tons of standard equivalent by 2035 [6]. The climate change problem resulted from increasing levels of energy and CO_2 emissions has emerged as the profound challenges in recent decades. Consequently, at the 21st Conference of Parties in Paris, Malaysia has pledged a voluntary target of reducing its CO_2 emissions intensity by 45% (based on its 2005 levels) by 2030 [11]. The voluntary target has drawn nationwide attention in Malaysia as it become a challenge in moving towards developed and high-income nation by 2020 [12]. This is due to the fact that the demand for energy would increases as the country progresses, which resulted to an increase in CO_2 emissions. Figure 1 illustrates that between 1990 and 2015, the GDP and CO_2 emissions increases at 5.1% and 5.6% annual growth rate, respectively. This suggests that the CO_2 emissions in Malaysia has increased in line with the growth of GDP. Since the CO_2 emissions intensity is measured as CO_2 emissions over GDP, hence, the strategy for reduction of the CO_2 intensity is either by increasing the GDP adequately while maintaining the total CO_2 emissions, or by constraining the increase of absolute CO_2 emissions.

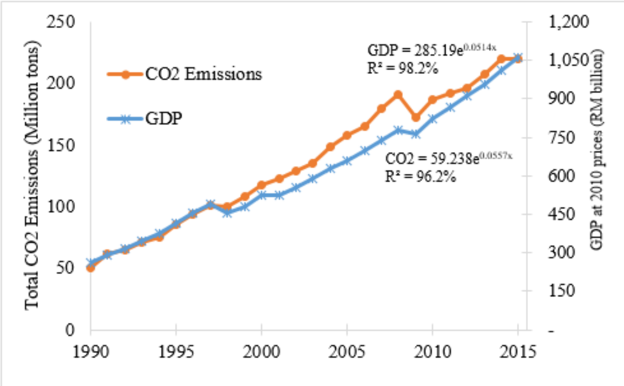

Fig 1: CO_2 Emissions and GDP Trends in Malaysia (1990 – 2015)
Source: [48], [6].

The combination of rapid economic expansion and continued population growth compels emissions to rise. Previous literature suggested that series of alternative strategies need to be implemented to achieve this emissions reduction target [13]. To address this issue, environmental friendly measures for transportation will be paramount to fulfill the desired aspiration for emission reduction. Undoubtedly, considering huge incremental increase in vehicle number and volume for passenger transport demand, the road transport sector will be a crucial sector that need to be addressed [14]. Some concerns are raised that the efforts to reduce CO_2 emissions would affect the transport demand growth, which would resulted to negative impact on the growth of economy. However, efficient vehicle technology seem to support a low-carbon growth path in reducing the CO_2 emissions intensity without hampering the growth of economy [15].

Therefore, this study aimed to investigate the key influencing factors of CO_2 emissions in the road transport sector and underscores the effective policy measures to achieve the national target. The remaining sections in this paper are structured as follows: Section 2 discusses the previous literature related to the study. Section 3 describes the conceptual framework followed by Section 4 on data sources and methodology. Section 5 provides the results analysis. The conclusions and policy implications are presented in Section 6.

2. Literature Review

The current research is extensively concerned with energy and CO_2 emissions in the transport sector with different method. A number of techniques and modeling approaches were applied to investigate the mitigation strategies and factors that affect the growth of CO_2 emissions in various sectors. Among the top three methods from literature are time series analysis, regression analysis and decomposition analysis. Using time series analysis, [16], [17] found cointegration of fuel price (FP) and income per capita on transport fuel consumption (FC). The later research suggest that fuel price subsidy was economically inefficient and investment on technology to increase productivity level was found to be able to reduce CO_2 emissions in the transport sector. [18] examined the impact of GDP, population growth and fuel consumption on the CO_2 emissions for Malaysia. Their result were consistent with [19] who suggested that FC and CO_2 emissions could be reduced through low-carbon technologies. [20] examined the relationships among urbanisation, industrial structure, energy, and CO_2 emissions intensity of 30 provinces in China. They used data from 2000 to 2015, their study confirmed that urbanisation and technology advancement of industrial structures would promote energy saving and CO_2 emissions reduction.

Using regression method analysis, [21],[22] investigated the relationship between urbanization, energy intensity, GDP and income and suggested that emissions could be reduced by increasing FE and alternative fuel use to renewables energy. [23] examined the effects of energy structure, population, GDP, and energy intensity on CO_2 emissions for China. They revealed that the CO_2 emissions were mostly driven by GDP followed by the scale of population and changes in energy structure. The study highlighted that fuel efficient (FE) technology was the most effective way for emissions reduction. [24] analysed the impact of population, GDP, transport volume on CO_2 emissions in the European Union (EU) transportation sector from 1990 to 2014. They found that population and energy intensity were the factors explaining CO_2 emissions and suggested that alternative mode of transport to the road would have most significant impact on reducing CO_2 emissions in the EU transport activity.

Using decomposition analysis, [25] used data of 1995-2012 period to investigate factors (i.e., GDP per capita, transportation intensity, transportation share, energy intensity, emissions coefficient and population) contributing to CO_2 emissions in China's transportation sector. They found that income was the dominant factor that results in the increase of emissions, while energy intensity was the main driving factor to lower CO_2 emissions. They suggested stricter energy standard to improve energy efficiency. [26] used input-output tables for 1992, 1997, 2002, 2007, and 2012 Tables with 35 sectors to investigate the driving factor of China's CO_2 emissions in China. Their study found that the growth of emissions was almost entirely driven by expansion of final demand. Moreover, [27] explored sectoral changes in energy efficiency using an input-output table from 1995 to 2011 and concluded that efficient technology would improve energy use and growth of CO_2 emissions.

Though the issue concerning energy and CO_2 emissions have been extensively discussed in previous literature, there are 2 gaps. The first short-comings is that most studies were concentrated on the key factors such as GDP, Population and fuel consumption. While there exist other factors such as fuel price, fuel efficiency and distance travel, empirical results explaining these factors on road transport CO_2 emissions are rather limited. The second short-comings is that most studies focused on the whole transport sector while the different road transport end-use demand such as diesel vehicle and petrol vehicles is neglected. Consequently, this study measured these gaps and investigated the inter-relationship and impact of fuel consumption (FC), distance travel (DT), fuel efficiency (FE) and fuel price (FP) on the CO_2 emissions of the road transport sector by different vehicle technology (i.e., petrol & diesel) in Malaysia.

3. Conceptual Framework

Based on the aforementioned literature, the conceptual framework was developed to examine the factors that influence the CO_2 emissions in the road transportation. The primary interest of dependent variable in the study was CO_2 emissions. The variance in the dependent variable can be explained by four independent variables namely FC, FE, FP, and DT.

In Malaysia, as the economy grew rapidly, the FC, especially petrol and diesel consumption seems to increase more rapidly than in other sectors [18]. It is therefore assumed that increasing fuel consumption tends to have a positive effect on CO_2 emissions. This condition is in accordance with the evidence of many researchers who found a positive effect between fuel consumption and CO_2 emissions [28].

The growing economy and increasing population in Malaysia has increased transport activities in both urban and intercity and has led to increase in fuel consumption and environment degradation through increased emissions [29]. This is apparent from the trend of passenger demand travel in Malaysia, which has witnessed an increase of 68% between 2005 and 2015. Therefore, it is assumed that distance travel (DT) has positive effects on CO_2 emissions.

Fuel efficiency (FE) merits special attention and calls for better quality of fuel and efficient vehicle technology in the sector. The effect of fuel efficiency improvement would result in less CO_2 emissions due to improving combustion strategies that can significantly improve engine efficiency and minimise energy use and emissions produced in the engine itself [30]. Hence, it is assumed that fuel efficiency (FE) has a negative effect on CO_2 emissions production.

Furthermore, fuel prices (FP) would also have a significant impact on the production of CO_2 emissions. As per capita income rises, the dominant effect of increases in fuel prices has been more demand for vehicle fuel economy rather than reduced driving [31]. In other words, people tend to drive efficient vehicles with higher fuel economy rather than sacrifice making trips in the face of rising petrol prices. Due to this fact, it is assumed that fuel price has a negative effect on CO_2 emissions production, and the impact is assumed to be different for different types of vehicle.

The assumptions of these relationships among variables of the study are shown schematically in Figure 2.

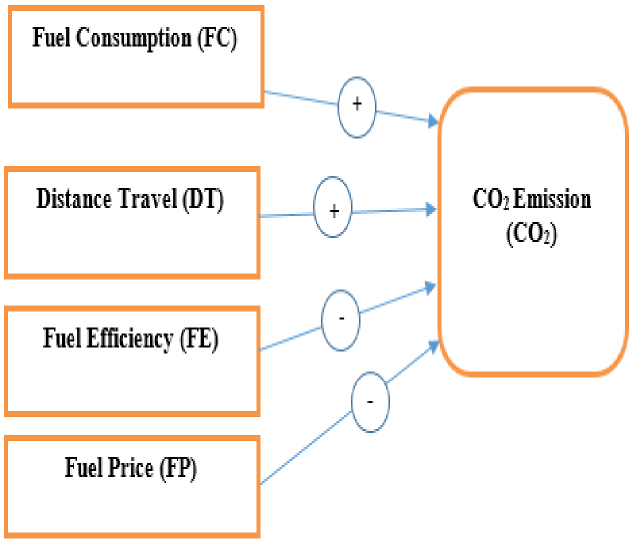

Fig. 2: Conceptual Framework of CO_2 Emissions Model in Road Transport Sector

Accordingly, it is hypothesized that:

H1a: There are significant inter-relationships between CO_2 emissions and its determinants (FC, DT, FE and FP) in petrol vehicle.

H1b: There are significant inter-relationships between CO_2 emissions and its determinants (FC, DT, FE and FP) in diesel vehicle.

H2a: There are statistically significant impacts of determinants (FC, DT, FE and FP) on CO_2 emission level in petrol vehicle.

H2b: There are statistically significant impacts of determinants (FC, DT, FE and FP) on CO_2 emission level in diesel vehicle.

4. Data Source & Methodology

4.1 Data Sources

In datasets on FC, DT, FE, and FP of road transport for 1990-2015 period was collected from various official data sources. The vehicle types used were motorcycles, motorcars, hire and drive cars, taxis, buses, and goods vehicle. This data was aggregated based on two main types of vehicle technology used in Malaysia i.e., Petrol and diesel vehicles. The natural gas vehicles were not accounted in the analysis as it comprised a marginal share of total vehicles in Malaysia. Therefore, the data sets were only divided into two i.e., petrol vehicle technology and diesel vehicle technology.

The annual data of FP, FC, and CO_2 emissions were collected from national statistical publications of the Energy Commission, [3] and from International Energy Agency. The data for FE and DT were not readily available. Consequently, the annual data of average mileage, vehicle numbers, occupancy or load factors, and average fuel efficiency by vehicle types from published literatures [8] were used to estimate relative FE, and DT of different vehicle technology types. The data sets are summarised in Table 1.

Table 1: Variables, Unit and Data Sources

Variables	Unit	Data Sources
Fuel Consumption (FC)	Kilotonnes of oil equivalent (ktoe)	National Energy Balance Report published by Energy Commission, Malaysia (EC).
Fuel efficiency (FE)	Km/ litre	International Energy Agency (IEA).
Distance Travel (DT)	Billion passenger km	Ministry of Transport, Malaysia and Malaysian Institute of Road Safety Research.
Fuel Price (FP)	RM/liter	National Energy Balance Report published by Energy Commission, Malaysia (EC).
CO_2 Emissions (E)	Million tonnes	CO_2 Emissions Combustion Report published by International Energy Agency (IEA).

4.2 Methodology

The methodology for testing procedure comprised of two part i.e., data quality test and multiple regression analysis. The first part of analysis was carry out to observe the data condition and data normality. In this analysis, the mean values and standard deviations were used to observe the data quality. The skewness, kurtosis and Jargue-Bera test were used to observe the normality distribution of the data. The inter-relationship analysis was then conducted to determine the relationships among the variables (FC, DT, FE, and FP) on CO_2 emissions.

The second part of analysis was a multiple regression model to examine the impact between CO_2 emissions and its determinants. The stepwise techniques were used in the model to test the effects of all determinants on CO_2 emissions. This technique reiterates the analysis by each parameter and independently considers the exclusion or inclusion of the parameters with every step.

Generally, the regression model was formulated as in Equation (1).

$$E = \beta_0 + \beta_1 FC_1 + \beta_2 FE_2 + \beta_3 DT_3 + \beta_4 FP_4 + \mu \quad \text{(Eq.1)}$$

Where,

E is the CO_2 emissions in transport sector

β_0 is the constant, intercept of the model

βn are the regression coefficients (i.e., $\beta_1, \beta_2, \beta_3, \beta_4$)

FC is the fuel consumption by type of fuel and technology

FE is the fuel efficiency by type of fuel and technology

DT is the distance travel by type of fuel and technology

FP is the fuel price by type of fuel and technology

μ is the Error Term

Building on general Equation (1), the regression analysis was then developed separately for two models (see Section 4.1). Model 1 denotes petrol vehicles technology (p) datasets and Model 2 denotes diesel vehicles technology (d) datasets as shown in Equation 2 and Equation 3, respectively.

$$Ep = \beta 0 + \beta 1\ FCp1 + \beta 2FEp2 + \beta 3DTp3 + \beta 4\ FPp4 + \mu \quad \text{(Eq.2)}$$

$$Ed = \delta 0 + \delta 1\ FCd1 + \delta 2\ FEd2 + \delta 3DTd3 + \delta 4\ FPd4 + \mu \quad \text{(Eq.3)}$$

The models' estimated coefficients result are shown and discussed in Section 5.

5. Result & Discussion

5.1. Descriptive Statistics, Normality Analysis and Inter-Relationship

Table 2 presents the statistical descriptions results for each determinant. The result of data quality were tabulated comprising minimum, maximum, mean and standard deviation, while the result of normal distribution data consisting of skewness, kurtosis and Jarque-Bera. The result observed a small standard deviation relative to the mean for all factors, implying good data quality. The skewness of the data were within the range of ±1 and kurtosis of the data were within the range of ±2, indicating good normality for the factors investigated [32]. The Jarque-Bera value [33],[34].

Table 2: Descriptive Statistics of CO_2 Emission Model.

Variables	CO_2	FCP	DTP	FEP	FPP	FCD	DTD	FED	FPD
Minimum	15.37	2889.0	106.40	7.32	1.48	1351.24	40.86	5.52	1.51
Maximum	65.50	12554.0	662.1	9.58	1.90	6439.48	129.21	8.12	2.01
Mean	33.09	7124.42	334.86	8.40	1.72	3157.92	89.14	6.21	1.79
Standard Deviation	11.46	2728.35	175.15	.7249	.1605	1356.14	27.62	.8245	.1904
Skewness	.687	.369	.389	.184	-.340	.344	-.264	.055	-.330
Kurtosis	1.184	-.216	-1.133	-1.244	-1.650	-.324	-1.135	-1.226	-1.660
Jarque-Bera (JB) Statistics	2.414	.697	2.011	1.796	3.120	0.711	1.701	1.637	3.121
Jarque-Bera (JB) Probability*	.299	.706	.366	.407	.210	.701	.427	.441	.210
Observation (n)	26	26	26	26	26	26	26	26	26

Note: (*) P-value ≥ 0.001
Source: Output of Eviews Package Version 10.

The Pearson correlation coefficient of the factors was analysed to determine the features of relationships (in terms of strength and direction) the between the dependent variable (E) and the independent variables (FC, DT, FE, and FP). The results of correlation coefficients for petrol and diesel vehicle technology are shown in Table 3 and Table 4, respectively. The inter-relationship correlation coefficient between CO_2 emissions and the variables for Petrol vehicle are within the range of ± 0.793 to ±0.977 at the 1% significance level. While the correlation coefficient for Diesel vehicle are within the range of ± 0.784 to ±0.985 at the 1% significance level. FC (FCP, FCD), and DT (DTP, DTD) have positive relationships with CO_2 emissions, implying that higher FC and DT are liable to increase CO_2 emissions [35]. FP (FPP, FPD), and FE (FEP, FED) of both petrol and diesel vehicles have a negative relationship with CO_2 emissions, indicating that higher FP and FE increases are likely to reduce CO_2 emissions.

Table 3: Inter-relationships for Petrol Vehicle Technology.

Factors	CO_2	FCP	DTP	FEP	FPP
CO_2	1.000				
FCP	0.958	1.000			
DTP	0.949	0.947	1.000		
FEP	-0.940	-0.953	-0.977	1.000	
FPP	-0.793	-0.826	-0.920	0.898	1.000

Note: Correlation is significant at 0.01 (2-tailed).
Source: Output of Eviews Package Version 10.

Table 4: Inter-relationships for Diesel Vehicle Technology.

Factors	CO_2	FCD	DTD	FED	FPD
CO_2	1.000				
FCD	0.910	1.000			
DTD	0.911	0.893	1.000		
FED	-0.946	-0.938	-0.985	1.000	
FPD	-0.784	-0.841	-0.887	0.902	1.000

Note: Correlation is significant at 0.01 (2-tailed).
Source: Output of Eviews Package Version 10.

5.2. Impact Analysis between CO2 Emissions and its Driving Factors

Multiple regression were conducted to examine the impact between CO_2 emissions and its determinants based on the step-wise method. The best results from stepwise regression for the Petrol Technology Vehicle (Model 1) in indicated in Table 5, which shows relevant statistical diagnostic tests are all significant, supporting the overall goodness of fit of the model. The results also suggest the significance and weights of multiple variables (i.e., FCP and DTP) on the CO_2 emissions with robust standard errors to minimise heteroscedasticity.

Table 5: Influencing factors for Petrol Technology Vehicles

Model	Unstandardised coefficients		Standardised Coefficients	t-value	P-value	VIF
	β	Std. Error	Beta			
Constant	7.055	2.025	-	3.484	.002	-
FCP	.002	.001	.574	3.428	.002*	9.767
DTP	.026	.011	.405	2.414	.024**	9.767
F=162.398, significant= 0.000, R^2=0.932, Adjusted R^2= 0.928, Durbin-Watson =1.562.						

*Notes: * and ** denotes significant level at 1% and 5%, respectively.*
Source: Output of SPSS Package Version 21.

The value of adjusted R^2 is .928 (R^2=.932) for the model shows 92.8% changes in response variable of CO_2 emissions occurs because changes in the combination of FCP and DTP. Also, the model indicated that the F-test is significantly supporting the overall goodness of fit of the model with a significance level at 1% (F = 162.398). The Durbin-Watson statistic of 1.562 also suggests that the error terms are not auto-correlated from the model. Also, the Variance Inflation Factors (VIF) of each variable in the model are acceptable to deal with multicollinearity problem at 9.767 [36].

The FCP seems to have a significant impact on CO_2 emissions in Model 1. This result is also consistent with those of other researchers, which reported domination of fuel consumption in the road transportation sector for the case of Australia [37] and Spain [38]. This is explained by the fact that petrol dominated energy consumption accounting for almost 70% of the total fuel consumption [3]. Also, DTP seems to have the highest impact on CO_2 emissions. This result is consistent with previous studies that found distance travel as one of the factors that affect CO_2 emissions production [39], [40]. This result is expected because petrol technologies constitute the largest share of vehicles population and travel demand (80%) in Malaysia road transport sector [41],[7]. The other variables of fuel price (FPP) and fuel efficiency (FEP) seem to have a statistically insignificant impact on CO_2 emissions in the model if other variables remain unchanged. This is probably because these variables are inadequate to measure CO_2 emissions for petrol technology vehicles.

Table 6 shows the best results from stepwise regression for the Diesel Technology Vehicle (Model 2) where the relevant statistical diagnostic tests are all significant, indicating overall goodness of fit of the model. The result also suggests the significance and weights of multiple variables (i.e., FED and FPD) on CO_2 emissions with robust standard errors to minimise heteroscedasticity.

Table 6: Influencing factors for Diesel Technology Vehicles

Model	Unstandardised coefficients		Standardised Coefficients	t-value	P-value	VIF
	δ	Std. Error	Alpha			
Constant	114.33	6.359	-	17.980	.000*	-
FED	-17.85	1.887	-1.284	-9.458	.000*	5.383
FPD	22.56	8.171	.375	2.761	.011**	5.383
F=134.442, significant= 0.000, R^2=0.921, Adjusted R^2= 0.914, Durbin-Watson =1.396.						

*Notes: * and ** denotes significant level at 1% and 5%, respectively.*
Source: Output of SPSS Package Version 21.

The value adjusted R^2 is .914 (R^2=.921) for the model, shows that 91.4% of the changes in the response variable of CO_2 emissions occur because of changes in the combination of two controlled variables which are fuel efficiency (FED) and fuel price (FPD). Also, the result indicated that the F-test is significantly supporting the overall goodness of fit of the model with a significance level at 1% (F = 134.442). The Durbin-Watson statistic of 1.396 suggests that the error terms are not auto-correlated, as recommended by [42] and [43]. Hence, the credibility and stability of the model are considered to be fair. The VIF of each variable is also considerably good at 5.383.
The FED seems to have a significant impact on CO_2 emissions. The negative coefficient of FED also implies that the use of diesel vehicles would result in a decline in CO_2 emissions due to its fuel efficiency [38],[40]. The diesel vehicles mainly used by passenger transport (i.e., taxies, buses, etc) and freight transport for goods and long distance travel [7]. The results are in agreement with past findings, which suggest that the higher fuel efficiency of diesel vehicles stimulate the use of diesel technology [4],[13],[15].
The results also revealed that fuel price (FPD) had the highest impact on CO_2 emissions for diesel technology vehicles. The results suggest that increasing FPD would increase CO_2 emissions. However, the impact of fuel price on CO_2 emissions seems to be positive which is contrary to the research framework and some studies [44],[35]. The marginal share of diesel vehicles (about 30%) in the market, as well as relative lower fuel price of diesel as compared to petrol in Malaysia, may cause a different impact of FPD found in the model.
The results of the inter-relationship and impact analysis of the variables are summarised in Tables 7. For inter-relationship analysis, the results showed that all the determinants (FC, DT, FE, and FP) support the hypothesis of H1a and H1b. While for impact analysis, the current results generally revealed that only the determinants of FC and DT support the hypothesis of H2a while FE and FP support the hypothesis of H2b.

Table 7: Results of Hypothesis Testing of Analysis

Hypothesis		Results
H1a	There are significant relationships between CO_2 emissions and its determinants (i.e., FC, DT, FE, and FP) in petrol vehicles.	Supported
H1b	There are significant relationships between CO_2 emissions and its determinants (i.e., FC, DT, FE, and FP) in diesel vehicles.	Supported
H2a	There are significant impacts of determinants (i.e., FC, DT, FE, and FP) on CO_2 emissions level in petrol vehicles.	Supported
H2b	There are significant impacts of determinants (i.e., FC, DT, FE, and FP) on CO_2 emissions level in diesel vehicles.	Supported

6. Conclusions & Policy Implications

This study investigated the factors that influenced the CO_2 emissions in Malaysia's road transport sector. The multiple regression analysis over the period of 1990 – 2015 were used and the results indicated significant effects between CO_2 emissions and its determinants (FC, DT, FE and FP). The study revealed that emissions from road transport show different impact in each technology vehicles, hence policy measures of emission reduction should allow for this disparity.
The results showed that for petrol vehicle technology, both fuel consumption and distance travel are the key factors influencing the CO_2 emissions. This dominance of fuel consumption and travel demand in petrol vehicles were associated with its negative impact on the environment. This result could help policy makers in managing the fuel diversification and travel demand by considering alternative fuel use, green technology vehicles and more efficient public transportation to balance the environmental quality in Malaysia. For diesel vehicle technology, it is evident that fuel prices and fuel efficiency are the key influencing factor which significantly impact CO_2 emission. In terms of fuel efficiency, the results suggest that the higher fuel efficiency of diesel vehicles stimulates the use of diesel technology, which reduces CO_2 emissions production. This occurs because diesel cars are more efficient than petrol vehicles, leading to a decrease in the general cost of using cars. This in turn causes reduction in the CO_2 emissions due to its lower energy consumption to meet transport activities. On the other hand, the result suggests a positive impact of fuel price on CO_2 emissions. From the viewpoint of CO_2 emissions, the current fuel price factor is significant, but is not able to reduce CO_2 emissions. This occurs because of the current marginal share of diesel vehicles (about 30%) in the market, as well as the relatively lower fuel price of diesel as compared to petrol in Malaysia. This case is interesting because the fuel price factor on CO_2 emissions may be detrimental on larger scales of diesel vehicles.
From the economic perspective, the significant inter-relationship analyses found in the study suggest that fuel subsidy removal seems to contribute a significant impact to reduce the CO_2 emissions level. However, as global oil prices are declining plus increasing income level in the future, the fuel price increase would cause a marginal impact as it increases affordability to purchase and uses private vehicle for transportation. Therefore, additional traffic and demand measures, such as congestion charges and carbon tax might be required to create a price signal to incentivise vehicle users for fuel consumption and CO_2 emissions reduction.
From the energy planning perspective, the demand in the road transport sector has been deeply invoked as a result of urbanisation and income growth, which cause large amounts of CO_2 emissions. The results obtained suggest that alternative fuel use, fuel improvement, travel management, and fuel pricing mechanisms seem to be important policies to address the CO_2 emissions problem in the road transportation. As huge amount of passenger vehicles runs on petrol (93%), the intensification of efficient vehicle i.e., electric and hybrid can reduce CO_2 emissions in the sector [45]. Fuel modal shift should be triggered through promotion and fiscal incentives shall be continued to accelerate the use of efficient vehicles.
Furthermore, energy efficient technology need to be improved through preferential policies i.e., fuel economy standard [9] to encourage the car manufacturers to employ energy efficient technologies. This policy can help for increasing the penetration rate of efficient vehicles in the economy. The practices in other areas such as the Singapore, Japan, the United States, and Europe have proven that fuel economy standard is effective in reducing energy

usage as well as CO_2 emissions. However, to build this policy, human capacity need to be developed and regulatory authority needs to be institutionalised.

As DT has been observed as notable factor for diesel vehicles, fuel switching to biofuels can reduce the fuel consumption to meet the mobility needs [44],[46]. The currently used of B7 in diesel vehicles appears to support the country's CO_2 emissions reduction. Therefore, the plan to use B15 (blend of 15% palm biodiesel) by 2020 is commendable towards CO2 emissions reduction in Malaysia [47].

The results from the study has identified the influencing factors and potential measures for reducing CO_2 emissions in the local context. However, the current study only focused on the local perspective of the road transport sector. Travel management strategy to shift from private vehicles to public transport i.e., mass rapid transit, light rail transit, etc. seem to contribute effectively for CO_2 emissions reduction [7]. Hence, further research can be expanded to include other types of transportation modes i.e., air, maritime, and rail to enhance representation of the transportation system. Furthermore, exploration for other factors such as vehicle curb weight, speed of the vehicle, etc. may also be considered to address different patterns of CO_2 emissions between such differing variables categories.

References

[1] Zhang, C., Nian, J. (2013). Panel estimation for transport sector CO2 emissions and its affecting factors: A regional analysis in China. *Energy Policy*. 63. 918-926.

[2] Profillidis, A.V., Botzoris, N.G., Galanis, T.A. (2014), Environmental effects and externalities from the transport sector and sustainable transportation planning – A review. International Journal of Energy Economics and Policy, 4(4), 647-661.

[3] Energy Commission, (EC). (2017), National Energy Balance 2012. Malaysia: Ministry of Energy, Green Technology and Water.

[4] Indati, M.S., Bekhet, H.A., (2016). Analysis of CO_2 emissions reduction in the Malaysian transportation sector: An optimization approach. *Energy Policy*. 89, 171-183.

[5] Ministry of Transport Malaysia (MOT), 2017. Transport Statistics Malaysia (2001-2017). Available onine from http://www.mot.gov.my. Last Visit: December 2017.

[6] International Energy Agency, (IEA). (2017), CO2 Emission from Fuel Combustion. Paris: IEA.

[7] Ong, H.C., Mahlia, T.M.I. & Masjuki, H.H. (2012). A review on energy pattern and policy for transportation sector in Malaysia. *Renewable and Sustainable Energy Reviews*, 16(1), 532–542.

[8] Indati, M.S., Bekhet, H.A. (2014), Highlighting of the factors and policies affecting CO2 emission level in Malaysian transportation sector.Environmental Earth Science and Engineering, 8(1), 10-18.

[9] Silitonga, A.S., Atabani, A.E., Mahlia, T.M.I. (2012), Review on Fuel economy standard and label for vehicle in selected ASEAN countries. Renewable and Sustainable Energy Reviews, 16, 1683-1695.

[10] Mofleh, A., Taib, S., Salah, W.A. (2010), Malaysian energy demand and emissions from the transportation sector. Transport, 25(4), 448-453.

[11] Rasiah, R., Al-Amin, A.Q., Ahmed, A., Filho, W. L., Calvo, E., (2016). Climate mitigation roadmap: assessing low carbon scenarios for Malaysia. *Journal of Cleaner Production*. 133. 272 -283.

[12] Economic Planning Unit, (EPU). (2015), Eleventh Malaysia Plan 2016-2020 Anchoring Growth on People. Putrajaya, Malaysia: Prime Minister's Department.

[13] Aizura, A.B., Mahlia, T.M.I., Masjuki, H.H. (2010), Potential fuel savings and emission reduction from fuel economy standards implementation for motor vehicle. Clean Technologies and Environmental Policy, 12(3), 255-263.

[14] Cheng, Y.-H, Chang, Y.-H., Lu, I.J. (2015). Urban transportation energy and carbon dioxide emission reduction strategies. *Applied Energy*.157, 953-973.

[15] Shahid, S., Minhans, A., Othman, C.P. (2014), Assessment of greenhouse gas emission reduction measures in transportation sector in Malaysia. Journal Teknologi, 70(4), 1-8.

[16] Sultan, R. (2010), Short-run and long-run elasticity of gasoline and demand in Mauritius: An ARDL bound test approach. Emerging Trends in Economics and Management Science, 1(2), 90-95.

[17] Ackah, I., Adu, F. (2014), Modelling gasoline demand in Ghana:A structural time series approach. International Journal of Energy Economics and Policy, 4(1), 76-82.

[18] Begum, R.A., Sohag, K., Sharifah, S.A., Mokhtar, J. (2015), CO2 emissions, energy consumption, economic and population growth in Malaysia. Renewable and Sustainable Energy Reviews, 41, 594-601.

[19] Ivy, Y.L.L., Bekhet, H.A. (2015), Examining the feedback response of residential electricity consumption towards changes in its determinants: Evidence from Malaysia. International Journal of Energy Economics and Policy, 5(3), 772-781.

[20] Lin, B, Zhu, J. (2017). Energy and carbon intensity in China during the urbanization and industrialization process: A panel VAR approach. *Journal of Cleaner Production*. 168, 780 -790.

[21] Sadorsky, P. (2013) .Do urbanization and industrialization affect energy intensity in developing countries? *Energy Economics*. 37. 52-59.

[22] Sadorsky, P. (2014).The Effect of Urbanization and Industrialization on Energy Use in Emerging Economies: Implications for Sustainable Development. *American Journal of Economics and Sociology*. 73 (2), 392- 409.

[23] Xu, S.C., He, Z.X., Long, R.Y. (2014), Factors that influence carbon emissions due to energy consumption in China: Decomposition analysis using LMDI. Applied Energy, 127, 182-193.

[24] Andres, L., Padilla, E. (2018). Driving factors of GHG emissions in the EU transport activity. *Transport Policy*. 61.60–74.

[25] Li, W., Li, H., Zhang, H., Sun, S. (2016). The Analysis of CO_2 Emissions and Reduction Potential in China's Transport Sector. *Mathematical Problems in Engineering*. 2016. 1-12.

[26] Ji, J., Hu, G., Wu, Y., Ma, X. (2017). China's fast growing CO2 emissions driven by increasing consumption in 1992-2012: A structural decomposition analysis. *Earth and Environmental Science*.59. 1-9.

[27] Huang, X.Y., Zhou, J.Q., Wang, Z., Deng, L.C., Hong, S. (2017). Structural Decomposition Analysis of China's Industrial Energy Consumption Based on Input-Output Analysis. *Earth and Environmental Science*. 63, 1-10.

[28] Gokmenouglu, K. Taspinar, N. (2016). The relationship between CO2 emissions, energy consumption, economic growth an FDI: The case of Turkey. *Journal of International Trade and Economic Development*, 25, 706-723.

[29] Bharadwaj, S., Ballare, S., Rohit, Munish, K.C. (2017). Impact of congestion on greenhouse gas emissions for road transport in Mumbai metropolitan region. *Transportation Research Procedia*. 25, 3538–3551.

[30] Martin, N.P.D., Justin D. K. Bishop, J.D.K., and Adam M. Boies. A.M. (2017). How Well Do We Know the Future of CO_2 Emissions? Projecting Fleet Emissions from Light Duty Vehicle Technology Drivers. *Environment Science Technology*, 51 (5), 3093–3101. 311–322.

[31] Yang, D., Timmermans, H. (2012). Effects of Fuel Price Fluctuation on Individual CO2 Traffic Emissions: Empirical Findings from Pseudo Panel Data. *Procedia - Social and Behavioral Sciences*. 54, 493 – 502.

[32] George, D., & Mallery, M. (2010). SPSS for Windows Step by Step: A Simple Guide and Reference, 17.0 update (10a ed.). Boston: Pearson.

[33] Das, K.R., Imon, A. H. M. R. (2016). A Brief Review of Tests for Normality. *American Journal of Theoretical and Applied Statistics*, 5(1), 5-12.

[34] Uyanik, G.K., Guler, N. (2013). A Study on Multiple Linear Regression. *Social and Behavioral Sciences*, 106. 234 -240.

[35] Wang, X. Q., Huang, G. H., & Lin, Q. G. (2012). An interval mixed-integer non-linear programming model to support regional electric power systems planning with CO2 capture and storage under uncertainty, *Environmental System Research*, 1(1), 1–13.

[36] Bello, M.O., Solarin, S.A., Yen, Y.Y. (2018). Hydropower and potential for interfuel substituon: The case of electricity sector in Malaysia. *Energy*. 151, 966-983.

[37] Pearce, P. (2017). Taxes to influence energy use in road transportation in Australia. *Renewable Energy Environment Sustainability*. 2 (16). 1- 6.

[38] Beuno, G. (2012), Analysis of scenario for the reduction of energy consumption and GHG emission in transport in basque country. *Renewable and Sustainable Energy Reviews*, 16, 1988-1998.

[39] Zanni, A.M. & Bristow, A.L. (2010). Emissions of CO_2 from road freight transport in London: Trends and policies for long run reductions. *Energy Policy*, 38, 1774-1786.
[40] Bonilla, D. (2009), Fuel demand on UK roads and dieselisation of fuel economy. *Energy Policy*, 37, 3769-3778.
[41] Briggs, H.G., Leong, H.K. (2016). *Malaysia Stocktaking Report on Sustainable Transport and Climate Change*, Bonn und Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.
[42] Field, A.P. (2009). Discovering statistics using SPSS (3rd eds). London, UK: Sage Publications.
[43] Braun, M.R., Altan, H., & Beck, S.B.M. (2014). Using regression analysis to predict the future energy consumption of a supermarket in the UK. *Applied Energy*, *130*, 305–313.
[44] Xu, B., & Lin, B. (2015). Factors affecting CO2 emissions in China's transport sector: a dynamic nonparametric additive regression model. *Journal of Cleaner Production*, 101,311-322.
[45] Sang, Y.N., Bekhet, H.A. (2015), Modelling electric vehicle usage intentions: An empirical study in Malaysia. Journal of Cleaner Production, 92, 75-83.
[46] Borjesson, M., Ahlgren, E.O. (2011), Assessment of transport fuel taxation strategies thorugh integration of road transport in an energy system model – The case of Sweden. International Journal of Energy Research, 36, 648-669.
[47] Ghani, A.W. (2017). *Malaysia Biofuel Annual 2017*. Kuala Lumpur, Malaysia: Global Agricultural Information Network.
[48] Department of Statistics Malaysia, (DOSM). (2017), Population in Malaysia. Available from: http://www.statistics.gov.my/portal. Last visit: December 2017.