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Studying of the Impact of road, environment, driver, and traffic characteristics on CO_2 vehicles emissions on Egypt

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دراسة تأثير خصائص الطرق, البيئة, السائق وحركة المرور على انبعاثات ثاني أكسيد الكربون للمركبات في مصر

الملخص:

الهدف من هذا البحث هو دراسة العوامل التي تؤثر على انبعاثات ثاني أكسيد الكربون من المركبات على الطرق المصرية. تمت معايرة النماذج باستخدام سجلات انبعاثات المركبات التي تم جمعها خلال الدراسة للفترة (نوفمبر 2017). سجلت البيانات لثماني مركبات ، وتم تصنيف بيانات الانبعاث حسب نوع الوقود إلى ثلاث فئات (ديزل ، وغاز طبيعي ، ومركبات بنزين) ، ولإجراء تحليل مقارن لمختلف تقنيات النمذجة الإحصائية ، تم استخدام نماذج الانحدار الخطي المعممة مثل "الانحدار الخطي" مع وظيفة الارتباط للهوية ، والانحدار الخطي. مع وظيفة الارتباط من السجل ، وانحدار جاما مع وظيفة الارتباط من السجل وانحدار Tweedy مع وظيفة الارتباط في السجل "للتنبؤ بمعدلات انبعاث السيارة كدالة للمتغيرات المستقلة. تم الحصول على قياسات انبعاثات المركبات (CO2 (g / s المستخدمة في هذه الدراسة من جهاز شؤون البيئة المصري (EEAA) المسجلة للفترة (نوفمبر 2017) ، تم اختيار سبعة متغيرات مستقلة في هذا البحث (سرعة السيارة ، الزاوية بين المحاذاة الأفقية ، الملف الشخصي الدرجة ودرجة الحرارة المحيطة والضغط المحيط والرطوبة النسبية المحيطة وعدد الدوران في الدقيقة لمحرك السيارة) والتي تؤثر بشكل مباشر على انبعاثات المركبات لفئات المركبات المختلفة ثم مقارنة هذه النتائج التي تم الحصول عليها من النموذج الرياضي (SPSS). أخيرًا ، وجد أن نموذج الانحدار الخطي مع وظيفة الارتباط في السجل كان أفضل نموذج انحدار معمم لتمثيل الارتباط بين انبعاثات ثاني أكسيد الكربون لمركبات الديزل والغاز الطبيعي وانبعاثات مركبات البنزين.

ABSTRACT

The objective of this research is to study factors that effect on the CO_2 vehicles emissions on Egyptian roads. The models were calibrated using vehicles emission records collected during the study for the period (November 2017). Data recorded for eight vehicles, emission data were classified according to the fuel type to three categories (Diesel, Natural Gas and Petrol Vehicles), and to conduct a comparative analysis of various statistical modeling techniques generalized linear regression models were used such as "Linear Regression with Link Function of Identity, Linear Regression. with Link Function of Log, Gamma Regression with Link Function of Log and Tweedy Regression with Link Function of Log " to predict vehicle emission rates as a function of the independent variables.

Vehicles emission measurements CO_2 (g/s) used in this study were obtained from Egyptian Environmental Affairs Agency (EEAA) recorded for the period (November 2017), Seven independent variables were selected in this research (vehicle speed, angle between horizontal alignments, profile grade, ambient temperature, ambient pressure, ambient relative humidity and numbers of rotation per minute for vehicle engine) which affect directly on the vehicle emissions for the different vehicles categories then a comparison of these results obtained from the (SPSS) mathematical model.

Finally, it was found that Linear regression model with link function of log was the best generalized regression model to represent the correlation between CO_2 emission for Diesel vehicles, Natural Gas and Petrol vehicles emission.

Keywords: CO_2 emission-Diesel vehicles-Natural Gas vehicles-Petrol vehicles

1. Introduction

The road fleet in Egypt consists of various types of vehicles such as cars, taxis, buses and minibuses, trucks, motorcycles, tractors and special purpose vehicles. The number of vehicles registered in Egypt is continuously increasing at a rate much higher the rate of increase of the roads and this causes a sever traffic problems and increased fuel consumption and consequently increased GHG emissions (EEAA, 2016).

In recent years (after 2005) the total number of vehicles began to increase at a very high rate (11.8% annual increase rate in the period 2005/2010 compared to 2.2% in the period 2000/2005) (EEAA, 2016). This results from high increase rate of private cars and motorcycles. The annual increase rate of private cars jumped from 6.1% in the period 2000/2005 to 12.6% in the period 2005/2010 (EEAA, 2016).

The overall fleet composition is continuously changing, the percentage of private cars increase from 44.5% in 2000 to 49.1% in 2010. The percentages of the other types of vehicles such as buses and trucks remain constant or slightly decrease (EEAA, 2016).

2. Problem Statement and Research Objectives

The main objective of this study was to analyze factors influence vehicles CO_2 emissions. The procedure of the analysis was based on actual continuous speed profiles and emission estimation model. The study focused on vehicles emission measurements of CO_2 (g/s) because it was the major contributor to global warming. The underlying hypothesis is that vehicles emissions affected from several variables, these variables categorized to travel-related factors, highway characteristics and vehicle characteristics and other factors. Seven independent variables were selected in this research (vehicle speed, bearing angle between horizontal alignments, profile grade, ambient temperature, ambient pressure, ambient relative humidity and numbers of rotation per minute for vehicle engine) which affect directly on the vehicle CO_2 emissions for the different vehicles categories.

3. Methodology

This section presents the methodology and techniques which were applied in this research and data sources that were utilized in the modeling approach and the several mathematical approaches to estimate vehicle CO_2 emissions relationship with the independent variables which categorized to travel-related factors, highway characteristics and vehicle characteristics and other factors

4. Data Description

In this research, the available data for vehicles emissions were obtained from Egyptian Environmental Affairs Agency (EEAA) recorded for the period (November 2017), On-board Portable Emission Measurement System (PEMS) was used to collect the data of second-by-second emissions and speed variation of the vehicle under real-world conditions at any location traveled by the vehicle (Cicero-Fernández, P. 1997).

These data are in the form of look-up tables for microscopic emission rates measurements CO_2 (g/s), Temperature, Pressure, Relative Humidity, Numbers of Rotation per Minute for Vehicle Engine and vehicle speed. The raw data was collected every second during various driving cycles for each individual vehicle, Figure 1showed sample of the received data and Table 1 represents the different types for the eight vehicles which used in this research.

[

Reading no	Local Time	Latitude	Longitude	Alt [m]	CO_2 [g/s]	Revolution Per Minute RPM	Speed V [kph]	Temperature C°	Pressure P [kPa]	Relative Humitidy RH[%]
157	8:20:47	30.054897	31.240293	31.1	1.47	3,192	34	27.44	100.8	58
158	8:20:48	30.054964	31.240358	30.8	0.89	3,199	35	27.44	100.8	58
159	8:20:49	30.055033	31.240421	30.7	0.78	3,162	34	27.44	100.8	58
160	8:20:50	30.055096	31.240485	30.7	0.82	2,983	33	27.44	100.8	58
161	8:20:51	30.055159	31.240545	30.5	0.88	2,345	33	27.44	100.8	58
162	8:20:52	30.055225	31.240601	30.5	0.81	1,869	30	27.44	100.8	58
163	8:20:53	30.055276	31.240659	30.6	0.98	1,671	26	27.44	100.8	58
164	8:20:54	30.055321	31.240706	30.4	2.45	1,911	24	27.44	100.8	58
165	8:20:55	30.055365	31.24076	30.3	3.15	2,307	25	27.44	100.8	58
166	8:20:56	30.055407	31.240816	30.4	3.41	2,546	27	27.44	100.8	58
167	8:20:57	30.055455	31.240875	30.4	3.48	2,732	29	27.44	100.8	58
168	8:20:58	30.055508	31.240942	30.2	3.06	2,914	31	27.44	100.8	58
169	8:20:59	30.055568	31.240998	30	2.50	3,063	33	27.44	100.8	58
170	8:21:00	30.055631	31.241058	29.4	1.84	3,173	34	27.44	100.8	58
171	8:21:01	30.055693	31.241131	29.5	1.12	3,225	35	27.44	100.8	58
172	8:21:02	30.055753	31.241205	29.4	0.91	3,009	35	27.44	100.8	58
173	8:21:03	30.055813	31.241279	29.4	0.85	2,336	34	27.44	100.8	58
174	8:21:04	30.055872	31.241342	29.2	0.82	1,863	33	27.44	100.8	58
175	8:21:05	30.055927	31.241411	29.1	0.96	1,695	31	27.44	100.8	58
176	8:21:06	30.055979	31.24148	29.2	2.00	2,081	31	27.44	100.8	58
177	8:21:07	30.056031	31.241545	29.3	3.86	2,733	31	27.44	100.8	58
178	8:21:08	30.056087	31.24161	29.4	4.57	3,026	32	27.44	100.8	58
179	8:21:09	30.056146	31.241675	29.4	4.67	3,176	34	27.44	100.8	58
180	8:21:10	30.056214	31.241745	29.7	3.49	3,321	36	27.44	100.8	58
181	8:21:11	30.056283	31.241813	29.4	1.23	3,296	37	27.44	100.8	58

Figure 1. Sample of Received Data for Vehicle Emissions, (EEAA, 2017).

Table 1 Vehicle data brand, engine capacity, model year, fuel type and usage (EEAA, 20017).

Car No	Car brand	Engine Capacity CC	Model Year	Fuel Type	Usage
1	Mercedes	6,000	2,006	Diesel	Bus
2	Chevrolet	4,500	2,009	Diesel	Minibus
3	Toyota	2,500	2,010	Diesel	Microbus
4	Daewoo	6,000	2,010	Natural Gas	Bus
5	Foton	2,500	2,013	Natural Gas	Microbus
6	Speranza	1,600	2,010	Petrol	Taxi
7	Isuzu	2,000	1,989	Petrol	Private Car
8	Jeep Cherokee	3,700	2,008	Petrol	Private Car

A total reading of 48489 of vehicle emission exhaust were recorded for the eight vehicles, the number of emission readings for each vehicle was indicated in Figure 2

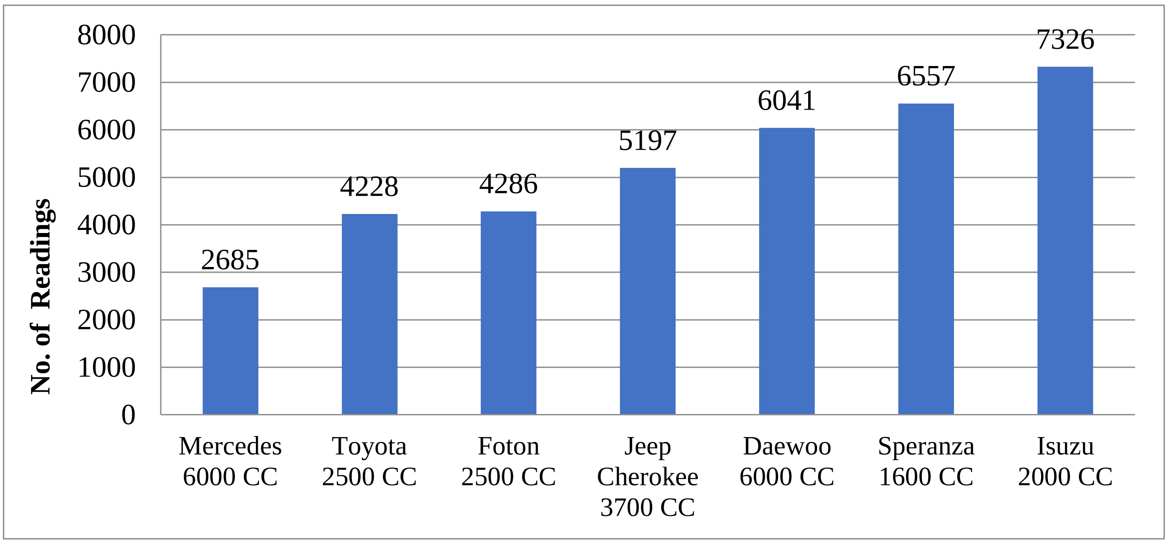

Figure 2: Emission readings for each vehicle, (EEAA, 2017).

4.1.1. Data Classification

The eight vehicles were classified according the fuel type to three categories the first was for Diesel Vehicles including the first three vehicles (Mercedes Bus, Chevrolet Minibus and Toyota Microbus), while the second category was for Natural Gas Vehicles containing the fourth and fifth vehicles (Daewoo Bus and Foton Microbus), at last category for Petrol Vehicles (Speranza Taxi, Isuzu Private Car and Jeep Cherokee Private Car). The total no of vehicle emission exhaust were illustrated in Figure 3.

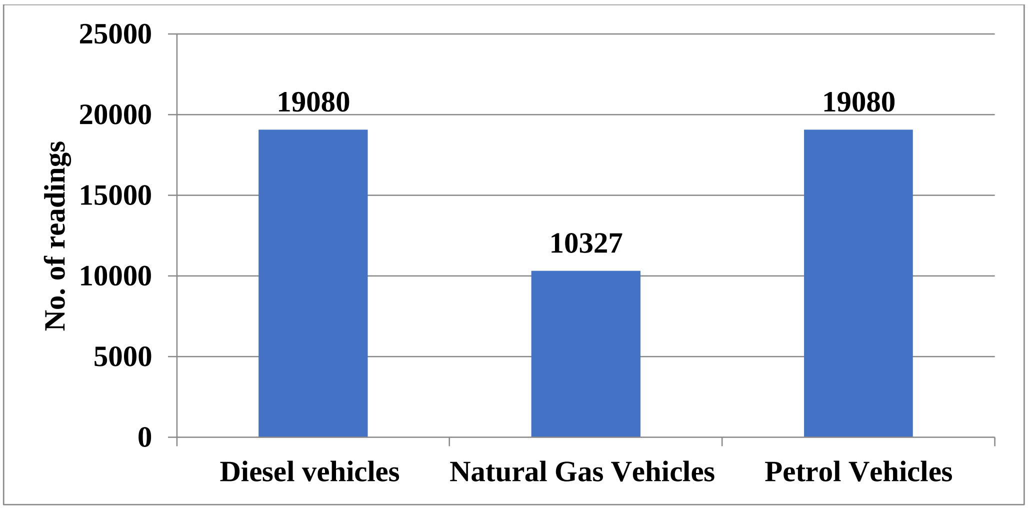

Figure 3 Total Emission Readings for Each Vehicle Category, (EEAA, 2017).

4.1.2. Dependent Variable

In previous researches it was found that CO_2 emission one of the main important vehicles emissions exhaust which represent dependent variables measurements.

4.1.3. Independent Variable

Seven independent variables were selected in this research which affect directly on vehicle emissions from transportation, Design speed is an essential parameter in the highway geometric design, and affects other design features (Harikishan, P 2018). Vehicle speed was chosen as essential element of travel related factors effect on vehicle emissions in this research. The bearing angle between horizontal alignment tangents and longitudinal road grades were selected to study the effect of highway characteristics on vehicle emissions. Numbers of rotation per minute for vehicle engine, ambient temperature, ambient pressure and ambient relative humidity were selected to study the effect of vehicle characteristics and weather conditions on vehicle emission as shown in Table 2.

Table 2 Dependent Variables.

No.	Variables	Symbol	Measure
1	Vehicle Speed	V	Kilometer Per Hour (KPH)
2	Angle between horizontal alignments	β	Degree (°)
3	Profile Grade	G	Percent (%)
4	Ambient Temperature	T	Celsius (C^o)
5	Ambient Pressure	P	kilopascal (kPa)
6	Ambient Relative Humidity	RH%	Percent (%)
7	Numbers of Rotation Per Minute for Vehicle Engine	RPM	Value

4.2. Generalized Linear Emission Models

Generalized Linear Models were introduced by (Nelder, J. A. and Wedderburn , 1972), in an attempt to make the assumptions of traditional regression models more realistic in order to suit the practical reality. The generalized linear model is a regression model, in which the dependent variable follows one of the probability distributions belonging to the exponential family, and these models are considered less restrictive than the traditional regression models.

5. Simple Regression Analysis

Simple Regression Analysis gives the correlation between dependent variable which represent vehicle CO_2 (g/s) emission for the three categories according to fuel type and the seven selected independent variables.

The correlation between dependent variables of Diesel vehicles emission and independent variables were discussed, Single regression show a strong relation between CO_2 emission with the independent variables RPM as illustrated in SPSS output tables and figures, The coefficient of determination (R^2) was found to be 0.638 which showed the good relation between CO_2 and RPM,.

The same procedure was conducted to test the relation between CO_2 emission for diesel vehicle and rest of independent variables, Single regression showed a strong relation between CO_2 emission with the independent variables V, β, T, P and RH while a poor relation with profile road grade G as the selected roads were almost flat grades.

Table 4 provide the summary of single regression for CO_2 Emission of Natural Gas Vehicles which represent the dependent variable and the independent variables, Single regression showed a strong relation between CO_2 emission with the independent variables RPM, T, P and RH while a poor relation with vehicle speed V, Bearing β and road profile grade G. Petrol vehicle CO_2emission showed a poor relation between CO_2 emission with all independent variables unless RPM variable.

Table 3 Single regression between CO_2 for diesel vehicles and RPM.

Model Description		
Model Name		Co_2 and RPM
Dependent Variable	1	Co_2
Equation	1	Quadratic
Independent Variable		RPM
Constant		Not included
Variable Whose Values Label Observations in Plots		Unspecified
Tolerance for Entering Terms in Equations		0.0001

Case Processing Summary	
	N
Total Cases	19082
Excluded Cases[a]	0
Forecasted Cases	0
Newly Created Cases	0

a. Cases with a missing value in any variable are excluded from the analysis.

Variable Processing Summary			
		Variables	
		Dependent	Independent
		CO_2	RPM
Number of Positive Values		19081	19082
Number of Zeros		1	0
Number of Negative Values		0	0
Number of Missing Values	User-Missing	0	0
	System-Missing	0	0

CO_2 - Quadratic

Model Summary [a]			
R	R Square	Adjusted R Square	Std. Error of the Estimate
0.799	0.638	0.638	1.905

The independent variable is RPM [a]

a. The equation was estimated without the constant term.

ANOVA[a]					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	121856.115	2	60928.057	16790.027	.000
Residual	69237.968	19080	3.629		
Total	191094.082	19082			

The independent variable is RPM [a]

a. The equation was estimated without the constant term.

Coefficients					
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
RPM	0.002	0.000	0.672	47.462	0.00
RPM	1.761E-7	0.000	0.132	9.360	0.00

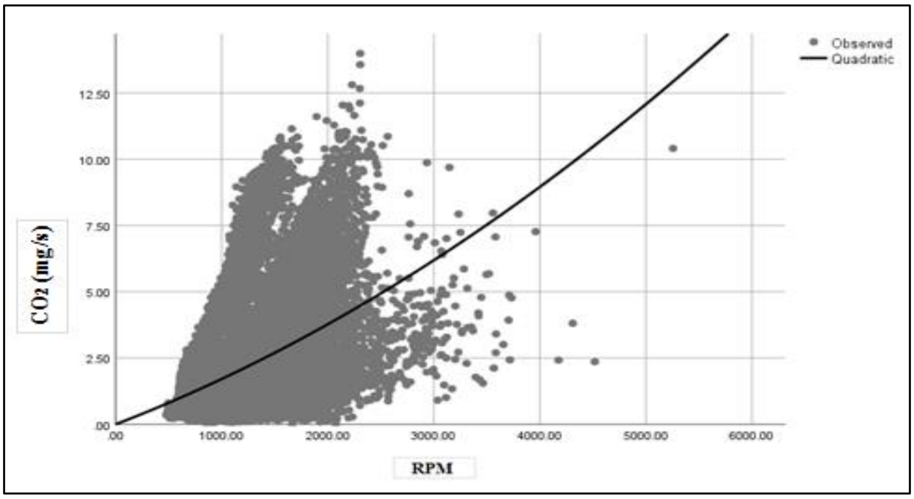

Figure 4 Scatter plot for CO_2 Emission with RPM.

Table 4 Simple regression analysis for diesel vehicles.

	Dependent Variable	Independent Variables	Equation	Adjusted R^2	Relation
Diesel Vehicles	CO_2 Emission for Diesel Vehicles	V	$CO_{2\,(D)} = 1.531*V$	0.594	Good
		β	$CO_{2\,(D)} = 1.804*\beta$	0.507	Good
		G	$CO_{2\,(D)} = 0.015*G$	0.084	Poor
		T	$CO_{2\,(D)} = 2.152*T$	0.523	Good
		P	$CO_{2\,(D)} = 0.722*P$	0.521	Good
		RH%	$CO_{2\,(D)} = 1.118*RH$	0.528	Good
		RPM	$CO_{2\,(D)} = 0.672*RPM$	0.638	Good
Natural Gas Vehicles	CO_2 Emission for Diesel Vehicles	V	$CO_{2\,(N)} = 1.905*V$	0.463	Poor
		β	$CO_{2\,(N)} = 1.867*\beta$	0.483	Poor
		G	$CO_{2\,(N)} = 0.017*G$	0.103	Poor
		T	$CO_{2\,(N)} = 1.260*T$	0.623	Good
		P	$CO_{2\,(N)} = 0.745*P$	0.555	Good
		RH%	$CO_{2\,(N)} = 3.077*RH$	0.694	Good
		RPM	$CO_{2\,(N)} = 0.509*RPM$	0.793	Good
Petrol Vehicles	CO_2 Emission for Petrol Vehicles	V	$CO_{2\,(P)} = 1.118*V$	0.437	Poor
		β	$CO_{2\,(P)} = 1.578*\beta$	0.34	Poor
		G	$CO_{2\,(P)} = 0.288*G$	0.083	Poor
		T	$CO_{2\,(P)} = 0.410*T$	0.392	Poor
		P	$CO_{2\,(P)} = 0.619*P$	0.383	Poor
		RH%	$CO_{2\,(P)} = 0.902*RH$	0.384	Poor
		RPM	$CO_{2\,(P)} = 0.323*RPM$	0.696	Good

6. Statistical Analysis

Many of parameters contribute together to increase or decrease vehicles CO_2 emissions, therefore simple regression analysis may give improper results, So Multiple Regression Models would be the proper one and the combined effect of these parameters on vehicles CO_2 emissions must be taken into consideration. Generalized Linear Models used to analyze the relationship between a single dependent variable of vehicles CO_2 emissions and several independent variables.

6.1. Results of Diesel Vehicle Emission Models

The relation between Diesel vehicles emission $CO_{2\,(D)}$ and independent variables were investigated by four models of generalized linear regression models as follow:

6.1.1. Linear Regression with Link Function of Identity

Linear regression model with Link Function of Identity (LRMLFI) was used based on the normal distribution by linking the independent variables with the expected value of the dependent variables $CO_{2\ (D)}$ through the Identity link function.

The goodness of fit indicators was given in Table 5, while the Omnibus test used to find out whether the model was significant or not was given in Table 6. The model was significant as the level of significance was less than 0.01

Table 5: Goodness of Fit indicators (LRMLFI of $CO_{2\ (D)}$)

Goodness of Fit[a]			
	Value	df	Value/df
Deviance	45514.690	19074	2.386
Scaled Deviance	19082.000	19074	
Pearson Chi–Square	45514.690	19074	2.386
Scaled Pearson Chi–Square	19082.000	19074	
Log Likelihood[b]	–35370.078		
Akaike's Information Criterion (AIC)	70758.155		
Finite Sample Corrected AIC (AICC)	70758.165		
Bayesian Information Criterion (BIC)	70828.864		
Consistent AIC (CAIC)	70837.864		

Table 6: Omnibus Test (LRMLFI of $CO_{2\ (D)}$)

Omnibus Test[a]		
Likelihood Ratio Chi–Square	df	Sig.
27377.532	5	0.000

All the variables were significant, as the level of significance was less than 0.05. We also find that R–square value was 50.1%, which was the percentage of the effect of the independent variables on $CO_{2\ (D)}$ emissions as given in Table 7, the model was as follow:

$$CO_{2\ (D)} = 0.003^{*} RPM + 0.009^{*} V + 0.001^{*} \beta + 0.426^{*}P + 0.043^{*}G$$

Table 7: Model Parameters (LRMLFI of $CO_{2\,(D)}$)

Parameter Estimates						
Parameter	B	Std. Error	Wald Chi–Square	df	sig	R–square
RPM	.003	3.1942E–5	8119.773	1	.000	0.501
V	0.009	.0009	88.075	1	.000	
β	0.001	.0001	26.455	1	.000	
P	0.426	.0708	36.154	1	.000	
G	0.043	.0038	126.294	1	.000	

6.1.2. Linear Regression with Link Function of Log

Linear regression with Link Function of log model (LRMLFL) was used based on the normal distribution by linking the independent variables with the expected value of the dependent variable $CO_{2\,(D)}$ through the log link function.

Table 8 provide the goodness of fit indicators and Table 9 showed the Omnibus test that used to find out whether the model was significant or not. The model was significant as the level of significance was less than 0.01.

All the variables were significant, as the level of significance was less than 0.05. We also find that R–square value was 51.30 %, which was the percentage of the effect of the independent variables on $CO_{2\,(D)}$ Emissions as given in Table 10, the model was as follow:

$$\text{Log } CO_{2\,(D)} = 0.001 * RPM + 0.007 * V + 0.000 * \beta - 0.004 * T + 0.133 * P + 0.022 * G$$

Table 8: Goodness of Fit indicators (LRMLFL $CO_{2\,(D)}$)

Goodness of Fit[a]			
	Value	df	Value/df
Deviance	44613.709	19073	2.339
Scaled Deviance	19082.000	19073	
Pearson Chi–Square	44613.709	19073	2.339
Scaled Pearson Chi–Square	19082.000	19073	
Log Likelihood[b]	–35179.316		
Akaike's Information Criterion (AIC)	70378.631		
Finite Sample Corrected AIC (AICC)	70378.643		
Bayesian Information Criterion (BIC)	70457.196		
Consistent AIC (CAIC)	70467.196		

Table 9: Omnibus Test (LRMLFL $CO_{2\ (D)}$)

Omnibus Test[a]		
Likelihood Ratio Chi–Square	df	Sig.
19341.579	6	.000

Table 10: Model Parameters (LRMLFL $CO_{2\ (D)}$)

Parameter Estimates						
Parameter	B	Std. Error	Wald Chi–Square	df	sig	R–square
RPM	.001	9.1779E–6	11030.716	1	.000	0.513
V	.007	.0003	394.946	1	.000	
β	.000	4.4021E–5	125.075	1	.000	
T	–.004	.0013	7.506	1	.006	
P	.133	.0289	21.156	1	.000	
G	.022	.0015	218.716	1	.000	

6.1.3. Gamma Regression with Link Function of Log

Gamma Regression with Link Function of Log model (GRMLFL) used based on gamma distribution by linking the independent variables with the expected value of the dependent variable $CO_{2\ (D)}$ through the link function of log.

The goodness of fit indicators was given in Table 11, while Table 12 provide the Omnibus test. The model was significant as the level of significance was less than 0.01

Table 11: Goodness of Fit indicators (GRMLFL $CO_{2\ (D)}$)

Goodness of Fit[a]			
	Value	df	Value/df
Deviance	7654.733	19073	.401
Scaled Deviance	20266.072	19073	
Pearson Chi–Square	6194.508	19073	.325
Scaled Pearson Chi–Square	16400.095	19073	
Log Likelihood[b]	–26050.806		
Akaike's Information Criterion (AIC)	52119.612		
Finite Sample Corrected AIC (AICC)	52119.621		
Bayesian Information Criterion (BIC)	52190.320		
Consistent AIC (CAIC)	52199.320		

Table 12: Omnibus Test for (GRMLFL $CO_{2\ (D)}$)

Omnibus Test[a]		
Likelihood Ratio Chi–Square	df	Sig.
32660.688	5	.000

All the variables were significant, as the level of significance was less than 0.05. We also find that R–square value was 32.90%, which was the percentage of the effect of the independent variables on $CO_{2\ (D)}$ emissions as given in Table 13, the model was as follow:

$$\text{Log } CO_{2\ (D)} = 0.001^* RPM + 0.005^* V + 0.000^* \beta + 0.081^*P + 0.018^*G$$

Table 13: Model Parameters (GRMLFL $CO_{2\ (D)}$)

Parameter Estimates						
Parameter	B	Std. Error	Wald Chi–Square	df	sig	R–square
RPM	.001	1.3964E–5	11035.817	1	.000	0.329
V	.005	.0004	178.741	1	.000	
β	.000	4.7782E–5	15.251	1	.000	
P	.081	.0285	8.174	1	.004	
G	.018	.0015	137.350	1	.000	

6.1.4. Tweedy Regression with Link Function of Log

Tweedy Regression with Link Function of Log model (TRMLFL) was used by linking the independent variables with the expected value of the dependent variables $CO_{2\ (D)}$ through the log link function.

Table 14 provide the goodness of fit indicators, Table 15 present Omnibus test that used to find out whether the model was significant or not, the model was significant as the level of significance was less than 0.01

Table 14: Goodness of Fit indicators (TRMLFL $CO_{2\ (D)}$)

Goodness of Fit[a]			
	Value	df	Value/df
Deviance	10105.084	19074	.530
Scaled Deviance	21011.393	19074	
Pearson Chi–Square	8885.452	19074	.466
Scaled Pearson Chi–Square	18475.425	19074	
Log Likelihood[b]	–27240.356		
Akaike's Information Criterion (AIC)	54498.713		
Finite Sample Corrected AIC (AICC)	54498.722		
Bayesian Information Criterion (BIC)	54569.421		
Consistent AIC (CAIC)	54578.421		

Table 15: Omnibus Test (TRMLFL $CO_{2\ (D)}$)

Omnibus Test[a]		
Likelihood Ratio Chi–Square	df	Sig.
34810.592	5	.000

All the variables were significant, as the level of significance was less than 0.01. We also find that R–square value was 25.9%, which was the percentage of the effect of the independent variables on $CO_{2\ (D)}$ emissions as given in Table 4–15, the model was as follow:

$$Log\ CO_{2\ (D)} = 0.001*RPM + 0.006*V + 0.000*\beta + 0.128*P + 0.021*G$$

Table 16: Model Parameters (TRMLFL $CO_{2\ (D)}$)

Parameter Estimates						
Parameter	B	Std. Error	Wald Chi–Square	df	sig	R–square
RPM	.001	1.1535E–5	12443.649	1	.000	0.259
V	.006	.0003	336.957	1	.000	
β	.000	4.5814E–5	37.799	1	.000	
P	.128	.0268	22.646	1	.000	
G	.021	.0015	191.885	1	.000	

6.1.5. Summary of CO_2 Emission for Diesel Vehicles

Analysis of statistics using the generalized regression model by different types of models show that Gamma and Tweedy Regression with Link Function of Log were not appropriated enough in analyzing CO_2 emission for diesel vehicles while Linear regression model with Link Function of Identity (LRMLFI) and Linear Regression Model with Link Function of Log (LRMLFL) models provide a better results.

The results showed that Linear Regression Model with Link Function of Log (LRMLFL) was the best generalized regression model as it had account a goodness of fit with a highest percent of correlation R^2 = 51.30%.

$$Log\ CO_{2\ (D)} = 0.001*RPM + 0.007*V - 0.004 * T + 0.133 * P + 0.022 * G$$

6.2. Results of Natural Gas Vehicle Emission Models

Four models of generalized linear regression models were used to investigate the relation between Natural Gas vehicles emission CO_2 (g/s) and each of independent variables as shown in Table 17.

As we illustrate before for CO_2 emission for diesel vehicles, the same procedure was conducted to test the relation between CO_2 emission for Natural Gas vehicle and the independent variables, Analysis of statistics using the generalized regression models showed that all used generalized regression models had given acceptable account a goodness of fit with a high percent of correlation R^2 value.

The results showed that Linear Regression Model with Link Function of Log (LRMLFL) was the best generalized regression model as it had account a goodness of fit with a highest percent of correlation R^2 = 92.50%.

$$Log\ CO_{2\ (N)} = -0.001*V - 9.007E{-5}*\beta - 0.035 * P + 0.002 * RH$$

6.3. Results of Petrol Vehicle Emission Models

Table 17 provide the analysis of statistics using the four models of generalized linear regression models, all used generalized regression models had given acceptable account a goodness of fit with a high percent of correlation R^2 value.

The results showed that Linear Regression Model with Link Function of Log (LRMLFL) was the best generalized regression model as it had account a goodness of fit with a highest percent of correlation $R^2 = 62.20\%$.

$$\text{Log } CO_{2\,(P)} = -0.001 * V - 0.018*T - 0.05*P - 0.013*RH + 0.018*G$$

Table 17: Generalized linear models for CO_2 emission for different vehicle categories.

	Dependent Variable	Generalized Linear Regression Models			
		Linear Regression with Link Function of Identity	**Linear Regression with Link Function of Log**	**Gamma Regression with Link Function of Log**	**Tweedy Regression with Link Function of Log**
Petrol Vehicles	**CO_2 Emission**	$CO_{2\,(P)} = 0.002 * RPM - 0.018 * V - 0.001 * \beta - 0.064 * T - 0.052 * RH + 0.012 * G$ $R^2 = 0.600$	$\text{Log } CO_{2\,(P)} = -0.001 * V - 0.018 * T - 0.05 * P - 0.013 * RH + 0.018 * G$ $R^2 = 0.622$	$\text{Log } CO_{2\,(P)} = 0.001 * PM - 0.004 * V - 0.024 * T - 0.159 * P - 0.021 * RH + 0.006 * G$ $R^2 = 0.579$	$\text{Log } CO_{2\,(P)} = 0.001 * RPM - 0.002 * V - 0.029 * T - 0.143 * P - 0.018 * RH + 0.009 * G$ $R^2 = 0.599$
Natural Gas Vehicles	**CO_2 Emission**	$CO_{2\,(N)} = 0.004 * RPM - 0.019 * V - 0.001 * \beta + 0.483 * P + 0.013 * RH$ $R^2 = 0.896$	$\text{Log } CO_{2\,(N)} = -0.00\ 1 * V - 9.007E{-5} * \beta - 0.035 * P + 0.002 * RH$ $R^2 = 0.925$	$\text{Log } CO_{2\,(N)} = 0.001 * V - 0.006 * T - 0.003 * RH + 0.012 * G$ $R^2 = 0.891$	$\text{Log } CO_{2\,(N)} = 0.001 * V - 0.009 * T - 0.005 * RH + 0.012 * G$ $R^2 = 0.896$
Diesel Vehicles	**CO_2 Emission**	$CO_{2\,(D)} = 0.003 * RPM + 0.009 * V + 0.001 * \beta + 0.426 * P + 0.043 * G$ $R^2 = 0.501$	$\text{Log } CO_{2\,(D)} = 0.001 * RPM + 0.007 * V - 0.004 * T + 0.133 * P + 0.022 * G$ $R^2 = 0.513$	$\text{Log } CO_{2\,(D)} = 0.001 * RPM + 0.005 * V + 0.081 * P + 0.018 * G$ $R^2 = 0.329$	$\text{Log } CO_{2\,(D)} = 0.001 * RPM + 0.006 * V + 0.128 * P + 0.021 * G$ $R^2 = 0.259$

7. General Conclusion for CO_2 Vehicle Emissions

- CO_2 emission for Diesel vehicles showed a good relation with vehicle speed, horizontal alignment bearing angle, ambient temperature, ambient pressure, ambient relative humidity and numbers of rotation per minute for vehicle engine while a poor relation with profile road grade as the selected roads were almost flat grades.

- CO_2 Emission for Natural Gas vehicles provided a good representative relation with ambient temperature, ambient pressure, ambient relative humidity and numbers of rotation per minute for vehicle engine while a poor relation with vehicle speed, horizontal alignment bearing angle and profile road grade.
- CO_2 emission for Petrol vehicles showed a good representative relationship with numbers of rotation per minute for vehicle engine while a poor relation with vehicle speed, horizontal alignment bearing angle, ambient temperature, ambient pressure, ambient relative humidity and profile road grade.
- Linear regression model with link function of log (LRMLFL) was the highest generalized regression model to represent the correlation between CO_2 emissions for Diesel vehicles.
- Natural Gas vehicles CO_2 emission measurements were well presented with generalized regression model, where the best model was the Linear Regression Model with Link Function of Log (LRMLFL).
- Linear regression model with link function of log (LRMLFL) was the best generalized regression model to represent the correlation between Petrol vehicles CO_2 emission with factors affecting it.

8. Recommendations

- For further studies in the field of vehicle emissions rates it is recommended to apply the Linear regression model with link function of log (LRMLFL), as it proved to be the best generalized regression models technique for CO_2 vehicle emission.
- CO_2 emission showed different performance in relation to the studied vehicle according to fuel types of Diesel, Natural Gas and Petrol vehicles.
- CO_2 emission showed different performance in relation to the studied vehicle types of private car, Microbus, Minibus and public Bus vehicles.
- Highway geometric design features/criteria that were not considered in this research, such as combinations of horizontal and vertical alignment, intersection, or interchange.
- The environmental impact of heavy-duty vehicles cannot be ignored in the modeling process. Heavy-duty gasoline and diesel engines should be modeled separately.
- Investigate the effect of traffic congestion on vehicle CO_2 emission rates on other major roads in Egypt.
- Studies should be made to find out how to increase awareness among drivers in terms of vehicles emission causes and how to be always in focus to safe environment.

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