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

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دراسة تأثير خصائص الطرق, البيئة, السائق وحركة المرور على انبعاثات أكاسيد النيتروجين للمركبات في مصر

الملخص العربى:

الهدف من هذا البحث هو دراسة العوامل التي تؤثر على انبعاثات أكاسيد النيتروجين 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 انبعاثات السيارة كدالة للمتغيرات المستقلة. تم الحصول على قياسات انبعاثات المركبات أكاسيد النيتروجين (ملغ / ثانية) 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 أكاسيد النيتروجين لمركبات الديزل وانبعاثات الغاز الطبيعي ومركبات البنزين.

ABSTRACT

The objective of this research is to study factors that effect on the NO_X 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 NO_X (mg/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 NO_X emission for Diesel vehicles, Natural Gas and Petrol vehicles emission.

Keywords: NO_x 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 NO_X 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 NO_X (mg/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 NO_X 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 NO_X emissions relationship with the independent variables which categorized to travel-related factors, highway characteristics and vehicle characteristics and other factors

3.1. 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 NO_X (mg/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]	NO_X [mg/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	0.180	3,192	34	27.44	100.8	58
158	8:20:48	30.054964	31.240358	30.8	0.130	3,199	35	27.44	100.8	58
159	8:20:49	30.055033	31.240421	30.7	0.130	3,162	34	27.44	100.8	58
160	8:20:50	30.055096	31.240485	30.7	0.140	2,983	33	27.44	100.8	58
161	8:20:51	30.055159	31.240545	30.5	0.130	2,345	33	27.44	100.8	58
162	8:20:52	30.055225	31.240601	30.5	0.100	1,869	30	27.44	100.8	58
163	8:20:53	30.055276	31.240659	30.6	0.130	1,671	26	27.44	100.8	58
164	8:20:54	30.055321	31.240706	30.4	0.280	1,911	24	27.44	100.8	58
165	8:20:55	30.055365	31.24076	30.3	0.330	2,307	25	27.44	100.8	58
166	8:20:56	30.055407	31.240816	30.4	0.360	2,546	27	27.44	100.8	58
167	8:20:57	30.055455	31.240875	30.4	0.400	2,732	29	27.44	100.8	58
168	8:20:58	30.055508	31.240942	30.2	0.320	2,914	31	27.44	100.8	58
169	8:20:59	30.055568	31.240998	30	0.340	3,063	33	27.44	100.8	58
170	8:21:00	30.055631	31.241058	29.4	0.250	3,173	34	27.44	100.8	58
171	8:21:01	30.055693	31.241131	29.5	0.130	3,225	35	27.44	100.8	58
172	8:21:02	30.055753	31.241205	29.4	0.100	3,009	35	27.44	100.8	58
173	8:21:03	30.055813	31.241279	29.4	0.080	2,336	34	27.44	100.8	58
174	8:21:04	30.055872	31.241342	29.2	0.070	1,863	33	27.44	100.8	58
175	8:21:05	30.055927	31.241411	29.1	0.080	1,695	31	27.44	100.8	58
176	8:21:06	30.055979	31.24148	29.2	0.160	2,081	31	27.44	100.8	58
177	8:21:07	30.056031	31.241545	29.3	0.290	2,733	31	27.44	100.8	58
178	8:21:08	30.056087	31.24161	29.4	0.370	3,026	32	27.44	100.8	58
179	8:21:09	30.056146	31.241675	29.4	0.580	3,176	34	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

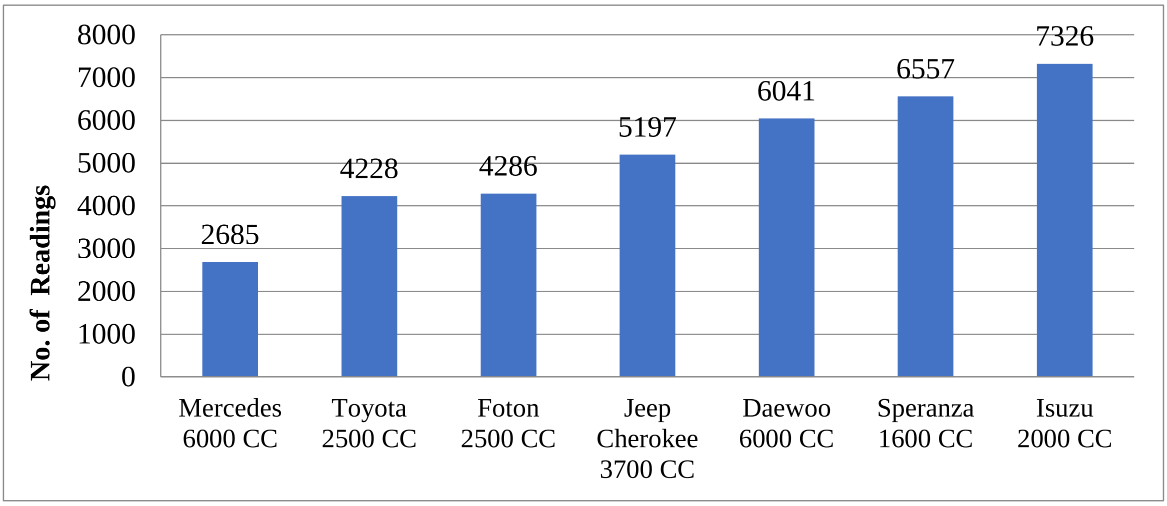

Figure 2: Emission readings for each vehicle, (EEAA, 2017).

3.1.1. 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.

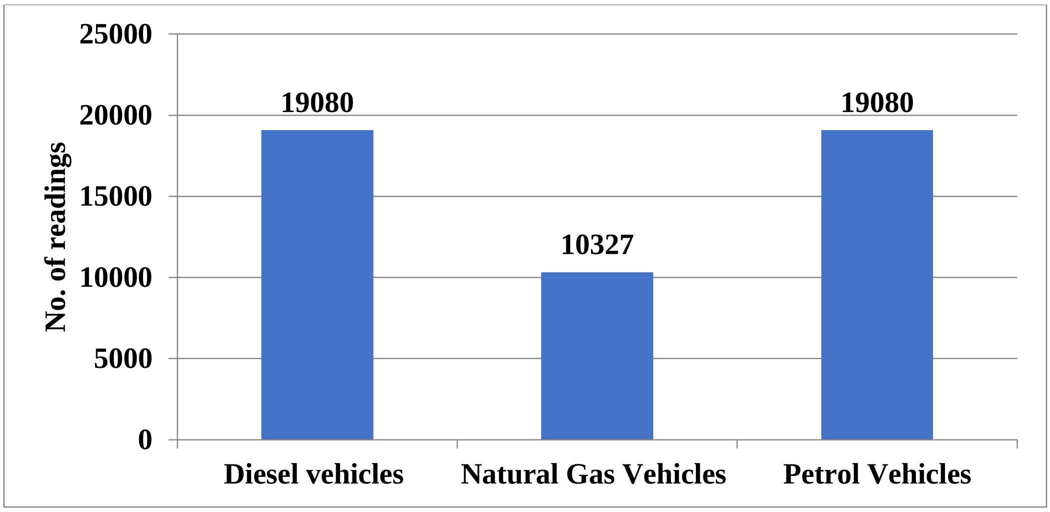

Figure 3 Total Emission Readings for Each Vehicle Category, (EEAA, 2017).

3.1.2. Dependent Variable

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

3.1.3. 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

3.2. 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.

4. Simple Regression Analysis

Simple Regression Analysis gives the correlation between dependent variable which represent vehicle NO_X (mg/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 NO_X emission with the independent variables RPM as illustrated in SPSS output tables and figures, The coefficient of determination (R^2) was found to be 0.644 which showed the good relation between NO_X and RPM,.

The same procedure was conducted to test the relation between NO_X emission for diesel vehicle and rest of independent variables, Single regression showed a strong relation between NO_X 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 NO_X Emission of Natural Gas Vehicles which represent the dependent variable and the independent variables, Single regression showed that NO_X emission had a good relation with the independent variables RPM, T and RH, and poor relation with vehicle speed V, bearing β, pressure P and road profile grade G.

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

Model Description		
Model Name		NO_X and RPM
Dependent Variable	1	NO_X
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
		NOx	RPM
Number of Positive Values		19082	19082
Number of Zeros		0	0
Number of Negative Values		0	0
Number of Missing Values	User-Missing	0	0
	System-Missing	0	0

NOx-Quadratic

Model Summary[a]			
R	R Square	Adjusted R Square	Std. Error of the Estimate
0.803	0.644	0.644	14.249

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	7015123.161	2	3507561.580	17275.115	0.000
Residual	3874027.791	19080	203.041		
Total	10889150.951	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	0.014	0.000	0.812	57.951	0.000
RPM ** 2	-1.036E-7	0.000	-0.010-	-0.736-	0.461

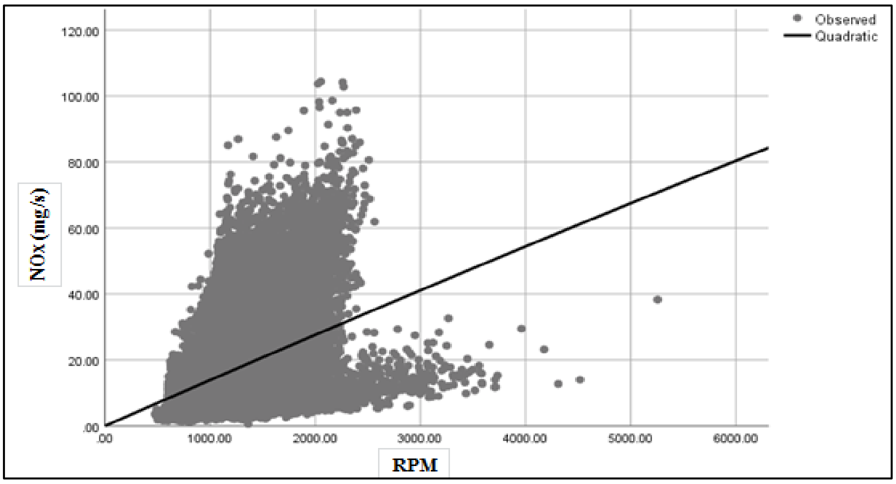

Figure 4 Scatter plot for NOx Emission with RPM.

Table 4 Simple regression analysis for diesel vehicles.

	Dependent Variable	Independent Variables	Equation	Adjusted R^2	Relation
Diesel Vehicles	**NO_X Emission for Diesel Vehicles**	V	$NO_{X\ (D)} = 1.721*V$	0.649	Good
		β	$NO_{X\ (D)} = 1.850*\beta$	0.515	Good
		G	$NO_{X\ (D)} = 0.012*G$	0.094	Poor
		T	$NO_{X\ (D)} = 1.539*T$	0.539	Good
		P	$NO_{X\ (D)} = 0.735*P$	0.54	Good
		RH%	$NO_{X\ (D)} = 1.197*RH$	0.533	Good
		RPM	$NO_{X\ (D)} = 0.812*RPM$	0.644	Good
Natural Gas Vehicles	**NO_X Emission for Diesel Vehicles**	V	$NO_{X\ (N)} = 1.603*V$	0.407	Poor
		β	$NO_{X\ (N)} = 1.717*\beta$	0.374	Poor
		G	$NO_{X\ (N)} = 0.057*G$	0.067	Poor
		T	$NO_{X\ (N)} = 1.587*T$	0.508	Good
		P	$NO_{X\ (N)} = 0.657*P$	0.432	Poor
		RH%	$NO_{X\ (N)} = 2.680*RH$	0.527	Good
		RPM	$NO_{X\ (N)} = 0.535*RPM$	0.615	Good
Petrol Vehicles	**NO_X Emission for Petrol Vehicles**	V	$NO_{X\ (P)} = 0.202*V$	0.153	Poor
		β	$NO_{X\ (P)} = 0.771*\beta$	0.078	Poor
		G	$NO_{X\ (P)} = 0.010*G$	0.016	Poor
		T	$NO_{X\ (P)} = 0.014*T$	0.089	Poor
		P	$NO_{X\ (P)} = 0.290*P$	0.084	Poor
		RH%	$NO_{X\ (P)} = 0.366*RH$	0.082	Poor
		RPM	$NO_{X\ (P)} = 0.023*RPM$	0.205	Poor

5. Statistical Analysis

Many of parameters contribute together to increase or decrease vehicles NO_X 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 NO_X emissions must be taken into consideration. Generalized Linear Models used to analyze the relationship between a single dependent variable of vehicles NO_X emissions and several independent variables.

5.1. Results of Diesel Vehicle Emission Models

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

5.1.1. 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 $NO_{X\ (D)}$ through the Identity link function.

The goodness of fit indicators was given in Table 5. While Table 6 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

Table 5: Goodness of Fit indicators (LRMLFI $NO_{X\ (D)}$)

Goodness of Fit[a]			
	Value	df	Value/df
Deviance	2226668.988	19073	116.745
Scaled Deviance	19082.000	19073	
Pearson Chi–Square	2226668.988	19073	116.745
Scaled Pearson Chi–Square	19082.000	19073	
Log Likelihood[b]	–72486.732		
Akaike's Information Criterion (AIC)	144993.465		
Finite Sample Corrected AIC (AICC)	144993.476		
Bayesian Information Criterion (BIC)	145072.030		
Consistent AIC (CAIC)	145082.030		

Table 6: Omnibus Test (LRMLFI $NO_{X\ (D)}$)

Omnibus Test[a]		
Likelihood Ratio Chi–Square	df	Sig.
30288.100	6	.000

All the variables were significant, as the level of significance was less than 0.01. We also find that R–square value was 55.5%, which was the percentage of the effect of the independent variables on $NO_{X\ (D)}$ Emissions as given in Table 7, the model was as follow:

$$NO_{X\ (D)} = 0.019 * RPM + 0.17 * V + 0.003 * \beta + 0.362 * T + 5.037 * P + 0.361 * G$$

Table 7: Model Parameters (LRMLFI $NO_{X\ (D)}$)

Parameter Estimates						
Parameter	B	Std. Error	Wald Chi–Square	df	sig	R–square
RPM	.019	.0002	7525.664	1	.000	0.555
V	.170	.0064	695.716	1	.000	
β	.003	.0009	13.627	1	.000	
T	.362	.0284	162.226	1	.000	
P	5.037	.5469	84.836	1	.000	
G	.361	.0266	184.274	1	.000	

5.1.2. 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 $NO_{X\ (D)}$ 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 0.01. We also find that R–square value was 65.1 %, which was the percentage of the effect of the independent variables on $NO_{X\ (D)}$ emissions as given in Table 10, the model was as follow:

$$\text{Log } NO_{X\ (D)} = 0.001*\ RPM + 0.013*\ V + 0.000*\ \beta - 0.012*T + 0.205*P + 0.025*G$$

Table 8: Goodness of Fit indicators (LRMLFL $NO_{X\ (D)}$)

Goodness of Fit[a]			
	Value	df	Value/df
Deviance	1747764.513	19073	91.636
Scaled Deviance	19082.000	19073	
Pearson Chi–Square	1747764.513	19073	91.636
Scaled Pearson Chi–Square	19082.000	19073	
Log Likelihood[b]	–70176.196		
Akaike's Information Criterion (AIC)	140372.392		
Finite Sample Corrected AIC (AICC)	140372.404		
Bayesian Information Criterion (BIC)	140450.957		
Consistent AIC (CAIC)	140460.957		

Table 9: Omnibus Test (LRMLFL $NO_{X\ (D)}$)

Omnibus Test[a]		
Likelihood Ratio Chi–Square	df	Sig.
33732.883	6	.000

Table 10: Model Parameters (LRMLFL $NO_{X\ (D)}$)

Parameter Estimates						
Parameter	B	Std. Error	Wald Chi–Square	Df	sig	R–square
RPM	.001	9.4374E–6	11378.669	1	.000	0.651
V	.013	.0003	2183.682	1	.000	
β	.000	3.4337E–5	194.722	1	.000	
T	.012	.0011	115.760	1	.000	
P	.205	.0215	90.567	1	.000	
G	.025	.0012	398.323	1	.000	

5.1.3. 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 $NO_{X\ (D)}$ through the link function of log.

The goodness of fit indicators was provided in Table 11, while Table 12 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

Table 11: Goodness of Fit indicators (GRMLFL $NO_{X\ (D)}$)

Goodness of Fit[a]			
	Value	df	Value/df
Deviance	4967.437	19073	.260
Scaled Deviance	19872.158	19073	
Pearson Chi–Square	4902.121	19073	.257
Scaled Pearson Chi–Square	19610.863	19073	
Log Likelihood[b]	–61890.189		
Akaike's Information Criterion (AIC)	123800.377		
Finite Sample Corrected AIC (AICC)	123800.389		
Bayesian Information Criterion (BIC)	123878.942		
Consistent AIC (CAIC)	123888.942		

Table 12: Omnibus Test (GRMLFL $NO_{X\ (D)}$)

Omnibus Test[a]		
Likelihood Ratio Chi–Square	df	Sig.
117849.973	6	.000

All the variables were significant, as the level of significance was less than 0.05. We also find that R–square value was 26.3%, which was the percentage of the effect of the independent variables on $NO_{X\ (D)}$ emissions as given in Table 13, the model was as follow:

$$\text{Log } NO_{X\ (D)} = 0.001*RPM + 0.006*V + 9.459E{-}5*\beta + 0.016*T + 0.176*P + 0.017*G$$

Table 13: Model Parameters (GRMLFL $NO_{X\ (D)}$)

Parameter Estimates						
Parameter	B	Std. Error	Wald Chi–Square	df	sig	R–square
RPM	.001	1.1271E–5	14403.765	1	.000	0.263
V	.006	.0003	457.433	1	.000	
β	9.459E–5	3.8913E–5	5.908	1	.015	
T	.016	.0013	156.837	1	.000	
P	.176	.0255	47.625	1	.000	
G	.017	.0012	197.038	1	.000	

5.1.4. 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 $NO_{X\ (D)}$ through the log link function.

The goodness of fit indicators was given in Table 14. Table 15 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

Table 14: Goodness of Fit indicators (TRMLFL $NO_{X\ (D)}$)

Goodness of Fit[a]			
	Value	df	Value/df
Deviance	18891.491	19073	.990
Scaled Deviance	20251.306	19073	
Pearson Chi–Square	19185.487	19073	1.006
Scaled Pearson Chi–Square	20566.464	19073	
Log Likelihood[b]	–62991.548		
Akaike's Information Criterion (AIC)	126003.096		
Finite Sample Corrected AIC (AICC)	126003.108		
Bayesian Information Criterion (BIC)	126081.661		
Consistent AIC (CAIC)	126091.661		

Table 15: Omnibus Test (TRMLFL $NO_{X\ (D)}$)

Omnibus Test[a]		
Likelihood Ratio Chi–Square	df	Sig.
116184.778	6	.000

All the variables were significant, as the level of significance was less than 0.01. We also find that R–square value was 46.8%, which was the percentage of the effect of the independent variables on $NO_{X\ (D)}$ Emissions as given in Table 16, the model was as follow:

$$\text{Log } NO_{X\ (D)} = 0.001^{*}\ RPM + 0.009^{*}\ V + 0.000^{*}\ \beta + 0.017^{*}T + 0.225^{*}P + 0.02^{*}G$$

Table 16: Model Parameters (TRMLFL $NO_{X\,(D)}$)

Parameter Estimates						
Parameter	B	Std. Error	Wald Chi–Square	df	sig	R–square
RPM	.001	1.0037E–5	14436.808	1	.000	0.468
V	.009	.0003	950.271	1	.000	
β	.000	3.8438E–5	30.430	1	.000	
T	.017	.0013	188.710	1	.000	
P	.225	.0250	81.350	1	.000	
G	.020	.0012	252.383	1	.000	

5.1.5. Summary of NO_X 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 NO_X 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.

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 = 65.10%.

$$\text{Log } NO_{X\,(D)} = 0.001*\text{RPM} + 0.013*V - 0.012*T + 0.205*P + 0.025*G$$

5.2. 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 NO_X (mg/s) and each of independent variables as shown in Table 17.

As we illustrate before for NO_X emission for diesel vehicles, the same procedure was conducted to test the relation between NO_X emission for Natural Gas vehicle and the independent variables, Analysis of statistics using the generalized regression models showed that Linear regression model with link function of identity (LRMLFI), linear regression with link function of log (LRMLFL) and tweedy regression with link function of log (TRMLFL) had given acceptable account a goodness of fit with a high percent of correlation R^2 value better than gamma regression with link function of log (GRMLFL).

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 R2 = 53.30%.

$$\text{Log } NO_{X\,(N)} = 0.012*V - 0.011*T - 0.018*RH + 0.013*G$$

5.3. Results of Petrol Vehicle Emission Models

NO_X (mg/s) emission for Petrol vehicles were investigated by four models of generalized linear regression models as provided in Table 17, Linear regression model with Link Function of Log (LRMLFL) was the best model as it was given the highest percent of correlation R^2 = 35.70% with account a goodness of fit values.

$$\text{Log } NO_{X\,(P)} = 0.024*V + 0.001*\beta + 0.025*T - 0.330*P - 0.128*RH + 0.034*G$$

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

Vehicle Category	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	NO_X Emission	$NO_{X\,(P)} = 0.005 * RPM + 0.027 * V - 0.003 * \beta - 2.374 * P - 0.446 * RH + 0.119 * G$ $R^2 = 0.198$	$Log\ NO_{X\,(P)} = 0.024 * V + 0.001 * \beta + 0.025 * T - 0.330 * P - 0.128 * RH + 0.034 * G$ $R^2 = 0.357$	$Log\ NO_{X\,(P)} = 0.001 * RPM - 0.002 * V - 0.001 * \beta - 0.053 * T - 0.128 * RH + 0.017 * G$ $R^2 = 0.233$	[illegible] $* RPM + 0.010 * V - 0.001 * \beta - 0.047 * T - 0.422 * P - 0.122 * RH + 0.032 * G$ [illegible]
Natural Gas Vehicles	NO_X Emission	$NO_{X\,(N)} = 0.043 * RPM + 0.623 * V - 0.033 * \beta + 7.981 * P - 0.906 * RH + 1.579 * G$ $R^2 = 0.524$	$Log\ NO_{X\,(N)} = 0.012 * V - 0.011 * T - 0.018 * RH + 0.013 * G$ $R^2 = 0.533$	$Log\ NO_{X\,(N)} = 0.001 * RPM + 0.018 * V - 0.020 * RH + 0.048 * G$ $R^2 = 0.475$	$Log\ NO_{X\,(N)} = 0.015 * V - 0.018 * T - 0.025 * RH + 0.036 * G$ $R^2 = 0.504$
Diesel Vehicles	NO_X Emission	$NO_{X\,(D)} = 0.019 * RPM + 0.17 * V + 0.003 * \beta + 0.362 * T + 5.037 * P + 0.361 * G$ $R^2 = 0.555$	$Log\ NO_{X\,(D)} = 0.001 * RPM + 0.013 * V - 0.012 * T + 0.205 * P + 0.025 * G$ $R^2 = 0.651$	[illegible] $0.001 * RPM + 0.006 * V + 9.459E{-}5 * \beta + 0.016 * T + 0.176 * P + 0.017 * G$ [illegible]	$Log\ NO_{X\,(D)} = 0.001 * RPM + 0.009 * V + 0.017 * T + 0.225 * P + 0.02 * G$ $R^2 = 0.468$

6. General Conclusion for CO_2 Vehicle Emissions

- NO_X 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.
- A good representative for the relationship between NO_X emission for Natural Gas vehicles with ambient temperature, ambient relative humidity and numbers of rotation per minute for vehicle engine while vehicle speed, horizontal alignment bearing angle, ambient pressure and profile road grade showed a poor relation with NO_X emission.
- A poor correlation between NO_X emission of Petrol vehicles and all independent variables.

- Linear regression model with link function of log (LRMLFL) was the highest generalized regression model to represent the correlation between NO_X emission for Diesel vehicles and factors affecting it.
- Natural Gas vehicles NO_X emission was 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 emission measurements NO_X (mg/s) with factors affecting it.

7. 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 vehicle emission.
- NO_X emission showed different performance in relation to the studied vehicle according to fuel types of Diesel, Natural Gas and Petrol vehicles.
- NO_X emission showed different performance in relation to the studied vehicle types of private car, Microbus, Minibus and public Bus vehicles.
- It is recommended that future research focus on improving the developed models to include signalized intersections as well as other emission processes such as extended idling, crankcase and start exhausts along with other criteria pollutants that were not studied in this research.
- Highway geometric design features/criteria that were not considered in this research, such as combinations of horizontal and vertical alignment, intersection, or interchange.
- Vehicles of different types, weights, model years, or powers, except for the design vehicles that were used in this research; vehicles have different environmental impacts in the highway design due to their own operating characteristics.
- Environmental impacts prediction system, a systematic tool predicting fuel consumption and emissions merely by inputting the selected conditions into the system.
- 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 NO_X 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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