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Article

Empirical Distribution of Emissions from Commercial Motorcycles (Okada) and Motor Vehicles in Abeokuta, Nigeria

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Abstract: Road transport emission via agents of air pollutant is rapidly increasing in highly dense metropolises, cities and urban areas in Nigeria. This study investigates the distributional form and properties of direct gaseous exhaust of carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2) and hydrocarbon (HC) by motor vehicles (MVs) and motorcycles (MCs) in Abeokuta, Ogun state, Nigeria with a view to know the appropriate distributions and their implications. It was divulged that HC is the most emphatic, highly release emitted air pollutant substance by MCs with distributional form of Weibull, and shape parameter of 1.48 suggesting around one minutes forty-eight seconds dissolve into the air hemisphere while O_2 and HC were the alarming substances for MVs. Furthermore, for CO, it was unveiled that Gamma and Weibull distributions were the ideal fit for MVs and MCs respectively; Normal and Logistic distributions best described CO_2 for MVs and MCs respectively; Gamma or Weibull and Logistic distributions performed well in modelling O_2 for MVs and MCs respectively. The ideal distributions for HC were Exponential and Weibull for MVs and MCs respectively. Hence, these air pollutants need to be monitored using the suggested models since continuous release at an alarming rate is a threat to human health.

Keyword: Air pollutant, Distributional form; Emission; Motor Vehicles and Motorcycles

1. Introduction

Road transportation is undoubtedly the dominated means of movement of people, goods, and freights worldwide especially in Africa. The economic development of any country, state, region, and zone depends solely on easy inward and outward of goods and persons via road mode of transportation by vehicular, tricycles and motorcycles (WHO, 2005). Nearly all the Africa nationals move from one region to another region via road mode. This led to approximately 98.6% of Nigerians sourcing for their daily breads through road transit. Due to this, the increasing number of cars and motorcycles has been alarming in major and busiest roads in Nigeria (Etim, 2016; Chao *et al*., 2014). Rapid population growth, increasingly congested of urban states like Lagos, Kano, Rivers, Ogun etc. and urbanization of rural areas have not only keep doubling the cars and motorcycles yearly but also created high levels of traffic related air pollutions via the emission of internal combustion engines of motor vehicles and motorcycles of road users. These emission combustions by motors that do normally release in large volume during traffic congestions constitutes gaseous air pollutants such as Nitrogen Oxide (NO_2), Carbon dioxide (CO_2), Particulate Matter (PM), oxygenated compounds, Sulphur Oxide (SO_2), Ammonia (NH_3), and Carbon monoxide (CO) etc. (Taiwo *et al*., 2014). According to Etim (2016), CO is the most constituted motor vehicles and motorcycles emitted atmospheric air pollution with close to 80 to 85 percent related mixture with the natural oxygen.

Takeshita (2012) affirmed that emission from engine combustions of vehicles explained up to 22.5 and 21.2% of the global emission of nitrogen oxides and PM. However, PM is usually in different sizes and mixture. PM from urban areas is usually made up to 30% of tailpipe emissions from the road transport particles. Apart from heavy-duty compressed natural gas, motor vehicles, and industrial machines do constitute more of CO. Low quality or improper composition of petroleum, diesel and fuel might double the release of the unhealthy waste product. The increasing number of vehicular movement in metropolitans has led to the constant emission and inhalation of the unhealthy emission (Osuntogun and Koku, 2007).

However, few researches have worked on the release of the unhealthy emission in some metropolitans' cities in Nigeria. Among the studies is the assessment of exhaust of hydrocarbon emission level via commercial motorcycles (Okada) in Abeokuta metropolitans by (Babajide *et a*l., 2015; Ojo and Awokola, 2012). It was revealed that the average exhaust concentrations of the 900 motorcycles are very high for as much as 1921 parts per million (ppm), with some emitting between 6000-9000ppm, confirming that a motorcycle could emit as much hydrocarbons as 30-50times that of motorcar. In similar vein, Olayinka *et al*. (2015) investigated the amount of concentration of CO_2, CO, NO_2, and SO_2 among others in some busy roads in Abeokuta metropolis in Nigeria. In furtherance of the assessment, this study will not only assess the significant of CO, CO_2, Oxygen (O_2) and Hydrocarbon (HC) via commercial motorcycles (Okada) and motor vehicles in Abeokuta metropolis, Nigeria but also to ascertain the empirical competitive distributions of each of the pollutant with their implications.

2. Materials and Methods

2.1. Data Sources and Description

The study was carried out in Ogun State; it is one of the busiest states in Nigeria and West Africa. It is located in the Southwestern zone of the country. It occupies a total land area of 16409.26sq.km. The estimated population of the state by 1991 census was put at 3,214,161. It is a 20 Local Government Area of the state. Oyo and Osun bound Ogun state in the North, in the south by Lagos and in the east by Republic of Benin. The state capital, Abeokuta, is 100km North of Lagos, the commercial nerve centre of the country. The state is on latitude $7^0\ 9'$ and $7^0 40'$N of the equator and longitude $3^0 26'$ and $3^0 40'$East of the Greenwich meridian (Olayinka *et al.* 2015). The samples were taken from four local governments namely Abeokuta, Sagamu, Ijebu-Ode and Sango-otta. Each of these areas has sample points of which CO, CO_2, O_2 and HC were monitored. The four areas have sample points selected for collection in the priority of high population and traffic congestion. Five personnel were employed and trained for data collection from moving motor vehicles and motorcycles; this includes both commercial and private. The data was collected for five (5) days in a week and this went on for the study period of two years. The equipment used for the collection of the emitted pollutants was called Kane gas analyser. Kane gas analyser is used to measure both the efficiency of combustion and the levels of pollutant gases. It accurately checks CO levels, hydrocarbon, measure O_2, CO_2, CO/CO_2 ratio and efficiency. The analyser is attached to the smoke centre of the vehicle to collect the pollutants. Since pollutants measured are always in continuous form, five major conventional types of continuous distributions are considered.

2.2. Gamma Distribution

Let "Y"be a random variable that is continuous for a real positive measured substance with positive real parameters "α"and "β", then, according to Walck (2007). "Y"is regarded as Gamma distribution if it Probability Density Function (PDF) is

$$f(y;\alpha,\beta) = \frac{\alpha(\alpha y)^{\beta-1} e^{-\alpha y}}{\Gamma(\beta)}; \qquad for\ \ 0 < y < +\infty$$

Where α is the scale parameter or scale factor, β is the shape parameter such that if $\beta < 1$ it is regarded as J-shape, if $\beta > 1$ it is called a uni-modal. In addition, if $\beta = 1$ is approximately regarded as Exponential Distribution. Its Cumulative Density Function (CDF) is,

$$F(y)=\frac{\Gamma\left(\beta,(\alpha\beta)^{c}\right)}{\Gamma(\beta)}; \quad for \quad c<0$$

2.3. Weibull Distribution

Let $"Y"$ be a random variable that is continuous for a real positive or negative measured substance with positive real quantity parameters $"\eta"$ and $"\sigma"$, then, $"Y"$ is regarded as Weibull distribution by Hallinan (1993) if its Probability Density Function (PDF) is

$$f(y;\eta,\sigma)=\frac{\eta}{\sigma}\left(\frac{y}{\sigma}\right)^{\eta-1}e^{-\left(\frac{y}{\sigma}\right)^{\eta}}; \quad o<y<+\infty$$

Its Cumulative Density Function (CDF) is,

$$F(y)=\int_{0}^{(y/\sigma)^{\eta}} e^{-y}\partial y=1-e^{-(y/\sigma)^{\eta}}$$

for a substitution of $y=(\mu/\sigma)^{\eta}$

2.4. Normal Distribution

Let $"Y"$ be a random variable that is continuous for a real positive or negative measured substance with location parameter $"\mu"$ or called mean (or shift) and the standard deviation $"\sigma"$ called scale parameter, then, $"Y"$ is regarded as a normal distribution or Gauss distribution if it Probability Density Function (PDF) is

$$f(y;\mu,\sigma)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}(y-\mu)^{2}} \quad ; \quad for \ -\infty<y<+\infty$$

It is to be noted that if $\mu=0$ and $\sigma=1$ the distribution is referred to as standard normal distribution (Karvanen, 2006). Its Cumulative Density Function (CDF) is,

$$F(y)=\frac{1}{2}\left[1+ERF\left(\frac{z-\mu}{\sqrt{2\sigma^{2}}}\right)\right]$$

Where ERF is the Error Function distribution and z is the standardized variate of the normal distribution.

2.5. Exponential Distribution

According to Johnson *et al.* (1994) if $"Y"$ is a random variable that is continuous for a real positive measured substance with positive real parameter $"\alpha"$, then, $"Y"$ is an exponential distribution with Probability Density Function

$$f(y;\alpha)=\frac{1}{\alpha}e^{-\frac{y}{\alpha}} \qquad 0<y<+\infty$$

Its Cumulative Density Function (CDF) is,

$$F(Y) = \int_0^y f(y;\alpha)\partial y = 1 - e^{-\frac{y}{\alpha}}$$

2.6. Cullen and Frey Graph

The Cullen and Frey graph is a an empirical plot of observations that enable to choose competing set of parametric distributions that could describe the modelling or phenomena observations or data via their descriptive statistics. It also makes use of the skeweness and kurtosis to fit observation to tailed parametric distributions (Cullen and Frey, 1999; Casella and Berger, 2002).

3. Results and Discussion

According to the Cullen and Frey graphs below, the continuous distributional forms considered for the pollutants under study for MVs and MCs are Normal, Uniform, Exponential, Logistic, Beta, Lognormal, Gamma and Weibull.

3.1. Descriptive and Distributional Form of Carbon Monoxide (CO) (Motor Vehicles and Motorcycles)

From the descriptive statistics in table 1, it can be inferred that the maximum amount of CO released by motor vehicles is around 4.39 higher than that of the commercial motorcycles. The amounts of CO released by motor vehicles clustered around 2.23 while MCs was 0.99. The variation of CO by motor vehicles that are usually emitted is higher with 0.0238% compared with 0.0099% by that of commercial motorcycles. The estimated skewness of the measured CO in ppm of commercial motorcycles is approximately two times that of motor vehicles but less than three for indication of skewness effect; with kurtosis of motorcycles within the limit of four while kurtosis of motor vehicles is greater than the moderate limit of four. The distributional graphs of carbon monoxide for motor vehicle and motor cycles are shown in figures 1-4.

Table 1. Summary of Descriptive Statistics of MVs and MCs for CO

Statistics	**MVs**	**MCs**
Minimum	0.01	0.05
Maximum	9.58	5.19
Median	1.52	1.37
Mean	2.23	1.53
Standard Deviation	2.38	0.99
Skewness	1.56	0.99
Kurtosis	4.85	3.83

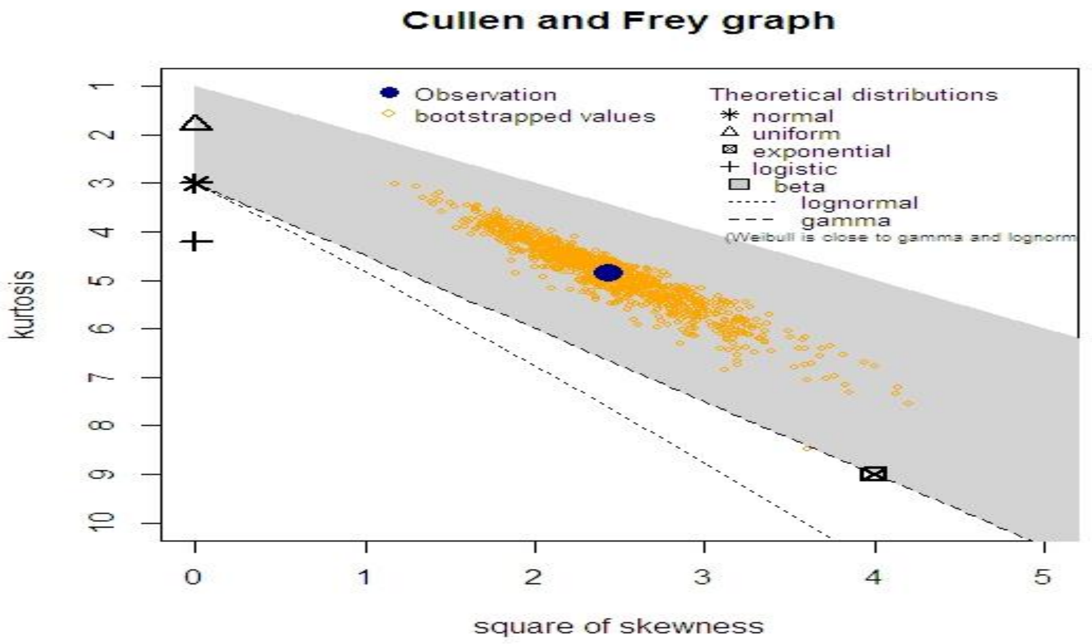

Figure 1. Cullen and Frey Distributional Graphs of MVs for CO

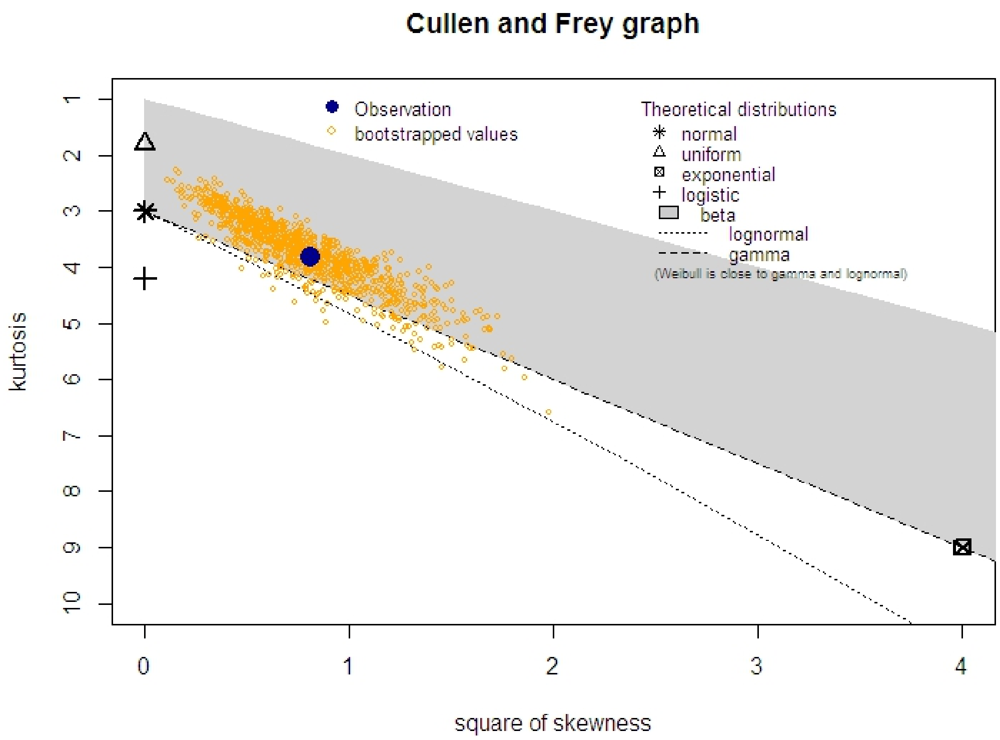

Figure 2. Cullen and Frey Distributional Graphs of MCs for CO

According to the plot of Akaike Information Criterion (AIC) in figures 3 and 4, Gamma and Weibull distributions emerged as the ideal distributions that best described the phenomenal/wavy form of Carbon Monoxide for motor vehicles and motorcycles respectively. These distributions has the minimum AIC. The derived statistics for Gamma and Weibull respectively are given in tables 2 and 3.

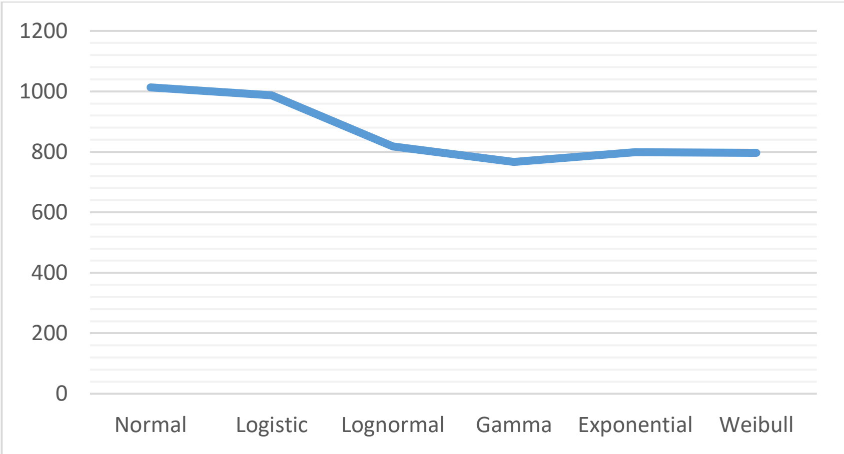

Figure 3. AIC of Distributions of CO for Motor Vehicles

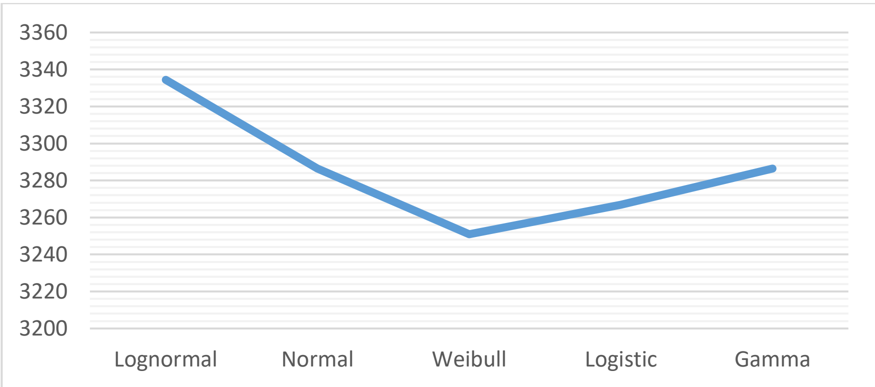

Figure 4. AIC of Distributions of CO for Motorcycles

Table 2. Parameters/Correlation Matrix (Motor Vehicles)

Parameters	Estimate	Standard Error	Correlation Matrix	
			Shape	Rate
Shape	0.85	0.07	1	0.75
Rate	0.38	0.04	0.75	1

Log-likelihood: -396.3453 AIC: 766.691 BIC: 803.487

Table 3. Parameters/Correlation Matrix (Motorcycles)

Parameters	Estimate	Standard Error	Correlation Matrix	
			Shape	Scale
Shape	1.54	0.09	1	0.31
Scale	1.69	0.08	0.31	1

Log-likelihood: -232.8648 AIC: 469.7296 BIC: 476.1044

From table 3, the positive correlation between the shape and rate connotes an agreement of 75% positive unity of the two indicators. It implies that as the rate of CO substances increases the emitted amount gained and controlled supresses the natural air. Since the shape estimate is less than one (85%), this suggested a relatively high variance in the measured and recorded CO while the rate affirmed a subsequent increment of 38% in the present recorded given the immediate past measured. In table 4, the shape parameter of Weibull distribution is 1.54; it means that the events occur is constant in time (decay time) is around one minute fifty-four seconds. The scale parameter of 1.69ppm connotes that for every 1.69-ppm effect of the substance, the distribution is like likely to change with time. The Weibull scale parameter is more reliable with less error of fluctuation of 0.08 compare to 0.09 for the shape parameter.

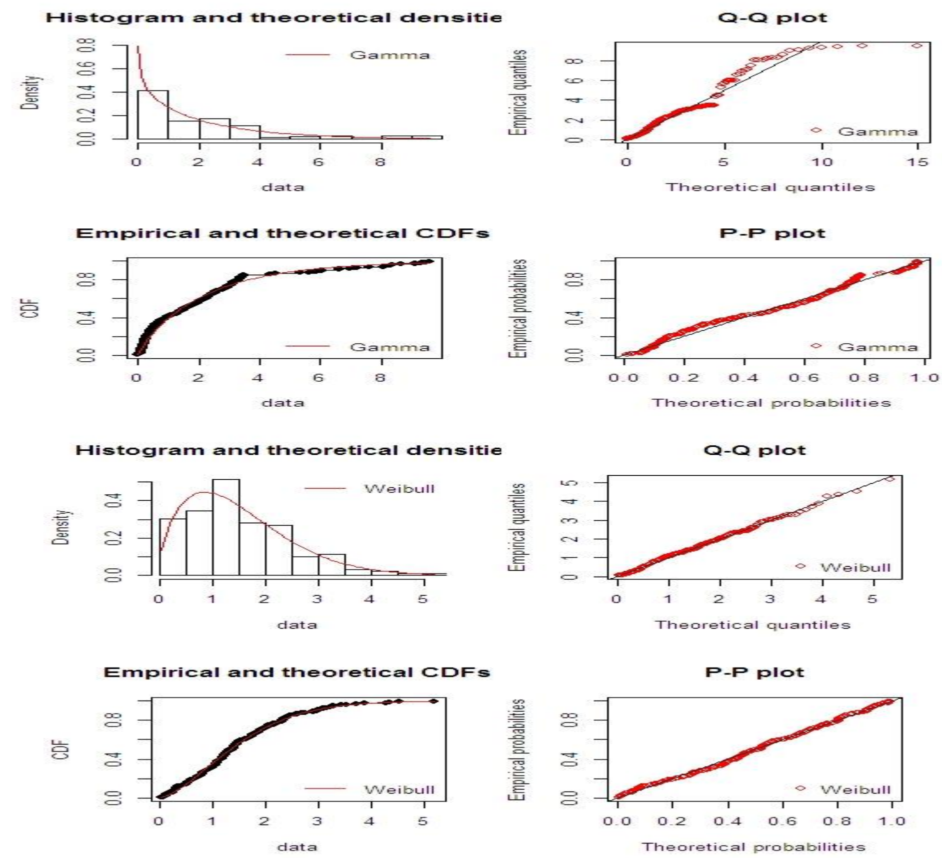

Figure 5. Theoretical and Empirical of Gamma and Weibull Distributions for CO by Motor Vehicles and Motorcycles

3.2. Descriptive and Distributional Form of Carbon Dioxide (CO_2) (Motor Vehicles and Motorcycles)

From the descriptive statistics in table 4, it can be deduced that the maximum amount of $C0_2$ released by motor vehicles is around 0.67 lesser than that of the commercial motorcycles in Abeokuta. The amounts of $C0_2$ released by motor vehicles clustered around 9.21 while the commercial motorcycles as a lesser clustering of 3.24. The variation of $C0_2$ by motor vehicles was far apart from each other with 2.98 variations while that of motorcycles is lesser apart (much more uniform) with 1.61 variations. The estimated skewness of the measured $C0_2$ in ppm of motor vehicles was negatively skewed while the skewness of motorcycles was positively skewed and less than three. The kurtosis of motor vehicles is less than the moderate limit of four while motorcycle is more than four times beyond the limit. The distributional graphs are given in figures 6 and 7.

Table 4. Summary of Descriptive Statistics of MVs and MCs for CO_2

Statistics	**MVs**	**MCs**
Minimum	0.4	0
Maximum	14.0	14.67
Median	9.6	3.1
Mean	9.21	3.24
Standard Deviation	2.98	1.61
Skewness	-0.81	2.21
Kurtosis	3.29	16.49

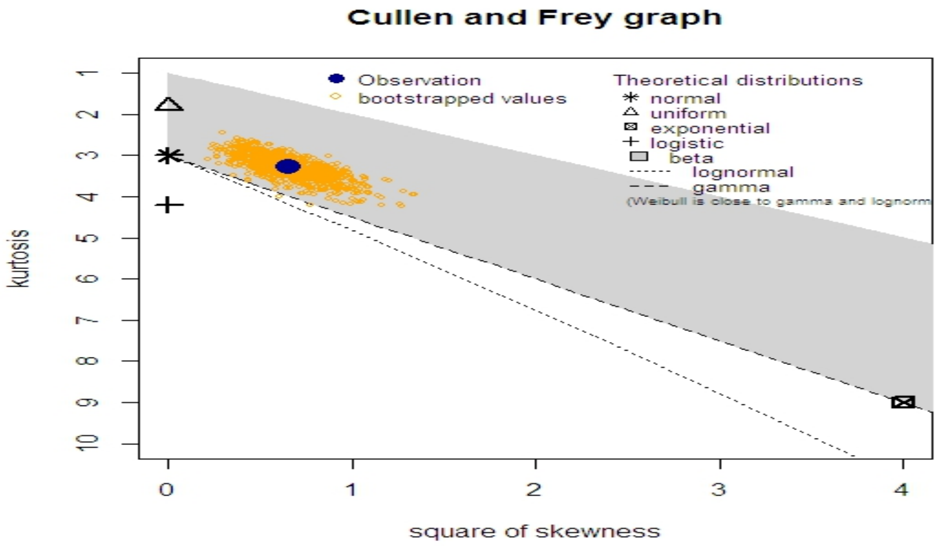

Figure 6. Cullen and Frey Distributional Graphs of CO_2 for Motor Vehicles

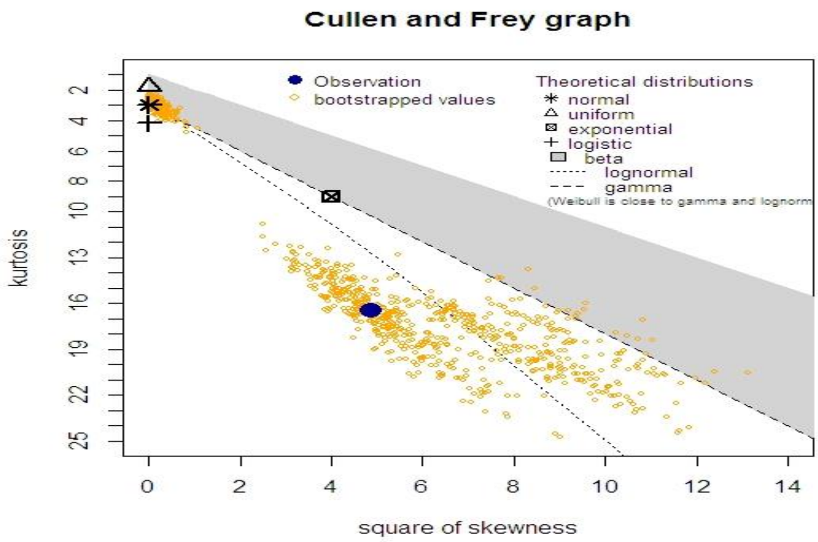

Figure 7. Cullen and Frey Distributional Graphs of CO_2 for Motorcycles

According to the plot of AIC in figures 8 and 9, Normal and Logistic distributions emerged as the ideal distributions that best described the phenomenal/wavy form of Carbon Dioxide for motor vehicles and motorcycles respectively. These distributions has the minimum AIC. The derived statistics for Normal and Logistic respectively are given in tables 5 and 6.

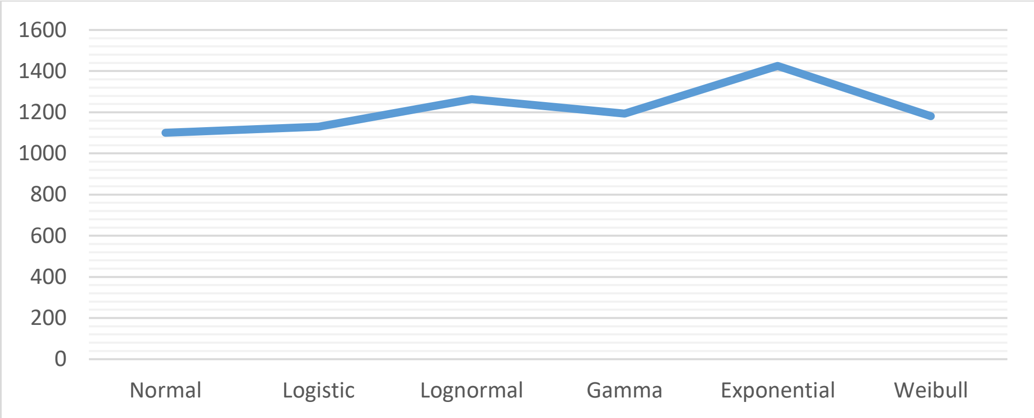

Figure 8. AIC of Distributions of CO_2 for Motor Vehicles

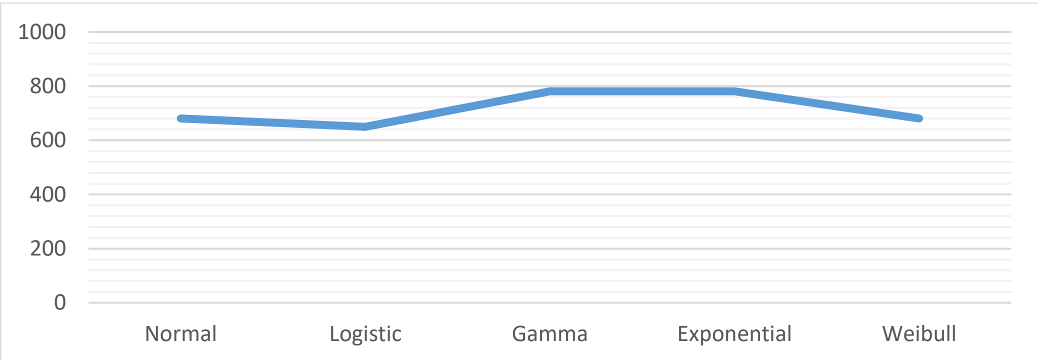

Figure 9. AIC of Distributions of CO_2 for Motorcycle

Table 5. Parameters/Correlation Matrix (Motor Vehicles)

Parameters	Estimate	Standard Error	Correlation Matrix	
			Mean	Std. Dev.
Mean	9.21	0.20	1	0
Std. Dev.	2.97	0.14	0	1

Log-likelihood: -554.2203 AIC: 1112.441 BIC: 1119.237

Table 6. Parameters/Correlation Matrix (Motorcycles)

Parameters	Estimate	Standard Error	Correlation Matrix	
			Location	Scale
Location	3.138	0.106	1	0.0331
Scale	0.820	0.051	0.0331	1

Log-likelihood: -322.8671 AIC: 649.7343 BIC: 656.1091

From table 5, the implication of the Gaussian distribution is that it tells us the degree of scatterings/un-closeness of measured of the substances; and how they vary in terms of magnitude. It has already been ascertained that $C0_2$ by motor vehicles cluttered around 9.21 and the variability is 0.0297%. There is a positive correlation between the mean and standard deviation; suggesting that the higher the cluster disparity, the higher the variability among the measurements. We saw in table 6 that $\log\left(p/1-p\right)=3.138+0.820\,CO_2$ and this connote that $e^{(0.820)}=2.270\approx 9/4$. This suggests that for nine (9) ppm increase in $C0_2$, the estimated odd (probability) of $C0_2$ emission into the air hemisphere is approximately four minutes.

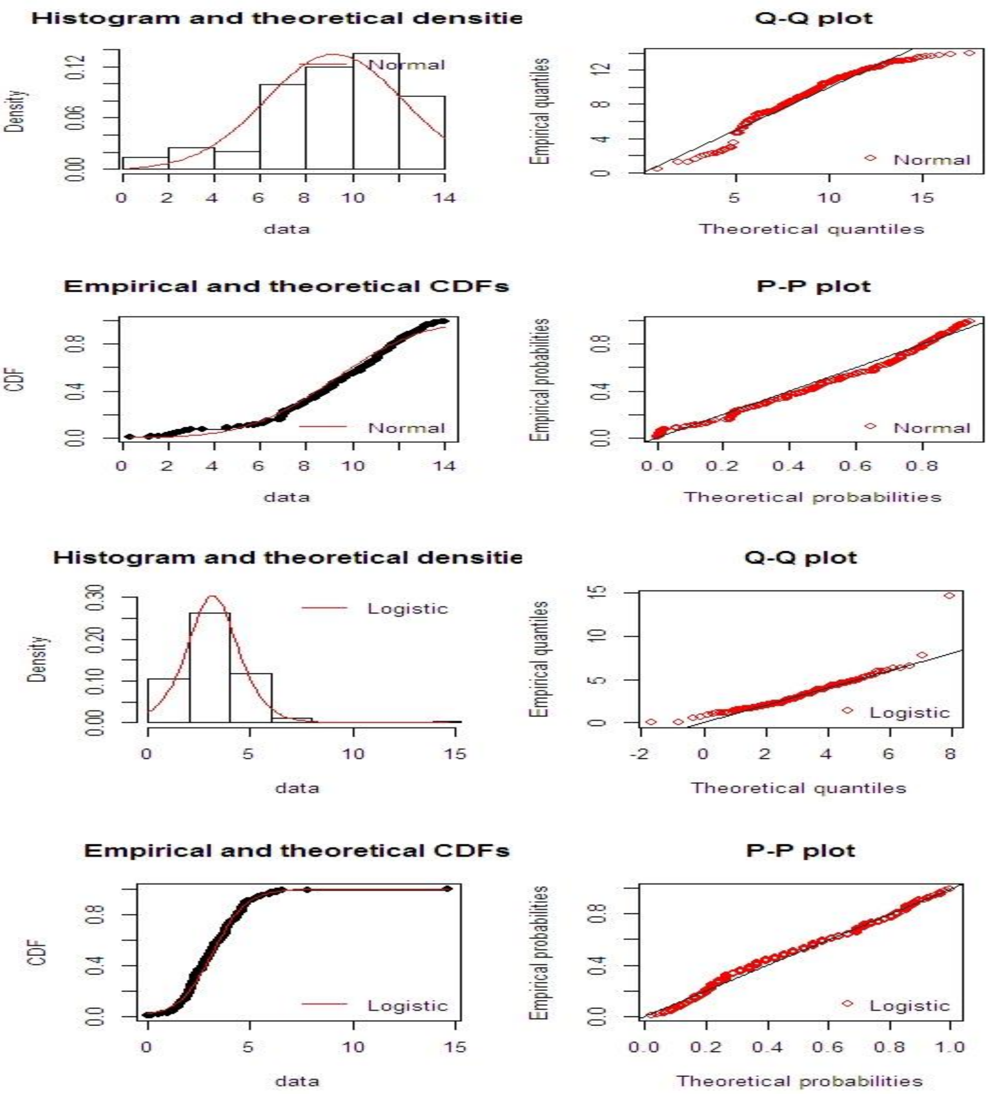

Figure 10. Theoretical and Empirical of Normal and Logistic Distributions for CO_2 by Motor Vehicles and Motorcycles

3.3. Descriptive and Distributional form of O_2 (Motor Vehicles and Motorcycles)

From the descriptive statistics in table 7, the maximum amount of O_2 released by motor vehicles is around 4.09 higher than that of the commercial motorcycles in Abeokuta. The amounts of O_2 released by motor vehicles clustered around 6.40 while commercial motorcycles is an emphatic clustering around 15.37. The variation of O_2 by motor vehicles was far apart from each other with 2.98 variations while that of motorcycles is lesser apart (much more uniform) with 2.27 variability. The measured O_2 of motor vehicles was positively skewed while motorcycles were negatively skewed. Both of their kurtoses are greater than the moderate limit of four such that motorcycle is four times beyond the limit of motor vehicles. The distributional graphs are given in figures 11 and 12.

According to the plots of AICs figures 13 and 14, Gamma or Weibull distributions are the distributional form for O_2 for motor vehicles while Logistic distribution is the distributional form for the commercial motorcycles. The derived statistics for Gamma, Weibull and Logistic respectively, are given in tables 8, 9 and 10.

Table 7. Summary of Descriptive Statistics of MVs and MCs for O_2

Statistics	MVs	MCs
Minimum	0.42	1
Maximum	23.85	19.76
Median	5.67	15.45
Mean	6.40	15.37
Standard Deviation	4.26	2.27
Skewness	1.14	-2.56
Kurtosis	4.61	16.69

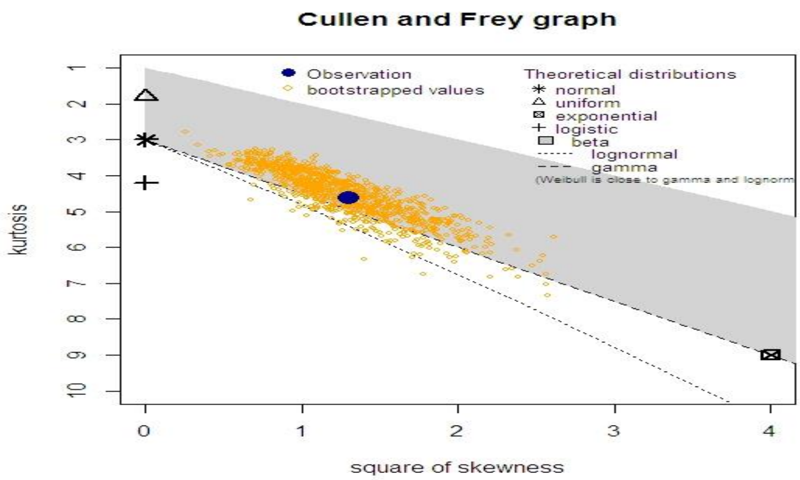

Figure 11. Cullen and Frey Distributional Graphs of O_2 for Motor Vehicles

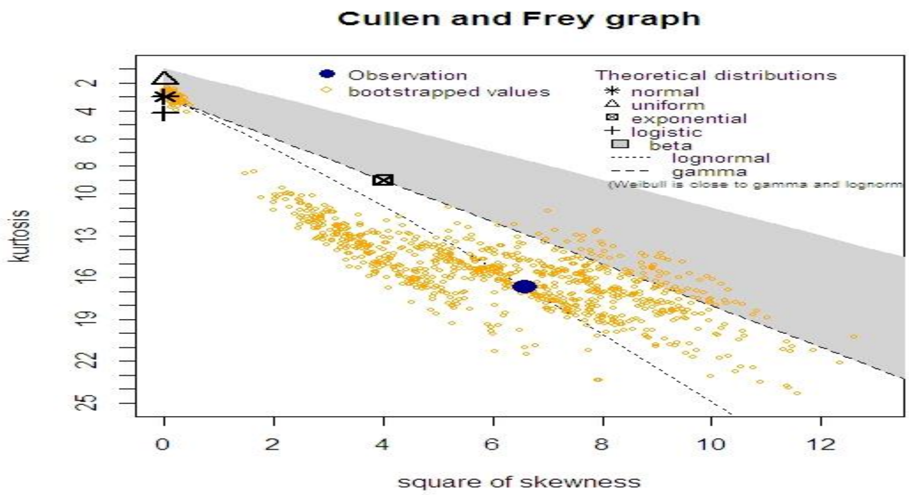

Figure 12. Cullen and Frey Distributional Graphs of O_2 for Motor Vehicles and Motorcycles Emitted

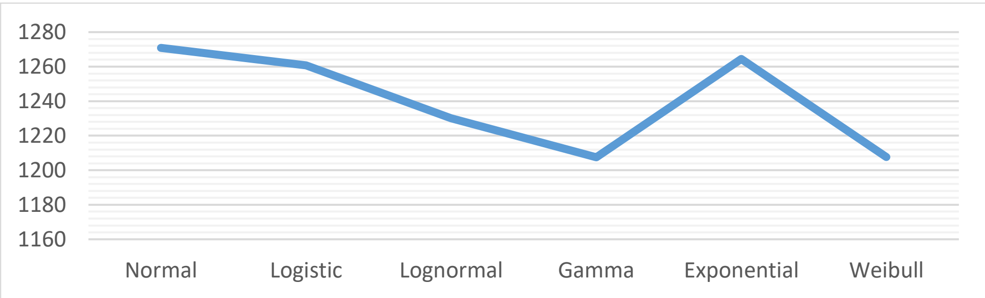

Figure 13. AIC of Distributions of O_2 for Motor Vehicle

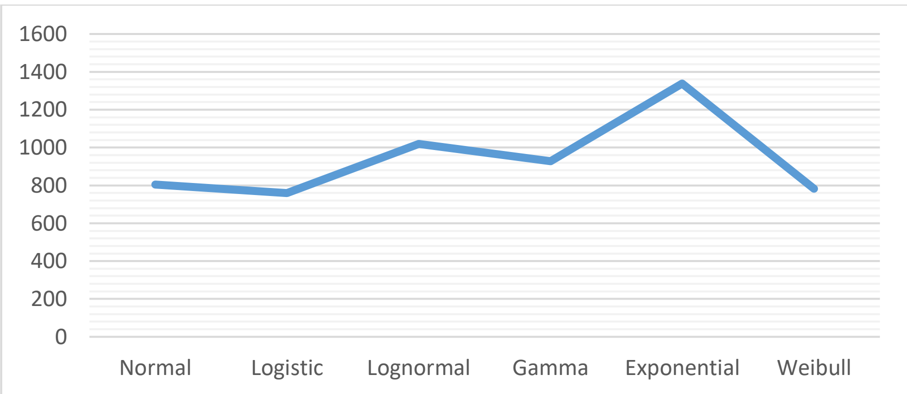

Figure 14. AIC of Distributions of O_2 for Motorcycle

Table 8. Parameters/Correlation Matrix (Motor vehicles)

Parameters	Estimate	Standard Error	Correlation Matrix	
			Shape	Rate
Shape	2.12	0.19	1	0.89
Rate	0.33	0.03	0.89	1

Log-likelihood: -601.7414 AIC: 1207.483 BIC: 1214.279

Table 9. Parameters/Correlation Matrix (Motor Vehicles)

Parameters	Estimate	Standard Error	Correlation Matrix	
			Shape	Scale
Shape	1.56	0.08	1	0.32
Scale	7.13	0.32	0.32	1

Log-likelihood: -601.8095 AIC: 1207.619 BIC: 1214.415

Table 10. Parameters/Correlation Matrix (Motorcycles)

Parameters	Estimate	Standard Error	Correlation Matrix	
			Location	Scale
Location	15.536	0.140	1	-0.023
Scale	1.096	0.068	-0.023	1

Log-likelihood: -377.7371 AIC: 759.4743 BIC: 765.8491

There was a positive correlation between the shape and rate and this implies that as the rate of O_2 substances increases the emitted amount gained and controlled supresses the natural air with the same amount. Since the shape estimate is greater than one, it suggested a uni-modal of the measured and recorded O_2 while the rate affirmed a subsequent increment of 33% in the present recorded given the immediate past measured. Given the shape parameter of Weibull distribution to be 1.56; it means that the events occur is constant in time (decay time) is around one minute fifty-six seconds. The scale parameter of 7.13 connotes that for every 7.13 effect of the substance, the distribution is like likely to change with time. The Weibull shape parameter is more reliable with less error of fluctuation of 0.08 compare to 0.32 for the scale parameter. For the Logistic distribution, $\log(p/1-p) = 15.536 + 1.096(O_2)$ and this connotes that $e^{(1.096)} = 2.99 \approx 3/1$. This suggests that for three (3%) increase in O_2, the estimated odd (probability) of O_2 emissions into the air hemisphere is by approximately a minute.

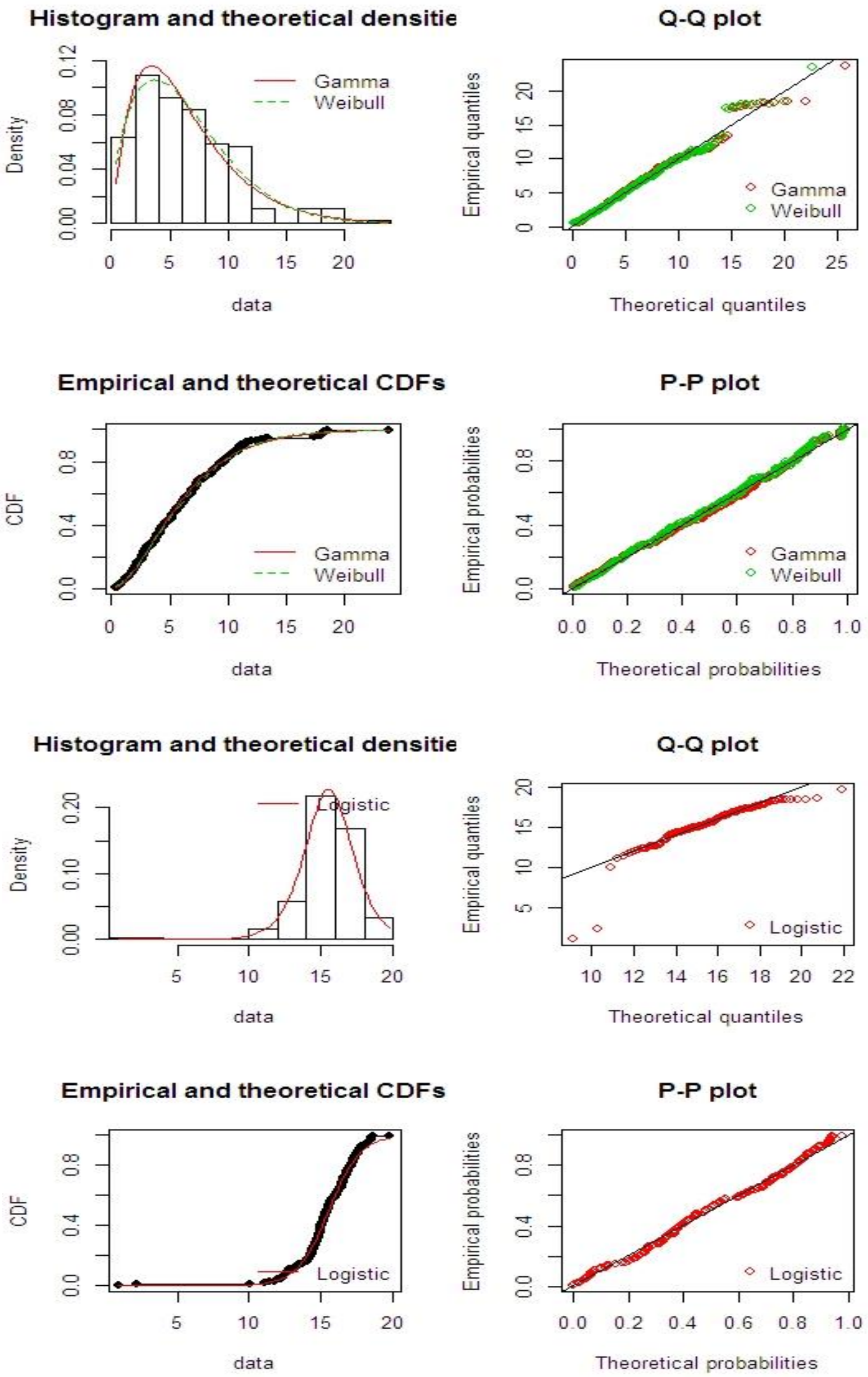

Figure 15. Theoretical and Empirical of Weibull and Gamma; and Logistic Distributions for O_2 by Motor Vehicles and Motorcycles

3.4. Descriptive and Distributional Form of Hydrocarbon (Motor Vehicles and Motorcycles)

From table 11, we can see that the maximum amount of HC released by motor vehicles is around 2384 far lesser than that of the commercial motorcycles; this affirmed and maintained that HC by motorcycle is the most constituted air pollutants by engine combustion. The amounts of HC released by motor vehicles clustered around 321.79 while the one of commercial motorcycles is alarming with 3539.63. The variation of HC by motor vehicles that are usually emitted is smaller with 3.1672% compared with 23.2794% by that of commercial motorcycles. The estimated skewness of the measured HC in ppm of motor vehicles is slightly above three and commercial motorcycles indicated a very miniature effect of skewness, which is less than one; with both of their kurtoses greater than the moderate limit of four. The distributional graphs are given in figures 16 and 17.

According to the plot of AICs figures 18 and 19, Exponential and Weibull emerged as the ideal distributions that best described the phenomenal/wavy form of hydrocarbon for motor vehicles and motorcycles respectively. These distributions has the minimum AIC. The derived statistics for Exponential and Weibull respectively are given in tables 12 and 13.

Table 11. Summary of Descriptive Statistics of MVs and MCs for Hydrocarbon

Statistics	MVs	MCs
Minimum	0	11
Maximum	2384	14413
Median	249	3192
Mean	321.79	3539.63
Standard Deviation	316.72	2327.94
Skewness	3.40	1.35
Kurtosis	20.03	6.30

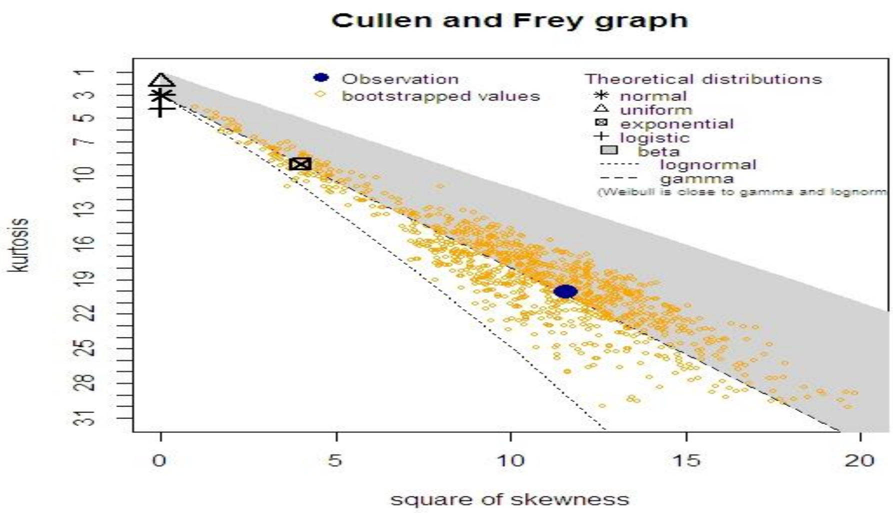

Figure 16. Cullen and Frey Distributional Graph of HC for Motor Vehicles

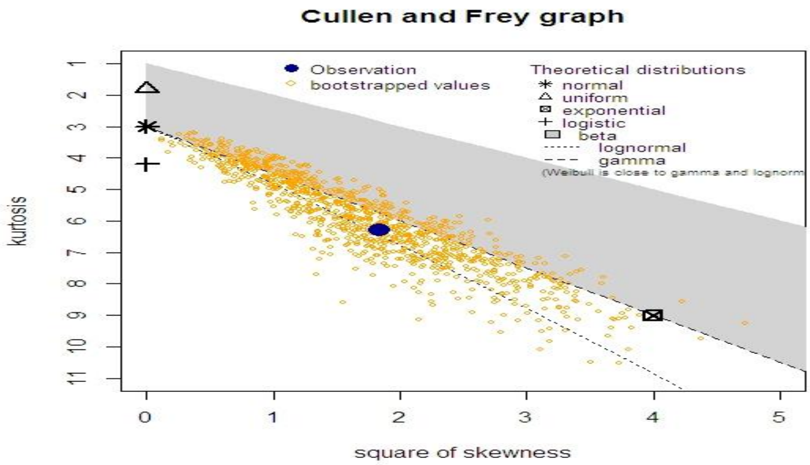

Figure 17. Cullen and Frey Distributional Graph of HC for Motorcycles

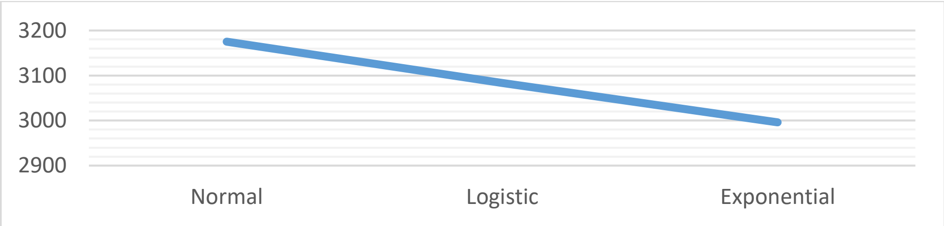

Figure 18. AIC of Distributions of HC for Motor Vehicles

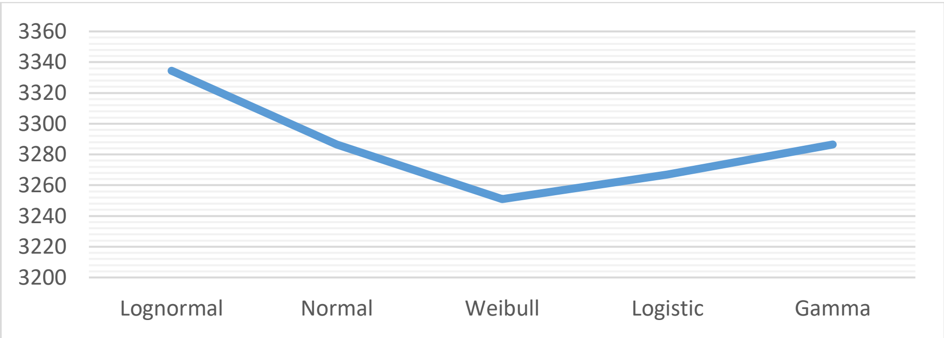

Figure 19. AIC of Distributions of HC for Motorcycles

From table 12, hydrocarbon combustion in motor vehicle increases geometrically by 0.31% in the emitted hemisphere. Its estimate is a reliable one with near to zero (0.00018) standard error. In table 13, the shape parameter 1.48; means that the events occur is constant in time (decay time) is around one minutes forty-eight seconds. The scale parameter of 3882.54 ppm connotes that for every 3882.54-ppm effect of the substance, the distribution is like likely to change with time.

Table 12. Parameters/Correlation Matrix (Motor Vehicles)

Parameters	Estimate	Standard Error
Rate	0.0031	0.00018

Log-likelihood: -1497.033 AIC: 2996.066 BIC: 2999.464

Table 13. Parameters/Correlation Matrix

Parameters	Estimate	Standard Error	Correlation Matrix	
			Shape	Scale
Shape	1.48	0.09	1	0.29
Scale	3882.54	204.43	0.29	1

Log-likelihood: -1623.481 AIC: 3250.961 BIC: 3257.336

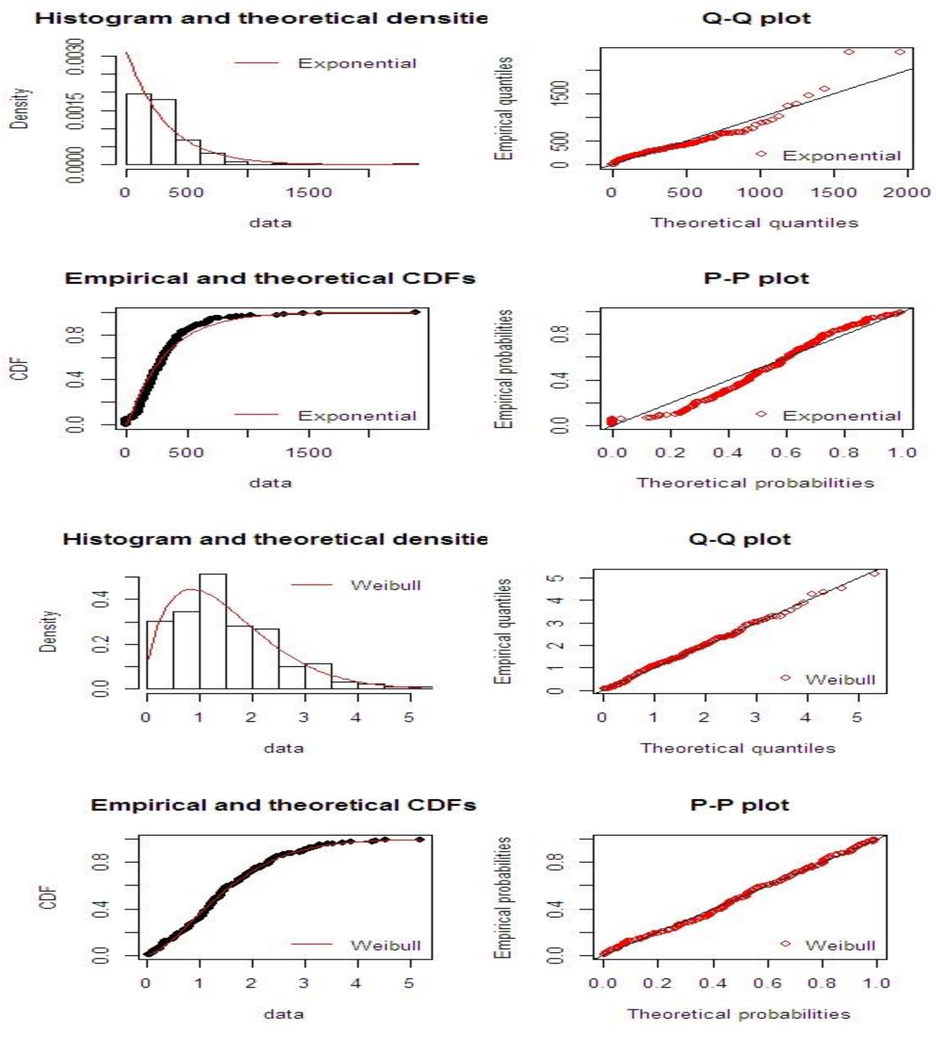

Figure 20. Theoretical and Empirical of Exponential and Weibull Distributions for HC by Motor Vehicles and Motorcycles.

4. Conclusion

External engine combustion of the two major road means of transportations; motor vehicles and motorcycles have been the larger percent of air pollutant substances and emissions. It has been ascertained that these substances are not only release in higher concentrations during traffic jam but also in highly congested metropolises, cities and urban areas with increasing number of vehicles and motorcycles on a daily bases. Additionally, these releases are usually surmounted during rushing hours (morning and evening) of working days and festive periods. The results obtained unfold that the Gamma and Weibull distributions are the ideal fit for motor vehicles and motorcycles CO emitted phenomena respectively; Normal and Logistic distributions best-described motor vehicles and motorcycles CO_2 emitted phenomena respectively; Gamma or Weibull and Logistic distributions performed well in modelling O_2 emitted phenomena respectively. Exponential and Weibull distributions are the ideal fit for motor vehicles and motorcycles HC emitted phenomena respectively. Lastly, it was unveiled that the HC is the most and higher concentration released and emitted air pollutant substances via the engine combustion of motorcycles while O_2 and HC are the alarming substances for that of motor vehicles; but not up to that of HC by motorcycles.

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