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Evaluation Affecting of Traffic Characteristics on CO Emission: Ramadi Network as a Case Study

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A B S T R A C T

The reduction of gases emissions as one of its most significant long-term strategies in any country in the world. Many Iraqi cities suffered from the uncontrolled increasing in the number of vehicles which has a positive relationship with the emission of gases especially the carbon monoxide. This research aims to assess traffic effect characteristics such as logarithm of average flow, the percentage of heavy vehicles, and free flow speed on the emission of carbon monoxide. The study selected the main roads in Al- Ramadi network, the data was collected for traffic characteristics and carbon monoxide between 2018 to 2020.

A random parameters technique was used to construct a model to estimate carbon monoxide emissions for 345 roadway segments. This approach was chosen because it can account for variability caused by traffic characteristics, resulting in more accurate predictions than other approaches. The results of the random parameters model show that the carbon monoxide emission increased due to increase the logarithmic of average flow, the percentage of heavy vehicles, and free flow speed. According to the model results, the parameters of logarithm of average flow, percentages of heavy vehicles, and free flow speed varied across the roadway segments.

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1. Introduction

Increases in the number of modes of transportation are followed by an increase in traffic density (traffic congestion) on urban roads, an increase in travel times, an increase in fuel consumption, and rapid component wear [Fedotov et al., 2018]. This results in the release of large amounts of carbon monoxide as a result of combustion in automobile engines [Barth & Poriboonsomsin, 2008]. Traffic emissions, carbon monoxide (CO), are the main source of air pollution, and vehicle exhaust is the main source of traffic emissions [Bastin et al., 2015; Famela et al., 2015; Borg et al., 2016]. The probability of emissions is mostly studied by numerous authors adopting different methodologies. The Poisson technique and negative binomial models are the most commonly used methods. These techniques were used to predict the amounts of emissions. Recent studies have used random parameter regression models as their methodology [Abid, 2015; Acheampong & Boateng, 2019; Wang & Li,

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2019; Wang & Zhao, 2015; Wang & Chen, 2019; Wu et al., 2019]. This paper shows how the negative binomial stochastic regression method can be used to consider how traffic characteristics affect emissions. The usage of random effects model building as a new method is demonstrated in this research to determine the impact of (average daily flow (Ln ADF), percentage of heavy vehicles (HV%) and free flow speed (FFS)) on carbon monoxide emissions in the city of Ramadi due to the method's ability to allow this and correct the variance as a result of a large wide range of elements relating to traffic characteristics.

2. Method

The random parameter models permit the variance of the different elements that change between Co emission rate observations by permitting these parameters to be random. According to the basic Poisson model, the probability of Co emission for the roadway section i with n Co rate is as follows:

$P(n_i)=\exp(-\lambda i)\,\lambda i^{n_i} n_i!$ …… (1)

The symbols refer to:

$P(ni)$: Likelihood of n Co rate on section i based on the Poisson distribution.

λi: the average Co emission rate on a roadway section i.

ni: Co emission rate observed on every roadway section.

Several assumptions must be satisfied when employing a Poisson model. First, it is assumed that the carbon monoxide emissions of the network equi-dispersed, where λi = condition variation. For such collision data to just be Equi-dispersed, the independent variables traffic, Xj must account for all differences in λi for each route section. The link between λi and Xj in Equation 2 could be described by a log-linear model, in which the natural log of λi is linearly connected to the production of $Xj$and regression coefficients βj [Washington et al., 2010]. Using Poisson distribution and a log-linear function, the anticipated number of independent variables is associated with the carbon monoxide emissions on a certain section of roadway (in this research, traffic characteristics).

$\lambda i=\exp(\beta jXj)$…… (2)

The symbols refer to:

Xj: independent variables.

βj: calculated parameters of regression for independent variables. Therefore, a Poisson distribution doesn't really adequately represent emission data since it requires the data to just be Equi-dispersed, in which the average of emission is distributed uniformly $E(ni)$ equates to the variance VAR (ni). Frequently, emission data is dispersed $E(ni)$ < VAR (ni)), adding the gamma distribution factor to model of Poisson, a negative binomial distribution is employed Structure to represent the data. The negative binomial distribution is produced by rewriting:

$\lambda i=\exp(\beta jXj+\varepsilon i)$ …… (3)

The symbols refer to:

εi: random error (gamma distribution) with a mean equal 1 and variance $\sigma 2$.

This research employed random parameter model, which accounting for unobserved inhomogeneity [Green, 2007]. Random parameters that may vary across data in negative binomial and Poisson models were integrated using a simulated maximum likelihood estimate method. Independent parameters can be represented as follows to incorporate random parameters in classify models:

$\beta ij=\beta j+\varphi i$…… (4)

The symbols refer to:

βij: the mean estimated independent variables regression parameters βj.

φi: a random variable (like a normally distribution variable with mean 0 and variance $\sigma 2$).

Using the formula, The Poisson parameter develops into $\lambda i\varphi i/=\exp(\beta jXj)$ in the Poisson model and $\lambda i\varphi i/=\exp(\beta jXj+\varepsilon i)$ in the negative binomial distribution modeling, now the probabilities for Poisson or negative binomial distributions are comparable $P(ni\varphi i)/$. Using this variant of random parameters, the log-likelihood can be calculated.

$LL=\Sigma In\forall i \int g(\varphi i)\, P(ni\varphi i)/d\varphi i\varphi i$… (5)

The symbols refer to:

$g(\varphi i)$: function of probability density.

Due to the efficient distribution of drawings for the numerical method of the statistical models, a simulation expectation - maximization method with Halton draws was used due to the computationally demanding nature of maximum likelihood estimations of a random parameter Poisson and Negative binomial models' probability estimates.

The elasticity effect is the percentage variation in the average emissions caused by a change of 1, 10, or 100% in the independent variable. [Shanker et al., 1995]. Express the elasticity using Equation 6:

$$E^{\lambda_i}_{X_{jk}} = (\partial Xj\mathrm{i}/\lambda \mathrm{i}) \cdot (Xjk/\partial Xjk) \ \ldots\ldots \ (6)$$

This is the elasticity of carbon monoxide emissions with regard to the k-th observations for the j independent variable on the road section i.

3. Data description

To investigate the effects of traffic characteristics (average daily flow (Ln ADF), percentage of heavy vehicles (HV%), and free flow speed (FFS)) and assess their contribution to carbon monoxide emissions and their impact on the network. The city's road network was drawn using GIS software (see fig.1) with a total length of 172502 m. The network was divided into fixed sections with a length of 500 m as shown in Table (1). The length was chosen to reflect the change that each section of the road would cause in carbon monoxide emissions due to the effect of traffic characteristics. The characteristics of traffic as average daily flow (Ln ADF) and percentage of heavy vehicles (HV%) were collected by manual counting while free flow speed (FFS) was measured with a speed gun device. The analysis was carried out by estimating FPNB and RPNB models for different site categories.

Table 1 – presents the number of roadway segments in each road width class

Road Width (m)	Number of roadway segments	Total length of A roads (m)
15 – 20	67	33489
20 – 25	17	8536
25 – 30	97	48376
30 – 35	14	7132
35 – 40	63	31290
40 – 45	10	5148
45 – 50	5	2714
50 – 55	6	3055
55 – 60	22	10758
60 -65	2	898
65 -70	6	0
70 -75	36	3171
100	345	17935
Total	67	172502

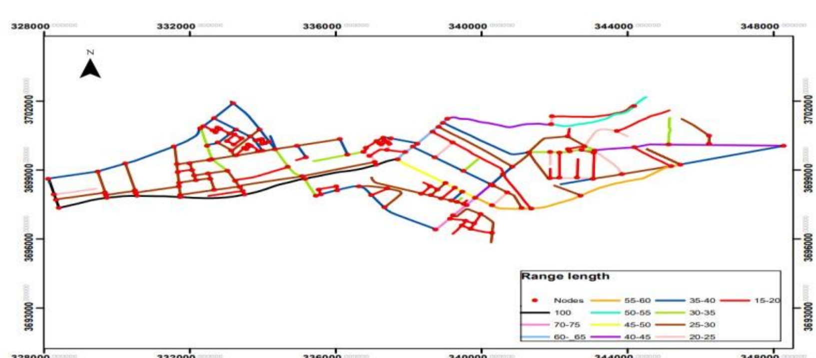

Fig. 1 Selecting arterial roads in the Ramadi road network

Table (2) provides a display of the descriptive statistics for the dependent and independent variables that were utilized in the process of estimating the amount of CO emission utilizing random parameters model.

Table 2 – Summary statistics of CO emission and traffic characteristics

Variable	Min	Max	Mean	S.D.
CO emission	0.54	10.5	5.76	1.33
Ln ADF	7.48	9.29	8.19	0.57
HV%	1	22	7.14	2.88
FFS	40	125	65.7	16.77
Number of observations		345		

4. Models results

able (3) shows the random parameter model results for the CO emissions under the effect of traffic characteristics (Logarithm of average daily flow (Ln ADF), percentage of heavy vehicles (%Hv), and free flow speed (FFS)).

Table 3 – Parameter estimation of Co emission model

Variable	Coefficient	t- value
Constant	-1.728	-2.32
Ln ADF	0.003	4.05
Std.	0.014	3.72
%HV	0.009	5.86
Std.	0.222	8.25
FFS	0.001	4.55
Std.	0.002	6.74

The value of the model parameter that represents the Ln ADF was shown to vary considerably between the roadway segments with a mean 0.003 and a standard deviation 0.014, see Table 2). Based on these results 42% of the normal distribution was less than 0. While 58% of the normal distribution was greater than 0 as shown in Fig.2.

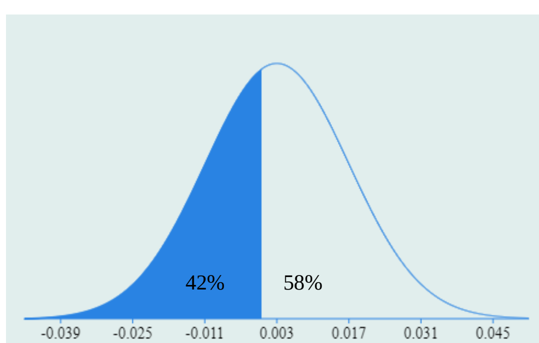

Fig. 2 Estimation of the distribution for Ln ADF parameters for CO emission model

These results reviled that increasing of Ln ADF at 42% of roadway segments led to increase the CO emission. On the other hand, for 58% of roadway segments increasing of Ln ADF led to decrease the CO emission. There was a positive relationship between Co emission and the percentage of heavy vehicles. The parameter for percentage of heavy vehicles resulted as random parameter which indicated that the effect of this variable will vary across roadway segments. As shown in Table 2 the percentage of heavy vehicles with a mean 0.009 and a 0.222 standard deviation. These results show that the percentage of heavy vehicles has a positive effect for 48% of roadway segments, while this parameter had a negative effect for 52% of roadway segments (see Fig. 3).

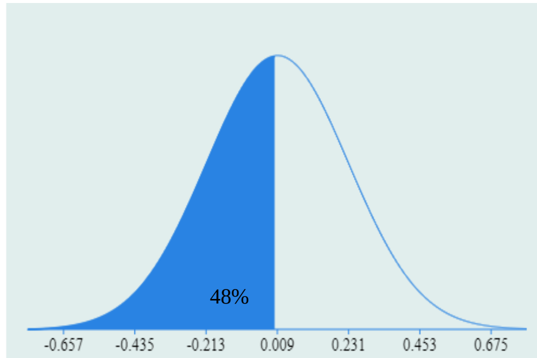

Fig. 3 Estimation of the distribution for %HV parameters for CO emission model

The random parameters model results show that roadway segments with higher free flow speed had a higher CO emission. The free flow speed parameter has a normal distribution with a mean of 0.001 and a standard deviation of 0.002, and it is normally distributed. These result showed that the increase in free flow speed, as shown in Fig. 4, would result in an increase in CO emission in 31% of the highway segments and a decrease in 69% of the roadway segments.

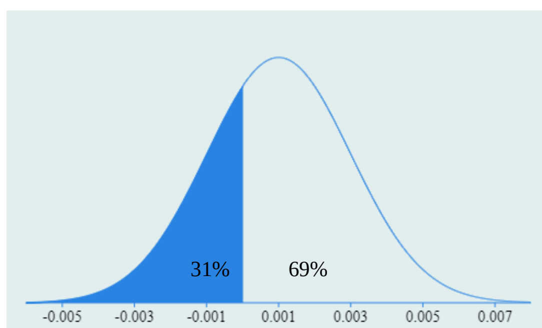

Fig. 4 Estimation of the distribution for FFS parameters for CO emission model

To measure the weight of each variable (traffic characteristic (Ln ADF, %HV, and FFS) on the CO emission, the elasticity effect was measured. The change in amount of CO emission was measured based on A 10% increase in Ln ADF, %HV and FFS. Fig. 5 shows the elasticity effect of Ln ADF, %HV and FFS on Co emission.

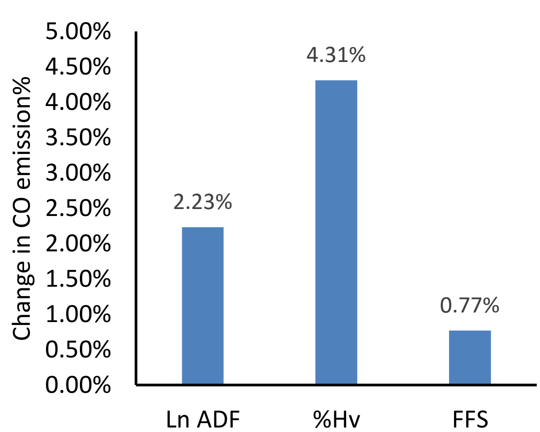

Fig. 5 Estimated elasticity effects of a 10% increase in Ln ADF, HV% and FFS on Co emission

5. Conclusion

Increases in CO emissions were seen across the board in the Ramadi city throughout the study period from 2018 to 2020 due to increasing in traffic volumes. Thus this research attempt to evaluate the effect characteristics of traffic such as Ln ADF, % HV and FFS on the CO emissions. In order to take into account, the unobserved heterogeneity that raised from independent variables (Ln ADF, % HV and FFS), a random parameters model was developed to estimate the CO emissions at Ramadi main roads network. The random parameters model results show that there was a positive significant relationship between Ln ADF, percentage of heavy vehicles, and free flow speed; and Co emissions. All variables resulted as random parameters which means the effect of these variables will vary across roadway segments. The elasticity effect of Ln ADF, %HV and FFS shows that a 10 % increase in these variables will increase the CO emission by 2.23%, 4.31%, and 0.77%, respectively. This indicated that the %HV has the higher impact on the Co emission.

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