The Motorcycle Emission Characteristics in Developing Countries: Logit and Regression Analysis of I/M Data in Makassar City, Indonesia

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Abstract: The present paper aims to analyze the characteristics of motorcycle emission levels in Makassar City, Indonesia. Some motorcycle characteristics such vehicle age, engine size, traveled distance, and brands are explored. The study uses data of the motorcycle emission test results from I/M (Inspection and Maintenance) program in the city during 2010-2012. In analyzing the influence of the characteristics on the motorcycle emission, we develop the probability failure of the motorcycle emission test using binomial logit model. Regarding the model result, the study continues to develop a relationship model between the significant characteristics and the motorcycle emission levels using regression models. The results show that the motorcycle age is the significant variable in the logit model. Further, the polynomial regression model orde-3 shows that the CO and HC emission levels increase in following the motorcycle age increasing. The results provide an expectation in developing motorcycle emission prediction model in further studies.

Keywords: Motorcycle, CO and HC Emission, logit, Regression, Makassar

1. INTRODUCTION

In the last decade, the rapidly increasing of the motorcycle population in many cities in developing countries including in Makassar City, Indonesia, has been generating urban traffic problems in the city such traffic congestion, noise and air pollution (Hustim et al., 2011; Hustim and Fujimoto, 2012). Addressed to air pollution, motor vehicles emit 14% of fossil-fuel-based carbon dioxide, 50% to 60% of carbon monoxide and hydrocarbons, and about 30% of nitrogen oxides emissions (Hwang et al., 2007). Regarding this, the emission reduction is the important and urgent issue on discussion about solving problem to global warming and climate change issue (Aly, et al., 2011). One of the efforts in reducing the emission from the transportation sector is that the road administrators have to control road traffic in emitting pollution.

Regarding the concern, an inspection and maintenance (I/M) program to control air pollution from mobile source on road has been implemented (Simamora, 2006). However, there are ongoing debates addressed to the program effectiveness in reduction the emissions (see, for example, Hubbard, 1997; Wasburn et al., 2001; and Bin 2003). The I/M program has been conducting in some large cities in Indonesia such as in Jakarta, Bogor, Depok, Tangerang, and Bekasi area (Sudarmanto et al., 2007), Bandung, and Surabaya (Sudarmanto et al., 2010), and also Makassar (Aly, et al., 2011).

Some scholars had been explored the achievements of the I/M program, particularly in grasp the emission level of on road vehicle and test failure model of cars on vehicle emission test related to factors that caused of the failure. For example, Pujadas et al. (2004) compared between experimental and calculated vehicle idle emission factors for Madrid fleet case using probit model, while Beydon et al. (2006) developed a different approach model using logit and regression analysis models. In Indonesia cases, Sudarmanto et al. (2007) proposed bivariate probit model to present the failure of on-road emission measurement of passenger cars in Jakarta City, Indonesia. As well as, Aly, et al. (2011) used binomial logit model approach for Makassar I/M data. Furthermore, related to the motorcycle emission in Indonesia, Sudarmanto et al. (2010) also elaborated the similar probit model for motorcycles emission in Jakarta-Bandung-Surbaya, Indonesia.

In order to contribute and to extend those researches, the present paper attempts to analyze the characteristics of the motorcycle emission regarding the motorcycle emission measurement results in idle condition on the I/M program in Makassar City, Indonesia. In this regard, the present paper firstly develops a binomial logit model in describing the emission test failure of motorcycle, and secondly constructs regression models for the relationship models between motorcycle emission levels of CO (Carbon monoxide) and HC (Hydro carbon), and the significant variable of the logit model.

The rest of this paper is organized as follows. Section 2 describes the structure of the binomial logit model to test failure of motorcycle emission test of motorcycles. Section 3 presents the data description using in this study. Then, Section 4 provides the analysis results of the motorcycle emission characteristics utilizing the logit and the regression models. Finally, Section 5 presents discussion about the result of the models and conclusions.

2. THE LOGIT MODEL FOR TEST FAILURE OF THE MOTORCYCLE EMISSION

2.1 The General Structure of Logit Model

The logit model is one of models approaches to represent relationship between response (dependent) variable (*Y*) that categorical and one or more predictor variables (*X*) that not only categorical but also continual. When the dependent variable consist of two category, i.e. $Y = 1$ (success) and $Y = 0$ (fail), then binomial logit model could be applied. Furthermore, both categories of the dependent variable result in *Y* follow the Bernoulli distribution. The probability function of *Y* with parameter γ is stated as follows:

$$P(Y = y) = \gamma^{y}\left(1-\gamma\right)^{1-y} \tag{1}$$

where, y = 0, 1. Then, probabilities of each categories are P(Y=1) = γ and P(Y=0) = 1 – γ with E(y) = γ, for $0 \le \gamma \le 1$.

Generally, probability of the logit which deal with n predictor variables could be formulated as follows:

$$P(Y = y) = \frac{e^{-(\beta_0+\beta_1 x_1+\beta_2 x_2+...+\beta_n x_n)}}{1+e^{-(\beta_0+\beta_1 x_1+\beta_2 x_2+...+\beta_n x_n)}} \tag{2}$$

where x_n is a vector of observed variables that represent relevant attributes to dependent variable, *Y*. β_n is parameter of x_n that should be estimated, and β_0 is a constant of the model.

2.2 The Variable Specifications

The specifications of variables taking account in to the model are divided into two categories, i.e. the failure result of the motorcycle emission test as the dependent variable, characteristics of motorcycles as independent variables. There are two types of the emission test results on assessment standard of the motorcycle emission, i.e. $Y = 0$ if the motorcycle emission value exceeds the standard value, it called test failure, and $Y = 1$ if the emission is still under the standard, it called test success or pass. Some characteristics of motorcycles related to operational capability, such motorcycle age (in years old), engine size (in cc), and traveled distance (in km) which are identified as determinant factors in contribution on motorcycle emission levels are introduced into the model as independent variables, i.e. X_{Va}, X_{Es}, and X_{Td}, respectively.

2.3 The Assessment Standard of the Motorcycle Emission Levels

In assessment of the results of the vehicle emission measurement is failure or pass, this study uses the motorcycle emission standards in Indonesia which published by Indonesia Ministry of Environment (2006). Table 1 shows the emission value standard of motorcycle categories.

Table 1. Motorcycle emission standards in Indonesia

Motorcycle category	Production year	CO (%)	HC (ppm)	Test method
2 cylinders	< 2010	4.5	12,000	Idle
4 cylinders	< 2010	4.5	2,400	Idle
2 & 4 cylinders	> 2010	4.5	2,000	Idle

Table 1 shows that the motorcycle emission standard of CO and HC emission types based on engine types and production years. In this regard, engine types of motorcycles are categorized into 2 cylinders and 4 cylinders, while the 2010 is the limit year between old and new motorcycle categories. All motorcycle categories have maximum value of CO standard about 4.5%. The motorcycles which categorized into 2 cylinders and < 2010 have limit value of HC approximately 12,000 ppm, while the category of 4 cylinders and < 2010 has only maximum value until 2,400 ppm. Particularly the new motorcycle category (production year > 2010), HC is limited until 2,000 ppm.

2.4 Binary Logit Model Development for Failure of Motorcycle Emission Test

Regarding the general structure of the logit model approach and in case available two alternatives such in failure probability of motorcycle emission test, the study applies the binomial logic model (BNL). By using Equation (2) and the independent variables, the failure probability of motorcycle emission test $P_1(y|x)$ can be expressed in the following equation:

$$P\left(y|x\right)=\frac{e^{-(\beta_0+\beta_1x_1+\beta_2x_2+...+\beta_nx_n)}}{1+e^{-(\beta_0+\beta_1x_1+\beta_2x_2+...+\beta_nx_n)}} \tag{3}$$

where,

x_n : a vector of observed variables that represent relevant attributes to Y.

β_n : parameter of x_n that should be estimated, and

β_0 : a constant of the model.

2.5 The Parameter Estimation of the Binary Logit Model

This study adopts the maximum likelihood theory in estimating the parameter values of the binomial logit model. The estimation procedure of the maximum likelihood value involves development of a joint probability density function of the observed sample, called the likelihood function, through estimation of parameter values which maximize the likelihood function. The likelihood function in case T observation face j alternatives result is defined as follows (Koppelman and Bhat, 2006; Train, 2009):

$$L(\beta)=\prod_{\forall_t \in_T}\prod_{\forall_j \in_j}\left(P_{jt}(\beta)\right)^{\delta_{jt}} \tag{4}$$

where,

δ_{jt} : chose indicator (=1 if j is happen by observation t and 0, otherwise) and

P_{jt} : the probability when the observation t give event j.

The solution in order to maximize the *log-likelihood function* is the second derivation of the function with respect to β. In this regard, the parameters values of the model are estimated using the statistical package software, i.e. SPSS Version 17.0.

3. DATA DESCRIPTIONS

3.1 The Sampling Data of the Motorcycle Emission Measurement

This study uses data from the results of vehicle emission inspection and maintenance program in Makassar City, one of large cities in Indonesia. The program has been conducted periodically in order to measure the emission level of vehicle which passing on an arterial road in the city. The survey used a set equipment of emission test in order to measure CO and HC emission level of motorcycle under idle condition. On the survey, the other information of motorcycle characteristics for the both categories was collected in the survey by using interview method approach to user or owner of the cars sampling. The information include vehicle age, engine size, travel distance, brand and type of car. In this study, we use panel data of the motorcycle emission measurement during three years, i.e. 2010, 2011, and 2012.

Table 2 presents the number of motorcycle sampling which chosen randomly during the survey. Totally, there are 324 motorcycles has been measured since 2010 until 2012. In 2010, there are 51 tested motorcycles, and the motorcycle number increase in 2011 and 2012, i.e. 142 and 131 respectively.

Table 2. Motorcycle emission standards in Indonesia

Period (Year)	Date of testing	Road Location (Street)	Number of Data
2010	May 5^{th}	Boulevard	51
2011	October 18^{th}	Sudirman	142
2012	November 6^{th}	Sudirman	131
Total Sampling			324

3.2 The Motorcycle Age Characteristic

Some statistic indicators of the motorcycle age such older, younger, mean, mode, median are presented in Table 3. The table shows that the motorcycle sampling in this study has average age about 3 years old. However, the motorcycle age about more than 15 years old is still available. Comprehensively, the motorcycle sampling is dominated by age 1 until 2 years old.

Table 3. The motorcycle age characteristics

Statistic Indicators	Motorcycle age of each testing year			
	2010	2011	2012	Total
The oldest	29.0	19.0	18.0	29.0
The youngest	0.0	0.0	0.0	0.0
Mean	4.3	2.3	3.2	3.0
Mode	1.0	1.0	1.0	1.0
Median	2.5	1.0	3.0	2.0
Sampling number	51.0	142.0	131.0	324.0

3.3 Traveled Distance of the Motorcycles

The characteristics of traveled distance by motorcycles regarding the odometer dial when the survey is conducted are provided in Table 4. The table shows that the motorcycle sampling in this study has the longest traveled distance about 884,175 km, while the shortest traveled distance is 305 km. Averagely, the motorcycle sampling has 44,588 km-traveled distance, and the median of the traveled distance of the motorcycles is 20,694 km.

Table 4. The traveled distance of motorcycle

Statistic Indicators	Traveled distance of motorcycle of each sampling year data (Km)			
	2010	2011	2012	Total
The longest	832,410.0	516,272.0	884,175.0	884,175.0
The shortest	0.0	305.0	2,057.0	305.0
Mean	99795.4	32,040.4	37,547.3	44,588.1
Median	29169.0	19,682.0	20,012.0	20,694.0

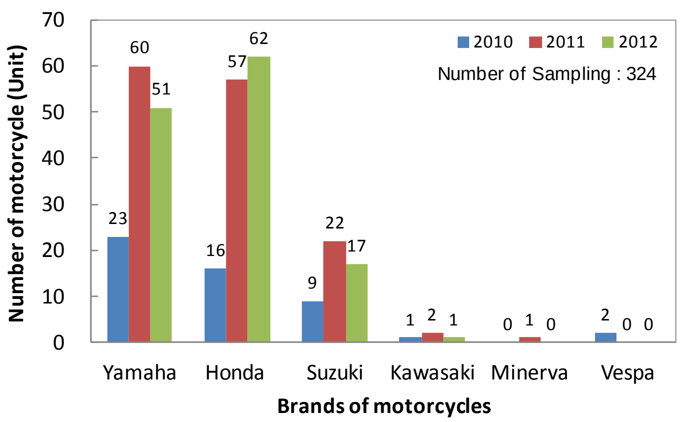


Figure 1. Brands of the motorcycle sampling

3.4 The Motorcycle Brands

The brands of the motorcycle sampling in this study are presented in Figure 1. Figure 1 shows that the motorcycles operated in Makassar have some brands, such Yamaha, Honda, Suzuki, Kawasaki, Minerva, and Vespa. Further, the figure shows that both brands, Yamaha and Honda, are major brands of motorcycles in the city. However, the brands of Suzuki and Kawasaki also have significant number, respectively. Meanwhile, the brands of Minerva and

Vespa are minor number of motorcycles in Makassar, Indonesia.

4. THE MOTORCYCLE EMISSION CHARACTERISTICS

4.1 Traveled Distance of the Motorcycles

The results of the motorcycle emission test are evaluated into two categories regarding the Indonesia Emission Standard for Motorcycle. Both categories are passed emission test and failure emission test. The evaluation results are shown in Figure 2. Figure 2 shows that mostly motorcycle passed the emission test. This phenomenon is supported by the age condition of the tested motorcycle which dominated by 0 – 2 years old.

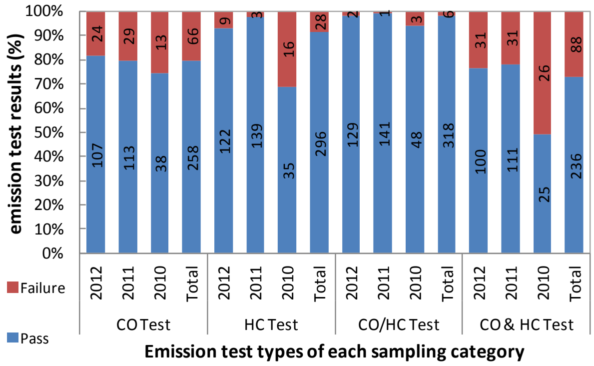
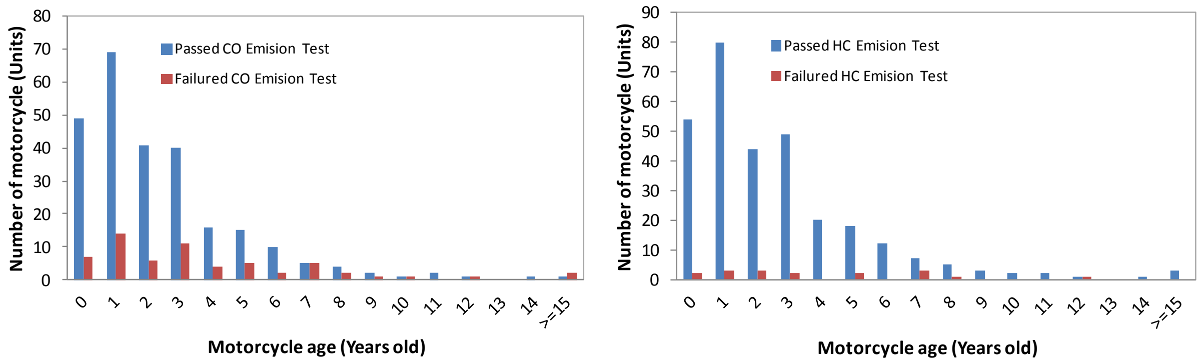


Figure 2 Percentage of motorcycle emission test results of each sampling category

4.2 Percentage of Motorcycle Emission Test Results Related to the Motorcycle Age

Regarding the motorcycle age, the assessment results of the motorcycle emission test are presented in Figure 3a and Figure 3b for CO and HC emission types, respectively. Figure 3a and Figure 3b show that mostly new motorcycles passed CO and HC emission test.



a. CO Emission type

b. HC Emission type

Figure 3 Percentage of motorcycle emission test results related to the motorcycle age

4.3 The Parameter Estimation Results of the Binary Logit Model

In order to obtain the significant variables of the motorcycles which influence the emission levels of motorcycle, we developed four binary logit models of the failure probability of emission test. The four models involve CO test failure model, HC test failure model, CO and HC test failure model, and CO or HC test failure model. Calibration and validation of the binary logit models are provided in Table 5.

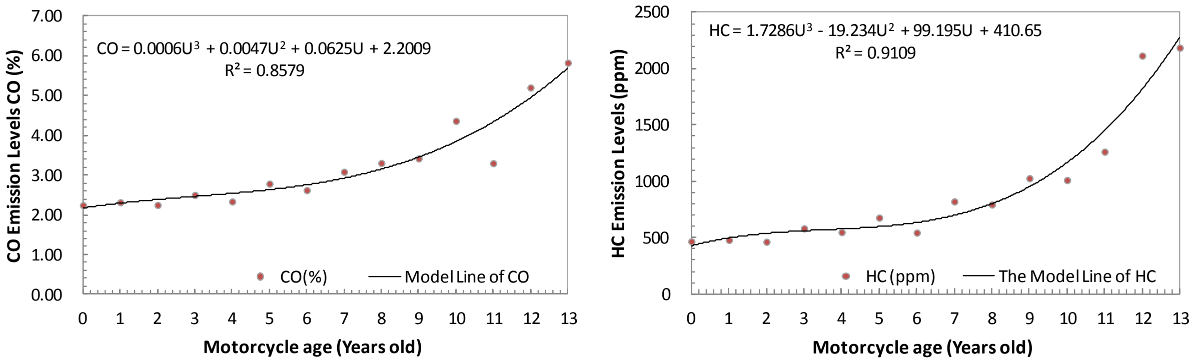
Table 5. Parameter values of test failure model of motorcycle emission type

Variable	Symbols	Parameters values of the test failure models							
		CO test		HC test		CO and HC test		CO or HC test	
		Value	*Sig.*	Value	*Sig.*	Value	*Sig.*	Value	*Sig.*
Vehicle age (X_{Va})	β_1	**0.213**	**0.000**	**0.087**	**0.093**	**0.164**	**0.009**	**0.193**	**0.000**
Engine size (X_{Es})	β_2	-0.008	0.375	-0.007	0.616	-0.026	0.239	-0.007	0.409
Traveled dist.(X_{Td})	β_3	0.000	0.133	0.000	0.973	0.000	0.790	0.000	0.196
Constant	β_0	-1.005	0.336	-2.311	0.170	-1.862	0.446	-0.890	0.347
Number of data	n	324		324		324		324	
Hit ratio (%)		82.0		94.5		98.4		78.5	
Likelihood ratio	ρ^2	0.128		0.026		0.133		0.108	

Table 5 presented that the log-likelihood ratio index, ρ^2 of the models mostly similar in around 0.1 except the HC test failure model which has ratio about 0.03. In case of logit model assessment, this ratio indicates that the significant of a logit model could be accepted (Alviansyah, 2005; Ramli et al., 2010; Aly et al., 2011). Meanwhile, the low rho square value of the HC model is caused by the low data variation of emission test as depicted in Figure 2. The acceptability of the binary logit models in this study is supported by the hit ratios (the “percent correctly predicted”) of each model that have around 80% until 90%. Furthermore, Table 5 shows that the motorcycle age is the variable which significantly influenced the failure probability of emission test in the four models. This indicated by the significant values (Sig.) of the variable less than 0.05 (it means significance level under 95%). However, the Sig. values of the HC test failure is slightly higher than 0.05. In addition, the others variables of the models are not enough significant to contribute to the models due to their Sig. values more than 0.05. Briefly, this study will elaborate further the influence of the motorcycle age on the motorcycle emission levels using regression model approach in the following sub-section.

4.4 The Relationship Model between Emission Levels and Age of Motorcycles

Regarding the characteristics of motorcycle emission, we attempted to continue in developing the relationship model between emission levels and age of the motorcycles. By using the regression model analysis (such linear, exponential, logarithmic, and polynomial models), we result the fit relationship model for CO and HC emission types, as presented in Figure 4a and Figure 4b, respectively. In this regard, the figures show only the highest R^2 among the models.



a. CO Emission type b. HC Emission type

Figure 4. The relationship between the motorcycle emission levels and the motorcycle age

Figure 4 indicates that the best relationship model is the polynomial model in orde-3.

The polynomial model between CO emission level (CO) and the motorcycle age (U) type is $CO = 0.0006U^3 + 0.0047U^2 + 0.0625U + 2.2009$. As well as, the polynomial model between HC emission level (HC) and the motorcycle age (U) type is $HC = 1.7286U^3 - 19.234U^2 + 99.195U + 410.65$. The R^2 values of both models are 0.8579 and 0.9109, respectively. Regarding the regression model, the levels of both emission types increase to follow the increasing of the motorcycle age. However, the increasing of the HC emission is slightly higher than the increasing of CO emission when the levels of both emission types are related to the motorcycle age.

5. DISCUSSIONS AND CONCLUSIONS

The motorcycle emission characteristics such motorcycle age, engine size capability, traveled distance in km, and the motorcycle emission levels of CO and HC in developing city such Makassar City in Indonesia have been evaluated in this study. Through the binary logit model analysis using the motorcycle emission measurement data of I/M program in Makassar during 2010 until 2012, we can state that the vehicle age of the motorcycles plays important role on the concentration levels of CO and HC emission of the motorcycles. The increasing of the motorcycle age arise the failure probability on motorcycle emission test. In the other side, the characteristics of engine size capacity and traveled distance of the motorcycles shows insignificant contribution to increasing of number of motorcycle that failure in CO and HC emission tests. These phenomena are in line with the characteristics of the passenger car emission levels in the city as presented by Aly et al. (2011).

Furthermore, the regression analysis of a relationship model between the CO and HC emission levels and the motorcycle age results a polynomial model in orde-3. The polynomial model shows that the increasing of the motorcycle age leads to the increasing of emission concentration for both types of the motorcycle emissions. However, the increasing of the CO emission is slightly lower than the increasing of HC emission when the levels of both emission types are related to the motorcycle age.

Those results could lead to encourage important role for government in order to control the motorcycle emission level of air pollution as part of inspection and maintenance (I/M) programs in Makassar City particularly. The Makassar government should restrict the number of motorcycle which may operate on the city roads regarding the motorcycle age. Briefly, the study results provide an expectation in developing motorcycle emission prediction model in further studies.

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