DOCTORAL DISSERTATION

STUDY OF EMISSION CONTROL FOR PASSENGER CAR IN INDONESIA THROUGH ENVIRONMENTAL IMPACT EVALUATION

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Abstract

Since September 2013, the Indonesian government has launched new policy named as Low Cost Green Car (LCGC). This has led to significantly increase in car purchases year by year. Meanwhile, the evaluation of environmental impact, which results from emission generation due to the increase of used cars, has not fully explored from previous studies. Therefore, to supplement these gaps, the research purpose of this thesis is to assess current emission generation and determine proper way to control emission level in the future. This main purpose is supported by the following specific objectives:(1) to analyze LCGC policy effect in terms of the change of emission amount of CO, HC, NO and CO_2 gases; (2) clarification of the necessity of the scrappage incentive program to reduce higher emission from older vehicles in terms of estimation of CO, HC, NO gas emissions; (3) to explore the possibility of idling-focused method as one of the technological approach to support emission control in the high traffic jam conditions in terms of CO, HC, NO gas emissions.

In Chapter 2, the effectiveness of policy under two scenarios: with and without LCGCs were examined. The affordable price of LCGCs and the strict enforcement of the vehicle purchase system allow us to estimate the growth in the amount of vehicles using minimum annual income as a measure of people's ability to buy a new car. People, who has an annual income of US$4,500–$10,000, was considered to be likely to buy an LCGC. Annual travel distance was obtained from a survey of drivers, while the deterioration factor was found in the Euro 2 standard. The results showed that the LCGC policy will potentially cause a significant increase in emissions of CO, HC, and NO by 2030. The LCGC scenario predicted 1,390, 31, and 280 tons of CO, NO, and HC, respectively, compared with 670, 15, and 137 tons, respectively, for the scenario without LCGCs, an increase of 51.7%, 48%, and 51.2%, respectively. For amount of CO_2, although LCGC policy could save more than 104,881 tons, the gap is increasing until end of projection in 2030, 3.3 times bigger between corresponding year, 49,411 tons and 14,892 tons for with and without LCGC policy, respectively.

In Chapter 3, to dig into more detail about the LCGC policy, incentive scenario for people to replace their non-euro car with a newer LCGC car through a scrappage program was examined. Willingness to replace old car into an LCGC car was determined through a questionnaire survey. From this survey, the financial aspect still dominated the motivation behind the replacement. This was shown from the choice of the highest incentive fee of $2,000 USD per unit. By applying 78% and 82% to describe the probability of changing to the LCGC car and the incentive option of $2,000 USD, respectively, the incentive program proven that it can reduce the population of non-euro cars with targeted car age greater than 24 years. From the results, it can be seen that emission amount of CO, NO, and HC decreased significantly with CO by 59.3%, NO by 68.1%, and HC by 35.4% compared to without the scrappage incentive program by 2030. Since each unit was replaced with a LCGC car, the population balance was zero. The increase of the emission level from the additional number of LCGC cars was not significant compared to the emissions from non-euro cars.

In Chapter 4, the potential avoidable emissions through idling situation in Jakarta city, one of the busiest cities in the world for traffic, was analyzed. New monitoring method was developed using a global positioning system coupled with global system for mobile provider. We determined that more than 46% of the recorded travel distance occurred with an average speed <5 km/h. Expanding idling driving to <10 km added a +10% contribution to the avoidable emissions. The 46% portions contributed to the current emission levels. The increase of avoidable emissions was strongly related to the high growth rate of vehicles by more than 9% every year. This was larger when compared to the annual road growth that only averages 0.01%. Eliminating emissions during idling conditions using a technological approach was one of promising options.

In Chapter 5, conclusions and recommendations of all chapters. From this discussion, comprehensive and continuous policy should be proposed to assure successful emission control in the future.

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List of Abbreviations

LCGC	Low Cost Green Car
CN	Cetane Number
MPV	Multi Purpose Vehicle
CO	Carbon Oxide
HC	Hydrocarbon
NO	Nitro oxide
RON	Research Octane Number
M	Monthly installment
BM	Amount borrowed
AM	Minimum annual income
DP	Downpayment
SC	Stock of cars
ATD	Annual Travel Distance
EF	Emissions Factor
DF	Deterioration Factor
NA	Number of LCGC
NB	Number of non-LCGC
E	Emissions
AFC	Annual Fuel Consumption
FCA	Annual Fuel Consumption for LCGC
FCB	Annual Fuel Consumption for non LCGC
GCA	Amount of carbon emitted by LCGC
GCB	Amount of carbon emitted by non LCGC
MD	Density of gasoline
WR	Willingness rate of changing old non-euro car to the LCGC car
NER	Number of non-euro cars with a car age more than 24 years replaced by the LCGC car
NE	Number of non-euro cars
A	Event of changing old non-euro cars with the LCGC cars
B	Event of choosing the offered incentive to replace the old non-euro car with an LCGC car
P (A)	Probability of changing the old non-euro car to an LCGC car
P (B)	Probability of choosing the offered incentive to replace their old non-euro car to an LCGC car
N	Number of targeted non-euro cars with a car age of more than 24 years
NER	Number of non-euro cars with a car age of more than 24 years old replaced with an LCGC car
NAE	Number of new LCGC registrations in relation to non-euro car replacement
EF_1	Emission factor for euro 2 standard
EF_2	Emission factor for non-euro standard
TD	Travel distance
T_{lost}	Time lost because of idling driving
T_{idle}	Time during idling condition

T_{total}	Total time needed for certain travel distance
V_a	Average speed with traffic condition
TD_{lost}	Travel distance lost due to time lost
V_a	Average speed with traffic condition
T_{idle}	Time during idling condition
E_{lost}	Emission lost during idling driving
TD_{av}	Annual average travel distance

CHAPTER 1 INTRODUCTION

1.1. Background

Study of emission control for passenger car in Indonesia is one of important topic. The urgency of this work is supported by car population data that increasing year by year significantly. Indonesia is one of the biggest car market which is possible to contributes high gas emissions with annual car growth >10%. Since 2001, only one regulating issued related to the vehicle performance toward environmental issue. High car growth gives high potential traffic jam. Moreover, no limitation of the car age worsening emission condition. Figure 1.1 shows population of the vehicle in categories of euro and non-euro car. LCGC include to euro car that fulfill the standard of Euro 2 emission.

From 2001, only one regulation launched in 2013, new policy named as Low Cost Green Car (LCGC) after one-year delay. This regulation technically control fuel consumption of 20 kilometers per liter with engine capacity in range of 0.99 liters to 1.2 liters for gasoline. Fuel specification is Research Octane Number (RON) 90 for gasoline and Cetane Number (CN) 51 for diesel with maximum wheel handle turning radius 4.6 meters. This radius reflects the size of the car, that usually has more than 4.7 meters turning radius (MOE, 2003). The LCGC car has smaller dimension compare to current passenger car from Multi Purpose Vehicle (MPV) or sedan type (engine capacity > 1.5 liters) (Gaikindo, 2015). This regulation is one next step after implementation in 2001 for Euro 2 Standard. All vehicles fulfilled this requirement will be categorized as LCGC car and reserve of getting tax cut incentive from the government (MOI, 2013). Decreasing of the potential sector of consuming big number of oil reserve is one of the historical backgrounds of this policy. The effectiveness of this policy towards environmental impact is one of the important topics that will be discussed in detail in the next chapter 2.

Moreover, non-euro car is still dominating 24.0% from total population of the gasoline passenger car in 2013. Non-euro car with technically is not equipped with additional catalytic converter, caused the combustion residue gases was pass through without any conversion. Consequently, higher emission will be emitted from non-euro car compare to euro car. No specific regulation controlling long life of vehicle, such as retirement age limitation makes non-euro car is uncontrollable and considerably still exist in stock car. Non-euro car with higher emission level is estimated contributing higher emission even though small portion from total car population. Non-euro emission contribution effect will be explained in chapter 3 by introducing scrappage incentive program to eliminate elder car and its effects.

High car growth gives positive and negative impact. For positive impact, it is signing the economical growth is increasing because of people purchase capability is increased. However, it also gives potential negative effect such as heavy traffic jam. During traffic condition, vehicles are idling, however still emitting gas emission during its idling, it is called unnecessary or avoidable emission. The effect of traffic jam condition to the emission level will be detail explained on chapter 4. We took case study of Jakarta metropolitan city. Jakarta is one of the busiest capitals in the world. Annually, the increase of the vehicle registered is more than 10%, which passenger car is contributing more than 9%. The traffic condition has worsening by the very slow road construction growth that is only 0.01% (2010-2014). We conducted exploratory research on the idling driving (traffic jam) and its impact to the emission level.

Based on these conditions, we constructed our research to know how emission level changed after implementation of LCGC policy as policy assessment, effect of the elder car by scrappage incentive program, and traffic jam effect to the emission level of CO, HC, and NO.

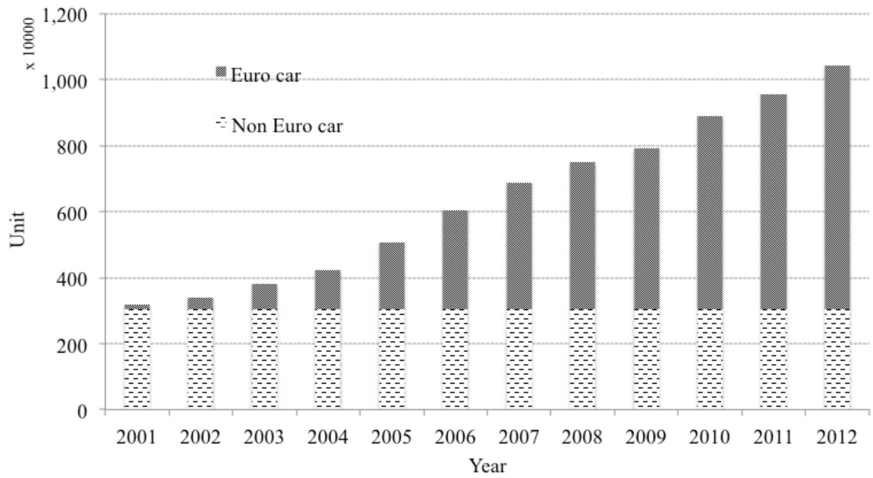


Figure 1. 1 Car population data from 2001 until 2012 (BPS, 2013)

1.2. Scope and Problem Statement

The increase of car population because of LCGC policy, non-euro car existence with higher gas emission, and high traffic jam are stated as the problem in this research. Each problem will be further discussed on next chapter 2, chapter 3, and chapter 4.

This work focused estimation of emission change after LCGC policy implemented. The scope of this research is for overall car population in Indonesia without considering each area characteristic of driving behavior, which might effect to the annual travel distance. This research took average of sampled car annual travel distance from the survey from five different locations, neglecting each area variation. Driving environment such as road condition; asphalt, non-asphalt, climbing road, that might cause the variation of the gas emission and fuel consumption is also out of this research. Considering individual car emission and fuel consumption need actual measurement to the car or in the air ambient. High car population area cause actual car measurement is difficult to conduct, beside the necessity of high budget.

Table 1. 1 Research scope for each chapter

	Car category			Output	Reference
	Euro		Non-euro		
	LCGC	non-LCGC			
Topic 1	√	√	√	CO, HC, NO CO_2	Economical impact (CO_2) National Indonesia
Topic 2	√		√	CO, HC, NO	National Indonesia
Topic 3	√		√	CO, HC, NO	Case study: Jakarta city

1.3. Research Objective

These research objectives are;

1. Analyze LCGC policy effect by estimating CO, HC, NO gas and CO_2) gas emission. Emission level change will be expressed by comparing between with and without LCGC condition to measure the effectiveness of this policy in the future projection.
2. Study of the necessity of the scrappage incentive program to reduce higher emission from elder vehicles and estimate CO, HC, NO gas emission level.
3. Study of the possibility of the technology approach to support emission control in the high traffic

jam environment and estimate CO, HC, NO gas emission level.

1.4. Research Question

Research questions are constructed following research objective above. Hence, we have constructed 3 questions.

1. What is the effect of the implementation of LCGC policy to the gas emission CO, HC, NO gas and CO_2?
2. What is the contribution of the non-euro car and scrappage incentive program to reduce CO, HC, NO gas?
3. What is the impact of the traffic jam to the CO, HC, NO gas?

1.6. Framework

We divided this research into three series topic; LCGC policy emission impact (policy assessment), elder vehicle retirement acceleration (scrappage incentive program), and introducing of idling driving (technology approach). Those three topics are connected and utilized to estimate emission gas (CO, HC, NO gas and CO_2)

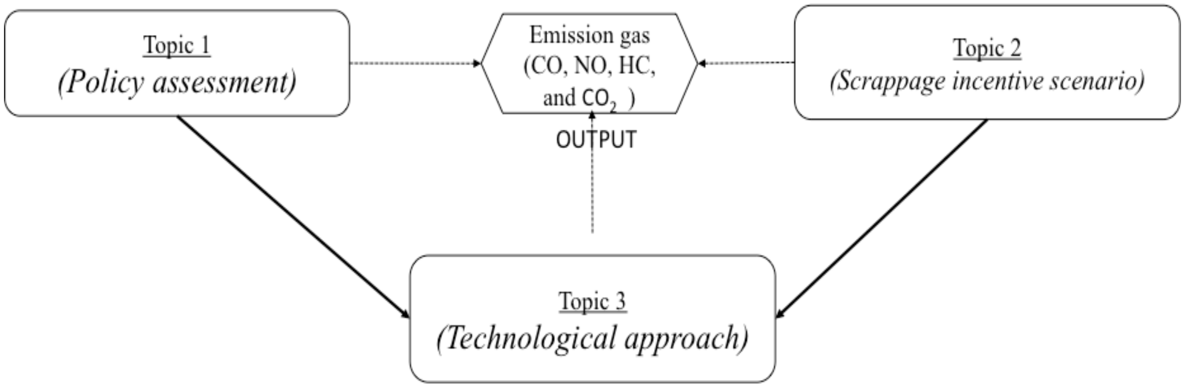


Figure 1. 2 Research framework

This thesis consists of 6 chapters; chapter 1 introduction, chapter 2 estimation of gas emission change from the effect of new policy for gasoline passenger car in Indonesia in future projection, chapter 3 Study of incentive scrappage program in accelerating old-car replacement to reduce gas emission from gasoline passenger car in Indonesia, chapter 4 study of idling driving effect to gas emission level in traffic jam environment case study of Jakarta metropolitan traffic for gasoline car, chapter 5 a comparative study of controlling emission from gasoline car in Indonesia and japan, and chapter 6 conclusions and recommendation.

Research background, objective, question, scope, and framework will be described on chapter 1. Then chapter 2 will further discuss effect of LCGC policy and estimate gas emission in the future projection. Chapter 3 will focus on study of incentive scrappage program to reduce gas emission from non-euro car, and chapter 3 will try to reduce unnecessary gas emission during idling in traffic jam condition. The output of those three chapters will be expressed on the gas emission level change (CO, HC, NO)

CHAPTER 2 Future Projection of Gasoline Passenger Car Gas Emission of the effect of Low Cost Green Car (LCGC) Policy

2.1. Introduction

In September 2013, the Indonesian government Ministry of Industry launched a new policy known as low-cost green car (LCGC) after a one-year delay. This policy is one of low emission carbon (LEC) concept with several specifications, for example, fuel consumption of 20 km per liter and an engine capacity of between 0.99 and 1.2 liters for gasoline-fueled cars and 1.5 L for diesel-fueled cars based on United Nation-Regulation 101 (United Nations, 2013). The fuel specification is based on a Research Octane Number of 90 for gasoline and a Cetane Number of 51 for diesel with a maximum wheel handle-turning radius of 4.6 meters (MOI, 2013). This turning radius reflects the size of the LCGCs, because cars usually have a turning radius of more than 4.7 meters (MOE, 2003). The LCGCs are smaller than current multi-purpose vehicles (MPVs) or passenger sedans (with an engine capacity > 1.5 liters) (Gaikindo, 2015).

By way of compensation, all owners of vehicles fulfilling this requirement will receive an incentive in the form of a tax cut (MOI, 2013). This regulation has been introduced in response to the decline in domestic oil reserves and the high level of consumption in the transportation sector. These concerns have been exacerbated by the growth in the number of passenger vehicles, with the total number tripling between 2001 and 2012 (Gaikindo, 2015). Consequently, CO_2 emissions from vehicles have also increased significantly. According to data provided by the CDIAC (2013), Indonesia was ranked 12th in the world in terms of CO_2 emissions. One of Indonesia's main sources of CO_2 emissions is the consumption of liquid petroleum products, which accounted for more than 36% of total emissions (CDIAC, 2013).

From the economic efficiency point of view, a cost–benefit analysis (MOF, 2013) outlined expectations as a result of the implementation of the LCGC policy. It was expected that the policy could attract US$1.4 billion in new investment, increase tax revenue by US$26 million, and provide new jobs for 315,835 people. The decrease in fuel consumption is also predicted to contribute to reductions in CO_2 emissions. However, detailed calculations in relation to emissions were not provided.

Thus, the purpose of this chapter is to analyze the predicted effects of the LCGC policy by estimating changes in CO, HC, NO, and CO_2 emissions.

2.2. Materials and Method

2.2.1 Research Framework

The research framework contains three important elements. The LCGC ownership model shows how LCGCs will penetrate the current vehicle market. The LCGC policy regulation specifying a maximum car price leads to a specific segment of the population with an annual income that enables them to purchase an LCGC based on a constructed ownership model. The car population model estimates the changes in the numbers of various types of cars after the LCGC policy is implemented. Changes in emissions of CO, NO, HC, and CO_2 are derived using an emissions estimation model. These models use primary data from a survey of car owners, in particular annual travel distance and fuel consumption, and secondary data from government and association reports.

Cars are classified based on the emissions control standard, and are divided into two categories; Euro cars, which meet the Euro 2 emissions standard, and non-Euro cars. While we focus on Euro cars, non-Euro cars must be considered because of their emissions, current condition, and numbers remaining in the market, as there is no regulation limiting the life of vehicles in Indonesia. The number of non-Euro cars remained unchanged following the implementation of the Euro 2 emissions standard as part of the "Decree of The State Minister of Environment of Republic Indonesia No 141 Year 2003," which was enacted in 2003 and implemented from 2005 until 2007 (Nugroho & Fujiwara, 2005). The numbers of non-Euro cars are shown in the results of our analysis to identify the proportion of these cars in the overall car population and their estimated effect on emissions levels. From technical perspective, euro and non-euro car are differentiated by the installing of the additional catalytic converter to the exhaust gas combustion to convert hazardous emission gas to the appropriate level.(Nugroho & Fujiwara, 2005)

In this research framework, we specify two scenarios: with LCGCs and without LCGCs. All vehicles satisfying the requirements of the LCGC policy are categorized as LCGCs, otherwise they are categorized as non-LCGCs. It was found that the LCGC category, which includes vehicles manufactured after 2013, is dominated by Euro cars, while the non-LCGC category, which includes vehicles manufactured prior to 2013, includes both Euro and non-Euro cars.

Sensitivity analysis was also conducted to validate the model. Several elements of the car ownership model are important determinants of future projections, and thus we compared emissions levels under various conditions to estimate the potential effects of the LCGC policy. The difference between the two scenarios was considered to represent the effectiveness of the LCGC policy from an environmental perspective, as it identified the levels of emissions from controlled gasoline-fueled passenger cars. This research framework is effective for the period since the LCGC policy was implemented in 2013. Figures relating to non-LCGCs prior to 2013 were obtained from government reports.

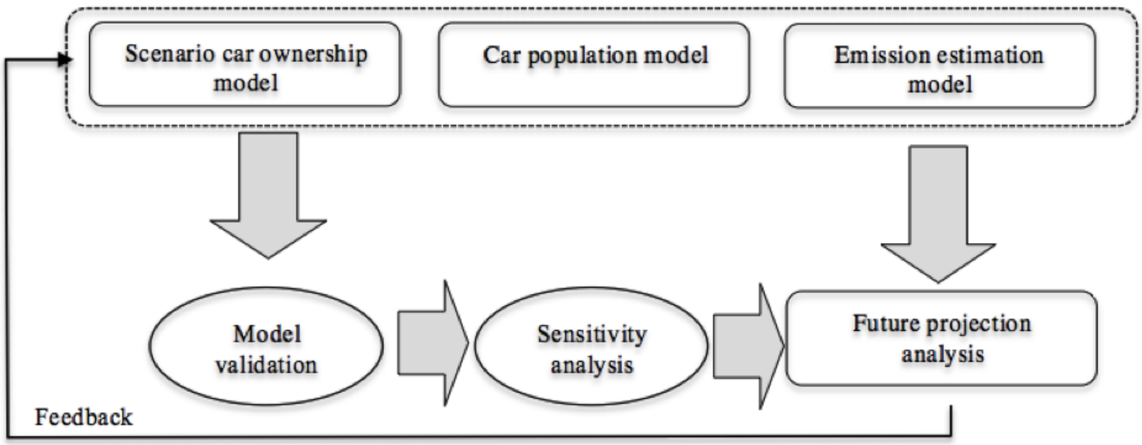


Figure 2. 1 Research framework for car ownership, car population, emission and future projection

2.2.2 Research scope

This study focuses on estimating the changes in vehicle emissions levels after the LCGC policy was implemented in Indonesia. The scope of the study is the total car population in Indonesia, and regional characteristics such as driving behavior, which might affect annual travel distance, are not considered. We took the average of annual travel distances from five different locations, ignoring regional variations. The driving environment, which includes road conditions such as road surface and gradient that might cause variations in the levels of emissions and fuel consumption, is also beyond the scope of this research. Measurements of the emissions and fuel consumption of individual cars, as well as the ambient air conditions are necessary, and the high number of cars means that these measurements are difficult and expensive to obtain.

2.2.3 LCGC and non-LCGC scenario car ownership model

We built two scenarios based on people's minimum annual income to determines the capability of the people to purchase car: with LCGCs and without LCGCs, as shown in Table 2.1. The definition of with LCGC policy is capability of people when LCGC policy implemented to own LCGC car, while without LCGC car is capability of people to purchase non-LCGC car if LCGC car is not implemented. When LCGC policy is not introduced, market will be dominated only non-LCGC car.

We set the average LCGC price at US$9,500 (MOI, 2013), as regulated by the government, and the non-LCGC price at US$20,000, which was the average list price of a Toyota MPV (TAM, 2013), which accounts for more than 50% of vehicle sales in Indonesia (Gaikindo, 2015).

Table 2. 1 Scenarios with and without LCGC

Elements	LCGC scenario (5 years loan)	Non-LCGC scenario (5 years loan)
Average price (USD)	9,500	20,000
Downpayment (%)	30	30
Downpayment amount (DP) (USD)	2,850	6,000
Interest rate (%)	12.42	12.42
Duration (N) (Months)	60	60
Borrowing amount (BM) (USD)	6,650	14,000
Interest payment (I) (USD)	826	1,739
Monthly installment (M) (USD)	125	262
Monthly income eligible (ME) (USD)	415	787
Minimum annual income (AM) (USD)	4,984	9,443

In the LCGC scenario, the number of people with a minimum annual income of US$4,984 determines the number of cars. All people in this segment (>US$4,984) will be deemed to select an LCGC car once the policy is implemented. Meanwhile, in the scenario without LCGCs, only people with a minimum annual income of US$9,443 will have the option of purchasing a non-LCGC. In these scenarios, people's minimum annual income was used to estimate the growth in the car population. Crossover purchases, double ups, and repeat buying are not included in this estimation, nor is driving behavior in relation to both vehicle types. Annual travel distance, which was obtained from the survey data, is applicable to both vehicle types. Considering those particular elements need further discussion in the next work.

Our estimates of growth in the car population after the implementation of the LCGC policy using an income-based approach was based on the study of (Sanjaya, Kevin Kynan, Diah Indriani, 2014). We analyzed people's survey responses regarding the main reason for choosing an LCGC, and concluded that of the five options offered (financial benefit, environmental benefit, social and norm pressure, self-image, and interest in new technology), financial benefit is the main reason why people select an LCGC. Pongthanaisawan and Sorapipatana 2010 reported that in a developing country such as Thailand, with economic growth estimated to be 3.2% in 2016 and 3.5% in 2017 (ADB, 2016), the number of private vehicles increases as people's income rises. Initially, motorcycles are the dominant form of transport; however, as soon as income reaches a certain level, consumers shift from motorcycles to cars because of their convenience, comfort, and safety. Indonesia, with estimated economic growth of 3.4 in 2016 and 3.5 in 2017, as reported by the Asian Development Bank (ADB), is expected to display a similar tendency (ADB, 2016).

A down payment of 30% of the price of the car is required, as regulated by Bank of Indonesia (BI, 2013) for individuals purchasing cars for private use. Prior to the enforcement of this policy, the amount required by way of a down payment was not strictly regulated, and the percentage was allowed to vary depending on the degree of trust on the part of the car dealer. Therefore, purchase capability was difficult to measure. An interest rate of fixed 12.42%, which can fluctuate monthly, was derived from the average annual interest rates of ten major banks in Indonesia (BI, 2015). The advent of an economic crisis could render interest rates difficult to control; however, this possibility was excluded, because we consider such a crisis to be an irregular condition. We set the loan duration to a maximum of 60 months (five years) in accordance with the terms offered by four major banks according to their official websites (BCA, 2016)(Mandiri, 2016)(BRI, 2016). Longer loan duration is considered to be the most desirable option for customers, as it enables them to spread their loan repayments, thereby reducing the financial impact. A down payment of 30% of the car's price means they are required to pay US$2,850 for an LCGC and US$6,000 for a non-LCGC, with interest payments (I) of US$826 and US$1,1739, respectively. The monthly income eligible (ME) with 30% for car loan allocation is derived using equation (2.1):

$$ME = [BM/N\,(1 + I)] \cdot 30\% \quad (2.1)$$

where ME is the monthly income eligible (US$), N is the duration of the loan (months), BM is the amount borrowed (US$), and I is the interest rate (US$). Considering 30% of first allocation of the loan down payment, we assume buyer spend their 30% income for car loan. Detail remain 60% income spend ways are not included to this research. Utilizing ME as monthly income eligible, minimum annual income is calculated using equation (2.2):

$$AM = ME \cdot 12 \quad (2.2)$$

where AM is the minimum annual income of the potential buyer (US$), that were obtained from monthly income eligible for 12 months. AM determines the capability people to purchase either LCGC car or non-LCGC car.

Therefore, the minimum annual income required to purchase either an LCGC or a non-LCGC would be US$4,984 or US$9,443, respectively, as shown in Table 2.1. To estimate the numbers of potential LCGC and non-LCGC buyers, we divide annual income data into the following segments: <US$350, US$350–$550, US$550–$800, US$800–$1,100, US$1,100–$1,600, US$1,600–$2,500, US$2,500–$4,500, US$4,500–$10,000, US$10,000–$25,000, and >US$25,000. The population in each income segment is shown in Appendix A (GIDD, 2015).

It can be seen from Table 2.1 that both the AM of US$4,984 for buying an LCGC and that of US$9,443 for buying a non-LCGC fall within the US$4,500–$10,000 segment. It will be taken from segment range annual income US$10,000–$25,000. The difference between the AM (US$4,984) and the lower limit of the segment of US$4,500 (9.7%) will be considered on the estimating new buyer calculation. We approach number of LCGC and non-LCGC car with the number of population of range US$4,500–$10,000 and US$10,000–$25,000. Hence, these annual income segments are used to represent the potential numbers of buyers of LCGCs and non-LCGCs, respectively. Number of LCGC and non-LCGC car population is a projection of the number of the people who has annual income in range US$4,500–$10,000 and US$10,000–$25,000. In this chapter, we approached potential buyer of each car type by considering all people in the correspondent annual income segment purchase the car. Considering complex participation rate in actual market will be the next important topic to increase the accuracy completing this research.

2.2.4 Car population model

The car population model represents the stock of cars (SC) after the implementation of the LCGC policy using the ownership model shown in Table 2.1. The total SC includes LCGC (NA) and non-LCGC (NB). NB includes both Euro cars and non-Euro cars, while NA only includes Euro cars following the enforcement of the emissions standard (Nugroho & Fujiwara, 2005).

Considering that the LCGC policy is designed to boost economic growth through new investment (MOF, 2013), the low-cost of vehicles (maximum US$10,000) allows a new annual income segment to enter the market. We define the total *SC* as the sum of the number of LCGCs, the number of non-LCGCs, and current existing non-euro cars. Non-euro cars are considered contributing stock car since there is no specific regulation strictly control the car age, as shown in equation (2.3):

$$SC = NA + NB + NE \quad (2.3)$$

where SC is the total stock of cars, NA is the number of LCGC, and NB is the number of non-LCGC.

For the period prior to the implementation of the LCGC policy in 2013, we used secondary data from the annual report provided by (Gaikindo, 2015). However, after policy implementation, there are both NA and NB in the total SC. Hence, we use segmented annual data from (GIDD, 2015) to estimate both values. A reduction in the number of cars as a result of a natural disaster is considered to be an irregular condition that would require more detailed investigation.

2.2.5 Emission estimation model for CO, HC, NO gas

To estimate projected emissions of CO, NO, HC, and CO_2, we use annual travel distance (ATD), annual fuel consumption (AFC), an emissions factor (EF), and a deterioration factor (DF). Equation (2.4) is used to calculate CO, NO, and HC emissions, while CO_2 emissions are calculated using equation (2.8).

2.2.5.1 Emission gas calculation

Total emissions (E) are calculated using equation (2.4). This equation has been used in previous studies such as (Huo, 2011) when modeling vehicle emissions in various cities in China:

$$\mathrm{E} = \mathrm{ATD} \cdot \mathrm{EF} \cdot \mathrm{DF} \cdot \mathrm{SC}$$

$$= \left(\frac{1}{n}\sum_{i=1}^{n} x_i\right) \cdot \mathrm{EF} \cdot \mathrm{DF} \quad (2.4)$$

where E is total emissions of CO, HC, and NO (tons) after LCGC policy implementation, ATD is the annual travel distance (km), EF is the emissions factor (10^{-6} kg/km), DF is the deterioration factor (60% after 80,000 km; CO, 3.52×10^{-3} kg /km; HC, 0.08×10^{-3} kg /km; NO, 0.72×10^{-3} kg /km), SC is the total stock of cars, n is the number of respondents, x_i is each respondent's odometer reading (km), NA is the number of LCGC, and NB is the number of non-LCGC. The values of ATD and SC are much higher than those of EF and DF, and thus have a significant impact on E, although improvements in EF and DF will also help to control E. The inclusion of DF increases the accuracy of changes in the level of emissions because of the deterioration of catalytic converters over time.

2.2.5.2 Annual Travel Distance (ATD)

To estimate the ATD, we conducted a survey who own and drive a car in one of Indonesia's three biggest cities, Jakarta, Surabaya, and Medan, which account for more than 32.9% of all passenger vehicles in Indonesia (BPS, 2013). The respondents completed the questionnaire during an interview, and were required to answer all questions, which were constructed to ensure that they could be answered legitimately. We also questioned respondents about their driving behavior such as their driving style during passing asphalt road and loading behavior.

ATD was calculated as the average of all respondents' odometer readings. The odometer reading method is one way of estimating distance travelled (Hossain & Gargett, 2011), while another way involves calculations based on fuel purchases. ATD is the sum of each respondent's odometer reading divided by the total number of respondents' odometer readings (x_i), as shown in equation (2.5):

$$\mathrm{ATD} = {}^{1}/_{n} \sum_{i=1}^{n} x_i \quad (2.5)$$

where ATD is the annual travel distance (km), n is the number of respondents, and x_i is each respondent's odometer reading (km). To avoid misreading, we ensured that each respondent was able to confirm that their odometer had not been replaced as a result of an accident or damage incurred in other ways.

The survey of 120 respondents from three large cities is assumed to provide representative values for the purposes of this study. However, factors such as infrastructure capacity, driving behavior, and actual odometer measurements should be examined in future studies using a larger sample size.

2.2.6 Emissions Factor (EF) and Deterioration Factor (DF)

The determination of the EF considers the degradation of the catalytic converter that is installed to control emissions from internal combustion engines. This degradation occurs as a result of a decline in the catalytic converter’s conversion capacity. This can be caused by fuel quality, combustion conditions, and aging. Table 2.2 shows that the emissions standards for CO, 3.52x 10^{-3} kg /km; HC, 0.08x10^{-3} kg /km; NO, 0.72x10^{-3} kg /km) respectively (Nugroho & Fujiwara, 2005).

The DF of 60% reflects the findings of a study indicating that emissions of CO, NO, and HC increase by 60% from initial levels after the vehicle has travelled 80,000 km (Boulter, 2009). This increase is also caused by deterioration of the catalytic converter, which cannot be neglected (Borken-Kleefeld & Chen, 2015), and therefore should be included in calculations. Driving behavior and vehicle maintenance are other important factors that can affect this degradation. However, in this study, we do not include these factors in our calculations.

Since there is no regulation restricting the age of vehicles, the life of the vehicle is not considered. Indonesia is yet to introduce either a retirement program for old cars or a replacement program for newer cars, as has been done in several countries such as France (Yamamoto, Madre, & Kitamura, 2004), Germany (Böckers, Heimeshoff, & Müller, 2012), and Ireland (Hennessy & Richard, 2011). However, old non-Euro cars are not included in this study.

Table 2. 2 Emissions standard and deterioration factor for Euro 2 vehicles

Vehicle type	Fuel Consumption (km/L)	Vehicle type	Emission Standard	Condition	Amount of gas emission (10^{-3} kg/km)			Deterioration factor
					CO	NO	HC	
LCGC car	20	For both LCGC and non-LCGC car	Euro 2	Initial value	2.2	0.05	0.45	60% increase after 80,000 km
non-LCGC car	9.8			After 80,000 km travelled	3.52	0.08	0.72	

2.2.7 Emission estimation model for CO_2 gas

CO_2 is created from the combustion of fossil fuels. The United States Environmental Protection Agency (EPA) has reported that typically, more than 99% of the carbon in the fuel will be emitted as CO_2, while very small amounts of HC and CO are also emitted, these being converted to CO_2 in the atmosphere (EPA, 2014). The EPA uses an EF of 2.348 x10^{-3} ton-CO_2/liter of gasoline (EPA, 2014). To calculate the amount of CO_2 emitted, it is necessary to know the amount of fuel that is consumed.

2.2.7.1 Annual Fuel Consumption (AFC)

AFC for LCGC (FCA) and non-LCGC (FCB) was obtained from respondents’ fuel usage records provided in response to a survey question. Average FCB was calculated based on respondents’ AFC (y_i). Since there was no regulation controlling the minimum fuel consumption, FCB cannot be standardized to that of an LCGC, with minimum fuel consumption of 20 km/L, hence, dividing ATD by 20 provides an estimate of AFC by LCGC (FCA), as shown in equation (2.6), while the calculation of FCB is given by equation (7):

$$\mathrm{FCA} = \frac{\mathrm{ATD}}{20} \tag{2.6}$$

$$\mathrm{FCB} = \frac{1}{n}\sum_{i=1}^{n} x_i, \tag{2.7}$$

where FCA is the AFC for LCGC (L), FCB is the AFC for non-LCGC (L), n is the number of respondents, and x_i is each respondent's AFC (L), GCA is the amount of carbon emitted by LCGC, and GCB is the amount of carbon emitted by non-LCGCs. AFC for non-LCGCs is estimated based on the average fuel usage reported by respondents during the survey (see equation (2.3)).

$$\mathrm{GC} = \mathrm{GCA} + \mathrm{GCB} + \mathrm{GCE}$$

$$\mathrm{GC} = \left[(\mathrm{FCA} \cdot \mathrm{NA}) + (\mathrm{FCB} \cdot \mathrm{NB}) + (FCB \cdot NE)\right] \cdot \mathrm{EF}$$

$$= \left[\left(\frac{\mathrm{ATD}}{20}\right) \cdot \mathrm{NA} + \left(\frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{y_i}\right) \cdot \mathrm{NB}\right] \cdot \mathrm{EF} \tag{2.8}$$

where GC is the amount of CO_2 (tons), GCA is the amount of CO_2 from LCGCs (tons), GCB is the amount of CO_2 from non-LCGCs (tons), NA is the number of LCGC, NB is the number of non-LCGC, FCA is the AFC for LCGC (L), FCB is the AFC for non-LCGC (L), and EF as emission factor for CO_2 (ton-CO_2/liter).

$$\mathrm{SCO} = [(\mathrm{FCB} - \mathrm{FCA})]\ \mathrm{NA} \cdot \mathrm{EF} \tag{2.9}$$

Because LCGCs are required to comply with the specification of 20 km/L, as shown in equation (2.6), we use this Figure for our calculations. Although the LCGC standard for minimum fuel consumption is following the designated driving pattern, we consider it is not significantly affect to the actual fuel consumption, since that driving pattern is reflected from the actual driving pattern that be standardized.

2.2.8 Sensitivity analysis

We conducted a sensitivity analysis to determine the most significant factors affecting the estimation results. We selected three elements, namely, average car price, amount of down payment, and duration of loan. Adjusting those elements produced either positive or negative responses in relation to projected emissions. A reduction in emissions is considered a positive response, while an increase in emissions is considered a negative response. In relation to the average car price and down payment, we set sensitivity to ±10% of the initial average price and down payment, while loan duration was set to between three and eight years. Adjusting down payment ±10% is to cover price difference between one location to others location, due to wide range of Indonesia as a big country with different logistic infrastructure between one island to others islands. It is allowable to take logic value as parameter in sensitivity analysis (Morrison, D.A., Kingwell, R.S., Pannell, D.J. and Ewing, 1986). Adjusting the values of these elements affected the estimated amounts of CO, NO, HC, and CO_2 emissions.

2.3 Results and Discussions

2.3.1 Stock car (SC) estimation

Here, we estimate the change in SC following the implementation of the LCGC policy. We compare the scenarios with and without the LCGC policy by utilizing the annual income segment of US$4,500–$10,000 (see Appendix A), approached and fitted with regression analysis. The fitted regression line is determined by the value of the coefficient of determination, which varies between 0 and 1. A higher value indicates a better accommodation of the data distribution. The value nearly 1 is considered generated equation is properly expressed the actual distribution.

The SC shown in Figure 2.2 consists of both NA and NB and non euro car. In the period before the LCGC policy was introduced, the SC showed an average annual growth rate of 3%. Car purchases were not well controlled, either in terms of financial schemes or ownership restrictions, nor was the minimum down payment strictly regulated. This meant that the down payment could vary, and did not necessarily reflect the ability of the buyer to purchase a new car. Car loans were based on trust between the car dealer, the leasing company, and the prospective buyer.

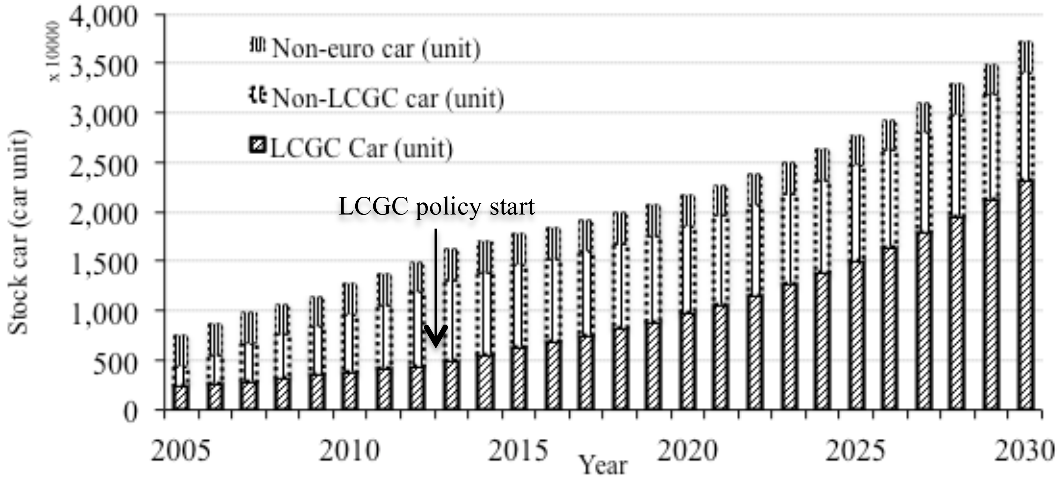


Figure 2. 2 Growth in the stock of cars with and without the LCGC policy

Figure 2.2 shows the situation before and after the LCGC policy was implemented. As shown on Figure 2.2, future projection for the scenario with and without LCGC policy was plotted. After LCGC policy implemented in 2013, stock car in the market consisting euro and non-euro car, with additional two categories for euro car, LCGC and non LCGC car. Both LCGC and non LCGC fulfill Euro 2 emission standard. Additionally, non-euro car which is emission uncontrolled car with steady number is also still exist in the market. The effect of the elimination program will be further discussed on the chapter 3.

The data shown in Table 2.1 were used to estimate the trends in the SC with and without the LCGC policy. After dispersing in 2013, scenario with LCGC is growing up significantly because people with an annual income of \$4,500–\$10,000 (see Appendix), who were not previously able to purchase a new car, were able to enter the market as new car buyers. Although there was stricter enforcement of down payment requirements, this did not significantly hinder the growth in the number of new car buyers in this income segment. Figure 2.2 show that the introduction of the LCGC policy provided a boost to the car market, prompting strong growth in sales of new vehicles. Price remained the most important factor influencing people's decision to purchase a new car.

Following the implementation of the LCGC policy, the SC has gradually increased since 2014, and this is projected to continue until 2023. By 2030, the number of passenger vehicles is expected to be double what it would have been without the introduction of the LCGC policy. Without the introduction of LCGCs, the *SC* is limited to non-LCGCs, which are more expensive, and thus require purchasers to have a higher minimum annual income to fulfill the car ownership scenario outlined in Table 2.1. Furthermore, by 2030, the total number of cars will reach approximately 35 million, which is three times greater than the estimated number of cars without the introduction of the LCGC policy. The difference between the scenarios with and without the LCGC policy is the result of the inclusion of new buyers with annual incomes in the range US\$4,500–\$10,000. Thus, the minimum annual income is a significant factor.

2.3.2 Estimation of the effect of deterioration

The emissions of CO, HC, and NO for an individual car were calculated using equation (2.4) to take into account ATD, EF, and DF shown in Table 2.2. ATD, which was calculated using data from the survey as per equation (5), was 13,000 km per year. The purpose of the travel varied, and included commuting from home to the office, business, or leisure pursuits.

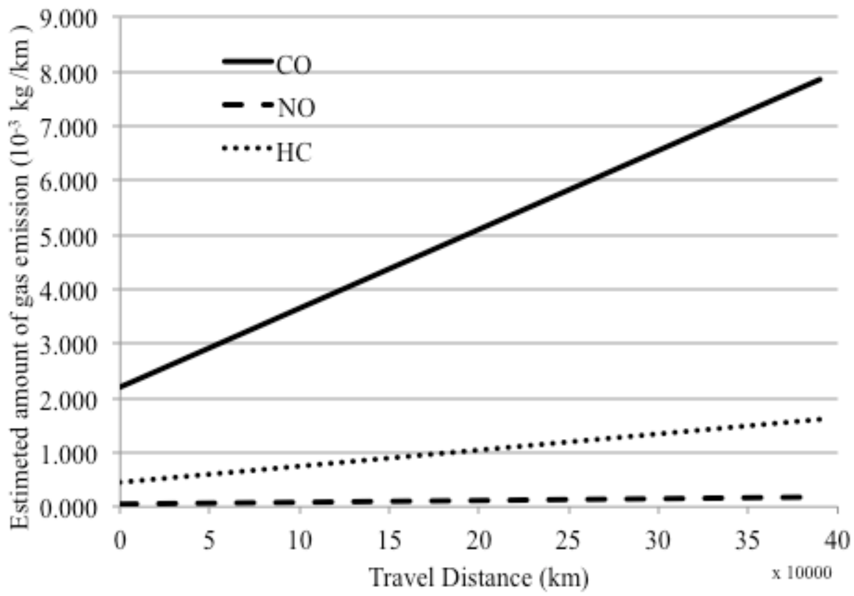


Figure 2. 3 Effects of the deterioration factor on amount of emission gas CO, NO, and HC for individual car condition

The effects of the deterioration of the catalytic converter are shown in Figure 2.3. Table 2.1 shows that emissions will be 60% higher after 80,000 km of travel, which corresponds to a car age of seven years, as the ATD was calculated as 13,000 km. The Euro 2 emissions standard specifies levels of $0.05x10^{-3}$ kg/km and $0.45x10^{-3}$ kg/km for NO and HC respectively, while CO is at the much higher level of $2.2x10^{-3}$ kg/km. Emissions increase as the vehicle travel distance increases. Increasing travel distance also reflects increasing car age. Given that emissions increase by 60% after 80,000 km, the new levels for CO are $3.52x10^{-3}$ kg/km, $4.84x10^{-3}$ kg/km, and $6.16x10^{-3}$ kg/km after 80,00, 160,000, and 240,000 km, respectively. These travel distances correspond to car ages of seven, 14, and 21 years, respectively. Since there is no limit to car life, these emissions levels will increase indefinitely.

2.4 Estimation of CO, HC, NO gas emission, validation, and future projection

Figure 2.4 shows that emissions of CO, NO, and HC condition after LCGC policy implemented. in the LCGC scenario are higher than those in the scenario without LCGCs. The car population is divided into three categories LCGC car, non-LCGC car, and non-euro car. The result trend is determined by the trend of the car population by car ownership model Table 2.1 that car population are obtained from the capability of the people to own car.

Emissions of CO (Figure 2.4a), NO (Figure 2.4b), and HC (Figure 2.4c) will be approximately 1.2 times greater by 2020 under the LCGC policy compare to 2013. Further, NO and HC emissions will be 19% and 36% higher, respectively, by 2020 than they were in 2013. Surprisingly, CO emissions also increase, from 3,002.3 thousand tons in 2013 to 3,826.7 thousand tons in 2020. This differs significantly from the estimated increase without policy implementation. The significant difference is estimated caused by new penetration from middle class population group.

By 2030, the LCGC scenario will result in significant increases in emissions compared with the scenario without LCGC. Emissions of CO, NO, and HC under the LCGC scenario will be 6,512.4 thousand tons, 179.3 thousand tons and 1,181.7 thousand tons, respectively, compared with 3,678.0 thousand tons, 114.7 thousand tons, and 602.1 thousand tons, respectively, under the scenario without LCGC, an increase of 77.0%, 56.3%, and 96.7%, respectively. Although the market share of LCGCs will increase significantly, the increase in emissions is a consequence of the implementation of the LCGC policy, something that has probably not previously been considered. The fact that an increasing level of car ownership is seen as a positive economic trend is likely the main reason for the implementation of the LCGC policy.

(a)

(b)

(c)

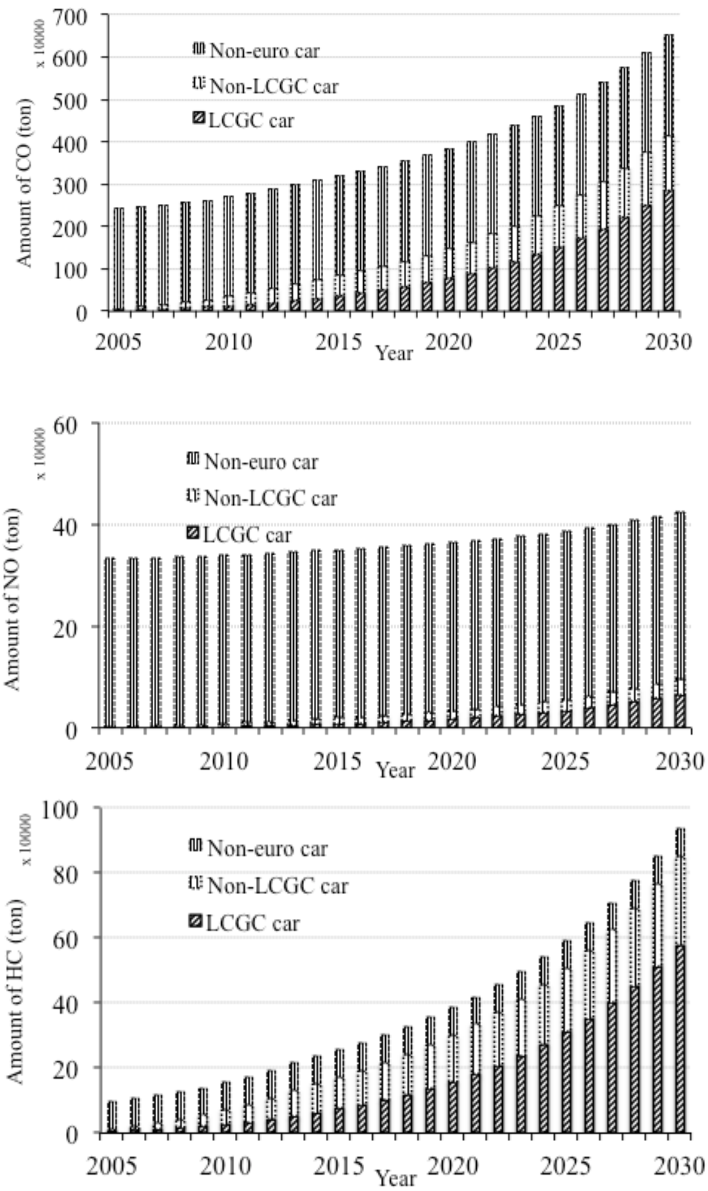


Figure 2. 4 Previous and projected emissions of CO (a), NO (b), and HC (c)

The gaps between emissions under the LCGC scenario and those under the scenario without LCGC in each case are similar to the gap between the growth in the total number of cars with and without the LCGC policy shown in Figure 2.2. This confirms that the total number of cars is the most important factor in determining the overall level of emissions. As long as there is no change to the emissions control system in vehicles or to the emissions standard, all vehicles are assumed to produce emissions in accordance with the Euro 2 standard.

Stricter emissions regulations will force automotive manufacturers to improve the technology in their vehicles to meet the more stringent requirements. The effect of the LCGC policy on the environment is a crucial issue. Considering only some of the effects of a new policy, while overlooking other possible effects, means that the overall cost of policy implementation might exceed the expected benefits. Thus, a comprehensive analysis should be undertaken prior to policy implementation.

This analysis indicates that controlling the number of cars is an effective means of controlling emissions. One way to control the number of cars is to limit new car purchases. However, this contradicts other government aims, because increased vehicle sales signify economic growth, as well as a rise in people's standard of living. Hence, controlling the number of cars is not as easy as simply preventing people from buying a new car. Others solutions should be considered, such as controlling the number of older cars, which contribute more emissions because of the deterioration of their catalytic converters, and motivating people to accelerate their car replacement plans. Regulating the down payment that was required when purchasing a new vehicle was expected to control the rapid growth in the number of vehicles by ensuring that only buyers with sufficient annual income could obtain loans. However, the simultaneous implementation of the LCGC policy led to an increase in the number of cars by making it possible for more people to purchase a car.

2.5 Estimation of CO_2 gas emission, validation and future projection

The amount of CO_2 from LCGC car (GCA) and non-LCGC car (GCB) was estimated by utilizing equation (8). GCA and GCB are influenced by FCA and FCB. Since FCA has been regulated by LCGC policy, by utilizing equation (2.6), FCA 650 L was obtained with ATD 13,000 km. However, for non-LCGC car, FCB was taken from data survey, we obtained FCB 1,200 L, with monthly fuel consumption 100 L or 9.8 km per L with same ATD consideration. It is nearly double compare to the specification of LCGC car. The similar value of annual fuel consumption for non-LCGC 1,210 L per year was also used in previous research (Silitonga, Atabani, Mahlia, & Sebayang, 2011) to simulate and estimate potential fuel saving by introducing fuel economy label for passenger car in Indonesia that also further calculated from cost benefit point of view in the next work (Atabani, Silitonga, & Mahlia, 2012). In this paper, standard value of annual fuel consumption is considered as an improvement portion from LCGC policy with minimum fuel consumption 20 km per L as obligatory of LCGC car. Value of FCB is approximately 1.8 times better than current non-LCGC car. However, the big value different between LCGC and non-LCGC (550 L/year) generated big gap between pre-LCGC data and estimated value. Lack of enforcing downpayment regulation is also contributed to the car ownership does not reflected their purchase ability from their annual income.

CO_2 emission under LCGC scenario shows tendency of increase until 2030 estimated calculation as shown on Figure (2.5). Comparing with and without LCGC policy, it is predicted big gaps occurs between both scenarios in the same designated year. The increase gradient is also larger; it reflects increase acceleration also bigger compare to without LCGC scenario. Although LCGC car has better fuel consumption performance than non-LCGC vehicle, the car growth of the LCGC car is not comparable to the improvement of the performance. For individual car performance or for certain number of car, it could be reduced however, if the total growth car is higher than the reduced portion, finally total amount of CO_2 emission will higher as shown on the Figure 2.5.

In 2023, for with LCGC, the difference nearly 1.5 times compare to 2013 after LCGC policy 10 years period was implemented. The gap is increasing until end of projection in 2030, 2.2 times bigger compare to initial year in 2013 with 66.1 millions ton of $C0_2$.

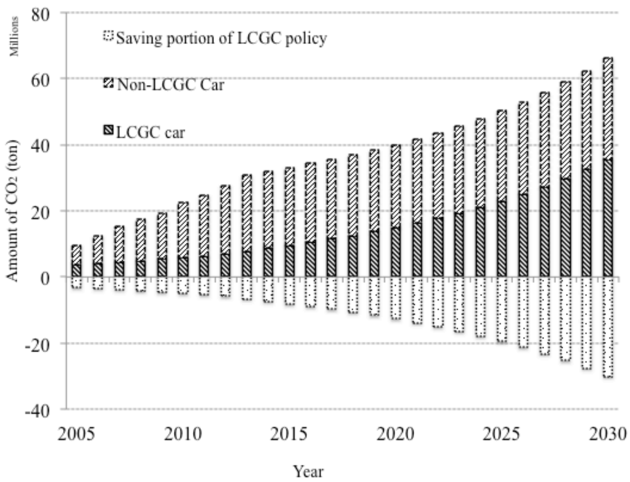


Figure 2. 5 Estimation of $C0_2$ increase after LCGC policy implemented

The saving portion from LCGC policy is shown on minus portion as positive effect from LCGC policy, because it controls fuel consumption with minimum requirement. An individual car is able to save more than half fuel consumption and CO_2 emission from engine combustion. Even though scenario with LCGC shows high CO_2 increase compare to without LCGC policy, however, in fact, it also contributed to the reduction of the CO_2 gas. From 2013 until 2030, it could reduce more than 23.5 millions tons of CO_2. The growth of the new car from LCGC portion becomes much bigger compare to the individual car reduction. Cumulative CO_2 emission form total new car population exceed saving from individual car improvement. Finally, the total CO_2 gas emission is larger than the scenario without LCGC policy.

2.6 Sensitivity analysis

We also conducted a sensitivity analysis to identify the significant factors contributing to the increase in emissions under both scenarios. We set sensitivity to ±10% of the initial average car price and down payment, while loan duration was set to between three and eight years. We took average price, down payment, and duration due to high input value in simulation.

Increasing the price of the car and the down payment required and shortening the loan duration are all ways to reduce emissions. Conversely, reducing the car price and the down payment required and extending the loan duration will lead to increased emissions of CO, NO, HC, and CO_2 under both scenarios. Shortening the loan duration to three years has the greatest impact on emissions because this increases the minimum annual income requirement to US$8,307 under the LCGC scenario and US$14,165 under the scenario without LCGCs. This is predicted to reduce emissions by around 84.6% and 41.7% in the scenarios with and without the LCGC policy, respectively. However, this will also lead to a significant reduction in vehicle sales, and thus a detailed cost–benefit analysis is required from an economic perspective.

Reducing the required down payment to 10% of the total car price also has a big impact under the LCGC policy scenario. A smaller down payment means that the minimum annual income required increases because purchasers have to pay higher monthly installments. A 10% down payment could reduce emissions by 42.4% from current levels under the LCGC scenario, while the reduction under the scenario without LCGCs is only 9.3%. It is predicted that the original non-LCGC policy is already higher. Conversely, extending the loan duration to eight years provides the biggest reduction in emissions under the scenario without LCGCs. It will cause AM is also decrease that make lower limit for annual income is also become wider. The improved fuel consumption of LCGCs (20 km/L) cannot offset the growth in the total number of cars, as shown in Figure 2.5, and thus total CO_2 emissions are greater compared with the scenario without LCGCs. Figure 2.5 shows that the growth in the number of cars is a significant determinant of the gap in terms of emissions between the scenario with LCGCs and that without LCGCs. Other options available include adjustments to related factors such as increasing the car price and down payment and shortening the loan duration. However, the key determinant remains the growth in the number of cars.

Improvements in driving behavior can be achieved by educating people to drive effectively, with effective travel distance and minimum emission. Equipping vehicles with improved technology to reduce emissions, for example, those produced while vehicles are idling in traffic jams, is also an option. The emissions standard could also be upgraded to Euro 3, Euro 4, or Euro 5, but this would require cleaner fuel with lower sulfur content.

Table 2. 3 Sensitivity analysis using average purchase price, down payment, and loan duration sensitivity analysis

Elements	Set value	With LCGC scenario		Without LCGC scenario	
		Minimum annual income (AM) (USD)	Rate of change of emission amount (CO, HC, NO, CO_2) (%)	Minimum annual income (AM) (USD)	Rate of change of emission amount (CO, HC, NO, CO_2) (%)
Average price (USD)	+10%	5,482	-21.8%	10,388	-3.9%
	-10%	4,486	0.3%	8,499	15.0%
Downpayment (DP) (USD)	+10%	6,408	-42.4%	10,927	-9.3%
	-10%	3,560	20.9%	6,071	39.3%
Duration (N)	3 year	8,307	-84.6%	14,165	-41.7%
	8 year	3,115	30.8%	5,312	46.9%

2.7 Considerations of Policy Option

Increasing price of the car, downpayment, and strengthen loan duration is several way to control the increase. On the other hand, reducing car price, or downpayment and extending loan duration will lead to the increasing of gas emission (CO, HC, NO, and CO_2) for both scenarios. The parameters of the car ownership model are adjustable following the latest condition and regulations. It gives potential ways to manipulate future estimation result.

Comprehensive policy is still necessary to study, to control the emission increase. Considering more detail about non-euro car (old car) is one of remaining topic that should be studied in the future. Controlling car growth is also one way to stabilize the emission increase condition. Motivating economical growth and controlling car growth should be balanced. To reach ideal condition, accelerating old car with higher emission level due to catalytic deterioration is also one way that can support to balance controlling car growth. Introducing technology to avoid unnecessary emission is also one thing that can be considered and further studied.

2.8 Conclusion

The implementation of an LCGC policy will have a potentially significant impact on changes in the levels of emissions of CO, NO, and HC. By 2030, emissions under the LCGC scenario are predicted to be significantly higher than those under a scenario without LCGC. Emissions of CO, NO, and HC under an LCGC scenario are estimated to be 6,512.4 thousand tons, 179.3 thousand tons and 1,181.7 thousand tons respectively, while those under a scenario without LCGC are estimated to be 3,678.0 thousand tons, 114.7 thousand tons, and 602.1 thousand tons, respectively, increases of 77.0%, 56.3%, and 96.7%, respectively. CO_2 emissions in 2030 under the LCGC scenario are estimated to be 2.2 times higher than condition in 2013. The improved fuel consumption of LCGC is insufficient to offset the predicted rapid growth in purchases of LCGC by people with an annual income of US$4,500–$10,000 who have been unable to purchase a car in the past.

Increasing the price of the car and the down payment required and shortening the loan duration are all ways to limit the growth in the number of vehicles. Conversely, reducing the car price and the down payment required and extending the loan duration will lead to an increase in emissions of CO, NO, HC, and CO_2 under both scenarios, i.e. with and without LCGC. Considering more detail about non-euro car (old car) is one of remaining topic that should be studied in the future.

A comprehensive study of the LCGC policy is necessary to ensure that emissions are kept to a minimum. Controlling the growth in the number of cars is one way to limit increases in emissions. However, a balance needs to be achieved between stimulating economic growth and controlling the growth in the number of cars. Accelerating the retirement of older cars with higher emissions levels as a result of deterioration of their catalytic converter is one way to achieve this balance. The introduction of new technology to reduce emissions in certain driving situations (e.g., while idling during traffic jams) or to reduce overall emissions (e.g., hybrid car technology) is another area that requires further study.

CHAPTER 3 Study of the incentive caused by the Scrappage program in accelerating old-car replacement in order to reduce gas emissions from gasoline passenger cars in Indonesia

3. 1 Introduction

The growth of the use of passenger gasoline cars in Indonesia has been significantly increasing over the last decade (Gaikindo, 2015). The increase of emissions from vehicles has become a concerning issue. The negative effect on the environment has become an important reason to control emissions from vehicles, and is both necessary and urgent. This growth will contribute to the increase in gas emission levels. Several actions have been undertaken by both the stakeholders and car manufacturers to improve the performance of vehicles, such as the Low Cost Green Car (LCGC) policy (Moi, 2013). This policy enforced car manufacturers to fulfil the requirements of the policy; 20 kilometres per litre for gasoline consumption. An LCGC-categorised car can be one option to reduce the emissions from vehicles as well as being an option to replace older cars.

However, there are no specific regulations controlling the life of vehicles, such as retirement age limitations. The age of the car can be considered to be unlimited. Consequently, the car population will potentially increase year by year without any particular regulations to limit and control growth. The small portion of cars retired due to natural disasters or traffic accidents can be neglected. It becomes crucial because the emission level of each car will also increase in line with its age. Newer car will have better emission levels compared to older vehicles after a certain level of usage and travelled distance. The contribution from older cars is bigger than from newer cars over the same travel distance. Furthermore, non-euro car have multiple emissions compare to euro cars. Figure 3.1 shows the composition of passenger cars in 2013 based on car age (BPS, 2013). Non-euro cars dominated 24.0% of the total population of gasoline passenger cars in 2013. Non-euro cars are defined as a vehicle, which is not equipped with a catalytic converter in the exhaust pipe running from the engine. Residue gases from the combustion of the fuel and air will pass through without any compression and conversion by the catalytic converter. In previous work, Nugroho and Fujiwara (2005) calculated euro and non-euro emission levels. Non-euro cars have a multiple emissions compared to euro cars, when it comes to CO, HC, and NO gases. Although the portion of euro cars has increased, because new car registration was dominated by euro cars after the implementation of the euro 2 regulation since 2001 (Nugroho and Fujiwara, 2005), the biggest portion of emissions from non-euro cars cannot be neglected and will continuously exist, unless non-euro cars are forced to retire.

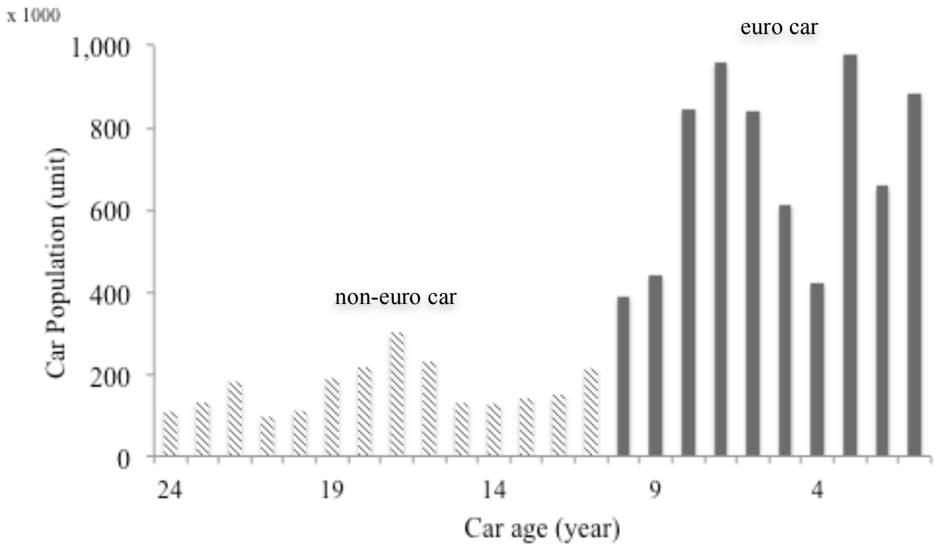


Figure 3. 1 Passenger car population based on age distribution

Therefore, accelerating the retirement of older non-euro cars is one of the potential options to reduce gas emission levels. In several countries, accelerating the retirement of older vehicles through an incentive program has been tried and implemented in previous years in multiple countries. France (Yamamoto et al., 2004), Ireland (Hennessy and Richard, 2011), Germany (Böckers et al., 2012) and Greece (Nicholas, 1999) have introduced an incentive program to reduce their old fleet. The number of incentive is different for each country. There are no similar patterns or positive correlations related to the amount of the incentive. The policy is taken based on each countries' condition. The scheme of the program is also different from country to country (minimum car age, amount of incentive, replacement model etc). The scrappage payment can lead to a large, immediate reduction in emissions (BenDor and Ford, 2006). In others developing countries, China, Mexico, and Chile have done retirement program for each car segment. In China, the target are gasoline and diesel car, while in Chile and Mexico, they only focused on diesel vehicles, truck or buses. (ICCT, 2015)

It had been discussed that the scrappage program had a positive effect on the reduction of emissions. The scrappage program appears to be cost-effective and may be a useful component of an overall policy to reduce emissions (Alberini et al., 1996). It has been shown that while a subsidy on the initial purchase of the car brings forward an optimal replacement time, the impact of the incentive for car replacement has been proven effective in Greece when compared with two other measures offered; traffic restriction and fuel taxes aimed at reducing car use (Nicholas, 1999). Scrappage payment can also lead to a large or immediate reduction in emissions (BenDor and Ford, 2006). These positive results might be applicable to Indonesia.

The purpose of this chapter is to discover the effects of the incentive scrappage program in relation to accelerating old car replacement and its effect on controlling the increase in the gas emission level in Indonesia. LCGC-categorised cars will be an option to replace retired cars. Emission level changes will be calculated to determine the effectiveness of the program. The final result will be expressed as CO, NO and HC as the environmental factor. The research into this topic has been very limited. This study is an important item of leading research in this particular field of study in Indonesia.

3.2 Materials and Method

3.2.1 Research Framework

We constructed the research framework to contain three main parts; the incentive scrappage program, the willingness to change, and emission replacement. As described in Figure 3.2, we introduced the incentive scrappage program. As the scrappage program is a voluntary program, in order to get to know the willingness of the people when it comes to changing their old car, we distributed questionnaires to 120 respondents. The questionnaire's purpose was to know the willingness of the car owner to replace their car. The questionnaire was constructed by offering a replacement for their old car, a new LCGC car. We promoted the LCGC car as an environmentally-friendly car with lower emissions, retailing at an affordable price, and being of high quality.

Voluntary replacement with zero incentive and incentives of $500 USD, $1,000 USD, $1,500 USD, and $2,000 USD were offered to determine the nature of the willingness to change. We also looked into the main reason for changing their old car, such as price, quality, and the environmental aspect. In the end, to cross-check their willingness, we also confirmed their environmental awareness when driving a car. For example, the car's periodical maintenance, and their driving habit during traffic jams, loading habits etc. Willingness to change will influence the proportion of stock cars in the market, which will be calculated as emission replacement concerning going from the old car to the LCGC car as the replacement option offered.

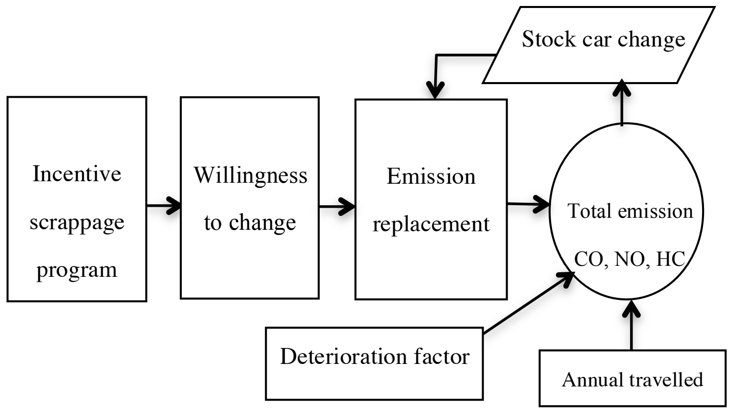


Figure 3. 2 Research framework

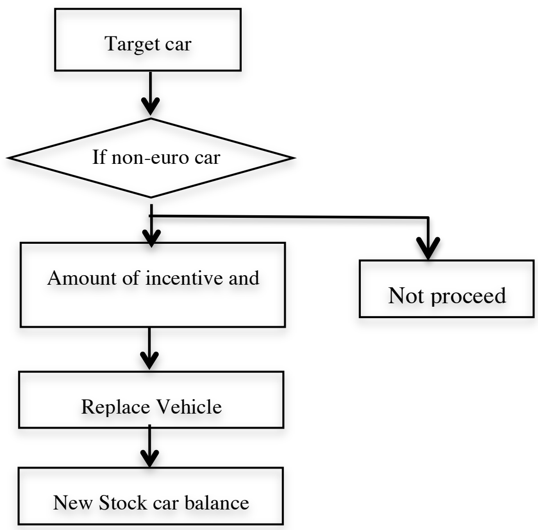


Figure 3. 3 Incentive program flow chart

Since we prepared the LCGC car as an option to replace the respondent's existing old car, we assumed that the car owner's income is in the segment of minimum annual income $4,500 USD-$10,000 USD. This segment is considered to be the group that can buy a new LCGC car with a 30% down-payment of the average LCGC car price of $9,500 USD. The annual interest rate was 12.42%, with a 5 year loan. The final emissions (CO, NO, HC) after the incentive scrappage program has been implemented will be estimated. The deterioration factor and the annual travel distance obtained from the 120 respondents will be used to calculate the emissions.

3.2.2 Willingness to change old non-euro car to LCGC car

Measuring willingness to change was the approach used to estimate how the old car owners respond to the incentive program concerning the replacement. The respondents were questioned about their intention and willingness to change to a newer car with several reasons to choose from. From the beginning, we have presumed that voluntary car retirement is still very difficult to implement (zero incentive as compensation). Voluntary replacement occurs only if the environmental awareness of the individual is very high. We also offered several replacement reasons; better fuel consumption, smaller engine capacity, better exhaust gas emission conversion, and other reasons prior to offering the specific LCGC car. To assure us of the choice of the respondent, we also re-questioned them to cross-check to ensure that their choice was the most appropriate answer after an interview. All of the questionnaire procedures were guided using the flowchart in

Figure 3.3. The screening started from the question confirming their car age. If the car's age was more than 24 years old, then we offered the incentive. The replacement was conducted after and if the owner decided that their chosen incentive option was to replace their old car with the LCGC car. Respondents who had no interest did not proceed to the next step. The reason for having no interest was varied. Respondents who owned euro and non-euro car showed their intention to participate in the program, so they were also considered as a contribution to the level of willingness. However, in the calculations, only the cars older than 24 years were targeted.

There were two factors that we considered to affect the willingness to express the probability of the owner replacing their old car. These were the probability of changing to the LCGC car P(A), and the probability of choosing the offered cash incentive P(B) respectively. WR is described as an independent correlation between two events, such as the probability of changing old non-euro cars to an LCGC car P (A), and the probability of choosing a cash incentive amount to replace their old non-euro car with an LCGC car P (B). If the two events are not influenced by one another, then the probability of both occurring is the product of the probabilities of each occurring separately. Independent correlation was considered because there is the probability of an old non-euro replacement with zero incentive or voluntary replacement. NER is the sum of the product between P (A) and P (B). Maximum probability 1 considers that 100% of old car owners will not replace their car, while minimum probability 0 assumes that all car owners will change their old car.

Hence, the willingness rate to change to the LCGC car with a certain amount of desired incentive can be described as:

$$\mathrm{WR} = \mathrm{P}(\mathrm{A} \cap \mathrm{B}) = \mathrm{P}(\mathrm{A}) \cdot \mathrm{P}(\mathrm{B}) \tag{3.1}$$

$$\mathrm{NER} = \left(\sum_{N=1} NE\right) \cdot \mathrm{WR} \tag{3.2}$$

WR	: Willingness rate of changing old non-euro car to the LCGC car
NER	: Number of non-euro cars with a car age more than 24 years replaced by the LCGC car (car unit)
NE	: Number of non-euro cars (car unit)
A	: Event of changing old non-euro cars with the LCGC cars
B	: Event of choosing the offered incentive to replace the old non-euro car with an LCGC car
P (A)	: Probability of changing the old non-euro car to an LCGC car
P (B)	: Probability of choosing the offered incentive to replace their old non-euro car to an LCGC car
N	: Number of targeted non-euro cars with a car age of more than 24 years (car unit)

In the previous research, the willingness to change the targeted vehicle and the amount of incentive was not mentioned clearly. The policy of the stakeholder and annual budget planning become one of the triggers used to decide on the scheme of the incentive scrappage program. For example, German policy required new cars purchased as a replacement to have a minimum age of nine years in exchange for the car scrapped. This has led to an eligible pool of 17 million cars, or 41% of all cars registered in Germany. Moreover, under the German program, the car does not have to be brand new, but a car registered to another person for at most 14 months can also qualify for the governmental subsidy of 2,500 euros per vehicle. This incentive is only guaranteed to private car owners, and commercial entities are excluded from the program.

The scenario of the scrappage program also varies. The cash return incentive gives the incentive in the form of cash to the old car owner without the obligation to change to a certain car type, or with the condition to replace it with a designated car, as two examples. The amount of incentive also depends on the necessity and condition in each country. Determining the scenario for non-euro cars older than 24 years is also aimed at limiting the calculations involved and considering that the amount of scrappage incentive is limited by the stakeholder budget. We assume that all vehicles registered up to 2001 before the emission standard Euro 2 was implemented are non-euro cars, even though the possibility of euro cars also existing at this time cannot be neglected. However, the number will be less compared to the number of existing non-euro cars.

3.2.3 Incentive scrappage program

We constructed the scrappage program with a compensation incentive scenario in order to reduce the significant contribution of non-euro cars to air pollution. We set several options for the available incentives in the questionnaire's construction. The purpose is to discover the tendency of the respondents when they replace their old non-euro car with a LCGC car. We set $0 USD, $500 USD, $1,000 USD, $1500 USD, and $2,000 USD as the cash options. This will reflect their replacement reason, be it because of their awareness of the environmental hazards or for financial reasons. This incentive is designed to stimulate the replacement as compensation for their actions. Setting the $0 USD incentive was used to determine their awareness level, as $0 USD is considered to be voluntary willingness. Car owners will replace their old car even without any incentive or compensation for the act. We also assume that if the awareness of the importance of the environment is high, then they will tend to replace their old car with a newer car even though no incentive is offered. The incentive introduction followed the Figure 3.3 flowchart. However, in this research, we have not included how the incentive budget will be absorbed and the source of the budget; it will be absorbed by the car price from the car manufacturer or intentionally from good will. The policy of the stakeholder was taken from the national budget.

3.2.4 Estimation of stock car change after the incentive scrappage program was implemented

The car stock changed after some of the non-euro cars were replaced with LCGC cars. Stock car change describes the changing of the old car and the new car in the context of the stock market. We can assume that all cars will be replaced with LCGC cars, and then individual old car retirement will be followed by new LCGC car registration. Car retirement due to natural disasters or traffic accidents were neglected in order to simplify the calculation. Stock cars (SC) will consist of the number of LCGC cars in the minimum annual income segment of $4,500 USD-$10,000 USD. This also details the car ownership model, the 30% down payment of the average LCGC car price of $9,500 USD, the annual interest rate of 12.42%, and the 5 year loan formulation. Non-LCGC cars owned by individuals with a minimum annual income of more than $10,000 USD will also be in the category of SC. From the incentive scrappage program, NAE will replace the replacement of non-euro car NERs. SC can be described as,

$$SC = (NA + NB + NAE) - NER \tag{3.3}$$

SC : Stock car (car unit)
NA : Number of LCGC cars (car unit)
NB : Number of non-LCGC cars (car unit)
NER : Number of non-euro cars with a car age of more than 24 years old replaced with an LCGC car (car unit)
NAE : Number of new LCGC registrations in relation to non-euro car replacement (car unit)

The substitution of the non-euro car with LCGC car will make new car registration is in equal, however, the car type is different, which effect to the individual emission contribution level between non-euro and LCGC car that categorized as euro car with strict emission standard Euro 2.

3.2.5 Emission Factor (EF) and Deterioration Factor (DF)

Euro 2 and non-euro cars have a big difference when it comes to the emission standard. Since non-euro cars are not equipped with a catalytic converter to convert its fuel and air combustion appropriately, gas residue will be emitted into the air without any compression and conversion. While Euro 2 cars have a lower emission standard, the degradation of the catalytic converter will cause the conversion capability to become worse after a certain travelled distance. As seen in Table 2.2, the emission standard of Euro 2 for CO is 2.2 gr/km, which describes that CO gas will be considered as having emitted from the exhaust pipe of the vehicle if it measures 2.2 grams for each 1 kilometre of travel. HC and NO have a value of 0.05 gr/km and 0.45 gr/km respective, which assumes that HC and NO will be emitted measuring 0.05 grams and 0.45 grams per one kilometre of travelled distance (Nugroho and Fujiwara. 2005).

The amount of CO, HC, and NO increases by 60% from the initial emission level after exceeding 80.000 kilometres of travel (Boulter, 2009). We have named this degradation the deterioration factor (DF). High mileage vehicles will produce more air pollutants. The degradation is caused by a deterioration of the catalytic converter, related to the output of the exhaust pipe combustion. The deterioration of the catalyst is one factor that cannot be neglected (Borken-Kleefeld & Chen, 2015), therefore it should be considered in the calculation.

3.2.6 Emission replacement after the incentive scrappage program was implemented

The replacement of NER with NAE will consequently change the emission conditions. NERs with higher potential emissions will be replaced by NAEs with better emission standards. It will also be considered as the elimination of the emissions from an individual old car replaced with the emissions from an LCGC car. The elimination will be derived from the difference between the retired and new car's emission level. This means that the elimination level cannot be zero, because new replacement cars also emit gas even though the level is much lower compared to the emission level of the old cars.

$$E = SC \cdot EF \cdot ATD \cdot DF \tag{3.4}$$

$$E = [(NA + NB + NAE) \cdot EF_1 - NER . EF_2] \cdot ATD \cdot DF \tag{3.5}$$

E : Total emission (CO, HC, NO) after LCGC implementation (ton)
SC : Stock car (Car Unit)
ATD : Annual travel distance (km)
EF_1 : Emission factor for euro 2 standard (10^{-3} kg/km)
EF_2 : Emission factor for non-euro standard (10^{-3} kg/km)
DF : Deterioration factor (60% increase after 80,000 kilometres travelled)
NA : Number of LCGC cars (car unit)
NB : Number of non-LCGC cars (car unit)
NER : Number of non-euro cars with a car age of more than 24 years where replaced with a LCGC car (car unit)
NAE : Number of new LCGC registrations after non-euro car replacement (car unit)

We differentiated between the emission standards of euro cars (EF_1) and non-euro cars (EF_2). The big difference between both standards became one of the most important elements in this estimation. For ATD, an annual travel distance of 13,000 kilometres was obtained from the odometer.

3.3 Results and Discussion

3.3.1 Euro and non-euro emission level difference

The individual emission level between euro and non-euro cars stands as an important factor for determining emission contribution. For each ATD 1,000 kilometres travelled, the emission rate of the CO, NO, and HC values were plotted for each year. For HC, the emission rate of the non-euro cars was more than

32 times bigger compared to the euro car. The NO gas contribution was more than 8 times bigger and the CO rate was more than 27 times bigger compared to the CO emission rate than that of the euro car. By accommodating equation (3.4) and the emission standard in Table 2.1, we have calculated the individual euro and non-euro emission contribution. The level of the emissions from the exhaust pipes became higher, simultaneously increasing with the degradation of the catalytic converter, which functionally inhibits the formation of exhaust gas emissions. The contribution from non-euro cars to the total annual emission level from gasoline passenger cars is significantly higher compared to euro cars. Each emission gas (CO, NO, HC) shows a big difference year by year.

To accommodate the emission level change caused by the car's increased age for Euro 2 cars, EF and DF was used in the calculation. The deterioration factor reflects the capability of the catalytic converter in the exhaust gas pipe to convert emission gases. For every 80,000 km travelled, the gas level will be 1.5 times bigger compared to the initial condition. This means that the emission amount differs correlating to an increase in age. An older car will potentially emit a bigger amount of emission gases compared to a younger car.

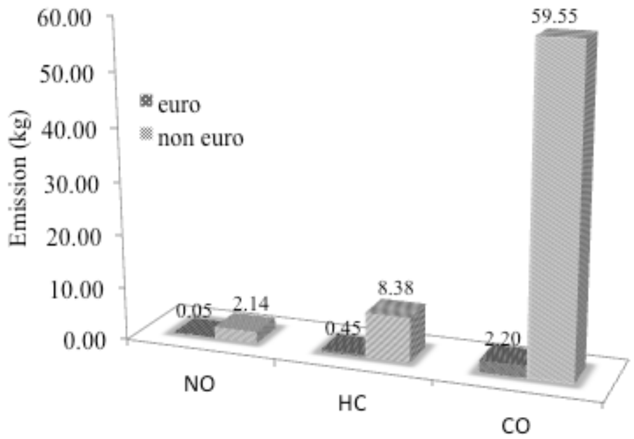


Figure 3. 4 Estimated result of proportion of emission level for euro and non-euro for (a) CO, (b) NO, (c) HC

3.3.2 Willingness to change the non-euro car to a LCGC car

The probability of the owner of the old car changing to a newer LCGC car was confirmed through a survey of 120 respondents in Indonesia from the five big cities (Jakarta, Semarang, Surabaya, Medan, and Makassar). More than 70% of the population is distributed within the five cities (BPS, 2013). Furthermore, more than 70% of car sales also occurs in these cities (Gaikindo, 2015). More than 82% of the respondents were willing to change their old car to an LCGC car with the maximum incentive value obtained being $2,000 USD, with the latter totalling 78%. This reflects that the financial aspect is still the most important factor when it comes to motivating the replacement compared to environmental awareness, which was also offered in the questionnaire. This was also supported by the questionnaire answer for voluntary retirement (zero incentive) being zero; none of the respondents chose the zero incentive option for non-euro car replacement.

By utilising equation (3.1), the willingness rate of changing old non-euro cars to an LCGC car (WR) can be obtained from the sum of the product between the probability of changing an old non-euro car to a LCGC car P (A) 70% (0.7) and the probability of choosing an amount of offered incentive to replace the old non-euro car with the LCGC car P (B) 82% (0.82), calculated as follows:

$$WR = P(A \cap B) = P(A) \cdot P(B)$$

$$= (0.78) \cdot (0.82)$$

$$= 0.64$$

3.3.3 Stock car change after the incentive scrappage program was implemented

We have taken the starting point of the incentive program to be 2013, continuously introduced until the number of non-euro cars in lowest number in 2030, which is 487 units from the non-euro stock of 109,147 unit for 24 years age and 1,073,106 unit for more than 25 year age in 2013 before scrappage program introduced. The targeted >24 year of non-euro car is also increase year by year due to the aging of the younger car. For example, in 2014, additional 130,957 units are added which in previous those units car are in 23-year age. This continues until 2030 with each additional segment of targeted car.

The number of the non-euro cars gradually decreased by 57% from its original number. At the same time, the number of LCGC cars increased by the same number since the condition of the incentive program is to encourage change to the LCGC car. In 2030, the portion of non-euro cars decreased drastically from 24% to 0.01% from the total stock. New registration of LCGC car were also added to the population of the euro car, since scrappage non-euro car will be replaced with additional LCGC car as replacement car.

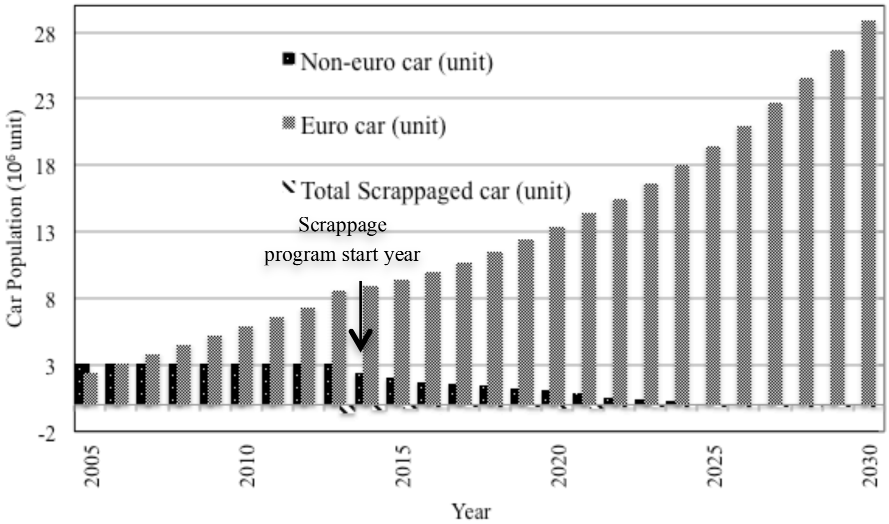


Figure 3. 5 Stock car change after incentive scrappage program implemented

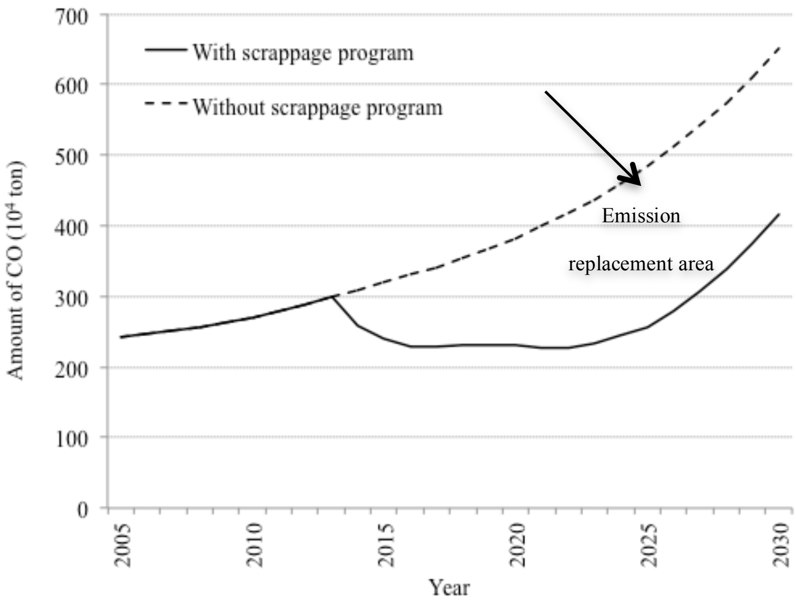
In Figure 3.5, we plotted the calculation result with vehicle categories euro and non euro car. Scrappage non euro car indicated the number of non euro car targeted and eliminated during scrappage program conducted. In the category of euro car, it is consist of LCGC and non LCGC vehicle as deeply discussed in Chapter 2.

The condition of stock cars in the market has been shown in Figure 3.5. The portion of non-euro cars is also much smaller compared to the population of euro cars in a certain year. The existing non-euro cars are constant until the implementation of the euro 1 standard regulation in Indonesia (Nugroho & Fujiwara, 2005). No particular regulation on the car's lifetime becomes the main reason that all non-euro cars were considered to still exist. It gradually decreased because of the retirement due to the incentive scrappage program introduced in 2013. The portion of non-euro cars will also vary depending on the duration of the scrappage incentive program. The minus portion of the scrappage non-euro car indicates the reduction of non-euro cars due to the non-euro car owners participating in the scrappage program. In this calculation, the duration is prolonged until the minimum value is reached at the end of the calculation in 2030. The budget of the incentive will become a very important factor to reach this ideal condition. As long as the implementation period is long, the effect on the current change will be also significant. However, it is not an easy thing to implement when it comes to the actual condition, moreover when with a limited budget.

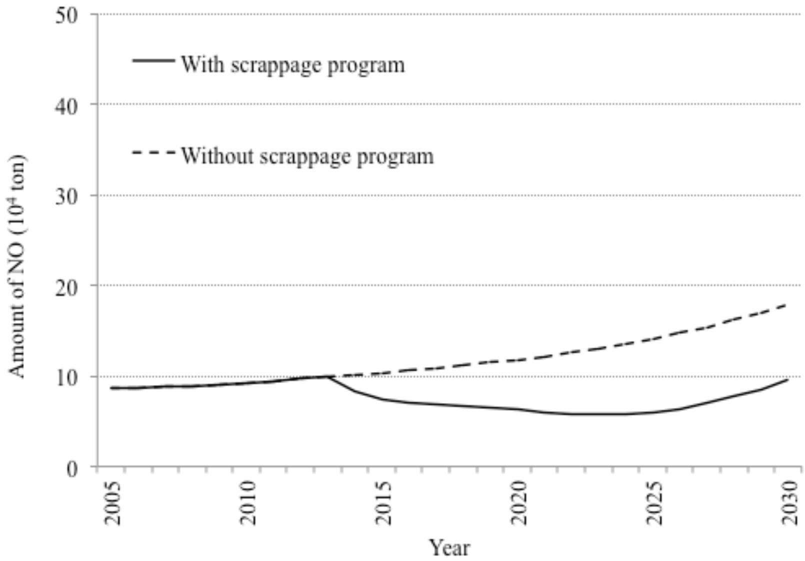
3.3.4 Emission (CO, NO, HC) gas replacement after the incentive scrappage program is implemented

We applied the simulation to estimate, utilising previous equation (3.5) above, to know the effectiveness of the incentive program in reducing the level of exhaust gas emissions, and how significant the elimination of the old car is on the emission level change (CO, NO, HC).

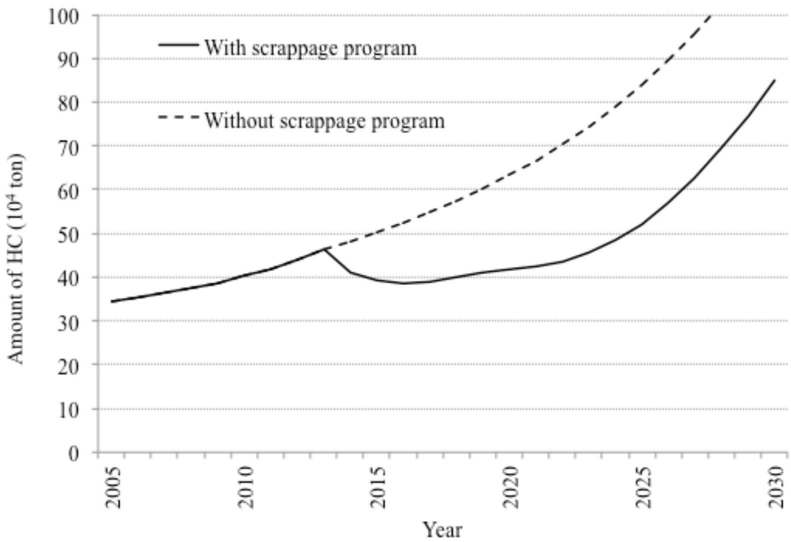
(a)



(b)



(c)



From the results shown in Figure 3.6, in general, each gas element (CO, NO, HC) decreased. The year 2013 became the initial reduced point because we applied the incentive scrappage program from 2013. This means that the retirement portion of non-euro cars will start to contribute to the decreasing of the emission level in 2016. For CO, it decreased in 2014 by approximately 19.5% compared to the starting condition in 2013 which 2,152,038 tons with scrappage program and 2,673,690 tons with without scrappage program.

The gap between with scrappage program and without the incentive program constantly increased by average 45.5%. In the end 2030, the difference is 72.1% between with and without scrappage program, with 47.4% difference toward the 2013 CO level, more than half of the CO emissions can be reduced, from 2,645,748 tons to 1,390,949 tons. The constant increase was 45.5% (1,399,978 tons) for each year because one unit of scrappage non-euro cars should be replaced with newer LCGC cars. The significant reduction was predicted because of the individual emission level difference between euro cars and non-euro cars as described in Figure 3.5, which shows that non-euro cars have 27 times more emissions than euro cars.

NO also trend to decreases from the beginning of the implementation compare to the without scrappage program. The difference gap between with and without scrappage program 2030 is more than 23.2% with 84,419 tons difference. The gap between with and without the scrappage program scenario has a 25.8% difference on average with the biggest gap occurring in 2024 at about 31.0%. The same tendency also happened for HC. In 2030, the difference between with and without scrappage program is more than 91.4% with average difference for each year around 69.4%. Once the emission level decreases, it will slightly increase due to the number of LCGC car replacements also increasing. The tendency of the decrease of each gas follows the difference of the individual comparison as in Figure 3.4. The reduction portion also happens in the order of CO, HC, and NO. As seen in Figure 6 (a), (b), (c), we can conclude that the retirement of non-euro cars has a significant contribution to the reduction of the level of gas emissions from gasoline passenger cars.

3.4 Considerations of Policy Option

From analysis result, contribution of non-euro car to the emission level is significantly high. Individual non-euro car emission level is estimated caused of the high contribution. Non-euro car with no catalytic converter equipped on the exhaust pipe of the engine, release combustion gas residues without conversion. Moreover, deterioration of the emission related elements caused elder vehicles emit higher emission compare to the newer car or shorter driving mileage.

For this reason, controlling car age limit is one of the options to control the higher emission from elder vehicle is highly recommended. The car age controlling way can be done by several ways, for example, scrappage incentive program for certain elder car, introducing of the car tax based on the car age or emission level. The controlling policy should involve related parties, government authority, car manufacture, distributor and customers to get comprehensive measure with optimum result.

3.5 Conclusion

Non-euro cars produce a significant emission contribution to the current level. Although its portion is only 24.0% out of the total stock (until the scrappage program was introduced), it provided a big contribution in 2010 (CO 81.2%, HC 94.1% and CO 93.2%). The incentive scrappage program had a significant effect on changing the emission level. By utilising the willingness rate concerning the retirement of non-euro cars and offering LCGC replacements, there was a positive effect on emission reduction. For the emission gases, CO, NO, and HC, the result showed a significance change compared to the scenario without the scrappage program. After the incentive program is implemented in 2016, the condition after 14 years in 2030 was that CO was reduced by 59.3%, NO by 68.1%, and HC by 35.4%. The individual difference between euro and non-euro cars is one of the main reasons for this significant reduction. Therefore, we reached the conclusion that eliminating non-euro cars is one of the options to reducing the gas emission level in the case of gasoline passenger cars.

Increasing the participation rate will accelerate the level of reduction. There might need to be a bigger incentive to attract people to replace their old car. Extending the targeted type of car is one way to increase emission reduction. However, after the implementation of the scrappage program and when non-euro cars have been successfully eliminated, the trend of the emission rate showed an increase as described in Figure 6. This might be caused by the increase of LCGC cars on the road with owners with a minimum annual income of $4,500 USD-$10,000 USD. This annual income range previously could not buy car because of high price. Therefore, further study is still needed, focusing on the control of the increase in gas emissions.

A comprehensive control policy is necessary to maintain gas emissions from vehicles. As we understand that even euro car that are equipped with catalytic converters are also degrading, this might cause older vehicles to emit higher gas emissions in line with the extended travel distance. Controlling car age limit is one of the options to control the higher level of emissions from older vehicle.

CHAPTER 4 Exploratory study of the idling driving effect on gas emission levels in a traffic jam environment *Case Study of Jakarta Metropolitan traffic on gasoline passenger cars*

4.1 Introduction

Jakarta, the target city in this paper, is one of the busiest capitals in the world. The traffic condition is also terrible. One of the traffic contributions comes from the rapid growth of vehicles. Annually, the increase of vehicles registered is more than 10%, in which passenger cars have contributed more than 9% over the last five years as described in Table 4.1. Motorcycles hold the highest percentage out of the documented vehicle composition, taking up more than 74% of the total vehicles (Badan Pusat Statistik Jakarta, 2015).

Moreover, the traffic condition has worsened due to the slow road construction growth that is based on the promptness of the Indonesian transportation authority over the last four years (2010-2014). While the average annual road construction growth has only been around 0.01%, this is less than 900 times the growth of vehicle demand (Jakarta, 2014). Consequently, the traffic density has become higher and this seems to accelerate the frequency of traffic jams. This high traffic density will also cause unnecessary air pollution from the exhaust pipes and fuel consumption that occurs.

In this paper, we have studied the effectiveness of idling control related to the traffic density condition in Jakarta city in order to investigate avoidable emissions during traffic jams. Regarding this topic, we have investigated the effectiveness of introducing a Low Cost Green Car (Pratama and Tokai 2018a) and scrappage incentive program for old cars (Pratama & Tokai, 2018b). In this paper, we tackled issues related to the idling driving condition. Idling generates a certain amount of emissions (Gaines, Rask, & Keller, 2012). As idling is relevant to road structure, there are a few idling controls that are effective for emission control. However, even after a government emission regulation was issued and due to the technological development of environmentally-friendly cars, peoples' driving behavior remains the target of automobile emission control.

During traffic jam conditions, vehicles are often in a state of idling. However, there will still be continuing emissions due to the engine combustion. As for the environmental impact, not only are there gas emissions (CO, NO, HC), but fuel will also be wasted. These conditions should be reduced or avoided entirely if possible. In previous work, (Shancita et al., 2014) discussed the impact of idle driving on emissions (CO, NO, HC) and fuel consumption, related to gasoline cars as well as diesel cars.

However, research working on clarifying of the effectiveness of controlling the idling state based on real world field surveys in Indonesia is very rare. One related research study was done by (Nugroho & Fujiwara, 2005), which measured the emission levels in Jakarta city. However, the idle driving condition has still not been estimated in detail. Because of the limited work related to this topic, fieldwork was also conducted to support the actual data available. For this pioneer research, we utilized GPS (Global Positioning System) technology to measure the actual idle driving condition in Jakarta city.

Based on the above problem identification, this research focused on the measurement of idle driving during traffic jam conditions in Jakarta city, calculating the potential avoidable emissions of CO, NO, HC and the impact of the aforementioned on the emission level of gasoline cars in Jakarta city as a future projection.

Table 4. 1 Data of vehicles in Jakarta

Year	Motor Cycles	Passenger Cars	Cargo Cars	Buses	Special Car	Total	Growth for Passenger Cars (%)
2009	7,518,098	2,116,282	550,924	309,385	-	10,494,689	-
2010	8,764,130	2,334,883	565,727	332,779	-	11,997,519	10.33%
2011	9,861,451	2,541,351	581,290	363,710	-	13,347,802	8.84%
2012	10,825,973	2,742,414	561,918	358,895	129,113	14,618,313	7.91%
2013	11,949,280	3,010,403	619,027	360,223	133,936	16,072,869	9.77%
2014	13,084,372	3,266,009	673,661	362,066	137,859	17,523,967	8.49%

4.2.1 Research Framework

The research framework was constructed by combining the fieldwork with the secondary data from the authorities and the calculation processes. In the first step, the measurement of the traffic density was the focus and became the input used to calculate the time and distance lost during bad traffic conditions. From the time and distance lost, the avoidable emissions were then estimated as described in Figure 4.1.

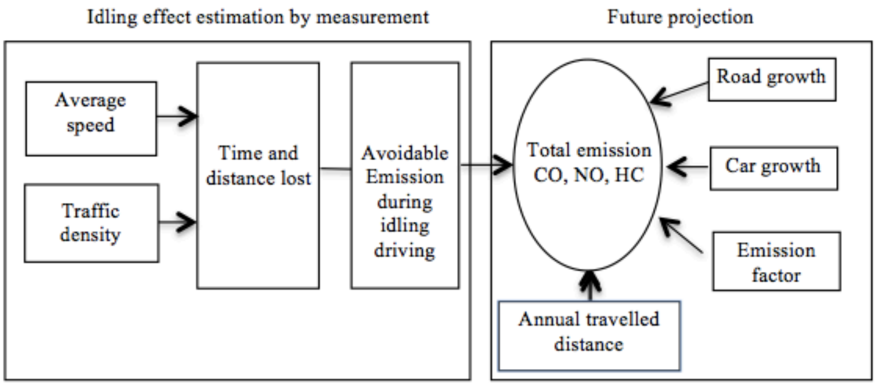


Figure 4. 1 Research framework of idling driving measurement and future projection

The total emissions were estimated and calculated while accommodating the emission factor and annual travelled distance. To support the calculation of the traffic condition changes, a road growth and car growth comparison was also considered.

4.2.2 Traffic density measurement (time and distance lost (or avoided))

4.2.2.1 Sample Selection and Determination

As we decided to use Jakarta city as the boundary sample area, we used several samples to represent the actual traffic conditions present in the city. The Government Bureau has classified the roads based on their function either as a primary road, secondary road, primary collector or secondary collector as shown in Table 4.2 (Jakarta, 2014).

Table 4. 2 Road data in Jakarta City (Unit: meter)

Year	Toll Road	Primary Road	Secondary Road	Primary Collector	Secondary Collector	Administrative	Total Length
2010	123,481.00	123,653.00	563,438.81	18,994.00	997,019.87	5,039,454.16	6,866,041
2011	123,481.00	123,653.00	563,438.81	18,994.00	1,057,666.87	5,045,059.16	6,932,293
2012	123,731.00	128,882.50	535,256.69	23,964.00	1,027,019.87	5,117,258.20	6,956,112
2013	123,731.00	128,882.50	535,256.69	23,694.00	1,027,019.87	5,117,258.20	6,955,842
2014	123,731.00	128,882.50	535,256.69	23,694.00	1,027,019.87	5,117,258.20	6,955,842

We approached the sample by selecting the most common roads - primary and secondary - to increase the accuracy of the data. For the primary roads, 100% were measured. However, for secondary roads, in order to simplify the data selection, we set the proportion of the targeted roads at 50%, 40%, 30%, 20%, and 10% along with their proportion from the total of the secondary roads in Jakarta city based on the area regency.

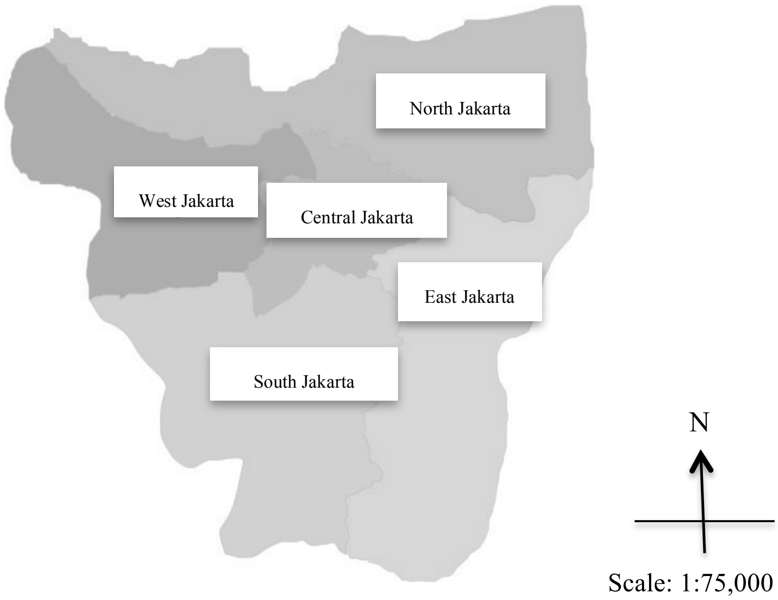


Figure 4. 2 Jakarta City Map

A map of Jakarta city has been shown in Figure 4.2 The North Jakarta area has the first rank with the highest road number of 54, resulting in 93,412 kilometers. Central and West Jakarta were placed in second and third rank with the number of roads being 74 (89,333 kilometers) and 68 (10,165 kilometers) respectively. We set the highest proportion as 50% for North Jakarta, 40% for Central Jakarta, 30% for West Jakarta, and the last as 10% for East Jakarta. The linear proportion was expected to increase the representing level of the data.

One path of the driving sample taken from the selected road will be considered as being 1 sample. The one road path will correspond to the one primary road or secondary road, neglecting the road length variation from each selected road. We also did not consider the driving direction for each path; both traffic directions will be accepted. For several roads, the local authority applied either a one-way direction or two-way direction system. On certain paths of road, particular regulations were also applied. For example, since August 2016, the local government has launched new regulations on odd-even car plate numbers to reduce the traffic condition at designated times, particularly in the area surrounding the important public places in the center of Jakarta. However, the number of these roads is low, and thus can be neglected in this experiment.

We also applied the sampling time category for each selected road. We considered that the traffic density of each time slot is potentially different. We created 4 sampling time slots; morning rush hour (06:00-09:00 am), normal weekday (09:00-16:00), evening rush hour (16:00-20:00), and holiday. The morning rush hour is considered to be a peak rush hour time because people are heading in to start work. People drive their car from their home to their office. Some people use public transport such as buses and trains. However, the number of people driving a car for their commute is presumed to still be high. People struggle to reach their office before the average working time, which is generally between 07:00 am and 08:00 am.

On a normal weekday, the traffic condition tends to lower in density. In the evening rush hour, in a general government office, public place, or company, they often end their activities between 16:00-17:00 pm. Therefore the time slot between 16:00-20:00 is considered to be a rush time because people have just finished their work and want to go home. Monday and Friday will be representative of the weekday sampling. We considered that people tend to drive their cars most on these days. This is because both days are connected with a holiday, Saturday and Sunday respectively. People consider driving their car at the end of the weekday (Friday) to directly go to a holiday activity and return on Sunday morning, occasionally going directly to the office. Therefore, Monday and Friday will represent the worst conditions of the weekday traffic. For holidays, the traffic condition is assumed to differ from the weekday condition. People are not driving outside for work, but they are driving to take a holiday, to go to a public pleasure place, or to visit family and friends. Saturday will be the representative of the holiday sample. For this sampling category, one road will be driven in the four times slot; morning rush hour, normal weekdays, evening rush hour, and holiday. By considering one path/road's driving as one sample, we measured a total of 1,100 path-roads (1,100 samples taken). We consider these samples to be able to represent the actual traffic conditions of Jakarta city.

4.2.3 Idling driving time measurement

Idle driving time is an important element in this experiment. The data will be used to estimate the avoidable emissions produced during the idling condition. We define idle driving as driving at a speed below 5 km/h (with <10 km/h as a reference) over a certain distance. We conducted data measurements using a Global Positioning System (GPS) tracker machine that was installed in the vehicle. The Global System for Mobile (GSM) provider sent the recorded data to the server, and an application program (*tracksolid*) was used to read and extract the data. The Transport Systems Centre (TSC) also developed an integrated Global Positioning System (GPS) to measure the traffic condition (Taylor, Woolley, & Zito, 2000).

The procedure involved in the data measurement was as follows:

STEP 1

Prepare all devices installed properly; check that the GPS tracker machine is working properly by checking to see if the indicator lamp is blinking (GPS positioning lamp, data recording lamp). We will also check to see if the GSM data sending method has enough of a data pulse to send the recorded data to the server. The data sending element has been set to record and send the collected data every 10 seconds.

STEP 2

Select the targeted pathway (road) from the city map. The selection of the pathway is determined as shown in Figure 4.2.

STEP 3

Start driving. The GPS tracker will record the car speed and positioning data (altitude, longitude), and send it to the server every 10 seconds. The sample data list has been shown in Appendix.

STEP 4

To finish the measurement, switching off the GPS tracker will end the process.

In the actual observation procedure, the observed car started from the 0 point assigned as 0 minute before travelling to the determined road with a certain distance. Every 10 seconds, the GPS tracker recorded the speed data and sent it to the server. After this, we extracted all of the data recorded, sent it to the server and exported it into an Excel file format to make it easy to analyze. If the speed was under 20 km/h, then we defined this as idle driving. The measurement was conducted using one vehicle and the same driver to avoid unexpected external factors occurring from people's driving habits or car specifications, to maintain the consistency of the measurement. Different drivers will cause deviation in the driving habits. The instruments used were the following:

Specifications:

Dimension	: 106 (L) x 54 (H) x 16 (W) mm
Weight	: 96 g
Backup Battery	: 450 mAh / 3.7 V
Operation Temperature	: -25°C - 60°C
Humidity	: 5%-95%
Standby Time	: 60 hours
GSM Frequencies	: 850/900/1800/1900 MHz
GPRS	: Class 12
GPS Channel	: 20
GPS Sensitivity	: - 159dBm
Acquisition Sensitivity	: -144dBm
Position Accuracy	: 10 m
TTFF (Open Sky)	: Cold Star <38s; Warm Start <15 s; Hot Start <2s
GSM GPS Antenna	: Built-in design
LED Indicator	: GSM-green, GPS-blue, Power-red
Data Transmit	: TCP, SMS
Geo-fence	: View any existing Geo-fence in the map
Speeding Alarm	: Report when speeds are higher than the pre-set value
Low Power Alarm	: Alarm when the backup battery is running out
Non-Movement Detection	: Movement alarm based on built-in 3D motion sensor
Mileage report	: Track by time/distance interval
Remote control	: Cut off petrol/electricity

Figure 4. 3 Speed recording instrument

4.2.4 Time lost from idle driving time and determining the average speed

The idle driving time was derived from the equation of the average speed defined as the distance traveled divided by the total traveled time. Average speed and traveled time were the reverse corresponding factors; when the traveled time was longer, consequently, the average speed was also reduced. On the other hand, the average speed will increase when the traveled time is shorter. A shorter traveled time indicates that the lost time during driving is less. A longer traveled time will show the reverse condition. Shorter traveled time is considered to be the better condition because lost time can be minimized. Time lost was defined using equations (4.1), (4.2) and (4.3), and represents the wasted time while in an idling condition. In idle driving, the car's engine is still in a working condition. However, the car does not travel at the minimum suggested speed.

We defined normal speed as the normal condition that is expected without or with less idle driving time. It has been expressed in the following equation, and V_a was calculated from the total traveled distance divided by the total traveled time minus the time spent in a traffic jam that we defined as idle driving time. The total travel distance was calculated from all of the recorded speed range data. The idle driving time was taken from the sum calculation of the speed range under 5 km/h. For the abnormal conditions that we were not expecting, such as travel in a traffic jam condition, we calculated, from the original condition, the total traveled divided by the total time needed for the travel. Since traffic with an idling time is considered to be an abnormal condition, the actual measured data will be the original condition that represents an abnormal condition. This is because the idling time is still inside the traffic jam.

The definition of a traffic jam is varied depending on the source. From the previous research, the Korean Highway Corporation (KHC) identified traffic congestion spots as being where vehicle speed falls below 30 km/h or when the traffic congestion continues for longer than 2 hours a day, 10 days a month. Daejeon city center uses the congestion criteria of when the vehicle speed is less than 14 km/h. Japan uses speed as a threshold value to identify potential traffic congestion areas. It is said that there is traffic congestion if the freeway travel speed falls below 40 km/h, if there are repeated 'Stop-and-Go's for more than 1 km, or if these conditions stay for more than 15 minutes (Choi, J.; Lee, C.; Lee, S.; Yu, 2007).

$$T_{drive} = T_{total} - T_{idle} \tag{4.1}$$

$$V_a = \frac{TD}{T_{drive}} \tag{4.2}$$

TD : Travel distance during measurement (km)
T_{drive} : Time needed without idling driving (h)
T_{idle} : Time during idling condition (h)
T_{total} : Total time needed for certain travel distance (h)
V_a : Average speed with traffic condition (km/h)

By utilizing the equation above, time lost can be expressed as the difference or gap between time spent in a traffic jam condition and the time without there being a traffic jam condition. The time lost for each sampling path of each road will be summarized in the calculation of the total time lost in Jakarta city. As shown in equation (4.3), lost travel distance $TD_{lost}$is calculated from the average speed with the presence of a traffic jam condition and the time spent in an idling condition. The average speed shows the opposite condition, compared to the time consumed both with traffic and without traffic. Because less idling time will consequently increase the average speed of the traffic, high traffic density with a higher idling condition will cause the average speed to improve. In principle, traffic with a high congestion condition is bad for the environment. This is because cars will continue to emit emission gases even though there is no travel. This condition should be seriously considered and avoided. Unnecessary emission gases should not come from the exhaust pipe while in an idling state. People also do not get any benefits from this condition because they cannot reach their travel target within an effective amount of time. With the expected normal average speed then being resumed, at least some of the travel distance lost can be retrieved. Travel distance lost due to idling driving is obtained from the percentage of the idling driving portion from the total actual measurement. We took idling driving speed <5 km/h and additional reference <10 km/h. The proportion of the idling driving determines travel distance lost as describe in following equation.

$$TD_{lost} = TD \cdot \text{percentage of } V_a \tag{4.3}$$

TD_{lost} : Travel distance lost due to time lost (km)
V_a : Average speed with traffic condition (km/h)

4.2.5 Avoidable emission estimation

Idle driving in a high traffic density condition or in traffic jam causes emissions. Avoidable emissions should not occur, and they can be minimized if the idling time is lessened. Emission gaps with and without idling, E, can be calculated from the vehicle data by utilizing the following equation (4.4). The emissions are the function of travel distance (TD), the emission factor (EF), and the deterioration factor from the catalytic converter (DF). As long as the value of EF and DF are considered to be constant for all conditions and cars, the most influential factor is travel distance. This is because the emission gap is obtained from multiplying the travel distance elements, emission factor, and deterioration factor, in which the distance element value is much higher compared to the other elements. The length of the travel distance in a certain time will produce the difference between the conditions. In the same way of thinking, the amount of emission pollutants in the normal traffic area with and without heavy traffic can be compared. E_{gap} is defined as difference between condition without considering idling driving and including idling driving which produced travel distance lost. Annual travel distance was obtained from the odometer reading in survey (13,000 km/year)

$$E_{lost} = \sum_{N}(TD_{av} - TD_{lost}) \cdot EF \cdot DF \quad (4.4)$$

E_{lost} : Emission lost during idling driving (ton)
TD_{av} : Annual average travel distance (km)
TD_{lost} : Travel distance lost due to time lost (km)
EF : Emission factor (gr/km)
DF : Deterioration factor (60% increase times after 80,000 kilometer travelled; CO 3.52 gr/km; HC 0.08 gr/km; NO 0.72 gr/km)
N : Number of car population in Jakarta

4.2.6 Future projection

Emissions in the future were estimated as a future projection by utilizing the driving measurement results. The levels of the avoidable emissions were derived from equations (4.3) and (4.4), which were used to determine the emission gap, with the condition of no idle driving being the ideal condition. The time lost during idle driving represents the lost travel distance in equation (4.1), which was used to calculate and differentiate from the annual travel distance obtained from the survey (Pratama & Tokai, 2018a). Taking into account the detailed driving patterns, including idle driving, increases the accuracy of the travel distance affecting the gas emissions from the vehicles.

Car growth was also used to estimate the number of cars on the road in the future. We estimated the future projection from 2010 up to 2040 and determined the gas emission tendencies. The projection start period is 5 years earlier compare to projection in chapter 2 and chapter 4 due to availability of the start data form 2010 for Jakarta city area, the end of the projection is prolonged until 2040 for this consequence. The contribution of the emissions emitted during idle driving was further analyzed.

4.3 Results and Discussions

4.3.1 Target Area

In this research, we selected Jakarta, the capital city of Indonesia, as the target area. Jakarta can be considered to be representative of the research object because 37% of the car population is focused in the Jakarta area (Febri Ardani Saragih, 2016), with an area of 664.01km^2 and a population of 9,992,842 people in 2017 (Dickson, 2017)**.** On the other hand, Jakarta was named the world's worse city for traffic in one index last year based on satellite navigation data, which found that the average driver started and stopped more than 33,000 times in a year. An estimated 70% of the city's air pollution comes from vehicles (Mead, 2016).

4.3.2 Measurement results of idling time in a traffic jam

We conducted measurements of selected roads in Jakarta city. We sampled the road traffic condition using a speed-recording instrument as shown in Figure 4.4. We recorded the entire paths road driving speeds to calculate the idling time while travelling on a certain road.

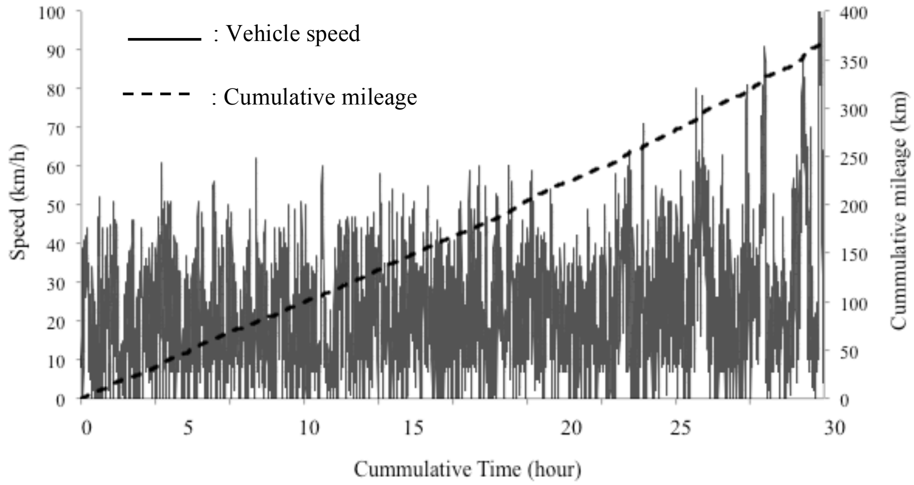
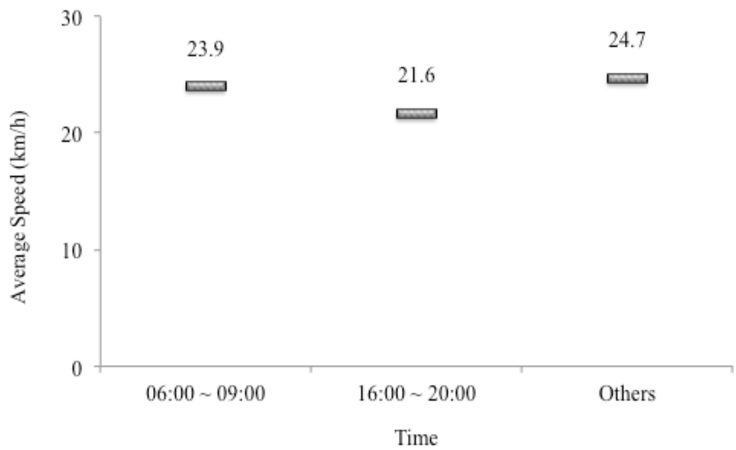


Figure 4. 4 Data measurement result - cumulative time and distance with average speed

We recorded the data as shown in Figure 4.4, with a total distance of 352 kilometers in the right-Y-axis, and a cumulative driving time of 29.9 hours in the X-axis, taken over a 10 day period. We filtered idling time by selecting when there was a car speed of less than 5 km/h, while considering that the idle driving fluctuated in the left-Y-axis. By accommodating equations (4.2) and (4.3), we calculated the lost travel distance TD_{lost}. Due to the time and financial limitations of this fieldwork, the travel distance was below the targeted 30% of the total road length. However, as a pioneer research study, we consider this data to be adequate.

From the results, the average speed was 23.9 km/h with the distribution for each time sampling shown in Figure 4.5 (a). The time periods of 06:00-09:00 and 16:00-20:00, described as the rush hours, had an average speed that was lower than the other time periods. The rush hour between 16:00-20:00 had the lowest average speed of 21.6 km/h and the time period 06:00-09:00 followed as the next lowest average speed. The highest average speed was 24.7 km/h. We estimate that the two rush hours contribute more traffic density, causing the average speed to go down compared to the other times.

(a)



(b)

(c)

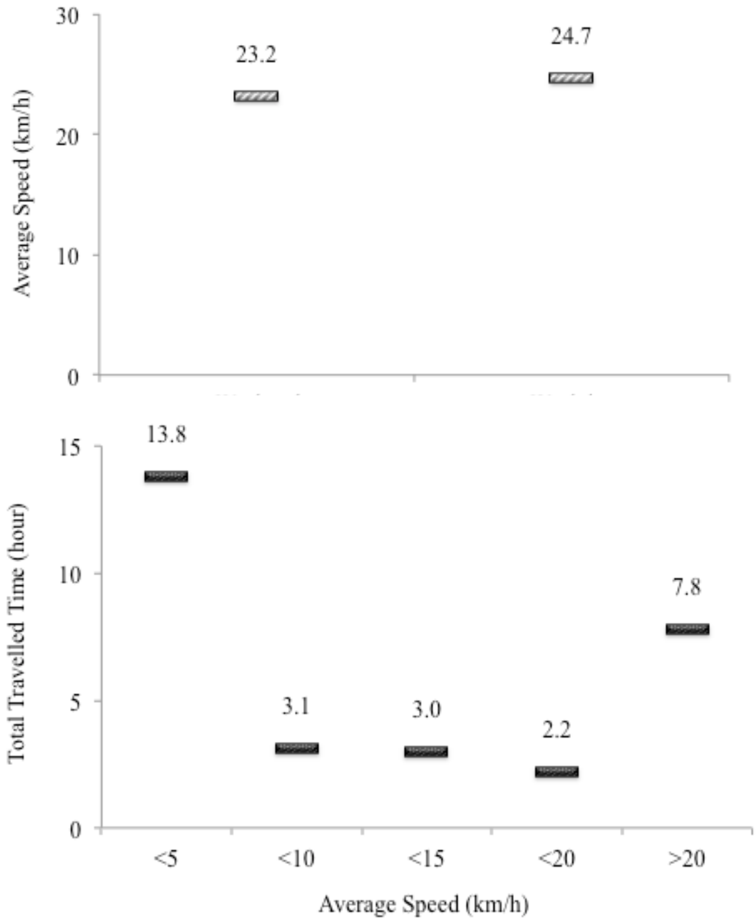


Figure 4. 5 Average speed in the different time periods. (b) Comparison of the average speed between the weekend and weekdays. (c) Total travel time for each average speed segment.

In Figure 4.5 (b), the weekday time was 6.3% slower compared to the weekend, with the weekday being 24.7 km/h and the weekend being 23.2 km/h. The weekend was shown to have a better traffic condition compared to the weekdays. We estimate that during the weekend, people travel with their family and use the car for leisure. During the weekdays, they prefer to use public transport due to the time taken and to avoid the time lost due to traffic jam conditions.

The distribution of the average speed has been shown in Figure 4.5 (c). The segment for the average speed >5 km/h showed the highest total travelled time compared to the others with a total traveled time of 13.8 hours down from the total travel time of 29.9 hours. The average speed <10 km/h was 3.1 hours, with <15 km/h for 3.0 hours, < 20km/h for 2.2 hours and >20 km/h for 7.8 hours. The average speed of <5 km/h dominated the traffic for more than 46% of the total travelled distance.

4.3.3 Emission estimation for the CO, HC, NO gases

The calculation of the total emissions lost was done by utilizing equation (4.4) for all vehicles registered in Jakarta city. The gas emissions of CO, NO, and HC have been shown in Figure 4.6. From Figure 4.6 (a), the amount of CO in 2020 shows that avoidable emissions during idle driving will reach more than 46.0% compared to the total emissions without the condition of idle driving. Avoidable emissions in 2020 will be more than double that in 2010 with more than a 41.65 thousand ton increase, which is more than 135.5%. A similar condition also occurs in 2030, with the emissions up by more than 138.3%, equivalent to 100.08 thousand tons compared to the amount of CO in 2020. The end of the projection in 2040 is approximately more than 5.7 times the condition in 2020, with a 338.54 tons difference. Compared with the normal condition that is not <5 km/h, idle driving in 2040 produces a 481.79 thousand ton difference, which is more than 46.0%. The condition becomes better if idle driving is expanded to <10 km/h. More than 10.0% of the contribution from the <10 km/h portions will be reduced.

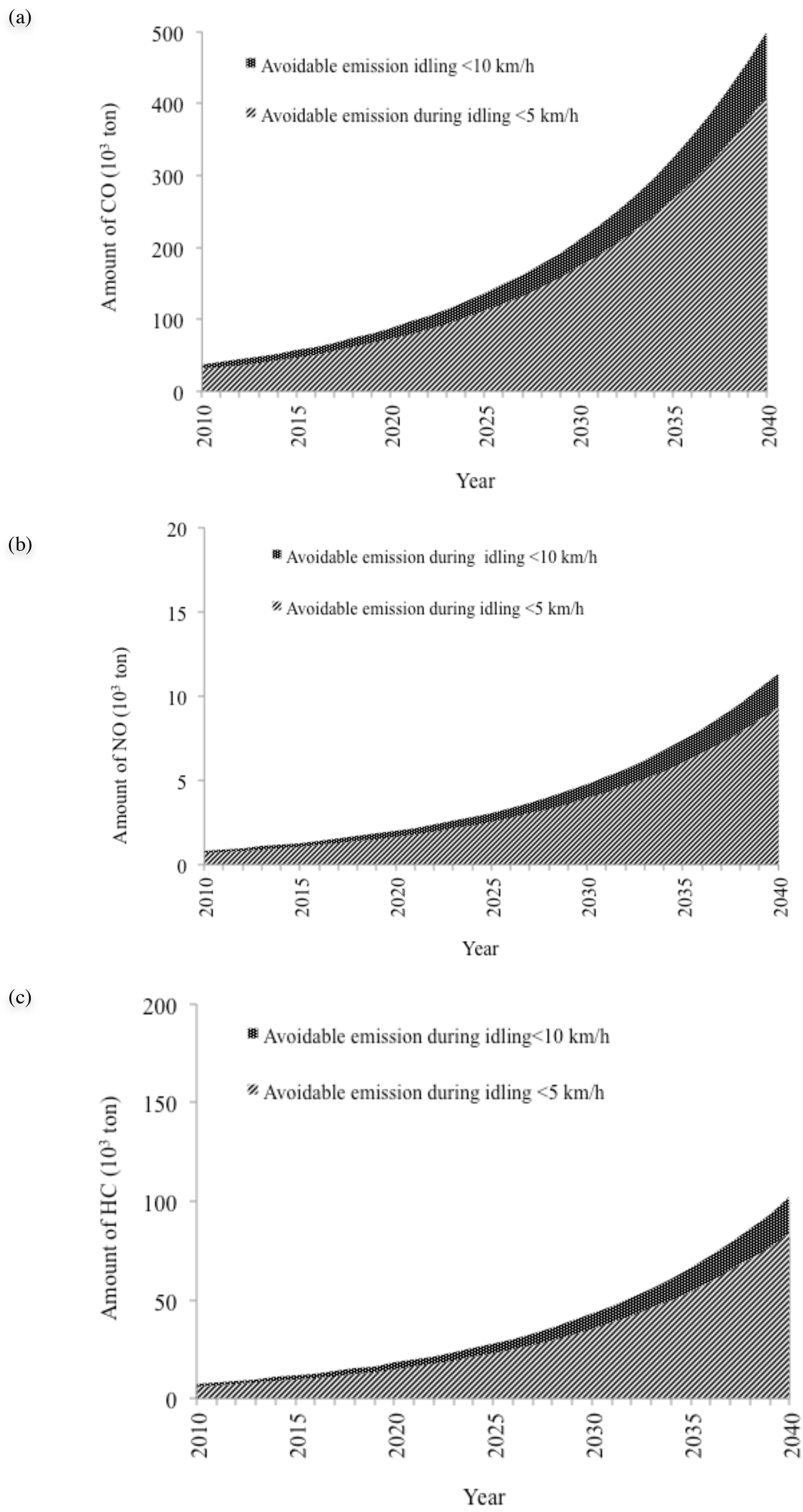


Figure 4. 6 Avoidable emissions of CO (a), NO (b), and HC (c) from the total emissions

NO and HC shows a similar portioning, with more than 46.0% of the NO and HC being released during idle driving in 2020 compared to the normal condition without idle driving. The avoidable emissions of NO and HC in 2030 were 138.3% compared to those in 2020, with an emission difference of 2,275 thousand tons and 20,472 thousand tons for NO and HC respectively. In 2040, the amount of NO and HC is up by 46.0% compared to the normal condition in the same year with a total difference of 10,950 thousand tons and 98,549 thousand tons for NO and HC respectively. The percentages of the avoidable emissions (CO, NO, HC) were determined by the percentage portion of the time lost during idle driving from when in the traffic jam condition.

4.4 Considerations of Policy Option

We have discussed the effevt of the emission occured during idling driving in case study of Jakarta city. We obtained contribution of the idling driving with idling definition vehicle speed less than 5 km/h, potentially contribute more than 46% and additional 10% from expanding idling driving to less than 10 km/h. From this result, reducing idling driving caused by car growth or unbalance between car growth and road infrastructure growth. Minimizing idling driving will reduce avoidable emission.

Controlling of the idling driving can be approached from technological approach such as introducing idle stop system to the vehicle to prevent gas emission occur during idling condition. It hibernates engine to work with minimum condition. Another way is education about engine emission friendly driving. For example, to switch off engine during traffic jam or traffic light.

4.5 Conclusion

In this paper, we focused on Jakarta city as one of busiest traffic centers in the world. We approached the problem by utilizing GPS technology to measure the actual traffic condition represented by idle driving time and calculated the potential avoidable emissions (CO, NO, HC) and their impact on the emission level of gasoline cars in Jakarta city as a future projection.

Traffic jams in Jakarta city contribute significant and avoidable emission levels. The average speed, by more than 46.0%, was dominated by <5 km/h. Expanding the condition of idle driving to <10 km will add a contribution of more than 10.0% to the time and distance lost to idle driving and emissions. In 2040, CO, NO and HC show similar tendencies with an emission difference of more than 46.0% or 481.79 thousand tons for CO, 2,275 thousand tons for NO, and 20,472 thousand tons for HC. Idle driving contributes a significant amount of emissions when in traffic jam conditions in Jakarta city. Due to the limited sample, increasing the size of the sample will potentially increase the accuracy of the calculation.

We strongly propose reducing these emissions by reducing the idling time. Implementing a technological approach and better idle driving education are two of the options available to solve the problem. The technology option will potentially eliminate emissions, such as implementing an idling stop system. Idle driving education can help drivers to avoid unnecessary emissions. For example, by turning off the engine while in an idle condition or turning off other connected electronic devices on board to reduce the load of the engine. Furthermore, considering more complex factors could increase the benefits of this research, such as the habits of drivers during a traffic jam, diesel engine contribution, or measuring the actual amount of emissions from the exhaust pipe. Improving the average speed is estimated as being able to significantly reduce gas emissions. However, it requires a huge budget and lead-time. Therefore, comprehensive planning and a roadmap become key to these improvements.

CHAPTER 5 Conclusions and Recommendation

5.1 Summary

Considering explanation from chapter 1 until chapter 3 with three main topics, we conclude as follows:

1. Implementation of LCGC policy has potentially big impact in the change of emission level of emission gas CO, HC and NO. Improvement of the fuel consumption of LCGC car is not balanced compare to the rapid growth of LCGC car from new annual income segment that could not buy car in the past. Controlling car growth is one way to stabilize the emission increase condition. Motivating economical growth and controlling car growth should be balanced. Accelerating old car with higher emission level due to catalytic deterioration is also one way that can support to balance controlling car growth. Introducing technology to avoid unnecessary emission is also one thing that can be considered and studied.
2. Non-euro cars produce a significant emission contribution to the current level, even though its portion is only 24.0% out of the total stock. The individual difference between euro and non-euro cars is one of the main reasons for this significant reduction. Retirement of non-euro car gave significant contribution to the reduction of the emission for gasoline passenger car. Therefore, controlling car age limit is one of the options to control the higher emission from elder vehicle.
3. Traffic jam in Jakarta city contribute high idle driving with average speed, by more than 46.0%, was dominated by <5 km/h, and additional 10% from <10 km/h. Idling driving contributes a significant amount of avoidable emission levels. Lost emission can be eliminated if vehicle could be maintained without emission during idling condition (stop in traffic jam). Reducing idling driving, implementing a technological approach for better idling driving to avoid unecessary emissions, for example Idle Stop system and education about driving behavior. (e.g switch off engine during traffic jam or traffic light) are several options to prevent and improve.

5.2 Limitation of Study

This research has several limitations. Several assumptions have taken to simplify the calculation or estimation. Car ownership modeling was constructed with simplified 30% allocation for car loan, neglecting detail and complex factors of the customer consuming behavior. Car projection modeling was also assumed every people who has fulfilled annual minimum income will own one unit of car without considering repeated buyer and multiple number of car owning. In emission calculation, gas emission calculation was also calculated based on regulation standard. Variation of the emission factor was not included, for example emission factor for each vehicle speed, temperature, and customer driving behavior. Those assumptions cannot be avoided due to data or references limitation. The scope of the research is also determined with minimum data sample. For example, data sample location, number of sample, or respondent variation because of the financial and time reason.

However, the modeling approach is one of the pioneers research on this field, especially in Indonesia. We expect the research on the field will continue to increase the benefit of this research to the society.

5.3 Contribution of Study

The results of this research have several important contributions as shown on Table 5.1, particularly to Indonesia as one of the developing country in South Asia. Those new contributions are:

1. We have constructed car ownership model to estimate car population after LCGC policy was implemented. The car population determines the emission level in the future.
2. It clarified that existence of the old vehicle cannot be neglected. Because it contributes higher emission

compare to the modern vehicle. It supports the authority to take an action to reduce those emissions. Pre survey analysis was done to predict people's willingness to change their elder car.

3. Actual measurement was conducted by utilizing GPS technology to calculate idling driving time. It also gives an option that technological approach can be one solution to control the emission growth in the limited condition. For example idling stop system to reduce idling emission during traffic jam in the big city such as Jakarta, Surabaya, Medan, and Makassar.

Table 5. 1 Result and new contributions

	Previous Related Work	Method/Pre-study	CURRENT RESEARCH		
			METHOD		NEW OUTPUT (ORIGINALITY)
Topic 1	It is empirically confirmed that emission reduction policy by new vehicle emission standard regulation (Nugroho & Fujiwara, 2005)	Study euro 2 standard implentation effect Case study : Jakarta by sampling car counting	Car ownership model	Considering deterioration factor	Emission level (CO, HC, NO) level
Topic 2	Accelerating the retirement of older vehicles through an incentive program had a positive effect on the reduction of emissions. France (Yamamoto et al., 2004), Ireland (Hennessy and Richard, 2011), Germany (Böckers et al., 2012) and Greece (Nicholas, 1999),	Willingness to change determined by trial	Pre survey to know willingness	Considering deterioration factor	Emission level (CO, HC, NO) level
Topic 3	It has discussed the impact of idle driving on emissions (CO, NO, HC. (Shancita et al., 2014)	Theoritical work	Actual measurement		Lost emission (CO, HC, NO) level

From the discussion results, we strongly recommend following items and step improvement as shown on Figure 5.1.

1. Positive impacts taken from scrappage incentive program and potential idling driving reduction are options that can be adopted.

2. Two-step improvements are recommended to implement, step 1 is introducing scrappage incentive program, and step 2 is introducing idling stop system to prevent unnecessary emission during traffic jam condition.

3. Comprehensive policy is still necessary to study, to control the emission increase. Controlling car growth is also one way to stabilize the emission increase condition. Motivating economical growth and controlling car growth should be balanced. To reach ideal condition, accelerating old car with higher emission level due to catalytic deterioration is also one way that can support to balance controlling car growth. From automobile industry, introducing technology to avoid unnecessary emission (e.g during traffic jam) or improving emission improvement (e.g Hybrid car technology) is also several ways that can be considered and further studied.

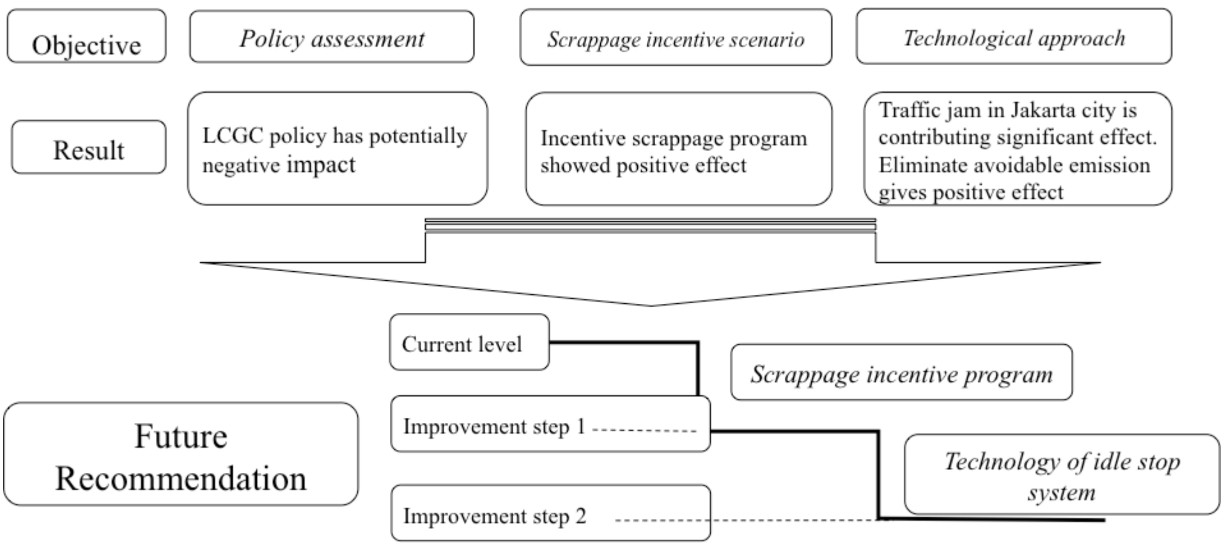


Figure 5. 1 Summary result and recommendations

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Appendix

1. Annual income data for each segment range

Year	Segmented annual income (USD)									
	<350	350-550	550-800	800-1,100	1,100-1,600	1,600-2,500	2,500-4,500	4500-10,000	10,000-25,000	Number of population (person)
2001	61,563,297	55,637,296	37,991,127	22,108,240	15,453,941	10,841,285	6,298,447	1,789,349	273,433	
2002	59,280,830	56,454,213	39,280,328	23,177,571	16,497,223	11,411,351	6,713,565	1,912,748	295,479	
2003	56,261,173	57,792,129	40,734,737	24,426,667	17,505,025	11,971,057	7,079,124	2,044,644	314,936	
2004	51,762,955	58,313,333	43,852,995	26,134,350	18,665,590	12,481,055	7,477,405	2,250,078	337,763	
2005	49,266,481	58,339,116	45,647,601	27,622,177	19,873,903	13,125,414	7,767,610	2,459,172	359,464	
2006	47,277,486	58,412,124	47,486,858	28,927,948	20,899,609	13,533,966	8,143,882	2,628,315	378,257	
2007	43,759,024	57,727,670	49,566,016	30,684,968	22,815,607	14,324,131	8,780,779	2,880,755	410,472	
2008	39,854,424	56,939,949	51,043,453	32,869,913	24,996,576	15,246,168	9,584,503	3,224,333	456,589	
2009	35,556,408	56,371,225	52,428,029	35,238,908	26,990,402	16,473,660	10,345,458	3,550,136	501,211	
2010	32,783,380	55,967,522	53,316,700	36,979,732	28,546,563	17,627,007	11,041,230	3,835,155	543,914	
2011	30,320,772	55,024,516	54,281,312	38,531,998	30,145,832	18,905,756	11,817,828	4,140,082	593,973	
2012	27,773,853	53,309,946	55,298,125	40,098,385	32,030,550	20,445,460	12,701,055	4,503,367	658,029	
2013	25,021,142	50,644,698	55,781,005	42,059,085	34,556,602	22,241,477	13,682,857	5,082,474	742,673	
2014	22,751,578	48,176,413	55,873,943	43,717,340	36,962,870	24,106,752	14,656,700	5,673,631	830,615	
2015	19,915,495	45,888,741	55,175,319	45,230,126	39,825,501	26,531,285	15,778,985	6,351,079	938,585	

(Source: Global Income Distribution Database, Database taken from UN National Bank, 2015)

2. Car population data

Year	Non Euro car	Euro car
1987	1,170,103	0
1988	1,073,106	0
1989	1,182,253	0
1990	1,313,210	0
1991	1,494,607	0
1992	1,590,750	0
1993	1,700,454	0
1994	1,890,340	0
1995	2,107,299	0
1996	2,409,088	0
1997	2,639,523	0
1998	2,769,375	0
1999	2,897,803	0
2000	3,038,913	0
2001	3,038,913	150,406
2002	3,038,913	364,520
2003	3,038,913	753,597
2004	3,038,913	1,192,988
2005	3,038,913	2,037,317
2006	3,038,913	2,996,378
2007	3,038,913	3,838,316
2008	3,038,913	4,450,939
2009	3,038,913	4,871,494
2010	3,038,913	5,852,128
2011	3,038,913	6,509,953
2012	3,038,913	7,393,346

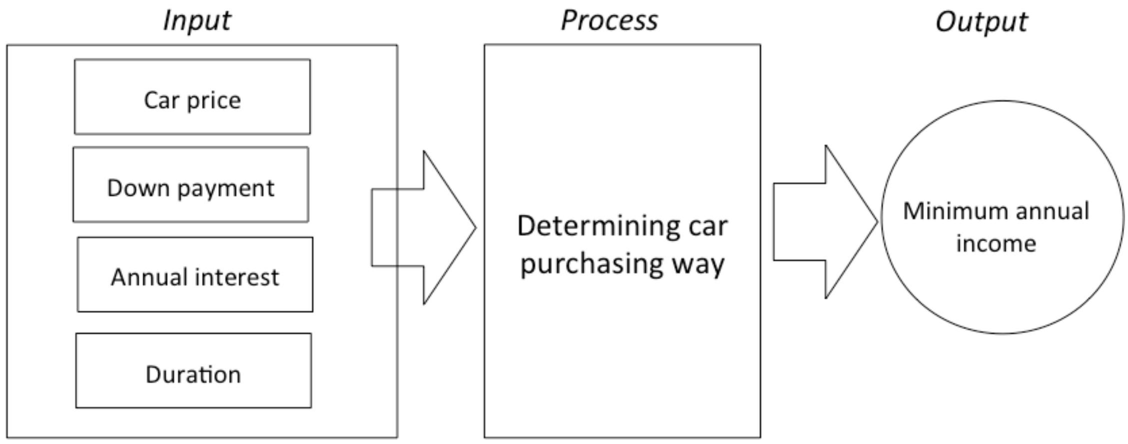
(Source: Central Bureau of Statistics Report 2013. Central Bureau of Statistics Report , 2013)

3. Car ownership model and its original calculation

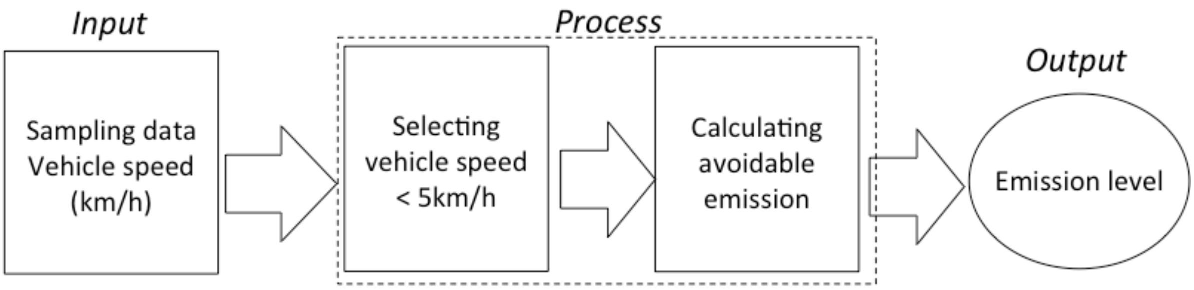
Elements	LCGC scenario (5 years loan)	Non-LCGC scenario (5 years loan)	
Average price (USD)	9,500	20,000	-
Downpayment (%)	30	30	Bank of Indonesia regulation
Downpayment amount (DP) (USD)	2,850	6,000	DP= Average Price ・ Downpayment
Annual interest rate (%)	12.42	12.42	
Duration (N) (Months)	60	60	
Borrowing amount (BM) (USD)	6,650	14,000	BM = average price - DP
Interest payment (I) (USD)	826	1,739	I= BM x annual interest rate
Monthly installment (M) (USD)	125	262	M = (BM/N) + (I/N)
Monthly income eligible (ME) (USD)	415	787	ME = M ・ 30% (30% for car loan allocation)
Minimum annual income (AM) (USD)	4,984	9,443	AM = ME ・12

(Source: Calculation)

4. Car ownership model input-output



5. Idling driving measurement input-output



6. Sample survey data

6.1 Distribution questionnaire

	Total	Jakarta	Medan	Surabaya
Total	200	100	50	50
Jakarta	50	100	0	0
Medan	25	0	100	0
Surabaya	25	0	0	100

6.2 Sex distribution

	Total	Jakarta	Medan	Surabaya
Total	200	100	50	50
Man	57.5	57	58	58
Woman	42.5	43	42	42

6.3 Income distribution

	Total	Jakarta	Medan	Surabaya
Total	200	100	50	50
Rp 3.000.001 - Rp 5.000.000	32.5	33	32	32
Rp 5.000.0001 - Rp 10.000.000	48.5	44	52	54
> Rp 10.000.000	19	23	16	14

6.4 Car age distribution

	Total	Jakarta	Medan	Surabaya
Total	120	60	30	30
< 1999	25	25	26.66667	23.33333
2000 - 2005	20.83333	20	20	23.33333
2006 - 2010	20.83333	21.66667	20	20
2011 - Now	33.33333	33.33333	33.33333	33.33333

6.5 Car by brand

	Total	Jakarta	Medan	Surabaya
Total	170	85	43	42
Cherokee Jeep	0.588235	1.176471	0	0
Audi A6	0.588235	1.176471	0	0
Mercy E300 AMG	0.588235	1.176471	0	0
Suzuki Baleno	0.588235	1.176471	0	0
Dauhatsu Hiline	0.588235	0	2.325581	0
Daihatsu Taruna	1.176471	0	4.651163	0
Daihatsu Zenia	4.117647	2.352941	2.325581	9.52381
Daihatsu Zebra	0.588235	0	0	2.380952
Toyota Avanza	8.235294	5.882353	11.62791	9.52381
Toyota Innova	5.882353	4.705882	0	14.28571
Toyota Vios	0.588235	1.176471	0	0
Toyota Camry	1.176471	2.352941	0	0
Toyota Harrier	0.588235	1.176471	0	0
Toyota Previa	0.588235	1.176471	0	0
Toyota Estimo	0.588235	1.176471	0	0
Toyota Mark	0.588235	1.176471	0	0
Toyota Fortuner	3.529412	0	9.302326	4.761905
Toyota Krista	1.764706	0	2.325581	4.761905
Toyota Rush	1.764706	0	2.325581	4.761905
Toyota Kijang LGX	1.764706	1.176471	0	4.761905
Toyota Rover	0.588235	0	2.325581	0
Toyota Yaris	1.176471	1.176471	2.325581	0
Toyota Dyna	2.941176	1.176471	4.651163	4.761905
Toyota Twincame	0.588235	0	2.325581	0
Toyota Kijang kapsul	0.588235	0	2.325581	0
Unknown	0.588235	1.176471	0	0
Honda Brio	0.588235	1.176471	0	0
Honda Oddysey	0.588235	1.176471	0	0
Honda CRV	1.176471	1.176471	2.325581	0
Honda City	0.588235	0	2.325581	0
Unknown	0.588235	1.176471	0	0
Mitsubishi	1.764706	2.352941	0	2.380952
Mitsubishi Pajero	3.529412	3.529412	4.651163	2.380952
Mitsubishi Grandis	1.176471	2.352941	0	0
Mitsubishi FN 517 M	0.588235	1.176471	0	0
Mitsubishi FP 415 D	1.176471	2.352941	0	0
Mitsubishi FE 114	0.588235	1.176471	0	0
Mitsubishi Fuso	1.176471	0	4.651163	0
Mitsubishi Colt Diesel PS	1.764706	1.176471	4.651163	0
Mitsubishi Lancer	0.588235	1.176471	0	0
Lexus RX 300	0.588235	1.176471	0	0
Lexus GS	1.176471	2.352941	0	0
Toyota Corolla	1.764706	3.529412	0	0
Toyota Kijang LGX	1.176471	2.352941	0	0
Hino Econo Diesel	1.176471	2.352941	0	0
Hino RKS	2.941176	2.352941	0	7.142857
Hino Ranger	1.176471	0	0	4.761905
Hino Dutro	0.588235	0	0	2.380952

Hino	2.941176	5.882353	0	0
Nissan Serena	1.764706	2.352941	0	2.380952
Nissan Ck 12	0.588235	0	0	2.380952
Nissan Terrano	0.588235	1.176471	0	0
VW Comby	0.588235	1.176471	0	0
Cherry QQ	0.588235	1.176471	0	0
BMW 320i	1.764706	3.529412	0	0
BMW 318i	0.588235	1.176471	0	0
Peugeot 206	0.588235	1.176471	0	0
Mercy A500	0.588235	0	2.325581	0
Mercy OH	0.588235	0	2.325581	0
Mercy c180	0.588235	1.176471	0	0
Unknown	1.764706	3.529412	0	0
Izusu NHR	0.588235	0	0	2.380952
Izusu Panther	2.941176	2.352941	6.976744	0
Izusu ELF	1.764706	0	4.651163	2.380952
Izusu Byson	0.588235	0	2.325581	0
Scania	0.588235	1.176471	0	0
Ford Ranger	0.588235	0	2.325581	0
Ford Everest	0.588235	0	2.325581	0
Suzuki Ertiga	2.352941	0	0	9.52381
Suzuki Carry	0.588235	0	0	2.380952
Suzuki Sedan	0.588235	0	2.325581	0
Suzuki Karimun	1.764706	3.529412	0	0
Suzuki SX 4	0.588235	1.176471	0	0
Daihatsu Sirion	0.588235	1.176471	0	0
Daihatsu Ayla	0.588235	1.176471	0	0
Daihatsu Roky	0.588235	0	2.325581	0
Unknown	0.588235	0	2.325581	0
Unknown	1.764706	2.352941	2.325581	0

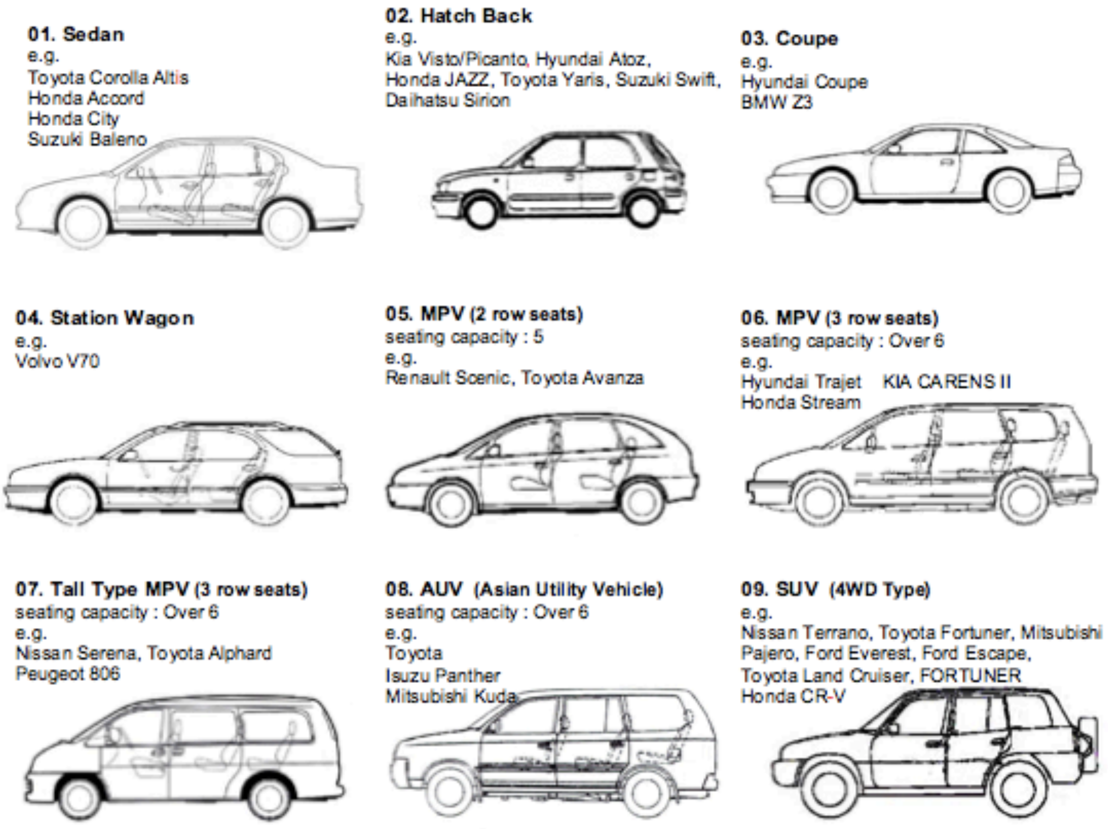
6.6 Willingness to change to LCGC car

Annual Income	Willingness to change with LCGC	
	Yes	No
USD3,600-USD6,000	65%	35%
USD6,000-USD12,000	80%	20%
USD12,000-	100%	0%
Average percentage (%)	**82%**	18%

6.7 Willingness to change to LCGC car by certain incentive

Car Year	Total	Willingness to change with LCGC (with incentive)					Not Willing
		USD500	USD500-USD1,000	USD1,100-USD1,500	USD1,600-USD2,000	> USD2,000	
2001	4	0	0	0	0	4	0
2000	4	0	0	1	0	2	1
1999	13	0	0	1	0	9	3
1998	5	0	0	0	0	3	2
1997	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0
1995	2	0	0	0	0	2	0
1994	1	0	0	0	0	1	0
1992	2	0	0	0	0	0	2
1991	1	0	0	0	0	1	0
<1990	4	0	0	0	1	3	0
Total	36	0	0	2	1	25	12
		Percentage from total				**78%**	22%

6.8 Guidance for survey



7. Car population after LCGC policy implemented

Year	Annual Income Population by segment (USD) 4,500-10,000 (LCGC segment) (Growth 9.0%)	Annual Income Population by segment (USD) 10,000-25,000 (Non-LCGC segment) (Growth 9.1%)	Car population after LCGC policy: Stock Car (SC) SC= NA + NB +NE (unit)	Non-euro car (NE) (unit)	LCGC Car (NA) (unit)	Non-LCGC car (NB) (unit)
2005	2,459,172	359,464	7,535,402	3,038,913	2,459,172	2,037,317
2006	2,628,315	378,257	8,663,606	3,038,913	2,628,315	2,996,378
2007	2,880,755	410,472	9,757,984	3,038,913	2,880,755	3,838,316
2008	3,224,333	456,589	10,714,185	3,038,913	3,224,333	4,450,939
2009	3,550,136	501,211	11,460,543	3,038,913	3,550,136	4,871,494
2010	3,835,155	543,914	12,726,196	3,038,913	3,835,155	5,852,128
2011	4,140,082	593,973	13,688,948	3,038,913	4,140,082	6,509,953
2012	4,503,367	658,029	14,935,626	3,038,913	4,503,367	7,393,346
2013	5,082,474	742,673	16,257,406	3,038,913	5,082,474	8,136,019
2014	5,673,631	830,615	16,936,505	3,038,913	5,673,631	8,223,961
2015	6,351,079	938,585	17,721,923	3,038,913	6,351,079	8,331,931
2016	6,925,061	1,024,298	18,381,618	3,038,913	6,925,061	8,417,644
2017	7,550,918	1,117,838	19,101,015	3,038,913	7,550,918	8,511,184
2018	8,233,336	1,219,921	19,885,516	3,038,913	8,233,336	8,613,267
2019	8,977,428	1,331,326	20,741,013	3,038,913	8,977,428	8,724,672
2020	9,788,769	1,452,904	21,673,932	3,038,913	9,788,769	8,846,250
2021	10,673,434	1,585,586	22,691,279	3,038,913	10,673,434	8,978,932
2022	11,638,052	1,730,384	23,800,694	3,038,913	11,638,052	9,123,730
2023	12,689,847	1,888,405	25,010,511	3,038,913	12,689,847	9,281,751
2024	13,836,699	2,060,857	26,329,815	3,038,913	13,836,699	9,454,203
2025	15,087,199	2,249,057	27,768,515	3,038,913	15,087,199	9,642,403
2026	16,450,713	2,454,444	29,337,416	3,038,913	16,450,713	9,847,790
2027	17,937,455	2,678,588	31,048,302	3,038,913	17,937,455	10,071,934
2028	19,558,563	2,923,200	32,914,022	3,038,913	19,558,563	10,316,546
2029	21,326,179	3,190,151	34,948,589	3,038,913	21,326,179	10,583,497
2030	23,253,544	3,481,480	37,167,284	3,038,913	23,253,544	10,874,826

8. Gas emission after LCGC implemented

Year	Car population (unit)				Total Emission (E) (ton) $E = ATD \cdot EF \cdot DF \cdot SC$								
					Amount of emission of non-euro car (ton)			Amount of emission of LCGC car (ton)			Amount of emission of non-LCGC car (ton)		
	Stock Car (SC) SC= NA + NB +NE (unit)	Non-euro car (NE) (unit)	LCGC Car (NA) (unit)	Non-LCGC car (NB) (unit)	CO	HC	NO	CO	HC	NO	CO	HC	NO
2005	7,535,402	3,038,913	2,459,172	2,037,317	2,352,574	331,059	84,543	36,717	7,510	834	30,418	6,221	691
2006	8,663,606	3,038,913	2,628,315	2,996,378	2,352,574	331,059	84,543	50,487	10,326	1,148	57,557	11,772	1,309
2007	9,757,984	3,038,913	2,880,755	3,838,316	2,352,574	331,059	84,543	67,661	13,838	1,539	90,151	18,437	2,051
2008	10,714,185	3,038,913	3,224,333	4,450,939	2,352,574	331,059	84,543	89,525	18,309	2,037	123,582	25,274	2,812
2009	11,460,543	3,038,913	3,550,136	4,871,494	2,352,574	331,059	84,543	113,759	23,265	2,589	156,101	31,924	3,553
2010	12,726,196	3,038,913	3,835,155	5,852,128	2,352,574	331,059	84,543	139,300	28,488	3,171	212,561	43,471	4,839
2011	13,688,948	3,038,913	4,140,082	6,509,953	2,352,574	331,059	84,543	168,089	34,376	3,827	264,306	54,053	6,017
2012	14,935,626	3,038,913	4,503,367	7,393,346	2,352,574	331,059	84,543	202,105	41,332	4,602	331,803	67,856	7,555
2013	16,257,406	3,038,913	5,082,474	8,136,019	2,352,574	331,059	84,543	249,839	51,094	5,689	399,941	81,791	9,107
2014	16,936,505	3,038,913	5,673,631	8,223,961	2,352,574	331,059	84,543	303,172	62,000	6,904	439,449	89,870	10,007
2015	17,721,923	3,038,913	6,351,079	8,331,931	2,352,574	331,059	84,543	366,543	74,960	8,347	480,865	98,339	10,951
2016	18,381,618	3,038,913	6,925,061	8,417,644	2,352,574	331,059	84,543	429,297	87,793	9,777	521,825	106,716	11,884
2017	19,101,015	3,038,913	7,550,918	8,511,184	2,352,574	331,059	84,543	500,400	102,334	11,397	564,037	115,348	12,846
2018	19,885,516	3,038,913	8,233,336	8,613,267	2,352,574	331,059	84,543	580,849	118,786	13,229	607,652	124,267	13,840
2019	20,741,013	3,038,913	8,977,428	8,724,672	2,352,574	331,059	84,543	671,751	137,375	15,300	652,838	133,508	14,869
2020	21,673,932	3,038,913	9,788,769	8,846,250	2,352,574	331,059	84,543	774,341	158,355	17,637	699,783	143,108	15,939
2021	22,691,279	3,038,913	10,673,434	8,978,932	2,352,574	331,059	84,543	889,986	182,004	20,272	748,693	153,110	17,054
2022	23,800,694	3,038,913	11,638,052	9,123,730	2,352,574	331,059	84,543	1,020,210	208,635	23,239	799,801	163,561	18,218
2023	25,010,511	3,038,913	12,689,847	9,281,751	2,352,574	331,059	84,543	1,166,703	238,593	26,576	853,363	174,515	19,439
2024	26,329,815	3,038,913	13,836,699	9,454,203	2,352,574	331,059	84,543	1,331,342	272,262	30,327	909,666	186,028	20,722
2025	27,768,515	3,038,913	15,087,199	9,642,403	2,352,574	331,059	84,543	1,516,211	310,068	34,539	969,028	198,168	22,074
2026	29,337,416	3,038,913	16,450,713	9,847,790	2,352,574	331,059	84,543	1,723,620	352,483	39,265	1,031,800	211,005	23,505
2027	31,048,302	3,038,913	17,937,455	10,071,934	2,352,574	331,059	84,543	1,956,135	400,032	44,562	1,098,376	224,619	25,022
2028	32,914,022	3,038,913	19,558,563	10,316,546	2,352,574	331,059	84,543	2,216,599	453,297	50,496	1,169,189	239,100	26,635
2029	34,948,589	3,038,913	21,326,179	10,583,497	2,352,574	331,059	84,543	2,508,166	512,922	57,139	1,244,722	254,547	28,356
2030	37,167,284	3,038,913	23,253,544	10,874,826	2,352,574	331,059	84,543	2,834,328	579,622	64,570	1,325,511	271,068	30,197

9. Gas emission CO_2 after LCGC implementation

Year	Car Population (unit)				Total of CO_2 emission (GC) (ton) $GC = GCA + GCB + GCE$				
	Stock Car (SC) $SC = NA + NB + NE$ (unit)	Non-euro car (NE) (unit)	LCGC Car (NA) (unit)	Non-LCGC car (NB) (unit)	Non-LCGC Car (GCB) $GCB = FCB \cdot NB \cdot EF$	Non-euro (GCE) $GCE = FCB \cdot NE \cdot EF$	LCGC car (GCA) $GCA = FCA \cdot NA \cdot EF$	LCGC car with non-LCGC spec $FCB \cdot NA \cdot EF$	Saving portion of LCGC policy (SCO) $SCO = [(FCB - FCA)] NA \cdot EF$
2005	7,535,402	3,038,913	2,459,172	2,037,317	5,740,344	8,562,441	3,753,188	6,928,963	-3,175,775
2006	8,663,606	3,038,913	2,628,315	2,996,378	8,442,595	8,562,441	4,011,334	7,405,540	-3,394,206
2007	9,757,984	3,038,913	2,880,755	3,838,316	10,814,839	8,562,441	4,396,608	8,116,815	-3,720,207
2008	10,714,185	3,038,913	3,224,333	4,450,939	12,540,966	8,562,441	4,920,977	9,084,881	-4,163,904
2009	11,460,543	3,038,913	3,550,136	4,871,494	13,725,921	8,562,441	5,418,218	10,002,863	-4,584,646
2010	12,726,196	3,038,913	3,835,155	5,852,128	16,488,956	8,562,441	5,853,214	10,805,933	-4,952,719
2011	13,688,948	3,038,913	4,140,082	6,509,953	18,342,444	8,562,441	6,318,593	11,665,095	-5,346,502
2012	14,935,626	3,038,913	4,503,367	7,393,346	20,831,492	8,562,441	6,873,039	12,688,687	-5,815,648
2013	16,257,406	3,038,913	5,082,474	8,136,019	22,924,047	8,562,441	7,756,872	14,320,379	-6,563,507
2014	16,936,505	3,038,913	5,673,631	8,223,961	23,171,833	8,562,441	8,659,096	15,986,023	-7,326,927
2015	17,721,923	3,038,913	6,351,079	8,331,931	23,476,049	8,562,441	9,693,017	17,894,800	-8,201,783
2016	18,381,618	3,038,913	6,925,061	8,417,644	23,717,554	8,562,441	10,569,029	19,512,053	-8,943,024
2017	19,101,015	3,038,913	7,550,918	8,511,184	23,981,113	8,562,441	11,524,211	21,275,466	-9,751,255
2018	19,885,516	3,038,913	8,233,336	8,613,267	24,268,741	8,562,441	12,565,718	23,198,248	-10,632,530
2019	20,741,013	3,038,913	8,977,428	8,724,672	24,582,635	8,562,441	13,701,351	25,294,802	-11,593,451
2020	21,673,932	3,038,913	9,788,769	8,846,250	24,925,195	8,562,441	14,939,619	27,580,834	-12,641,216
2021	22,691,279	3,038,913	10,673,434	8,978,932	25,299,038	8,562,441	16,289,795	30,073,468	-13,783,673
2022	23,800,694	3,038,913	11,638,052	9,123,730	25,707,021	8,562,441	17,761,994	32,791,374	-15,029,380
2023	25,010,511	3,038,913	12,689,847	9,281,751	26,152,261	8,562,441	19,367,245	35,754,913	-16,387,669
2024	26,329,815	3,038,913	13,836,699	9,454,203	26,638,162	8,562,441	21,117,570	38,986,284	-17,868,713
2025	27,768,515	3,038,913	15,087,199	9,642,403	27,168,435	8,562,441	23,026,083	42,509,691	-19,483,608
2026	29,337,416	3,038,913	16,450,713	9,847,790	27,747,134	8,562,441	25,107,078	46,351,528	-21,244,450
2027	31,048,302	3,038,913	17,937,455	10,071,934	28,378,681	8,562,441	27,376,144	50,540,574	-23,164,430
2028	32,914,022	3,038,913	19,558,563	10,316,546	29,067,901	8,562,441	29,850,279	55,108,207	-25,257,928
2029	34,948,589	3,038,913	21,326,179	10,583,497	29,820,062	8,562,441	32,548,014	60,088,642	-27,540,627
2030	37,167,284	3,038,913	23,253,544	10,874,826	30,640,911	8,562,441	35,489,559	65,519,187	-30,029,627

9.1 Annual fuel consumption

Car type	Annual fuel consumption (AFC) (liter/year)
LCGC (FCA) $FCA = \frac{ATD}{20}$	650
Non LCGC $FCB = \frac{1}{n}\sum_{i=1}^{n} x_i$	1200

9.2 Emission factor CO_2

Emission factor (EF) $C0_2$ (kg-$C0_2$/liter)	0.002348

10. Emission factor with deterioration factor by mileage (euro car)

Year	Year (n)	Cummulative Annual Travel Distance (km)	Emission Factor (EF) (10^{-3} kg/km)			Deterioration factor (DF)
			CO	HC	NO	
2005	1	13,000	1.15	0.23	0.03	60% increase after 80,000 km
2006	2	26,000	1.48	0.30	0.03	
2007	3	39,000	1.81	0.37	0.04	
2008	4	52,000	2.14	0.44	0.05	
2009	5	65,000	2.46	0.50	0.06	
2010	6	78,000	2.79	0.57	0.06	
2011	7	91,000	3.12	0.64	0.07	
2012	8	104,000	3.45	0.71	0.08	
2013	9	117,000	3.78	0.77	0.09	
2014	10	130,000	4.11	0.84	0.09	
2015	11	143,000	4.44	0.91	0.10	
2016	12	156,000	4.77	0.98	0.11	
2017	13	169,000	5.10	1.04	0.12	
2018	14	182,000	5.43	1.11	0.12	
2019	15	195,000	5.76	1.18	0.13	
2020	16	208,000	6.09	1.24	0.14	
2021	17	221,000	6.41	1.31	0.15	
2022	18	234,000	6.74	1.38	0.15	
2023	19	247,000	7.07	1.45	0.16	
2024	20	260,000	7.40	1.51	0.17	
2025	21	273,000	7.73	1.58	0.18	
2026	22	286,000	8.06	1.65	0.18	
2027	23	299,000	8.39	1.72	0.19	
2028	24	312,000	8.72	1.78	0.20	
2029	25	325,000	9.05	1.85	0.21	
2030	26	338,000	9.38	1.92	0.21	

(Source: Calculation)

10.1 Emission factor for non euro car

Gas emission	Amount of gas emission (10-3 kg/km) (EF_2) non euro car
NO	2.1
HC	8.4
CO	59.5

11. Car distribution by car age

Year	Non Euro	Car age distribution (year)																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	>25
1988	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1989	1,182,253	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1990	1,313,210	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1991	1,494,607	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1992	1,590,750	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1993	1,700,454	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1994	1,890,340	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1995	2,107,299	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1996	2,409,088	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1997	2,639,523	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1998	2,769,375	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1999	2,897,803	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	0	
2000	3,038,913	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	0	
2001	3,038,913	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	0	
2002	3,038,913	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	0	
2003	3,038,913	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	0	
2004	3,038,913	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	0	
2005	3,038,913	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	0	
2006	3,038,913	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	0	
2007	3,038,913	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	0	
2008	3,038,913	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	0	
2009	3,038,913	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	0	
2010	3,038,913	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	0	
2011	3,038,913	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	0	
2012	3,038,913	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106	
2013	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	109,147	1,073,106
2014	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	130,957	1,182,253
2015	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	181,397	1,313,210
2016	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	96,143	1,494,607
2017	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	109,704	1,590,750
2018	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	189,886	1,700,454
2019	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	216,959	1,890,340
2020	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	301,789	2,107,299
2021	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	230,435	2,409,088
2022	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	129,852	2,639,523
2023	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	128,428	2,769,375
2024	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,110	2,897,803
2025	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,038,913
2026	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,038,913
2027	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,038,913
2028	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,038,913
2029	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,038,913
2030	3,038,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,038,913

Car Population (unit)

Source: Calculation)

12. Targeted scrappage car

Year	Targeted Scrappage car by age (NE)		Scrappaged car by age (NE)		Total Scrappaged car $NER = \left(\sum_{N=1} NE\right) \cdot WR$	Number of car (unit)
	24 year	>25 year	24 year	>25 year		
2005	0	0	0	0	0	
2006	0	0	0	0	0	
2007	0	0	0	0	0	
2008	0	0	0	0	0	
2009	0	0	0	0	0	
2010	0	0	0	0	0	
2011	0	0	0	0	0	
2012	0	0	0	0	0	
2013	109,147	1,073,106	69,810	686,359	756,169	
2014	130,957	426,084	83,760	272,523	356,283	
2015	181,397	200,758	116,022	128,405	244,426	
2016	96,143	137,729	61,493	88,091	149,584	
2017	109,704	84,287	70,167	53,910	124,077	
2018	189,886	69,914	121,451	44,717	166,168	
2019	216,959	93,632	138,767	59,887	198,654	
2020	301,789	111,937	193,024	71,595	264,619	
2021	230,435	149,107	147,386	95,369	242,755	
2022	129,852	136,787	83,053	87,489	170,542	
2023	128,428	96,097	82,143	61,463	143,606	
2024	141,110	80,919	90,254	51,756	142,010	
2025	0	80,019	0	51,180	51,180	
2026	0	28,839	0	18,445	18,445	
2027	0	10,394	0	6,648	6,648	
2028	0	3,746	0	2,396	2,396	
2029	0	1,350	0	863	863	
2030	0	487	0	311	311	

(Source: Calculation)

13. Non-euro scrappaged car by year

Year	Stock car (NA+NB+NAE)-NER	Euro car (NA+NB+NAE) (unit)	Non-euro car (NE) (unit)	Total Scrappaged car (NER)(NAE) (unit)	Cummulative scrappaged car (unit)	
2005	7,535,402	4,496,489	3,038,913	0	0	Number of car (unit)
2006	8,663,606	5,624,693	3,038,913	0	0	
2007	9,757,984	6,719,071	3,038,913	0	0	
2008	10,714,185	7,675,272	3,038,913	0	0	
2009	11,460,543	8,421,630	3,038,913	0	0	
2010	12,726,196	9,687,283	3,038,913	0	0	
2011	13,688,948	10,650,035	3,038,913	0	0	
2012	14,935,626	11,896,713	3,038,913	0	0	
2013	16,257,406	13,974,662	3,038,913	-756,169	-756,169	
2014	16,936,505	14,253,875	2,282,744	-356,283	-1,112,452	
2015	17,721,923	14,927,436	1,926,461	-244,426	-1,356,878	
2016	18,381,618	15,492,289	1,682,035	-149,584	-1,506,463	
2017	19,101,015	16,186,179	1,532,450	-124,077	-1,630,540	
2018	19,885,516	17,012,771	1,408,373	-166,168	-1,796,708	
2019	20,741,013	17,900,754	1,242,205	-198,654	-1,995,362	
2020	21,673,932	18,899,638	1,043,551	-264,619	-2,259,981	
2021	22,691,279	19,895,121	778,932	-242,755	-2,502,736	
2022	23,800,694	20,932,324	536,177	-170,542	-2,673,278	
2023	25,010,511	22,115,204	365,635	-143,606	-2,816,884	
2024	26,329,815	23,432,912	222,029	-142,010	-2,958,894	
2025	27,768,515	24,780,782	80,019	-51,180	-3,010,074	
2026	29,337,416	26,316,949	28,839	-18,445	-3,028,519	
2027	31,048,302	28,016,037	10,394	-6,648	-3,035,167	
2028	32,914,022	29,877,505	3,746	-2,396	-3,037,563	
2029	34,948,589	31,910,540	1,350	-863	-3,038,426	
2030	37,167,284	34,128,682	487	-311	-3,038,738	

(Source: Calculation)

14. Gas emission after scrappaged program implementation

Year	Amount of emission of LCGC car and non-LCGC (ton) E = ATD·EF ·DF ·SC			With scrappage program Amount of emission (ton) SC・EF_1/EF_2・ATD・DF			Without scrappage program Amount of emission (ton) SC・EF_1/EF_2・ATD・DF		
	CO	HC	NO	CO	HC	NO	CO	HC	NO
2005	67,135	13,731	1,526	2,419,551	344,593	85,989	2,419,551	344,593	85,989
2006	108,044	22,097	2,457	2,460,460	352,959	86,920	2,460,460	352,959	86,920
2007	157,811	32,275	3,590	2,510,228	363,137	88,054	2,510,228	363,137	88,054
2008	213,107	43,583	4,849	2,565,523	374,445	89,313	2,565,523	374,445	89,313
2009	269,860	55,189	6,142	2,622,277	386,051	90,605	2,622,277	386,051	90,605
2010	351,861	71,959	8,009	2,704,278	402,821	92,473	2,704,278	402,821	92,473
2011	432,395	88,428	9,844	2,784,811	419,290	94,307	2,784,811	419,290	94,307
2012	533,908	109,188	12,156	2,886,324	440,050	96,620	2,886,324	440,050	96,620
2013	649,780	132,884	14,795	3,002,197	463,746	99,259	3,002,197	463,746	99,259
2014	742,621	151,870	16,911	2,509,688	400,404	80,357	3,095,037	482,732	101,374
2015	847,408	173,299	19,298	2,338,677	383,043	72,842	3,199,824	504,161	103,761
2016	951,122	194,509	21,661	2,253,181	377,640	68,411	3,303,538	525,370	106,124
2017	1,064,437	217,682	24,243	2,250,704	384,527	66,835	3,416,854	548,543	108,706
2018	1,188,501	243,053	27,069	2,278,720	396,389	66,213	3,540,917	573,914	111,533
2019	1,324,590	270,883	30,170	2,286,178	406,128	64,696	3,677,006	601,745	114,633
2020	1,474,123	301,462	33,577	2,281,934	415,079	62,581	3,826,540	632,324	118,040
2021	1,638,679	335,114	37,326	2,241,649	419,920	58,975	3,991,096	665,976	121,789
2022	1,820,011	372,196	41,457	2,235,064	430,573	56,360	4,172,427	703,058	125,921
2023	2,020,067	413,108	46,015	2,303,104	452,916	56,178	4,372,483	743,969	130,479
2024	2,241,009	458,290	51,049	2,412,881	482,464	57,220	4,593,425	789,152	135,513
2025	2,485,238	508,235	56,613	2,547,181	516,947	58,838	4,837,655	839,097	141,077
2026	2,755,420	563,488	62,769	2,777,745	566,627	63,571	5,107,837	894,349	147,233
2027	3,054,511	624,651	69,584	3,062,556	625,783	69,873	5,406,927	955,513	154,047
2028	3,385,788	692,397	77,132	3,388,688	692,805	77,236	5,738,204	1,023,259	161,595
2029	3,752,887	767,469	85,496	3,753,932	767,616	85,533	6,105,304	1,098,331	169,959
2030	4,159,839	850,691	94,768	4,160,215	850,744	94,781	6,512,255	1,181,552	179,231

(Source: Calculation)

15. Actual measurement result and each idling driving emission calculation

Year	Car population in Jakarta(SC) (unit) Car growth: 9.0%	Annual Travelled Distance (ATD) (km)	Lost of Annual Travelled distance (km) $TD_{lost} = TD \cdot$ percentage of V_a		Total emisision before considering idling driving (ton)			Avoidable emission during idling (ton) $TD_{lost} \cdot SC \cdot EF$					
			Average idling speed (km/h)		Gas emission								
								CO		HC		NO	
			V_a:<5 (46% of VKT)	V_a:<10 (10% of VKT)	CO	HC	NO	<5 km/h	<10 km/h	<5 km/h	<10 km/h	<5 km/h	<10 km/h
2010	2,334,883	13,000	5,980	1,300	66,778	13,659	1,518	30,718	37,395	6,283	7,649	698	850
2011	2,541,351	13,000	5,980	1,300	72,683	14,867	1,652	33,434	40,702	6,839	8,325	760	925
2012	2,742,414	13,000	5,980	1,300	78,433	16,043	1,783	36,079	43,923	7,380	8,984	820	998
2013	3,010,403	13,000	5,980	1,300	86,098	17,611	1,957	39,605	48,215	8,101	9,862	900	1,096
2014	3,266,009	13,000	5,980	1,300	93,408	19,106	2,123	42,968	52,308	8,789	10,699	977	1,189
2015	3,562,236	13,000	5,980	1,300	101,880	20,839	2,315	46,865	57,053	9,586	11,670	1,065	1,297
2016	3,885,331	13,000	5,980	1,300	111,120	22,729	2,525	51,115	62,227	10,455	12,728	1,162	1,414
2017	4,237,730	13,000	5,980	1,300	121,199	24,791	2,755	55,752	67,871	11,404	13,883	1,267	1,543
2018	4,622,092	13,000	5,980	1,300	132,192	27,039	3,004	60,808	74,027	12,438	15,142	1,382	1,682
2019	5,041,316	13,000	5,980	1,300	144,182	29,492	3,277	66,324	80,742	13,566	16,515	1,507	1,835
2020	5,498,564	13,000	5,980	1,300	157,259	32,167	3,574	72,339	88,065	14,797	18,013	1,644	2,001
2021	5,997,283	13,000	5,980	1,300	171,522	35,084	3,898	78,900	96,052	16,139	19,647	1,793	2,183
2022	6,541,237	13,000	5,980	1,300	187,079	38,266	4,252	86,057	104,764	17,602	21,429	1,956	2,381
2023	7,134,527	13,000	5,980	1,300	204,047	41,737	4,637	93,862	114,267	19,199	23,373	2,133	2,597
2024	7,781,629	13,000	5,980	1,300	222,555	45,523	5,058	102,375	124,631	20,940	25,493	2,327	2,833
2025	8,487,422	13,000	5,980	1,300	242,740	49,651	5,517	111,661	135,935	22,840	27,805	2,538	3,089
2026	9,257,232	13,000	5,980	1,300	264,757	54,155	6,017	121,788	148,264	24,911	30,327	2,768	3,370
2027	10,096,863	13,000	5,980	1,300	288,770	59,067	6,563	132,834	161,711	27,171	33,077	3,019	3,675
2028	11,012,648	13,000	5,980	1,300	314,962	64,424	7,158	144,882	176,379	29,635	36,077	3,293	4,009
2029	12,011,495	13,000	5,980	1,300	343,529	70,267	7,807	158,023	192,376	32,323	39,350	3,591	4,372
2030	13,100,938	13,000	5,980	1,300	374,687	76,640	8,516	172,356	209,825	35,255	42,919	3,917	4,769
2031	14,289,193	13,000	5,980	1,300	408,671	83,592	9,288	187,989	228,856	38,452	46,811	4,272	5,201
2032	15,585,223	13,000	5,980	1,300	445,737	91,174	10,130	205,039	249,613	41,940	51,057	4,660	5,673
2033	16,998,802	13,000	5,980	1,300	486,166	99,443	11,049	223,636	272,253	45,744	55,688	5,083	6,188
2034	18,540,594	13,000	5,980	1,300	530,261	108,462	12,051	243,920	296,946	49,893	60,739	5,544	6,749
2035	20,222,226	13,000	5,980	1,300	578,356	118,300	13,144	266,044	323,879	54,418	66,248	6,046	7,361
2036	22,056,382	13,000	5,980	1,300	630,813	129,030	14,337	290,174	353,255	59,354	72,257	6,595	8,029
2037	24,056,895	13,000	5,980	1,300	688,027	140,733	15,637	316,493	385,295	64,737	78,810	7,193	8,757
2038	26,238,856	13,000	5,980	1,300	750,431	153,497	17,055	345,198	420,242	70,609	85,958	7,845	9,551
2039	28,618,720	13,000	5,980	1,300	818,495	167,420	18,602	376,508	458,357	77,013	93,755	8,557	10,417
2040	31,214,438	13,000	5,980	1,300	892,733	182,604	20,289	410,657	499,930	83,998	102,258	9,333	11,362

Source: Calculation)

16. Actual measurement of idling driving in Jakarta (sample recorded data)

No.	Time	Longitude	Latitude	Speed(Km/h)	Direction(Degree)	Location Type
1	2016-08-19 09:11:08	106.884498	-6.139178	11	14	satellite positioning
2	2016-08-19 09:11:18	106.884347	-6.138974	8	348	satellite positioning
3	2016-08-19 09:11:38	106.883964	-6.13888	8	283	satellite positioning
4	2016-08-19 09:12:08	106.883716	-6.138799	10	289	satellite positioning
5	2016-08-19 09:12:18	106.883591	-6.138703	11	324	satellite positioning
6	2016-08-19 09:12:20	106.8836	-6.138638	17	3	satellite positioning
7	2016-08-19 09:12:25	106.883671	-6.138419	20	18	satellite positioning
8	2016-08-19 09:12:30	106.883778	-6.138095	28	15	satellite positioning
9	2016-08-19 09:12:35	106.883867	-6.137736	31	13	satellite positioning
10	2016-08-19 09:12:40	106.883973	-6.137298	36	12	satellite positioning
11	2016-08-19 09:12:45	106.884062	-6.136877	31	11	satellite positioning
12	2016-08-19 09:12:50	106.884098	-6.13661	13	13	satellite positioning
13	2016-08-19 09:12:55	106.884204	-6.136327	34	15	satellite positioning
14	2016-08-19 09:13:00	106.884329	-6.135848	39	14	satellite positioning
15	2016-08-19 09:13:05	106.884391	-6.135437	29	11	satellite positioning
16	2016-08-19 09:13:15	106.884533	-6.134804	15	27	satellite positioning
17	2016-08-19 09:13:17	106.884578	-6.134754	15	65	satellite positioning
18	2016-08-19 09:13:20	106.884702	-6.134765	22	105	satellite positioning
19	2016-08-19 09:13:25	106.885058	-6.134864	27	105	satellite positioning
20	2016-08-19 09:13:30	106.885298	-6.134945	13	102	satellite positioning
21	2016-08-19 09:13:35	106.885547	-6.135009	21	106	satellite positioning
22	2016-08-19 09:13:40	106.885876	-6.135098	26	104	satellite positioning
23	2016-08-19 09:13:45	106.886222	-6.135184	26	103	satellite positioning
24	2016-08-19 09:13:50	106.886542	-6.135259	24	103	satellite positioning
25	2016-08-19 09:13:55	106.88672	-6.135307	9	102	satellite positioning
26	2016-08-19 09:14:03	106.886791	-6.135308	0	96	satellite positioning
27	2016-08-19 09:14:25	106.886773	-6.135304	0	96	satellite positioning
28	2016-08-19 09:16:38	106.886987	-6.135246	0	96	satellite positioning
29	2016-08-19 09:16:38	106.886987	-6.135246	0	96	satellite positioning
30	2016-08-19 09:18:23	106.887013	-6.135501	8	114	satellite positioning
31	2016-08-19 09:18:28	106.887262	-6.135483	10	104	satellite positioning
32	2016-08-19 09:18:33	106.887547	-6.135493	10	103	satellite positioning
33	2016-08-19 09:18:38	106.88768	-6.135506	14	104	satellite positioning
34	2016-08-19 09:18:43	106.887929	-6.135572	23	107	satellite positioning
35	2016-08-19 09:18:48	106.888258	-6.135663	30	106	satellite positioning
36	2016-08-19 09:18:53	106.88872	-6.135764	37	102	satellite positioning
37	2016-08-19 09:18:58	106.8892	-6.135875	38	103	satellite positioning
38	2016-08-19 09:19:03	106.889733	-6.135986	41	102	satellite positioning
39	2016-08-19 09:19:08	106.890249	-6.136108	41	103	satellite positioning
40	2016-08-19 09:19:13	106.890702	-6.136222	35	104	satellite positioning
41	2016-08-19 09:19:18	106.891084	-6.136341	30	105	satellite positioning
42	2016-08-19 09:19:23	106.891467	-6.136407	30	98	satellite positioning
43	2016-08-19 09:19:28	106.891813	-6.136457	20	90	satellite positioning
44	2016-08-19 09:19:33	106.891956	-6.136397	12	38	satellite positioning
45	2016-08-19 09:19:38	106.892	-6.136181	23	7	satellite positioning
46	2016-08-19 09:19:43	106.892036	-6.135825	29	7	satellite positioning
47	2016-08-19 09:19:48	106.892009	-6.135414	32	356	satellite positioning
48	2016-08-19 09:19:53	106.891964	-6.134988	30	352	satellite positioning
49	2016-08-19 09:19:58	106.891911	-6.134589	32	357	satellite positioning
50	2016-08-19 09:20:03	106.89192	-6.134162	34	2	satellite positioning
51	2016-08-19 09:20:08	106.891964	-6.133723	37	7	satellite positioning
52	2016-08-19 09:20:13	106.892062	-6.133221	41	11	satellite positioning
53	2016-08-19 09:20:18	106.892196	-6.132772	33	22	satellite positioning
54	2016-08-19 09:20:23	106.892356	-6.132394	33	23	satellite positioning
55	2016-08-19 09:20:28	106.892578	-6.131988	36	28	satellite positioning
56	2016-08-19 09:20:33	106.892827	-6.131589	38	31	satellite positioning
57	2016-08-19 09:20:38	106.893093	-6.131119	42	25	satellite positioning
58	2016-08-19 09:20:43	106.893253	-6.130619	42	16	satellite positioning
59	2016-08-19 09:20:48	106.893378	-6.130099	42	11	satellite positioning
60	2016-08-19 09:20:53	106.893422	-6.129609	36	3	satellite positioning
61	2016-08-19 09:20:58	106.893431	-6.129205	29	358	satellite positioning
62	2016-08-19 09:21:03	106.893413	-6.128838	29	356	satellite positioning
63	2016-08-19 09:21:08	106.893387	-6.128433	33	358	satellite positioning
64	2016-08-19 09:21:13	106.893378	-6.128012	32	358	satellite positioning
65	2016-08-19 09:21:18	106.893387	-6.127581	36	359	satellite positioning
66	2016-08-19 09:21:23	106.893387	-6.127125	34	358	satellite positioning

(Source : actual measurement)

17. Questionnaire

Respondent No:

Questionnaire for Doctoral Research

Acknowledgement

This questionnaire is for dissertation purpose only. Any information given in this questionnaire will not be addressed for any purpose than educational research. The data will be analyzed and there will be possibilities for publication in the next action. Personal information (such as respondent's address, phone number, etc) will be kept secret will not be disclosed to any third party other than researcher.

Please kindly answer each questions carefully.

Thank you

Abdi Pratama
Doctoral Student
xxxx
Osaka University

A. Screening Question

1. Passenger car owner

   Passenger car is a four wheels vehicle that is used for private transportation purposes. For examples: Sedan, SUV, Van, Pick-up, etc.

   Based on explanation above, do you have any passenger car?

   a. Yes b. No

If you answer Question no. 1 [a. Yes], please proceed to next question, if [b. No] you may end this questionnaire, thank you very much.

2. Please mention the type of the car and brand and production year of the passenger cars that you owned (your may answer more than one. If you have more than 5 cars, please choose max 5 of your cars).

No. of car(s)	Type	Company maker	Brand	Year of production	Transmission type
example	Sedan	Toyota	Yaris	1998	Manual
1					
2					
3					
4					

B. Environmental knowledge

B-1 General knowledge

3. Do you litter waste on designated place?

    a. Yes b. No

4. Do you separate between organic waste and non-organic waste?

    a. Yes b. No

5. Do you often use these types of materials in everyday activities?

    a. Styrofoam 1. Often 2. Rarely 3. Never

    b. Plastic bag 1. Often 2. Rarely 3. Never

    c. Plastic utensils 1. Often 2. Rarely 3. Never

6. Do you re-use any items that still have utility value? For example: reuse of mineral water bottle, reuse of unused clothing for duster, car tire for flowerpot, etc

    a. Yes b. No

7. Do you recycle? (explanation of recycle)

    a. Yes b. No

8. Do you often leave electronic devices switched on without any usage?

    a. TV 1. Often 2. Rarely 3. Never

    b. AC 1. Often 2. Rarely 3. Never

    c. Laptop/computer 1. Often 2. Rarely 3. Never

7. How is your everyday usage on AC?

a. Average temperature :………… C

b. Usage frequency: …. hours/day

B-2 Detail

8. Have you ever heard the word ‘emission’?

    a. Yes b. No

9. If you answer [a. Yes] to [Q. 8], from where that you heard the word ‘emmission’?

    a. Advertising b. Media c. Books d. Friends e. Others (Please mention in detail: …………………………………………………………)

10. Do you know the definition of ‘emission’?

    a. Yes b. No

    Please write your definition of ‘emission’ in detail:

    ……
    ……
    ……………………………………………………………………………

11. Do you know the emission of your car?

    a. Yes b. No

12. If you answer yes on [Q11], how much is the emission of your car?

    …………….. gr/km

13. Have you heard about LCGC?

a. Yes b. No

14. Do you know the definition of LCGC?

a. Yes b. No

15. Please write your definition of LCGC in detail:

……
……
………………………………………………………………………………

16. LCGC is abbreviation of 'Low Cost Green Car'. Have you ever heard anything about this concept?

a. Yes b. No

17. If you answer [a. Yes] to Q16, please describe your definition of the concept of 'Low Cost Green Car':

……
……
………………………………………………………………………………

18. Could you mention examples of car that fill in the definition of 'Low Cost Green Car' that you have mentioned above? ……………………………………………………………

19. Have you heard about Hybrid car?

a. Yes b. No

20. Do you know the definition of Hybrid car?

a. Yes b. No

21. Please write your definition of Hybrid Car in detail:

……
……
………………………………………………………………………………

22. Could you mention examples of car that fill in the definition of 'Hybrid Car' that you have mentioned above? ……………………………………………………………

23. Have you heard about Idle stop car?

a. Yes b. No

24. Do you know the definition of Idle stop car?

a. Yes b. No

25. Please write your definition of Idle stop car in detail:

……
……
………………………………………………………………………………

25. Could you mention examples of car that fill in the definition of 'Idle stop car' that you have mentioned above? ……………………………………………………………

C. Environmental Attitude

26. How many liters do you need to refuel gasoline in 1 month? Please mark [✓] for your answer on the

table below. If you owned car more than one, you may choose max. 2 cars of yours that are most often used.

Car number:	20-50 liter	51-80 liter	81-120 liter
1.			
2.			

27. What is the type of gasoline used? You are allowed to answer more than one type of gasoline for each car. Please use cars you choose on Q.26. Please mark [✓] for your answer on the table below.

Car number:	Gasoline (Premium)	High Octane Gasoline (Pertamax)	Diesel (Solar)	High Octane Solar (BioSolar)
1.				
2.				

28. What is your consideration in using that type of gasoline? Please mark [✓] for your answer on the table below.

Type of gasoline chosen in Q.27 (Premium/Pertamax/Solar/BioSolar)	Reasons for usage		
	Price	Engine Performance	Environmental
1.			
2.			

29. What is average mileage of your car(s) per year? Please mark [✓] for your answer on the table below.

Car number	Mileage per year				
	<10.000 km	10.001-15.000 km	15.001-20.000 km	20.001-25.000 km	>25.000 km
1.					
2.					

30. What is average mileage of your car(s) per day? Please mark [✓] for your answer on the table below.

Car number	Mileage per day				
	<20 km	21-30 km	31-50 km	51-100 km	>100 km
1.					
2.					

31. Type of road that you often pass through with your car(s). You may answer more than one type of road but only one option for each type of road. Please mark [✓] for your answer on the table below.

Type of road	Often	Occasionally	Rare	Never
Smooth asphalt				
Asphalt with hole				

Climbing road				
Road with traffic jam				

32. What is your main purpose of car usage? You may answer more than one car usage for each car you owned. Please mark [✓] for your answer on the table below.

Car number	Car Usage				
	Work commute	Trading	Leisure	School commute	Others
1.					
2.					

33. I would like to know your behavior in driving your car. You can answer generally for any cars you owned. Please mark [✓] for your answer on the table below.

	Driving behavior	Never	Rarely	Sometimes	Often	Always
a.	The engine remains 'on' even during parking condition.					
b.	I turn off the engine during traffic light					
c.	I turn off the engine during heavy traffic jam					
d.	I load passengers as manufacture designated capacity					

34. How many times you change engine oil? (Per km). Please answer one option for each cars you owned. Please mark [✓] for your answer on the table below.

Car number	Oil Change (per km)			
	1000-2000 km	2001-3000 km	3001-5000 km	> 5000 km
1.				
2.				

D. Car dispose attitude

35. Do you willing to change your current car to below types of car? Please answer one option for each type of car. Please mark [✓] for your answer on the table below. (Select max.2 of your current owned cars. If you only have one car, please ignore table car no. 2)

Car No. 1: Year production ……………………(please specify)

Type of car	Willingness to change				
	Definitely not willing to change	Not really willing to change	Not sure	Quite willing to change	Definitely willing to change
Eco-friendly car					
Latest technology car					
LCGC					
Hybrid car					
Iddle Stop System car					

Car No. 2: Year production ……………………(please specify)

Type of car	Willingness to change				
	Definitely not willing to change	Not really willing to change	Not sure	Quite willing to change	Definitely willing to change
Eco-friendly car					
Latest technology car					
LCGC					
Hybrid car					
Iddle Stop System car					

36. How much money that you are willing to spend for a car with below specification. Please answer one option for each type of car. Please mark [✓] for your answer on the table below

Type of car	Amount of money (in IDR)				
	<100 million	101 million – 150 million	151 million – 200 million	200 million – 300 million	>300 million
Eco-friendly car					
Latest technology car					

LCGC					
Hybrid car					
Iddle Stop System car					

37. If type of cars mentioned in Q36 are sold in Indonesia, do you willing to change your current car with the specific price you choose above for each types of car?
a. Yes b. No
38. If the government is willing to give incentive to dispose your current car, to change to below specific cars, do you willing to dispose your current car?
a. Yes b. No
39. How much the scheme of incentive needed for dispose your current car? Please answer one option for car(s) owned. Please select max.2 of your current owned cars. If you only have one car, please ignore table car no. 2. Please mark [✓] for your answer on the table below.

Current car(s) owned	Amount of money (in IDR)				
	<5 million	5 million – 10 million	11 million – 15 million	16 million – 20 million	>20 million
Car no. 1 Year production …………… (please specify)					
Car no. 2 Year production …………… (please specify)					

40. If in Indonesia there is incentive scheme as mentioned above [Q39] for each type of car that you have chosen, do you willing to dispose your current car in order to change to new types of car?
a. Yes b. No
41. According to your answer in Q36 and Q39, which one do you prefer to do, to trade your current car or to dispose it in order to change it to new types of car?
a. Trade b. Dispose
42. If you are supposed to pay an amount of money to government in order to dispose your current car, do you willing to dispose it?
a. Yes b. No

43. If you answer [a. Yes] for Q.42, how much money that you are willing to give to government in order to dispose your current car? Please answer one option for car(s) owned. Please select max.2 of your current owned cars. If you only have one car, please ignore table car no. 2. Please mark [✓] for your answer on the table below. [If your answer is b. No for Q42, you may proceed to Q44.

Type of car	Amount of money (in IDR)				
	<5 million	5 million – 10 million	11 million – 15 million	16 million – 20 million	>20 million
Car no. 1 Year production …………… (please specify)					
Car no. 2 Year production …………… (please specify)					

E. Attitude in Buying Car(s)

44. What is your consideration in buying a car? You may answer more than one.
    a. Price
    b. Design
    c. Economical fuel
    d. Environmental friendly
    e. Brand
    f. Manufacture company name
    g. Newest technology
45. What type of financial that you prefer in buying car?

a. Cash b. Loan

46. Do you prefer to buy new car or second car?

a. New car b. second car

Demographic Questions:

47. Name :
48. Phone number : Mobile: ……………………… Home: …………………
49. Address :

50. Sex :

51. Age :

52. Latest education :

a. SD-SMP/ the same level

b. SMU/the same level

c. b. D3/the same level

d. c. S1

e. d. S2

f. e. S3 or above

53. Average income per month (in IDR) :

a. < 1 juta

b. 1.000.001 - 3.000.000

c. 3.000.001 juta – 5.000.000

d. 5.000.001 – 10.000.000

e. 10.000.001- 20.000.000

f. >20.000.001

54. Average spending per month (in IDR) :

a. < 1 juta

b. 1.000.001 - 3.000.000

c. 3.000.001 juta – 5.000.000

d. 5.000.001 – 10.000.000

e. 10.000.001- 20.000.000

f. >20.000.001