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Mitigation of Emissions through Fuel Economy Standards for Passenger Cars

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Abstract: The economy has grown rapidly Indonesia in the last two decades. This growth has increased the ownership of passenger cars. The number of users of passenger cars is predicted to grow dramatically in Indonesia in the future. To reduce fuel consumption in the transport sector, the department of energy and department of transportation should consider implementing minimum fuel economy standards for passenger cars. This paper attempts to predict the potential mitigation of emissions through fuel economy standards for passenger cars. The calculations were based on the growth of passenger cars ownership data. The study found that the fuel economy standards for passenger cars would mitigate a significant amount of emissions in the country.

Keywords: emission; fuel economy; passenger cars; motor vehicle.

Nomenclatures

AFC_{Ysc}	Annual fuel consumption in the year of survey conducted for a passenger car (L/year)
AI	Annual fuel efficiency improvement (%)
BFC_S	Baseline fuel consumption in the year of fuel economy standards enacted for passenger cars (L/year)
DT	Annual distance traveled (km/year)
Em_n	Emissions type *n* for a unit liter (kg/L)
ER_i	Emission reduction in year i of passenger cars (kg)
FC	Fuel consumption (km/L)
i	In the particular year
L	Lifespan of passenger car
Nv_i	Number of passenger cars in year i
Nv_{i-1}	Number of passenger cars in year i – 1
Nv_{i-L}	Number of passenger cars in year i – L
SF	Scaling factor
SF_i	Scaling factor of passenger cars in year i
SF_i^a	Scaling factor of passenger cars in year i
SSF_i	Shipment survival factor in year i for passenger cars (%)
Sh_i	Shipments of passenger cars in year i
SFC_S	Standards fuel consumption of passenger cars (L/Year)
T	Target year
TI_S	Total fuel efficiency improvement (%)
TFS	Total fuel savings by the total stock of passenger cars (L/Year)
TFS_i	Total fuel savings by the total stock of passenger cars in year I (L/Year)
TS_i	Total stock of passenger cars in year i
UES_i^a	Unit energy savings in year i of passenger cars (L/Year)
UES_s^a	Initial unit energy savings of passenger cars (L/Year)
UFS	Unit fuel savings of passenger cars (L/Year)
UFS_s	Initial unit fuel savings of passenger cars in year i (L/Year)
Ypd	Year of prediction
Ysc	Year of survey conducted
Yse	Year of standards enacted of passenger cars
Ysh	Year of shipment of passenger cars
Ysh_i	Year i of shipment of passenger cars
η_S	Percentage fuel economy standards improvement of passenger car (%)

1. Introduction

Nations traditionally classify their energy consumption into three sectors which are buildings, industry and transportation. As in other developing countries, due to course of economic development in an increasingly integrated country like Indonesia has generated growth in motor vehicles. Automobiles are one of the most common modes of transportation and have a big impact on modern life. Owning an automobile has become a life-style and therefore its population on the world roads is tremendously increased. In 2007, the population of Indonesia is 258,868,791 people [1]. Despite a reasonable real GNP growth, Indonesia remains a poor country, with an average GNP income per capita of Rp 35,804,041 (about US$ 3,580) in 2007. In Indonesia the majority

of the population uses bus, motorbike, private cars and taxi for transportation. As a result, in 2007 there were 43,678,258 vehicles in Indonesia of which 6,294,124 were passenger cars [2]. The real effect for future population of motor vehicles indicates that there is a need for an energy efficiency program and an environmental-friendly designed transport system. Air pollution is one of the environmental problems in Indonesia and the road transport is one of the major contributors. The implementation of fuel economy standards and labels for passenger cars is one the best policies to reduce energy consumption and emissions.

2. Methodology

The impact of fuel economy standards and labels are calculated separately and presented in three sections e.g., potential fuel saving, economic, environmental and the standards and labels referring [3-5]. The fuel economy impacts of the standards have been calculated based on the potential fuel savings and economical and environmental impact which are discussed in the following section. In order to calculate the potential fuel savings, the essential inputs are the car shipment, scaling factor, and shipment survival factor.

2.1. Annual fuel consumption

The annual fuel consumption of passenger car is obtained based on the average of fuel consumption survey data collected from respondent's (owners passenger) car in the particularly year. Annual fuel consumption can be expressed as

$$AFC_{Ysc} = FC \times DT \tag{1}$$

2.2. Baseline fuel consumption

The baseline fuel consumption can be predicted based on annual fuel efficiency improvement. The baseline fuel consumption can be expressed by the following equation:

$$BFC_s = AFC_{Ysc} \times (1 - AI)^{(Ypd - Ysc)} \tag{2}$$

2.3. Standard fuel consumption

The standard fuel consumption is a function of the baseline fuel consumption and percentages of fuel economy standards improvement. This can be calculated by the following equation:

$$SFC_s = BFC_s (1 - \eta_s) \tag{3}$$

2.4. Initial unit fuel savings

The initial fuel savings is the difference between baseline fuel consumption and standard fuel consumption of passenger car. The initial unit fuel savings is calculated using the equation below [5-9]:

$$UFS = BFC_s - SFC_s \tag{4}$$

2.5. Shipment

Shipment is the difference between the number of passenger cars in predicting years minus the number in previous year plus the number retired passenger cars in the current year. In mathematical form this can be expressed by the equation [5-6, 9-10]:

$$Sh_i = (Nv_i - Nv_{i-1}) + Nv_{i-L} \tag{5}$$

2.6. Total efficiency improvement

Total efficiency improvement is a ratio of initial unit fuel savings and baseline fuel consumption of passenger cars when the fuel economy standards programs are enacted. The total efficiency improvement is usually presented as a percentage. Thus, it can be expressed by the following equation [5-8, 10-12]:

$$TI_s = \frac{UFS_s}{BFC_s} \times 100\% \quad (6)$$

2.7. Scaling factor

The scaling factor is the ratio of annual efficiency improvement and the total efficiency improvement. The scaling factor would linearly scale down the unit fuel savings and the incremental cost to zero over the effective period of the standards. The scaling factor can be expressed in a mathematical form as follow [5-6, 8-13]:

$$SF = 1 - \left(Ysh_i - Yse\right) \times \frac{AI}{TI_s} \quad (7)$$

2.8. Unit fuel savings

The unit energy savings were adjusted downward by the scaling factor in the years after the standards are implemented. This factor accounts for natural progress in efficiency expected in the baseline case. The unit fuel saving is calculated by the following equation [5-9]:

$$UES_i^a = SF_i^a \times UES_s^a \quad (8)$$

2.9. Shipment survival factor

The shipment survival factor is a function of the annual retirement rate and the retirement function. If the standards setting is shorter than 2/3 of the average lifespan of product, shipment survival factor will be 100%. Shipment survival factor for passenger car can be calculated using the following equation [5, 8-10]:

$$SSF_i = 1 - \left[\frac{\left(Ysh - Yse\right) - 2/3\ L}{2/3 \times L}\right] \quad (9)$$

2.10. Total stock

The total stock is the stock of the passenger cars in a particular year and the number of cars affected by the fuel economy standards in previous year. The equation is as follows (5-13):

$$TS_i = \left(Sh_i \times SSF_i\right) + TS_{i-1} \quad (10)$$

2.11. Total fuel savings

Total fuel savings in a particularly year is the multiplication of the total stock of the passenger cars and the unit fuel savings in the particularly year. The total fuel savings can be expressed in mathematical from as the following equation [5, 8, 10]:

$$TFS = \sum_{i=s}^{T} TS_i \times UFS_s \times SF_i \quad (11)$$

2.12. Environmental impact of the standards

The environmental impact of the standard is the potential emission reduction. The common emissions from fossil fuel passenger cars consist of CO_2, HC, NOx and CO. The emissions reduction is

a function of energy savings. The environmental impact can be calculated by the following equation [3,5,10]:

$$ER_i = TFS_i \times \left(Em_1 + Em_2 + Em_3 + ... + Em_n\right) \quad (12)$$

3. Results and Discussion

The calculation results of potential fuel saving for petrol and diesel passenger car by implementing fuel economy standards in Indonesia are presented below. Fuel consumption with and without standards for petrol and diesel passenger cars are shown Figures 1 and 2.

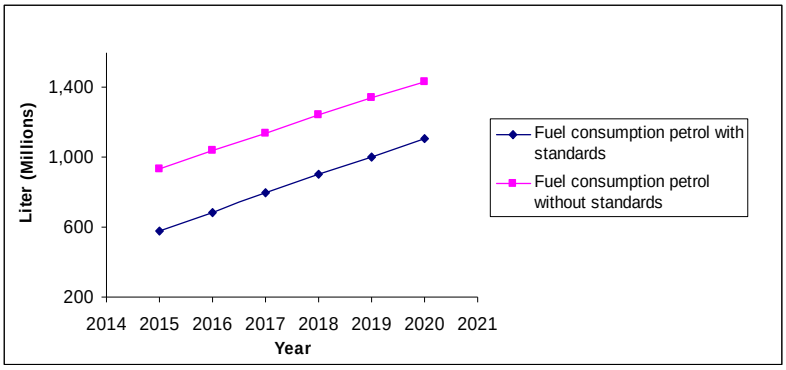

Figure 1. Fuel consumption with and without standards for petrol passenger cars

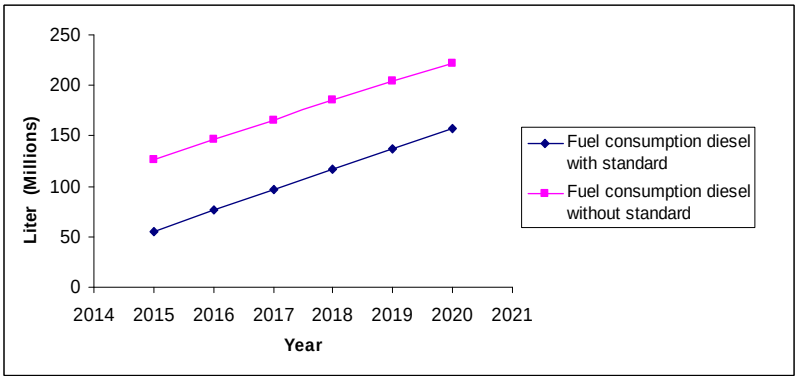

Figure 2.Fuel consumption with and without standards for diesel passenger cars

It has been noted that the fuel economy standards for passenger cars are only effective for a certain period because annual efficiency of petrol and diesel passenger cars are still improving 1.72% and 1.65% per year without the standards. Based on calculation, the standards for petrol passenger cars is only effective for 5 year from 2015 to 2020 and for diesel passenger cars it is effective 6 years from 2015 to 2021. Therefore from the figures, the minimum fuel economy standards for passenger cars in Indonesia implemented in 2015 would save 2,062,103,711 Liter of fuel from petrol passenger cars at the end of the year 2021, whereas 474,121,479 Liter of fuel would be saved from diesel passenger cars at the end of the year 2021.

The environmental impact of fuel economy standards is a function of energy savings which is the potential reduction of emissions that cause negative impact to the environment. It has been observed that there is an increasing atmospheric concentration of greenhouse gasses such as carbon dioxide (CO_2), hydrocarbon (HC), nitrogen oxide (NO_x) and carbon monoxide (CO). The calculation results are illustrated in Figures 3 and 4

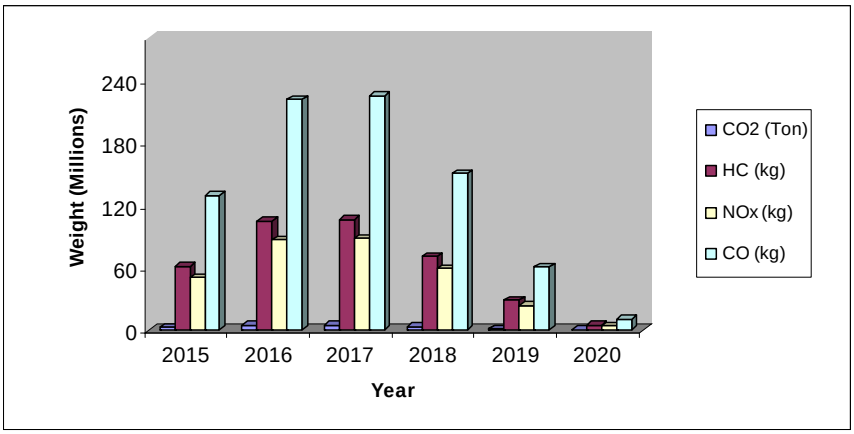

Figure 3. The calculation result of environmental impact by standards from petrol passenger cars

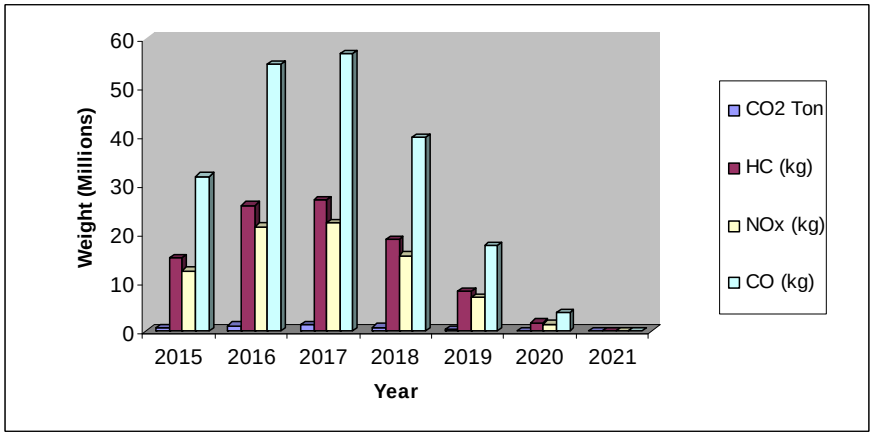

Figure 4. The calculation result of environmental impact by standards from diesel passenger cars

Therefore, the total CO_2 reduction from both petrol and diesel passenger cars will about 21,239,080 ton. The total HC reduction is about 474,656,586 kg. Similarly the total NO_x reduction is about 393,583,342 kg while total reduction of CO is about 1,006,820,657 kg.

4. Conclusions

The study has shown that a specific vehicle e.g., passenger cars fuel consumption to the consumers, manufacturers or market, government and environment will get benefits by implementing standards and labels for passenger cars. The result from study will save significant amount of fossil fuel, which indirectly will reduce emissions. Although the consumers will have to pay higher purchase prices for motor cars, the fuel bill will be lower. This study indicated that the fuel economy standards of passengers' cars in Indonesia is one of the most effective and communicative strategies to reach the targets or to provide and improve fuel consumption and can help to substantially reduce emissions from passenger cars. The fuel economy standards also provide benefits to the national economy and environment in the future. The cooperation from government, manufacturers, consumer of passenger cars to consider the plan and action program fuel economy standards can develop and implement national strategies and action plan for all national development goals.

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