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# Techno-economic Analysis of Liquid Petroleum Gas Fueled Vehicles as Public Transportation in Indonesia

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**ABSTRACT**

In Indonesia, the use of liquid petroleum gas (LPG) in vehicles has been promoted through government policy since 1988. However, the progress has not significantly run. Therefore, this paper presents the techno-economic analysis of LPG as road vehicles fuel alternative in comparison with gasoline RON 88 and RON 92 for public transportation in Indonesia. The techno-economic analysis is considered running cost, break-even point (BEP) distance, net present value (NPV), internal rate of return (IRR), payback period (PP), and sensitivity analysis. This analysis indicates that the BEP distance of public transportation vehicles are approximating at 55,351 km compared to gasoline RON 92 and 93,168 km compared to gasoline RON 88. Meanwhile, the result of the investment analysis shows that the investment feasibility indicators which include NPV, IRR, and PP show the investment was feasible but the investment is sensitive to fuel cost ratio between LPG and gasoline.

**Keywords:** Liquid Petroleum Gas Vehicles, Running Costs, Investment Feasibility
**JEL Classifications:** M21, O31, Q43

## 1. INTRODUCTION

Clean vehicle propulsion technology such as electric vehicle (EV) and a fuel cell (FC) is promising in the present and future. The EV and FC prove better environmental impact than gasoline and diesel vehicles though it was expensive on purchasing price (Messagie et al., 2013). On the other hand, replacing conventional fuel vehicles with the EV and FC technology in close time is impossible. Thus, the use of alternative fuels and alternative energy which have a better environmental impact and economic viability than conventional fossil fuel became the realistic option (Abdullahi, 2014; Yusma et al., 2016). In Indonesia, the use of liquid petroleum gas (LPG) in vehicles has been promoted through government policy since 1988. However, until 2014, public fleets using LPG are <6000 units (Mahendra et al., 2014). Therefore, this paper presents techno-economic analysis of LPG vehicles in comparison with gasoline RON 88 and RON 92.

LPG grow up for spark-ignition engine because it has several property advantages, such as energy content, octane number, auto-ignition temperature, flame velocity and flammability limits (Erkus et al., 2012; ESTAP, 2010; Harrow, 2008; Kowalewicz and Wojtyniak, 2005). The CO, $CO_2$, HC, and $NO_x$ produced by LPG engines are lower than gasoline engines, both on urban and extra-urban cycle (Saraf et al., 2009; Tasic et al., 2011). It is promising at present and future associated with tightness on exhaust emission regulations (Mohamad et al., 2012). However, the output torque and power of LPG vehicles reported slightly lower than gasoline (Bayraktar and Durgun, 2005; Salhab et al., 2011). On the bi-fuel engine experience, where LPG and gasoline can be operated alternately, resetting of the ignition timing and applying of spark advance variation can increase engine torque and power (Ehsan, 2006; Lawankar, 2012; Tomov, 2012); and Setiyo et al., 2016).

LPG can be applied directly to the existing vehicle by adding a converter kits. Initially, LPG fuel technology using a converter and mixer device that works much like a carburetor gasoline engines. Now, the LPG vehicles technology is already equaled to gasoline fuel technology by multi-point injection or even direct injection. A mixture of LPG vapor and air or LPG liquid is sucked or injected into the combustion chamber, depending on the system used. The vapor injection kits supply LPG in the vapor form to the intake port. Meanwhile, the liquid injection kits give liquid LPG to the intake port or directly to the combustion chamber (Time For Gas, 2013). The liquid direct injection systems are the latest generation of automotive LPG fuel system technology. Both vapor and liquid injection, the mixture is burned to generate power, such as gasoline engines work.

The LPG vehicles can run on fully dedicated fuel or bi-fuel systems. In the bi-fuel systems, LPG kits are added to the existing gasoline fuel system to give fuel operating alternately (NREL, 1994). In line with consumer demand, automotive manufacturers have to equip their products with LPG fuel system components as a new standard. Some of which are Holden Ecoline LPG and Ford EcolPi (Elgas, n.d.). These technologies have been already marketed in several countries that have LPG refueling site infrastructures, such as Australia and South Korea. Although LPG is derived from the refinery and has the equivalent energy content of gasoline, the price of LPG is lower than gasoline. Monitoring by WLPGA in 10 countries that encourage LPG as fuel for road vehicles, the consumption and the number of vehicles have been fluctuations in the last decade. However, generally, there is an increase, especially in developing countries (World LPG Association, 2015).

### 1.1. Global Implementation

The trend of LPG vehicles around the world have been reported and updated by World LPG Association. In the recent decade, LPG vehicles have increased about 9.4 million in 2003 (World LPG Association, 2005) and more than 17.4 million in 2010 (World LPG Association, 2012). In 2014, there were more than 25 million LPG vehicles, mostly as light duty vehicles (LDV) and the rest as high duty vehicles. South Korea, Russia, Poland, Australia, Turkey, India, and Thailand are examples of countries that successfully promote LPG as an alternative fuel for road vehicles. In Southeast Asia, Thailand successfully encourages LPG as an alternative fuel, including the number of vehicles, consumption, and the number of refueling sites (World LPG Association, 2015).

In those countries, people interest for converting their vehicles to LPG. The running costs using LPG are lower than gasoline, though they need the initial investment to install converter kits. Their capital will be back soon in a few thousand kilometers mileage. The break-even point (BEP) distance and fuel cost ratio of use LPG compared to gasoline in some Asian countries are presented in Table 1.

The government policy is essential to ensure the successful development of LPG infrastructure (Liu et al., 1997). Awareness and public education promote LPG have also been developed to make a significant contribution to market growth in some countries. The conversion program policy for public fleets has been very successful in several countries, including India and the United States. In Korea and Japan, restrictions on diesel vehicles have become an important factor in the success of the use of LPG. On the other hand, public concerns about safety and reliability of LPG clearly have affected the demand in several countries, including France and Netherlands (World LPG Association, 2015). In some cases, refueling facilities are inadequate and unevenly also can prevent the interest in using LPG.

**Table 1: The BEP and cost ratio of LPG vehicle in some Asian countries (World LPG Association, 2015)**

| Country | BEP distance compared to gasoline (km) | Fuel cost ratio (LPG to gasoline) |
|---|---|---|
| Japan | 169,405 | 0.62 |
| India | 22,141 | 0.59 |
| Turkey | 13,650 | 0.59 |
| South korea | 43,191 | 0.62 |
| Thailand | 28,508 | 0.32 |
| Average | 55,379 | 0.55 |

BEP: Break-even point, LPG: Liquid petroleum gas

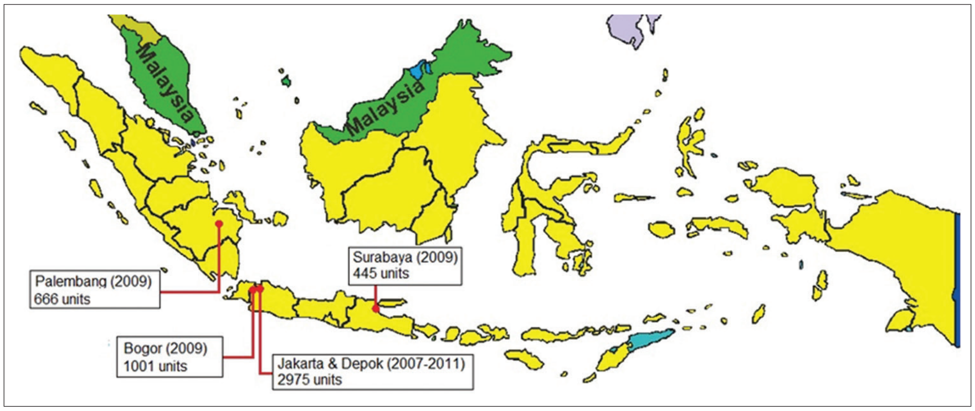
Based on the experience of successful countries encourage LPG for road vehicles, a comprehensive long-term policy is needed to ensure the success of LPG conversion, among others, related to fiscal incentives, regulatory incentives, and research and development incentives. Fiscal incentives include the sales and transfer tax of LPG vehicle, the provision of free converter kits, waivers of the registration fee, and waivers on-street parking of LPG vehicles. Regulatory incentives include the requirement of all public vehicles and service vehicles equipped with converter kits, freeing LPG vehicles through a road with a restriction, and establishing high standard exhaust emission (Abdini and Rahmat, 2013).

### 1.2. Current State of LPG vehicle in Indonesia

The policy for alternative energy (including LPG) is initiated by "Blue Sky Program" which was firstly launched in 1996 by the Ministry of Environment. Blue sky program is aimed at controlling air pollution and realizing environmentally conscious behavior either from stationary sources such as household and industrial or mobile sources such as vehicles. For the household sector, the Indonesian government has successful experience of converting kerosene to LPG during the period 2007-2011.The Indonesian government does not only successfully reduce the subsidy for petroleum fuels but also improve household cooking fuel, such as cleanliness, convenience, environment, and cost reduction (Samosir, 2010; Budya and Yasir Arofat, 2011).

The application of LPG for the LDVs as public transportation has started since 1988. However, over the next 30 years does not develop. Around the 2007's, the government's promotion of LPG as an alternative fuel for road vehicles (Susanti et al., 2010). The government incentives are started by distributing converter kits free of charge for public transportation in many cities such as Jakarta, Surabaya, Bogor, and Palembang as a pilot project. During 2007-2011, more than 5000 LPG kits were given for public transportation, such as taxis and public city cars (Figure 1). The government issued technical guidance about the standards of converter kits, infrastructures, workshops, and technicians. Then, Pertamina as one of the State-Owned Enterprises together with some private companies gradually builds the refueling site infrastructure in several cities. Now, LPG refueling site has been available in Jakarta, Surabaya, Bandung, Bogor, Palembang, Semarang, Solo, Yogyakarta, Denpasar, and Magelang. In addition, challenges and opportunities of LPG implementation for land transportation have been studied by Mahendra et al. (2013).

**Figure 1:** Distribution of liquid petroleum gas kits for public transportation in Indonesia (2007-2011)




LPG for road vehicle in Indonesia is called the liquefied gas vehicle or Vi-gas. Vi-gas consumption growth has been increased by the average of 40% per year, from 189 kl in 2008 to 913 kl in 2013, and it is estimated at more than 2000 kl in 2016. However, this number is too small compared to conventional fuel consumption, such as gasoline and diesel. Today, LPG vehicles are still dominated the official vehicles owned, State-owned Enterprises, and public transportation vehicles as a pilot project. Economic studies of LPG as public transport fuel related to the price control and infrastructure investment by the government has done by Samosir (2010) and Mahendra et al. (2014). However, society has not received valid information related to the benefits obtained when they switch conventional fuels to LPG for their existing vehicles.

### 1.3. Cost Identification

In general, the several costs should be considered by the car owners before switching to LPG, including capital costs, maintenance costs, and fuel costs (Liu et al., 1997). To switch gasoline to LPG, car owners can buy LPG vehicles produced by car manufacturers commonly called original equipment manufacturers (OEMs) or add converter kits on existing vehicle. LPG vehicle has the maintenance costs are lower than the gasoline vehicle because LPG contaminated lubricant fewer than gasoline. Cleaner burning characteristics due to the lower carbon content also reduces maintenance costs (Bosch, 2010). The running cost of LPG vehicles can be much lower than gasoline vehicles because the price difference of fuels in the refueling site.

Based on capital costs, maintenance costs, and fuel costs needed, this study discusses in detail a techno-economic analysis to assess the running costs of public transportation vehicles fueled LPG compared to gasoline RON 88 (premium) and gasoline RON 92 (pertamax). BEP the use of LPG in Indonesia will be described and compared to some countries in Asia. Meanwhile, the parameters of net present value (NPV), internal rate of return (IRR), payback period (PP), and sensitivity analysis will be used to assess the feasibility of investment for converting the vehicle to LPG.

## 2. ASSESSMENT PARAMETERS

In this study, the LDV which represent public transportation, such as taxis and public city car are simulated. The fuel consumption and mileage refer to the study reported by Samosir (2010) and the price of the fuel used is the current price in the refueling site. At the time of writing (April, 2016), the prices of gasoline in Indonesia in the refueling site are IDR 6,450 for RON 88 and IDR 7,550 for RON 92. Meanwhile, the price of LPG for road vehicles is IDR 5,100/L gasoline equivalent. Parameters for analysis are presented in Table 2.

### 2.1. BEP Distance

BEP analysis is used to assess equivalence between capital costs incurred for conversion and the fuel savings generated in term of distance traveled. The BEP of LPG compared to gasoline RON 88 and RON 92 calculated using the Equation (1).

$$BEP = \frac{FC}{(P_{gaso} - VC_{LPG})} \tag{1}$$

*FC* is the capital cost. $P_{gaso}$ is the gasoline fuel cost per kilometer depending on RON. $VC_{LPG}$ is the *LPG* fuel cost per kilometer. The gasoline and *LPG* fuel costs include the engine maintenance cost but did not consider the tire cost.

### 2.2. Economic Values and Assessment Parameter

To assess the feasibility of investment for conversion from gasoline to LPG, this study uses the parameter of NPV, IRR, and PP, and sensitivity analysis. NPV is the difference between expenditures and revenues that have been discounted using the social opportunity cost of capital as the discount factor. Other says that the NPV of cash flows expected in the future, discounted at this time. If the NPV is >0, this project is feasible. Meanwhile, the IRR is obtained when NPV = 0. If the IRR is greater than bank interest, this project is feasible. Generally, NPV is calculated by Equation (2) as follow.

$$NPV = \left(Ci_0 - Co_i\right) + \frac{(Ci_1 - Co_1)}{(1+i)} + \frac{(Ci_2 - Co_2)}{(1+i)^2} + \ldots + \frac{(Ci_n - Co_n)}{(1+i)^n} + \frac{S}{(1+i)^n} - I_0 \tag{2}$$

Where, $C_i$ is the cash inflows, *Co* is the cash outflows, *i* is the bank interest, *n* is the period, *S* is the salvage values in the end of period, and $I_0$ is the initial investment or capital costs. In this study, the lifetime LPG kits are assumed of 10 years and depreciation rate is calculated by straight-line method. Thus, the salvage value of the converter kits is 50% of capital costs without installation cost. If

**Table 2: Parameters for analysis**

| Item description | Unit | Value | Source |
|---|---|---|---|
| Mileages per year | km | 100,000 | Samosir (2010) |
| Fuel consumption | km/L | 10 | Samosir (2010) |
| Annual fuel consumption | L | 10,000 | A/B |
| Gasoline 88 RON price per liter | IDR | 6450 | Price in refueling site (April, 2016) |
| Gasoline 92 RON price per liter | IDR | 7550 | Price in refueling site (April, 2016) |
| LPG price per liter (equivalent to gasoline) | IDR | 5100 | Price in refueling site (April, 2016) |
| Annual fuel cost for gasoline 88 RON | IDR | 64,500,000 | (C×D) |
| Annual fuel cost for gasoline 92 RON | IDR | 75,500,000 | (C×E) |
| Annual fuel cost for LPG | IDR | 51,000,000 | (C×F) |
| Annual saving LPG to gasoline 88 RON | IDR | 13,500,000 | (G-I) |
| Annual saving LPG to gasoline 92 RON | IDR | 24,500,000 | (H-I) |
| Capital cost of LPG conversion | IDR | 15,000,000 | Considering the installation cost |
| Maintenance cost for LPG per km | IDR | 130 | Estimated from RACQ (2014) |
| Maintenance cost for LPG per km | IDR | 104 | Assumed to be 20% lower than gasoline operation because extended reliability of engine oil and spark plugs |
| Salvage value in the end of 60 months | IDR | 5,500,000 | 50% of LPG kits price (Zain, 2016) |

LPG: Liquid petroleum gas

net benefit ($C_i$-$Co$) and interest ($i$) are assumed not changed during $n$ period, Equation (2) can be rewritten as Equation (3) below.

$$NPV = \frac{(Ci-Co)x\,[1-(1+i)^{-n}]}{i} + \frac{S}{(1+i)^n} - I_0 \quad (5)$$

After NPV and IRR are known, investment assessment is done by calculating the PP. The PP is the ratio between the capital costs with acumulative proceeds (Equation 4). This project is declared feasible if the PP is reached before the specified total time investment.

$$PP = \frac{Investment\ costs}{Accumulative\ proceed} \quad (4)$$

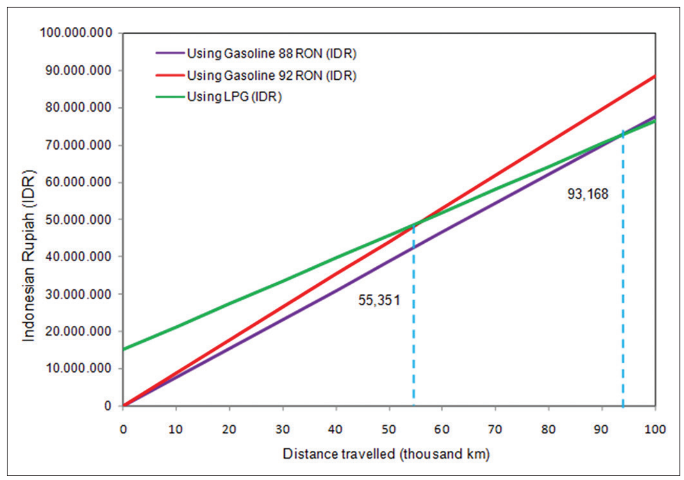
Furthermore, the sensitivity analysis was performed to anticipate changes in the value of parameters, including vehicle distance traveled per year and the cost ratio between gasoline and LPG. The fuels prices on the refueling site in Indonesia have fluctuated in recent years. Distance traveled per year is also a possibility to change due to congestion and economic conditions that affect people's mobility. Thus, uncertainty of fuel prices and annual distance traveled is also an important consideration in this analysis.

## 3. RESULTS AND DISCUSSION

### 3.1. Running Cost and BEP

In this study, the vehicle running costs and BEP are calculated based on the assumption that there is no change in fuel prices. The calculation shows that the running costs per kilometer distance traveled of LPG vehicles in Indonesia with LPG, gasoline RON 88 and RON 92 gasoline are IDR 560, IDR 705, and IDR 815, respectively. The cost is already included fuel costs and estimates maintenance costs. BEP calculation performed on LPG vehicles is switching from gasoline, not the OEMs product. The Maintenance costs in both of fuel (gasoline and LPG) are derived to IDR per kilometer. Using Equation (1) and the parameter values listed in Table 2, the results of running cost and BEP calculation are presented in Figure 2. For public transportation with fuel consumption of 10 km/L, BEP distance of LPG was achieved at 55,351 km compared to gasoline RON 92 and 93,168 km compared to gasoline RON 88.

**Figure 2:** Running cost and break-even point of vehicles driven by liquid petroleum gas and by gasoline




In the Asia, the fastest BEP is in Turkey by only 13,650 km and the longest is in Japan by 169,405 km. While, the BEP average of five major LPG vehicle markets in Asia is 54,977 km. In Indonesia context, by assuming the LPG vehicle is the switch from gasoline RON 92, the BEP is lower than the Asian average. However, if it compared to gasoline RON 88, BEP is higher than Asian average.

### 3.2. Investment Feasibility Analysis

In this study, analysis of the feasibility of investment for converting gasoline to LPG system using the effective interest with compounded interest rate per month. The interest is assuming at 1% per month. The maximum limit of investment feasibility is set for 60 months (5 years). Using Equation (2) and the parameter values listed in the Table 1, the results of NPV and IRR calculation are presented in Figure 3.

Figure 3 presents the profitability of investment for the public transport company to convert its fleet to LPG. Using Equation (4), the PPs of investment was achieved at 13.3 months and 7.35 month against to RON 88 and RON 92, respectively. However, several conditions need to be considered, including changes in oil prices causing changes in fuel cost ratio, uncertainties mileage per year, and bank interest. Therefore, the sensitivity analysis is performed to estimate the probability of investment. The parameters that may affect the changes made to the tolerance of 30% from baseline. Figure 4 presents a sensitivity analysis of the calculation results.

Based on the sensitivity analysis presented in Figure 4, the investment for converting gasoline to LPG is very sensitive to gasoline price, both on RON 88 and RON 92. In the time of writing, the fuel cost ratio of LPG against to gasoline in Indonesia is 0.79 and 0.68 for RON 88 and RON 92, respectively. Meanwhile, the average fuel cost ratio of five major LPG vehicle markets in Asia (Japan, India, Turkey, South Korea, and Thailand) is 0.55. Furthermore, some conditions that may occur (worst, bad, normal, good, and best) made to assess the risk of investment. The parameters for each condition are presented in Table 3 while the budgeting decision is presented in Table 4, respectively.

Based on Table 4, the expected NPV of LPG to gasoline RON 88 and RON 92 were IDR 44,587,935 and IDR 86,810,176, respectively. Furthermore, the coefficient of variation (CV) of LPG to r RON 88 and RON 92 were 1.10 and 0.71, respectively. The CV of <2 indicates that the investment is acceptable.

## 4. CONCLUSIONS

A series of running cost analysis showed that the BEP distance of LPG-fueled vehicles in Indonesia is relatively higher than the average of five major LPG market in Asia (Japan, India, Turkey, South Korea, and Thailand). However, the result of the investment analysis shows that the investment feasibility indicators which include NPV, IRR, and PP show the investment was feasible, both for comparison with gasoline RON 88 and RON 92. From the sensitivity analysis, this investment is very sensitive to fuel cost ratio between LPG and gasoline. Meanwhile, the capital cost and mileage per year are only a small effect to the NPV. In conclusion, in normal economic conditions, the investment to

**Figure 3:** (a) Net present value and (b) internal rate of return calculation in comparison with gasoline RON 88 and 92

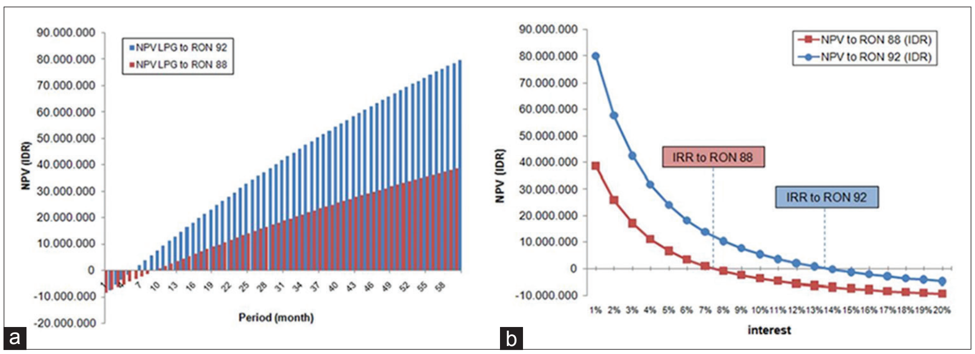



**Table 3: Scenario analysis**

| Condition | Probability (%) | Mileage/year (km) | Gasoline RON 88 price/L (IDR) | Gasoline RON 92 price/L (IDR) | WACC (%) | NPV gasoline RON 88 (IDR) | NPV gasoline RON 92 (IDR) | Squared deviation time probability | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Gasoline RON 88 | Gasoline RON 92 |
| A | B | C | D | E | F | G | H | I | J |
| Worst | 10 | 70,000 | 4515 | 5285 | 1.3 | 31,813,434 | 11,621,129 | 5.83717E+14 | 9.68872E+14 |
| Bad | 15 | 85,000 | 5483 | 6417 | 1.2 | 2,026,600 | 27,746,747 | 3.25937E+14 | 5.23273E+14 |
| Normal | 50 | 100,000 | 6450 | 7550 | 1.0 | 38,601,891 | 79,810,676 | 1.79164E+13 | 2.44965E+13 |
| Good | 15 | 115,000 | 7418 | 8682 | 0.9 | 90,141,344 | 144,596,881 | 3.11267E+14 | 5.00895E+14 |
| Best | 10 | 130,000 | 8385 | 9815 | 0.7 | 152,511,216 | 222,154,063 | 1.16474E+15 | 1.8318E+15 |
| ∑ | | | | | | | | 2.40358E+15 | 3.84933E+15 |

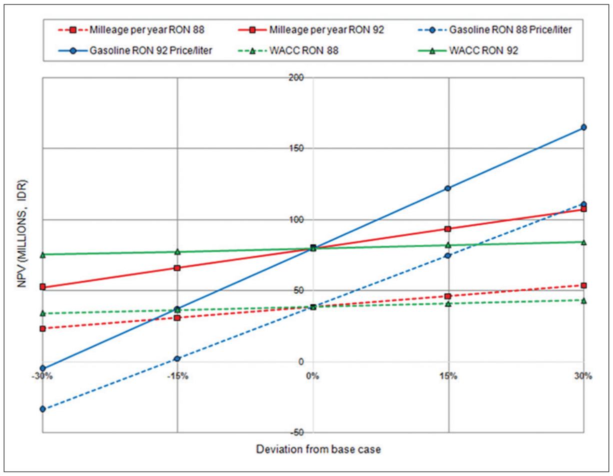
NPV: Net present value

**Table 4: Budgeting decision**

| Description | Value | Formula |
|---|---|---|
| Expected NPV of LPG to Gasoline RON 88 | 44,587,935 | (B1*G1)+(B2*G2)+(B3*G3)+(B4*G4)+(B5*G5) from Table 3 |
| Expected NPV of LPG to Gasoline RON 92 | 86,810,176 | (B1*H1)+(B2*H2)+(B3*H3)+(B4*H4)+(B5*H5) from Table 3 |
| SD of LPG to Gasoline RON 88 | 49,026,329 | (I6^0.5) from Table 3 |
| SD of LPG to Gasoline RON 92 | 62,043,003 | (J6^0.5) from Table 3 |
| CV of LPG to RON 88 | 1.10 | $\left(\frac{\text{Standar deviation gasoline RON88}}{\text{Expected NPV gasoline RON88}}\right)$ |
| CV of LPG to RON 92 | 0.71 | $\left(\frac{\text{Standar deviation gasoline RON92}}{\text{Expected NPV gasoline RON92}}\right)$ |

CV: Coefficient of variation, SD: Standard deviation, NPV: Net present value, LPG: Liquid petroleum gas

**Figure 4:** Sensitivity analysis




switch from gasoline to LPG for public transportation in Indonesia is a promising decision.

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