EVALUATION OF THE FEASIBILITY OF PUBLIC TRANSPORT VEHICLES FUEL CONVERSION IN JABOTABEK AREA

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ABSTRACT

NGV has been used as a vehicular fuel in Indonesia, particularly in Jakarta. However, the success of this NGV utilization is still in question. Currently, only taxicabs and a view dedicated buses have successfully utilized NGV for its fuel. This condition need to be analyzed in order to specify key factors that should be taken into account and to overcome many problems that might be encountered for the success of fuel conversion from current fuel in use to CNG or LPG. The analysis isconducted based on the NGV users, retailers and the government points of view. At this stage, the evaluation is focused on the users standpoint.

The assessment is carried out by developing mathematical model on the feasibility of vehicle fuel conversion in which public transport vehicle fuel conversion in Jabotabek (Jakarta, Bogor, Tangerang and Bekasi) area has been included as a case study. The model is derived in term of parameters that are significantly controllable and dominantly effect on the fuel conversion. These parameters include kit conversion price, fuel selling price and average daily travel of the vehicles.

The results of the evaluation shows that most of public transport vehicles in Jakarta, except taxicabs and dedicated buses, are not feasible to be converted from current fuel in use to LPG or CNG because of the actual dominant parameters including the kit price, current fuel price and average daily travel do not meet the feasible condition.

Therefore, actions such as fuel pricing mechanism need to be taken into account for the success of the fuel conversion purposes to support Blue Sky Program implementation in Indonesia, particularly in Jabotabek (Jakarta, Bogor, Tangerang, Bekasi) area.

I. INTRODUCTION

One of the objectives of the Blue Sky Program establishment in Indonesia, particularly in Jabotabek area, is to reduce air pollution from fuel utilization. This reduction will be achieved by improving fuel specification and developing natural gas (Compressed Natural Gas, CNG or Liquefied Petroleum Gas, LPG) utilization as vehicular fuel to substitute the current liquid petroleum fuel such as gasoline and Automotive Diesel Oil (diesel fuel). However, it is necessary to carry out the techno-economic analysis for the substitution. This analysis is required in order to specify the key factors that should be considered and to overcome many problems that might be encountered. Based on the results of this analysis, an action plan would then be established for the fuel substitution to support the Blue Sky Program.

The key factors that should be taken into account in carrying out the analysis comprise the following:

1. The feasibility of vehicle fuel conversion, from gasoline/diesel fuel to Natural Gas Vehicles (NGV). The feasibility of vehicle fuel conversion from gasoline/diesel fuel to CNG or LPG has an important role in vehicular fuel conversion. If the conversion is not feasible, fuel substitution will never take place. Therefore, this feasibility and factors related should be evaluated in order to enable maximizing the substitution. This feasibility evaluation is carried out from the users, producers and retailers point of view. The fuel conversion should be feasible for all parties involved.
2. Potential of the fuel substitution. If the feasibility has been determined, the magnitude of the conversion needs be estimated to find the potential of the substitution. This is required to anticipate additional CNG or LPG demand.
3. Kit conversion suppliers and workshops. Since the substitution requires kit conversion installation at vehicle of which its fuel will be converted, it is necessary to evaluate the kits provision, registered workshops and certified technicians. The evaluation needs to be carried out to maintain the continuity of the fuel substitution.
4. The availability of CNG and LPG in Jabotabek area. The supply of CNG or LPG and its infrastructure in Jabotabek area need to be assessed to meet the additional demand for the fuel substitution purposes. CNG or LPG for vehicular fuel is supplied through each filling station.

5. NGV filling stations. To keep the availability of CNG or LPG for the fuel substitution, existing and development of NGV filling station needs to be considered. Otherwise, the availability will be under supply.
6. Safety approval body and standard and code. Conversion kit should be installed in vehicles of which its fuel will be converted from gasoline/diesel fuel to CNG or LPG. The installation should meet recognized standard and code for safety assurance purposes. Therefore, Safety Approval Body is required to assure that the installation has matched the standard and code requirement.
7. Fuel pricing policy. The feasibility of both vehicle fuel conversion and filling station construction relies on fuel price. The feasibility will mean nothing without preferable fuel pricing policy. In other words, the success of vehicle fuel conversion, from gasoline/diesel fuel to CNG or LPG, will not be achieved if favorable fuel pricing policy can not be established. Therefore, the pricing policy needs be proposed in action plan in order that the substitution can take place.

At this stage, the evaluation will be focused on the feasibility of public transport vehicle conversion as the users of CNG/LPG. This is carried out by developing economic model in term of parameters that are dominantly influence to the feasibility. These include specific fuel consumption, fuel price difference, kit conversion price and average daily travel.

From users point of view, CNG or LPG will be used as vehicular fuel if the users can take benefit from the utilization. This benefit is especially in the form of saving incurred due to the fuel price difference between gasoline/diesel fuel and CNG or LPG. The larger the benefit can be obtained the more preferable in the use of CNG or LPG. However, other factors including average daily travel and kit conversion price affect the level of this benefit. Therefore, with the objective of profit maximization to the users, the feasibility of vehicle fuel conversion needs to be analyzed.

II. MATHEMATICAL MODEL OF THE FEASIBILITY OF VEHICLE FUEL CONVERSION

The model is developed based on Break Even Point of investment required to install kit conversion in which the vehicle fuel will be converted from gasoline/diesel fuel to CNG or LPG. Therefore, expenses for gasoline/diesel fuel fueled vehicle should equal to NGV fueled vehicle. Taking into account the following assumptions :

- Break Even Point would be achieved during lifetime of kit conversion.
- No change of prices
- Specific Fuel Consumption of vehicle is constant.
- Constant Discount Factor during lifetime of kit convension.

The model is then derived such as follows :

- **Diesel fuel/gasoline fueled vehicle**

Year	Average fuel cost	Average maintenance cost
1	$F_g.X_d.SFC.Y_n$	$X_d.P_l.V_l.Y_n/V_m$
2	$F_g.X_d.SFC.Y_n.(1+DCF)$	$(1+DCF).X_d.P_l.V_l.Y_n/V_m$
3	$F_g.X_d.SFC.Y_n.(1+DCF)^2$	$(1+DCF)^2.Xd.P_l.V_l.Y_n/V_m$
4	$F_g.X_d.SFC.Y_n.(1+DCF)^3$	$(1+DCF)^3.X_d.P_l.V_l.Y_n/V_m$
5	$F_g.X_d.SFC.Y_n.(1+DCF)^4$	$(1+DCF)^4.X_d.P_l.V_l.Y_n/V_m$

Total Expenditure per annum =

Average Fuel Cost/Year +Maintenance Cost/Year

Total Expenditure during lifetime of kit conversion N years i.e. 5 years for Gasoline/diesel fuel fueled vehicle (say equation A) =

$$\sum_{Year=1}^{Year=5} (\text{Average Fuel Cost/Year} + \text{Maintenance Cost/Year}) =$$

$$(F_g.X_d.SFC.Y_n + X_d.P_l.V_l.Y_n / V_m).$$
$$\{1+[(1+DCF)+(1+DCF)^2+(1+DCF)^3+(1+DCF)^4]\}$$

- **NGV fueled vehicle**

Year	Avg. fuel cost	Avg. kit price	Avg. maintenance cost
1	$F_c.X_d.SFC.Y_n$	K_p/Y_n	$X_d.P_l.V_l.Y_n/V_m$
2	$F_c.X_d.SFC.Y_n.(1+DCF)$	$K_p/Y_n.(1+DCF)$	$(1+DCF).X_d.P_l.V_l.Y_n/V_m$
3	$F_c.X_d.SFC.Y_n.(1+DCF)^2$	$K_p/Y_n.(1+DCF)^2$	$(1+DCF)^2.Xd.P_l.V_l.Y_n/V_m$
4	$F_c.X_d.SFC.Y_n.(1+DCF)^3$	$K_p/Y_n.(1+DCF)^3$	$(1+DCF)^3.X_d.P_l.V_l.Y_n/V_m$
5	$F_c.X_d.SFC.Y_n.(1+DCF)^4$	$K_p/Y_n.(1+DCF)^4$	$(1+DCF)^4.X_d.P_l.V_l.Y_n/V_m$

Total Expenditure per annum =

Avg. Fuel Cost/Year + Maintenance Cost/Year + Avg. Kit Price/Year

Total Expenditure during lifetime of kit conversion N years i.e. 5 years for NGV fuel vehicle (say equation B)=

$$\sum_{Year=1}^{Year=5} (\text{Avg. Fuel Cost/Year} + \text{Maintenance Cost/Year} + \text{Avg. Kit Price/Year}) =$$

$$(F_c.X_d.SFC.Y_n + \frac{K_p}{Y_n} + \frac{X_d.P_l.V_l.Y_n}{V_m}).$$
$$\{1+[(1+DCF)+(1+DCF)^2+(1+DCF)^3+(1+DCF)^4]\}$$

At Break Even Point, equation. A = equation B. Therefore

$$F_g.X_d.SFC.Y_n + X_d.P_l.V_l.Y_n/V_m =$$
$$F_c.X_d.SFC.Y_n + K_p/Y_n + X_d.P_l.V_l.Y_n/V_m$$

$F_g . X_d . SFC . Y_n = F_c . X_d . SFC . Y_n + K_p / Y_n$

and hence,

$K_p / Y_r \times X_d = SFC \times N \times (F_g - F_c)$ (1)

where,

K_p : Kit conversion price, Rp.
Y_r : Operating day of vehicle in a year, 300 days.
X_d : Average daily travel, km
SFC : Specific fuel consumption, L/km
DCF : Discounted factor, %
N : Life time of kit conversion, year
F_g : Fuel oil selling price, Rp./L
F_c : NGV selling price, Rp./Le

III. CASE STUDY : THE FEASIBILITY OF PUBLIC TRANSPORT VEHICLE FUEL CONVERSION IN JABOTABEK AREA

Equation (1) shows the relationship between kit price, average daily travel and fuel price difference (between Gasoline/diesel fuel and NGV) at particular operating day per annum, specific fuel consumption and fixed pay back period of kit investment.

It is supposed to say that a one year payback period of kit investment will be acceptable to the users, the relationship between fuel price difference and the ratio of kit price and average daily travel is shown in equation (2) :

$K_p / X_d = 300 \times (F_g - F_c) \times SFC$ (2)

Based on equation (2), using SFC data from PPPTMGB "LEMIGAS", current fuel price and estimated kit conversion constant price, the feasible average daily travel of public transport vehicle to be converted is shown in Table 1.

Table-1 shows that each vehicle has its own feasible average daily travel due to the variation of SFC, kit price and type of fuel conversion. If the actual daily travel of each vehicle less than the feasible daily travel such as shown in Table 1, the fuel substitution will not take place.

However, based on .daily travel data from DLLAJR DKI, there is no public transport vehicle cover the feasible daily travel such as described in Table-1 except for taxi cab. This is because of each vehicle requires a feasible fuel price difference to meet the feasible fuel conversion as indicated in Table 2. If current fuel price difference is less than the feasible one, the fuel substitution will not happen.

Another way to achieve the feasible fuel conversion is to control kit conversion price which is imported for the fuel substitution purposes. Using equation (2), the feasible kit price for each vehicle is estimated in Table-3. If the actual kit conversion price is more than the feasible kit price pointed out in Table-3, the feasible vehicle fuel conversion will not be achieved. However, if the actual price is less than or equal to the feasible one, the fuel substitu-

Table 1
The feasible average daily travel based on current fuel price in Jabotabek area, 2000

Vehicle type	SFC[1] (L/km)	Fuel price difference (Rp./L)	Daily travel, (Km)	Estimated kit price, (million Rp.)	Fuel conversion,
Bajaj	0.067	600	373	5.0	Gasoline/LPG
Taxi Cab	0.107	600	299	8.0	Gasoline/LPG
Taxi Cab	0.107	900	200	8.0	Gasoline/CNG
Mini Bus	0.098	600	510	8.0	Gasoline/CNG
Mini Bus	0.098	900	340	8.0	Gasoline/CNG
Bus	0.125	350	1905	25.0	Diesel fuel/CNG
Micro Bus	0.121	350	1968	25.0	Diesel fuel/CNG

1) PPPTMGB "LEMIGAS"
Gasoline price : Rp. 1450/L, diesel fuel price : Rp. 900/L, CNG price : Rp. 550/Le, LPG price ; Rp 840/Le

Table 2
The feasible fuel price difference for public transpor vehicle fuel conversion in Jabotabek Area, 2000.

No.	Vehicle type	SFC (L/km)	Daily travel[2], (km)	Fuel Price difference, Rp./L	Fuel conversion
1	Bajaj	0.067	100-150	2239-1493	Gasoline to CNG/LPG
2	Taxi Cab	0.107	300-350	599-513	Gasoline to CNG/LPG
3	Mini Bus	0.098	60-130	5102-2355	Gasoline to CNG/LPG
4	Bus	0.125	200-1300	3333-513	Diesel fuel to CNG
5	Micro Bus	0.121	150-1050	4591-656	Diesel fuel to CNG

2) Analyzed from DLLAJR DKI data

Table 3
The feasible kit conversion price based on current fuel price in Jabotabek Area, 2000

Vehicle type	SFC1 (L/km)	Fuel price difference (Rp./L)	Daily travel2, (km)	Feasible kit price, (million Rp.)	Fuel conversion,
Bajaj	0.067	600	100-150	1.2-1.8	Gasoline/LPG
Taxi Cab	0.107	600	300-350	9.0-10.5	Gasoline/LPG
Taxi Cab	0.107	900	300-350	13.5-15.8	Gasoline/CNG
Mini Bus	0.098	600	60-130	1.1-2.3	Gasoline/CNG
Mini Bus	0.098	900	60-130	1.6-3.4	Gasoline/CNG
Bus	0.125	350	200-1300	2.6-17.1	Diesel fuel/CNG
Micro Bus	0.121	350	150-1050	1.9-13.3	Diesel fuel/CNG

tion will take place. In practice, such case has been proved by the success of taxi cab fuel conversion in Jakarta, for instance.

IV. SUGGESTED FUEL PRICING MECHANISM

It has been shown that fuel selling price affects significantly to the feasibility of fuel vehicle conversion (from gasoline/diesel fuel to CNG or LPG). Therefore, these feasibility should be taken into account in fuel pricing policy establishment in order that the fuel substitution can be successfully implemented.

Once gasoline/diesel fuel selling price has been determined, what is NGV worth in order that the prices is acceptable to the users. To answer the question, from the users point of view, the following factors need to be considered in NGV pricing mechanism:

- ☑ Conversion kit price.
- ☑ Average daily travel of vehicle.
- ☑ Fuel price difference between gasoline/diesel fuel and NGV.
- ☑ The feasibility of vehicle fuel conversion.

Based on the draft of Oil And Gas Sector Restructuring Policy For Indonesia, natural gas prices to the small-volume "City Gas" consumers will be regulated by establishing a price ceiling, to be linked, for instance, to alter-

native fuels used by these small-volume consumers. The price ceiling will be sufficient to cover economic gas supply cost, including a return on approved investment. Therefore, based on this policy, the prevailing CNG or LPG fuel retail price should be acceptable to the users.

V. CONCLUSIONS

Based on the evaluation of the feasibility of vehicle fuel conversion, some important points can be summarized below,

1. Parameters that are significantly controllable and dominantly effect on the feasibility of vehicle fuel conversion include kit conversion price, fuel selling price difference between gasoline/diesel fuel and NGV and average daily travel of the vehicles.
2. Most of public transport vehicles in Jakarta, except taxicabs and dedicated buses, are not feasible to be converted from current fuel in use to LPG or CNG because of the actual dominant parameters including the kit price, current fuel price and average daily travel are not meet the feasible condition.
3. The feasible vehicle fuel conversion will no achieved for the following conditions:
   a. Average daily travel of vehicle is less than the feasible daily travel.
   b. Current fuel price difference is less than the feasible fuel price difference
   c. Actual kit conversion price is more than the feasible kit price.
4. From the NGV users point of view, the following factors are suggested to be considered in fuel pricing determination for public transport vehicle:
   a. Conversion kit price.
   b. Average daily travel.
   c. Fuel price difference between gasoline/diesel fuel and CNG or LPG.
5. The developed model of the feasibility of vehicle fuel conversion has been accurately proved in practice by the success of taxicabs fuel conversion in Jakarta.

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