MATHEMATICAL MODEL ON THE FEASIBILITY OF NGV FILLING STATION CONSTRUCTION FOR PUBLIC TRANSPORT FUEL SUBSTITUTION IN JABOTABEK AREA

by
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ABSTRACT

A key factor that should be taken into account in implementing public transport fuel substitution in Jabotabek area is the feasibility of NGV (new) filling stations construction. This needs to be considered in order that the supply of NGV in the area can be secured. Otherwise, additional demand of NGV (CNG and/or LPG) for the substitution will not be met. A mathematical model of the feasibility of NGV filling station construction has been developed as a rule of thumb of the construction. The model is then applied to select the location of NGV filling station based on public transport population in Jabotabek 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 (ADO). The success of the substitution will be significantly depend on the following factors:

- The feasibility of vehicle fuel conversion, from gasoline/ADO to Natural Gas Vehicles (NGV). The feasibility of vehicle fuel conversion from gasoline/ADO to CNG or LPG has an important role in vehicular fuel conversion. If the conversion is not feasible, fuel substitution will never take place.
- Potential of the fuel substitution. If the feasibility has been determined, the magnitude of the conversion needs to be estimated to find the potential of the substitution. This is required to anticipate additional CNG or LPG demand.
- The availability of CNG and LPG in Jabotabek area. The supply of CNG or LPG and its infrastructure in Jabotabek area needs 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.
- The feasibility of NGV filling stations construction. To keep the availability of CNG or LPG for the fuel substitution, existing and development of NGV filling station need to be considered. Otherwise, the availability will be under supply.

The economic model of the filling station construction has been developed based on parameters which are dominantly affect the feasibility. These include NGV selling price, sales volume, investment required and production cost of NGV.

II. MATHEMATICAL MODEL OF THE FEASIBILITY OF NGV FILLING STATION CONSTRUCTION

The model is developed based on Break Even Point of investment required to install NGV filling station facilities. Taking into account the following assumptions:

- Break Even Point would be achieved at pay back period of investment.
- No change of prices (fixed fuel price).
- Constant Discount Factor.
- Constant average investment per annum is distributed during pay back period of time of investment.

The model is then derived such as follows:

Expenditures Calculation

Investment per annum = Sales volume x Production Cost.

Year	Investment per annum	Production Cost Per Annum
1	I_p /n	S_d x Y_n x P_x
2	(1+DCF) x I_p /n	(1+DCF). S_d x Y_n x P_x
3	$(1+DCF)^2$ x I_p /n	$(1+DCF)^2$. S_d x Y_n x P_x
. .		
n	$(1+DCF)^{n-1}$ x I_p /n	$(1+DCF)^{n-1}$. S_d x Y_n x P_x
Σ	$[1 + \Sigma (1+DCF)^{n-1}]$ x I_p /n	$[1 + \Sigma (1+DCF)^{n-1}]$ x S_d x Y_n x P_x

Investment per annum = I_p /n

Production Cost Per Annum = S_d x Y_n x P_x

Total Expenditures at pay back period = Total Investment per annum + Total Production Cost Per Annum

$$[1 + \sum_{1}^{n} (1+DCF)^{n-1}] \times I_p/n + [1 + \sum_{1}^{n} (1+DCF)^{n-1}] \times S_d \times Y_n \times P$$

Revenue Calculation

Revenue = Sale Volume x NGV selling Price

= S_d x Y_n x F_c

Year	Revenue per Annum
1	S_d x Y_n x F_c
2	S_d x Y_n x F_c.x (1+DCF)
3	S_d x Y_n x F_c x $(1+DCF)^2$
.	
n	S_d x Y_n x F_c x $(1+DCF)^{n-1}$
Σ	S_d x Y_n x F_c x $[1+ \Sigma (1+DCF)^{n-1}]$

Total Revenue at pay back period =

$$S_d \times Y_n \times F_c \times [1+ \sum_{1}^{n} (1+DCF)^{n-1}]$$

At Break Even Point, Total Revenue = Total Expenditures. Therefore

$$[1 + \sum_{1}^{n} (1+DCF)^{n-1}] \times I_p/n + [1 + \sum_{1}^{n} (1+DCF)^{n-1}] \times S_d \times Y_n \times P_x =$$

$$S_d \times Y_n \times F_c \times [1+ \sum_{1}^{n} (1+DCF)^{n-1}]$$

and hence,

$$F_c = I_p / \ n \times S_d \times Y_n - P_x \qquad (1)$$

where,

F_g : Fuel oil selling price, Rp./L

F_c : NGV selling price, Rp./Le

P_x : NGV production cost, Rp. / Le

S_d : Daily filling station sales volume, Le.

Y_n : Operating day per annum

DCF : Discount Factor

n : Pay back Period, Year.

I_p : Investment, Rp.

Table 1
Potential of Gasoline to CNG or LPG Public Transport Vehicle Fuel Substitution in Jabotabek Area, 2000

No.	Vehicle Type	Population	SFC (L/km)	Daily Travel, (km)	Fuel to be Substituted (1000 kL/Year)
1.	Bajaj	14,612	0.067	100-150	1.81 - 2.11
2.	Passenger Car	15,853	0.107	300-350	151.66 – 178.11
3.	Mini Bus	12,907	0.098	60-130	22.77 - 49.33
Total		43,372			176.24 - 229.55

Table 2
Potential of ADO to CNG Public Transport Vehicle Fuel Substitution in Jabotabek Area, 2000

No.	Vehicle Type	Population	SFC (L/km)	Daily Travel (km)	Fuel to be Substituted (1000 kL/Year)
1.	Bus	6454	0.125	200-1300	48.40-314.63
2.	Micro Bus	4981	0.121	150-1050	27.12-189.85
3.	Truck	7257	0.290	100-700	63.14-441.98
Total		18,692			138.66– 946.46

III. POTENTIAL OF VEHICLE FUEL SUBSTITUTION

Having calculated the feasibility of vehicle fuel conversion, potential of fuel substitution from gasoline/ADO to CNG or LPG needs to be estimated to find additional gas demand in Jabotabek area that should be provided. Otherwise, CNG or LPG supply in Jabotabek area will not meet the demand. The gas demand is estimated based on specific fuel consumption and fleet population by using energy content approach. In this estimation, it is assumed that one hundred per cent (100%) of gasoline and eighty per cent (80%) of ADO can be converted to CNG. However, ADO fuel cannot be converted to LPG due to technical reasons. The potential is estimated based on fleet population data (from local authority , DLLAJR), daily travel and average operating days per annum of 300. The potential of vehicle fuel oil to be substituted (Fuel to be Substituted/Year) is shown in Table 1 and Table 2 for gasoline and ADO vehicles respectively.

In carrying out the estimation, the following assumptions is taken into account:

Table 3
BEP of NGV Filling Stations Construction

Payback Period, Years	NGV Selling Price, Rp./Le	Daily Sale Volume, Le/day	Daily Vehicle Capacity	Operating Hours Per day
3	1,460	5,707.8	285.4	23.8
4	1,240	5,716.5	285.8	23.8
5	1,110	5,703.4	285.2	23.8

- CNG and LPG supply in Jabotabek area are available.
- Gasoline substitution to CNG or LPG is one hundred per cent whilst only eighty per cent conversion of ADO to CNG due to the technical consideration.
- ADO will not be able to be converted to LPG because fuel price difference is less than zero (LPG fuel selling price per liter equivalent is more expensive than ADO).
- Specific fuel consumption is constant.

VI. THE AVAILABILITY OF CNG AND LPG FUEL IN JABOTABEK AREA

The availability of CNG and LPG in Jabotabek area depends upon each filling station production capacity. CNG filling station is located on the existing gas distribution network line while LPG filling station can be placed everywhere as long as the location can be reached by LPG transporters for supplying the LPG.

Security of supply of CNG and LPG in Jabotabek area should be maintained to meet the additional demand for the fuel substitution. The supply can be secured by identifying existing infrastructure available for CNG or LPG fuel provision, i.e. filling stations. There are only sixteen CNG filling stations and less than ten LPG filling stations available and distributed in Jabotabek area, each has a capacity of 960 vehicles per day. Assuming a 20 liters fuel equivalent per vehicle can be filled in, only 92.16 thousand kLe/Year of CNG and less than 57.60 kLe/Year of LPG fuel can be produced. Compared to the potential of fuel oil to be substituted in Table 1 and Table 2, the cumulative filling stations production will not be able to meet the additional CNG or LPG demand. Therefore, to meet the demand, some CNG or LPG filling stations need to be constructed around Jabotabek area. However, the feasibility of the filling stations construction should be considered in order that it can be attractive to investors.

V. NGV FILLING STATIONS LOCATION SELECTION IN JABOTABEK AREA

Since the feasibility is an important role in filling stations construction, location of the new filling stations needs to be determined in order that the feasible condition can be achieved. Table 3 shows the feasible condition of filling stations construction in term of NGV selling price, daily sales volume and payback period by using equation (1), NGV production cost (Rp. 584/Le) and filling station investment of around Rp. 4,500,000,000 (US $ 450,000).

It is indicated from Table 3 that only NGV selling price variation affects payback period on NGV filling station investment whilst whatever the price will be, the feasible condition (acceptable payback period) can be achieved if the filling stations capacity are around 285 vehicles per day.

VI. CONCLUSIONS

From the above discussion, the following points can be summarized:

- The success of the fuel substitution will be significantly depends on:
  - The feasibility of vehicle fuel conversion, from gasoline/ADO to Natural Gas Vehicles (NGV).
  - Potential of the fuel substitution.
  - The availability of CNG and LPG in Jabotabek area.

· The feasibility of NGV filling stations construction.

- Security of supply of CNG and LPG in Jabotabek area should be maintained to meet the additional demand for the fuel substitution.
- To meet the potential of CNG/LPG demand for the fuel substitution, some CNG or LPG filling stations need to be constructed around Jabotabek area.
- Location of the new filling stations need to be determined in order that the feasible condition can be achieved.
- NGV selling price variation affects payback period on NGV filling station investment whilst the feasible condition (in term of acceptable payback period) can be achieved if the filling stations capacity are around 285 vehicles per day.

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