Development of Natural Gas Hub Network Based on Specific Total Annual Cost in East Java Region

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Abstract. Natural Gas is one of fossil fuel energy with the lowest CO₂ emission and has been widely used in Indonesia. However, the absorption of natural gas in Indonesia is still not optimal. Several regions have natural gas supply above the region's needs and some regions otherwise. The solution to these problems is to create a coordinated gas network in a system that called the hub method. In this method, all producers send their gas to the hub or collection point, then the gas is sent from the hub to consumers. Later a regasification station and LNG plant were connected into the hub. With this method, the problem of excess gas supply and lack of natural gas can be overcome. In this study, the natural gas network was developed by using hub method modelling with the case study in East Java. The first model is the grassroots model which assumes there is no natural gas network in the region. The second model is a combined model that was done by modifying/adding pipelines from existing pipelines. The two models were optimized by minimizing the total annual cost (TAC) needed which includes the cost of making and operating pipes and compressors. From the results obtained, the specific TAC which is the TAC divided by annual gas supply capacity from the grassroots, existing, and combined models are US$ 1.52/MMbtu, US$ 1.50/MMbtu, and US$ 1.44/MMbtu, respectively. Therefore, the combined model is the most optimal based on specific TAC.

1. Introduction

Indonesia is a country that has huge natural gas reserves. According to BPPT data in 2018, Indonesia's total natural gas reserves were recorded at 144.06 TSCF (trillion standard cubic feet). Of these, 101.22 TSCF was proven natural gas, while the remaining 42.84 TSCF was potential natural gas [1]. However, the absorption of natural gas in Indonesia is still not optimal. This is because Indonesia is an archipelagic country, where it will be more difficult and expensive in terms of transportation between regions. Also, the distribution of natural gas reserves in Indonesia is not evenly distributed in each region. Several regions have natural gas supply above the region's needs and some regions have a supply of natural gas under the region's needs [2].

Therefore, it is better to establish a coordinated gas network in a system. Where every producer and consumer in a region has a natural gas network that is connected. Then after that, the natural gas network...
is connected to an LNG terminal, which consists of a regasification station and a mini LNG plant. So that when there is an excess of gas supply, it can be sent to a mini LNG plant which will convert natural gas into liquefied natural gas (LNG) which can be sent outside the island. Likewise, when the region lacks gas supply, LNG from outside the region can be sent to a regasification station which will convert LNG into natural gas which will then be sent to consumers who need it through the connected natural gas network.

The natural gas network system in this study is called the hub. Hub according to Cambridge Dictionary is "the central or main part of something where there is most activity" which in this study defines a centralized natural gas system where the hub is the center or link between producers and consumers [3]. Where the process is, all producers send their gas to the hub or collection in LNG terminal through the hub. So, with the system in this study, the problem of excess gas supply and natural gas shortages can be overcome.

In this research, we take a case study from the development of this natural gas hub network in the East Java region. This is because the East Java region has several advantages including the number of producers and consumers of natural gas and the locations of producers (sources) and consumers (sinks) that are currently not necessarily close together.

2. Problem Statement
The formal problem statement of this study is presented below:
- The purpose of this study is to obtain a natural gas network model with the most optimal hub system based on the specific total annual cost (total annual cost per annual gas supply capacity).
- The method used is single objective optimization, with the objective function is the total annual cost.
- Development of natural gas hub network uses two models, namely the grassroots model and the combined model.
- The hub used for the grassroots model is a regression line from the points of the producer and consumer locations with a homogeneous hub pipe model.
- The initial pressure on the source flow, the final pressure on the sink flow, and the pressure along the hub pipe are assumed to be uniform which are 1000 psi, 500 psi, 200 psi, respectively.
- The natural gas transportation system used is a pipeline.
- The period time used is the optimum operating time of the pipeline, which is 15 years starting from 2018.
- For the unknown capacity data will be synthesized from the complementary data obtained.
- Software used for optimization is Microsoft Excel and Matlab 2017a.
- Design of natural gas transmission pipelines using API RP 14e standard.

3. Methodology
In this study, the development of natural gas hub network in East Java region using two types of model. First is by using a grassroots model and the second is a combined model.

3.1. Grassroots Model
According to the Cambridge Dictionary, grassroots is "not adapted from or added to existing facilities or operations: completely new" [3]. In this study, one of the ways to achieve the goal is to design a natural gas network without paying attention to the existing natural gas network which is then called the grassroots model. Methodology of this model is presented below:

3.1.1. Sink and Source Capacity Data Collection. The location boundary used in this research is East Java. Based on the availability of data from the literature, there were 11 sources of natural gas producers and 5 sinks of natural gas consumers in the East Java region [2]. The data source obtained is processed to obtain capacity data each year. This data processing is done by making a production profile of the
source. Then the data sink obtained is processed by breaking the sink data into several parts. The results of data processing presented in the table below with Table 1-4

**Table 1.** Source Capacity Data years 1 to 7 from 2018.

| No | Producers                        | Years (MMSCFD) |
|----|----------------------------------|----------------|
|    |                                  | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
| 1  | Pertamina Hulu Energi WMO       | 171.2 | 212.8 | 222.5 | 212.8 | 206.9 | 187.8 | 176.2 |
| 2  | Kangean Energi Indonesia       | 201.8 | 201.8 | 201.8 | 138.5 | 95  | 65.2 | 44.8 |
| 3  | LAPINDO                        | 13.8  | 13.8  | 13.8  | 13.8  | 13.8  | 13.8  | 13.8  |
| 4  | SANTOS                         | 66    | 41.2  | 25.7  | 16.1  | 10   | 6.3  | 3.9  |
| 5  | SAKA Indonesia Pangkah         | 24    | 24    | 24    | 15.8  | 10.4 | 6.9  | 4.5  |
| 6  | Pertamina EP Poleng            | 14.4  | 14.4  | 14.4  | 14.4  | 8.7  | 6.2  | 4.4  |
| 7  | Pertamina EP Sukowati          | 2     | 1.6   | 1.3   | 1.1   | 0.9  | 0.7  | 0.6  |
| 8  | Petronas Carigali Ketapang Ltd | 35.4  | 35.4  | 35.4  | 35.4  | 35.4  | 35.4  | 35.4  |
| 9  | Husky-CNOOC Madura Ltd         | 100   | 155   | 237.3 | 285.3 | 292.4 | 250.9 | 229.7 |
| 10 | Pertamina EP Cepu              | 0     | 7.8   | 15.6  | 23.4  | 171.8 | 171.8 | 171.8 |
| 11 | KrisEnergy                     | 0     | 14    | 28    | 42    | 70   | 70   | 70   |

**Table 2.** Source Capacity Data years 8 to 15 from 2018.

| No | Producers                        | Years (MMSCFD) |
|----|----------------------------------|----------------|
|    |                                  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
| 1  | Pertamina Hulu Energi WMO       | 138 | 99.3 | 75.8 | 46 | 27.9 | 16.9 | 10.3 | 6.2 |
| 2  | Kangean Energi Indonesia       | 30.7 | 21.1 | 14.5 | 9.9 | 6.8 | 4.7 | 3.2 | 2.2 |
| 3  | LAPINDO                        | 13.8 | 13.8 | 13.8 | 13.8 | 13.8 | 13.8 | 13.8 | 13.8 |
| 4  | SANTOS                         | 2.4  | 1.5  | 1    | 0.6  | 0.4  | 0.2  | 0.1  | 0.1 |
| 5  | SAKA Indonesia Pangkah         | 3    | 2    | 1.3  | 0.9  | 0.6  | 0.4  | 0.2  | 0.2 |
| 6  | Pertamina EP Poleng            | 3.1  | 2.2  | 1.6  | 1.1  | 0.8  | 0.6  | 0.4  | 0.3 |
| 7  | Pertamina EP Sukowati          | 0.5  | 0.4  | 0.3  | 0.3  | 0.2  | 0.2  | 0.1  | 0.1 |
| 8  | Petronas Carigali Ketapang Ltd | 17.7 | 14   | 11.1 | 8.8  | 7    | 5.6  | 4.4  | 3.5 |
| 9  | Husky-CNOOC Madura Ltd         | 215.8 | 206.6 | 176 | 109.7 | 72.2 | 47.5 | 31.3 | 20.6 |
| 10 | Pertamina EP Cepu              | 171.8 | 171.8 | 171.8 | 171.8 | 171.8 | 171.8 | 171.8 |
| 11 | KrisEnergy                     | 70   | 70   | 70   | 62.5 | 55.8 | 49.8 | 44.5 | 39.8 |

**Table 3.** Sink Capacity Data years 1 to 7 from 2018.

| No | Consumers                        | Years (MMSCFD) |
|----|----------------------------------|----------------|
|    |                                  | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
| 1  | Surabaya Industrial Estate Rungkut (SIER) | 13.3 | 13.5 | 13.6 | 13.8 | 13.9 | 14.1 | 14.2 |
| 2  | Pasuruan Industrial Estate Rembang (PIER) | 30.3 | 30.6 | 30.9 | 31.3 | 31.6 | 32.0 | 32.3 |
3. Sidoarjo Industrial Estate Berbek (SIEB)  4.7  4.8  4.8  4.9  5.0  5.0  5.1
4. Java Integrated Industrial and Port Estate (JIPE)  24.0  24.2  24.5  24.8  25.0  25.3  25.6
5. Gresik Industrial Estate  7.4  7.4  7.5  7.6  7.7  7.8  7.9
6. Maspion Industrial Estate  24.1  24.3  24.6  24.9  25.1  25.4  25.7
7. Ngoro Industrial Park  27.2  27.5  27.8  28.1  28.4  28.8  29.1
8. Industri & Pergudangan Safe ‘N Lock  4.2  4.2  4.3  4.3  4.4  4.4  4.5
9. Wira Jatim Industrial Estate  1.4  1.4  1.4  1.4  1.4  1.4  1.5
10. Sidoarjo Rangkah Industrial Estate (SiRIE)  10.9  11.0  11.1  11.3  11.4  11.5  11.6
11. Kawasan Industri Tuban (KIT)  12.1  12.3  12.4  12.5  12.7  12.8  13.0
12. Petrokimia Gresik  150  150  150  150  150  150  150
13. Sidoarjo  3.6  3.8  4.0  4.2  4.4  4.6  4.8
14. Surabaya  5.0  5.3  5.5  5.8  6.1  6.4  6.7
15. Gresik  1.4  1.5  1.6  1.7  1.7  1.8  1.9
16. Mojokerto  0.7  0.8  0.8  0.8  0.9  0.9  1.0
17. Pasuruan  0.7  0.8  0.8  0.8  0.9  0.9  1.0
18. Tuban  0.7  0.8  0.8  0.8  0.9  0.9  1.0
19. Kota Surabaya  0.5  0.5  0.6  0.6  0.6  0.6  0.7
20. Kabupaten Sidoarjo  0.4  0.4  0.4  0.4  0.5  0.5  0.5
21. Kota Mojokerto  0.0  0.0  0.0  0.0  0.0  0.0  0.0
22. Kabupaten Mojokerto (Pungging & Ng oro)  0.2  0.2  0.2  0.2  0.2  0.2  0.3
23. Unit Pembangkitan Perak Grati  75.7  74.0  73.2  73.1  73.7  75.1  77.3
24. Unit Pembangkitan Gresik  230  225  222  222  224  228  235

Table 4. Sink Capacity Data years 8 to 15 from 2018.

| No | Consumers                          | Years (MMSCFD) |
|----|------------------------------------|----------------|
|    |                                    | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
| 1  | Surabaya Industrial Estate Rungkut (SIER) | 14.4 | 14.6 | 14.7 | 14.9 | 15.0 | 15.2 | 15.4 | 15.5 |
| 2  | Pasuruan Industrial Estate Rembang (PIER)  | 32.7 | 33.0 | 33.4 | 33.8 | 34.1 | 34.5 | 34.9 | 35.3 |
| 3  | Sidoarjo Industrial Estate Berbek (SIEB)  | 5.1  | 5.2  | 5.2  | 5.3  | 5.3  | 5.4  | 5.5  | 5.5  |
| 4  | Java Integrated Industrial and Port Estate (JIPE) | 25.9 | 26.2 | 26.5 | 26.7 | 27.0 | 27.3 | 27.6 | 27.9 |
| 5  | Gresik Industrial Estate            | 7.9  | 8.0  | 8.1  | 8.2  | 8.3  | 8.4  | 8.5  | 8.6  |
| 6  | Maspion Industrial Estate           | 26.0 | 26.3 | 26.6 | 26.9 | 27.1 | 27.4 | 27.7 | 28.1 |
| 7  | Ngoro Industrial Park               | 29.4 | 29.7 | 30.0 | 30.4 | 30.7 | 31.0 | 31.4 | 31.7 |
| 8  | Industri & Pergudangan Safe ‘N Lock | 4.5  | 4.6  | 4.6  | 4.7  | 4.7  | 4.8  | 4.8  | 4.9  |
| 9  | Wira Jatim Industrial Estate        | 1.5  | 1.5  | 1.5  | 1.5  | 1.5  | 1.6  | 1.6  | 1.6  |
3.1.2. Sink and Source Coordinate Data Collection. The coordinate system is generally divided into two, Geographic Coordinate Systems (GCS) and Projected Coordinate Systems. In this study, the GCS is used because the coordinate data we use comes from Google Earth where the system on Google Earth uses GCS [4]. The coordinate data source and sink in the East Java region presented below with Table 5-6:

| Producers                                      | Coordinate Point                  |
|------------------------------------------------|-----------------------------------|
|                                                | Latitude  | Longitude   |
| Pertamina Hulu Energi WMO                      | -7.4075   | 113.0121    |
| Kangean Energi Indonesia                       | -6.9586   | 115.9301    |
| LAPINDO                                        | -7.5128   | 112.6755    |
| SANTOS                                         | -7.3999   | 114.0271    |
| SAKA Indonesia Pangkah                        | -6.6960   | 112.5321    |
| Pertamina EP Poleng                            | -6.6970   | 112.8842    |
| Pertamina EP Sukowati                          | -7.1090   | 111.9722    |
| Petronas Carigali Ketapang Ltd                 | -6.5562   | 113.1655    |
| Husky-CNOOC Madura Ltd                        | -7.2513   | 114.7180    |
| Pertamina EP Cepu                              | -7.2385   | 111.7281    |
| KrisEnergy                                     | -6.1412   | 112.0090    |

Table 5. Source Coordinate Data.
Table 6. Sink Coordinate Data.

| Consumers                                  | Coordinate Point |
|--------------------------------------------|------------------|
|                                            | Latitude | Longitude |
| Surabaya Industrial Estate Rungkut (SIER)  | -7.3364   | 112.7636  |
| Pasuruan Industrial Estate Rembang (PIER)  | -7.6055   | 112.8244  |
| Sidoarjo Industrial Estate Berbek (SIEB)   | -7.3426   | 112.7580  |
| Java Integrated Industrial and Port Estate (JIPE) | -7.0857 | 112.6068  |
| Gresik Industrial Estate                   | -7.1594   | 112.6351  |
| Maspion Industrial Estate                  | -7.1270   | 112.6122  |
| Ngoro Industrial Park                      | -7.5522   | 112.6182  |
| Industri & Pergudangan Safe ‘N Lock        | -7.4664   | 112.7547  |
| Wira Jatim Industrial Estate               | -7.3421   | 112.6891  |
| Sidoarjo Rangkah Industrial Estate (SiRIE) | -7.4601   | 112.7364  |
| Kawasan Industri Tuban (KIT)               | -6.7866   | 111.9087  |
| Petrokimia Gresik                          | -7.1570   | 112.6401  |
| Sidoarjo                                   | -7.4498   | 112.7015  |
| Surabaya                                   | -7.2575   | 112.7521  |
| Gresik                                     | -7.1653   | 112.6520  |
| Mojokerto                                  | -7.4705   | 112.4401  |
| Pasuruan                                   | -7.6469   | 112.8999  |
| Tuban                                      | -6.8950   | 112.0417  |
| Kota Surabaya                              | -7.2575   | 112.7521  |
| Kabupaten Sidoarjo                         | -7.4498   | 112.7015  |
| Kota Mojokerto                             | -7.4705   | 112.4401  |
| Kabupaten Mojokerto (Pungging & Ngoro)     | -7.5350   | 112.5948  |
| Unit Pembangkitan Perak Grati              | -7.6485   | 113.0280  |
| Unit Pembangkitan Gresik                   | -7.1690   | 112.6612  |

After the source and sink coordinate data obtained, the points are placed on the real map. The following distribution map is presented with in Figure 1:

![Figure 1. East Java Map of Source and Sink Distribution.](image-url)
3.1.3. Defines the hub line model. After data collection is done, the next method is to make a hub line model in the form of a linear line/pipe. This means the hub is a straight pipe without turn at all. The hub model is made in the form of a straight pipe because this model is the easiest and possible to make due to the distribution conditions of the source and sink points which tend to be spread out lengthwise. Hub is modeled with function:

\[ y = a \cdot x + b \]  

(1)

Where \( a \) is the slope of the line, and \( b \) is the intercept or point of intersection between the linear line model and the y-axis which then \( a \) and \( b \) become variables in optimization in this study [5].

3.1.4. Calculate the length and diameter of pipeline. There are 2 length that must be calculated. First is the length of transmission pipe (\( d_T \)) that can be calculated with function below:

\[ d_T = \left| -ax_s + y_s - b \right| \times \frac{\sqrt{a^2 + 1}}{111.3195} \]  

(2)

Where \( x_s \) and \( y_s \) is the location point of source / sink, and 111.3195 is the conversion of length from units of degrees to km in the Indonesian territory[6]. Second is the length of hub pipe (\( d_H \)) that can be calculated with function below:

\[ d_H = \left[ \sqrt{(\max(x_h) - \min(x_h))^2 + (\max(y_h) - \min(y_h))^2} \right] \times 111.3195 \]  

(3)

Where \( x_h \) and \( y_h \) is the location point of hub. Here is the following schematic natural gas network that we made in this study with figure 2:

![Figure 2. Schematic of Natural Gas Network](image)

And after calculate the length, we need to calculate diameter of pipe that need to calculate. To calculate, we use pressure drop as basis. Literature has shown that the most effective pipe transmission has a pressure drop of 3.5-5.83 psi / mile. [ (Mokhatab, Poe dan Mak 2015)] So, we decided to use a pressure drop of the pipe 5.83 psi / mile. Then by using the panhandle equation we can find the diameter of pipe. The panhandle equation is presented below:

\[ d = \left( \frac{Q_m}{0.028E} \left[ \frac{S^{0.961}ZTL_m}{P_1^2 - P_2^2} \right]^{0.51} \right)^{\frac{1}{2.53}} \]  

(4)

Where \( Q_e \) is the capacity, \( S \) is the specific gravity, and \( E \) is the efficiency factor where for a new pipe it is 1 [7].

3.1.5. Calculate Total Annual Cost. The total annual cost to create a natural gas network can be represented by the following equation:
\[ \text{Total Annual Cost} = \text{Annualized Capital Cost} + \text{Annual Operational Cost} \]  

To build the total cost model, we assume:

- Gas in the pipeline is single phase flow.
- Transmission pipeline is horizontal.
- Gas flow in the pipeline is steady – state.
- Gas temperature along a segment of pipe is constant.
- Gas temperature does not change after it comes out of compressor.
- Gas deviation factor (Z) along a segment of pipe is constant.
- Gas deviation factor (Z) does not change after it comes out of compressor.
- Compressor type is centrifugal.
- Tax, insurance, and other economic calculations are not included.

Annualized Capital Cost consists of 2 types of costs. That is Capital Investment Pipe (CIP) and Capital Investment Compressor (CIC). CIP can be calculated by the following equation:

\[ CIP = \frac{(1 + r)^n r}{(1 + r)^n - 1} (1 + R_p)C_p L d^m \]  

And CIC can be calculated by the following equation:

\[ CIC = \frac{(1 + r)^n r}{(1 + r)^n - 1} C_{hp} (g_{hp})^b \]  

Where \( g_{hp} \) is the power required by the compressor in units of horse power. \( g_{hp} \) can be calculated using the following equation.

\[ g_{hp} = \frac{6250 Q_m P_b T Z}{2061} \left[ \frac{(P_1 / P_0)^{(k-1) / (k R_p)}}{T_b (k - 1)} - 1 \right] + b l + s l \]  

Annual Operational Cost consists of 2 types of costs. That is Operational Cost Pipe (OC\_pipe) and Operational Cost Compressor (OC\_comp). OC\_pipe can be calculated by the following equation:

\[ OC_{pipe} = C_{fp} CIC \]  

And OC\_comp can be calculated by the following equation:

\[ OC_{comp} = \frac{(1 + r)^n r}{(1 + r)^n - 1} \sum_{n=1}^{15} (1 + C_{op}) E_{LC}(n) \]  

Where \( C_{op} \) is the operating cost required to run the compressor. Meanwhile, \( E_{LC} \) is the cost of electricity needed to drive the compressor. \( E_{LC} \) Can be calculated by the following equation:

\[ E_{LC}(n) = \frac{1}{8760} g_{kwh}(n) C_e H_y \]  

Where \( g_{kwh} \) is the power needed by the compressor in units of kwh which can be calculated by the following equation [8]:

\[ T_{total} = T_{annual} = C_{annual} = C_{capital} + C_{operation} \]
\[ g_{\text{kwh}}(n) = 19809.32 \frac{Q(n)P_T Z \left( \frac{P_T}{P_0} \right)^{\left( \frac{k-1}{k P_p} \right)} - 1}{T_b (k-1)} + 6532.32 (bl + sl) \]  

3.1.6. Optimization based on TAC. In this study, the optimization method is single objective optimization, where there is single object that must be optimized, namely the total annual cost. Where the variable which is changed or the independent variable is the coefficient a and b. The coefficients a and b are the coefficients of the hub line model. The following is the objective function of the optimization:

\[
\min_{(a,b)\in E_R} \text{Total Annual Cost} (a,b)
\]  

3.2. Combined Model

In this study, combined model means design of natural gas network that is modeled by taking into account the existing natural gas network. Methodology of this model is presented below:

3.2.1. Data Collection. This model use capacity and coordinate data from previous model. And besides that, this model needs the data of existing pipeline natural gas network. From several literature [2] [9] [10] [11] we synthesize/combine it into one existing design. Here is the existing design natural gas network is presented with figure 3:

![Figure 3. Pipeline Network of Existing Design](image)

3.2.2. Create Scenarios. In this method, we create scenarios by considering the existing pipeline.

3.2.3. Calculate the length and diameter of pipeline. For the length calculation, we scaled it from the map. And for diameter of pipeline calculation, it’s the same as previous model in equation (4).

3.2.4. Calculate Total Annual Cost Each Scenarios. The total annual cost calculation is the same as the previous model in equation (5). After calculating total annual cost each scenario, we pick the scenario with the lowest total annual cost.
4. Result and Discussion

4.1. Grassroots Model

In grassroots design, the optimization using single objective optimization method, where there is one single object that must be optimized, namely the total annual cost required to create and run the natural gas network created. The desired total annual cost is the minimum of each possibility calculated using the fmincon function in the Matlab 2017a software.

In the calculation process, the fmincon optimization process requires input in the form of the initial value of the independent variable, a and b [12]. However, there is a problem in the optimization process, where different initial values can result in different minimum values for total annual costs. This requires optimization of grassroots design to create several different possible initial values to obtain a total annual cost which is truly minimum. All possible variations in the initial values are obtained from a three possible synthesis of the two independent variables. Among them, the possibilities exist, namely approaching the optimum point with a top approach, zero approach, and bottom approach.

![Figure 3. 3D Optimum Area Graph of Independent Variable Relationship with TAC](image)

From the optimization results, the optimum variable for the grassroots design natural gas network is obtained as follows:
- \( a(\text{slope}) = -0.0042674668 \)
- \( b(\text{intercept}) = -6.7617361359 \)
- \( \text{total annual cost US$} = 342,825,473.26 \)

And here are the pipeline network visualization of the results is presented with figure 4:
4.2. Combined Model
In this study, the combined model means design of natural gas network that is modeled by taking into account the existing natural gas network. That means we need the length and total annual cost of existing design. After that, we use the data collected to create reasonable scenarios by considering existing design. After that, we calculate total annual cost each scenario. Then we pick the scenario with the lowest total annual cost.

4.2.1. Existing Design. One of the parameters needed to determine the best natural gas network in this study is the total annual cost. In this existing design, there is no source that can provide the total annual cost of the existing natural gas network, so an estimate of the total annual cost is required. Estimation of total annual cost is carried out with the following conditions:

- The calculation concept used is the hub concept described in the previous model
- The data on the length of the existing pipe that was not found, was estimated using the graphic approach method. In this study, the combined model means design of natural gas network that is modelled by taking into account the existing natural gas network. That means we need the length and total annual cost of existing design. After that, we use the data collected to create reasonable scenarios by considering existing design. After that, we calculate total annual cost each scenario. Then we pick the scenario with the lowest total annual cost.

4.2.2. Create Scenario. In the creation of a combined design scenario, several conditions are required with the following details:
- Model formation only takes into account two unconnected source points, Jambaran Tiung Biru (Pertamina EP Cepu) and Lengo Field (KrisEnergy), to increase the total distributed gas which is a deficiency of the existing design.
- Maintaining the Banyu Urip pipeline EPC-2 and EPC-3.
- If pipeline No.16 (Pertamina EP Sukowati - distribution line to Tuban) is not used, it will be plugged
Figure 5. Description Of Combined Design Condition

The Banyu Urip pipeline is a pipeline facility owned by ExxonMobil Cepu Limited which stretches from the Cepu area to the offshore area of Tuban. Banyu Urip pipeline consists of two pipe segments, namely EPC-2 and EPC-3. EPC-2 is a 72 km long onshore pipeline that connects Cepu with Tuban beach while EPC-3 is a 23 km offshore pipeline that connects the Tuban coast to FSO Gagak Rimang [13]. Based on the literature, it was found that the existing pipeline measures 20 inches [14]. Based on the conditions, there are two possible scenarios. The first scenario is without changing the existing pipeline, while the second scenario is by changing the existing pipe, pipe number 16. The following is an illustration of a comparison between two scenarios where the new pipeline route is yellow colored:
The calculation of the total annual cost value is carried out using the same reference as the calculation of the existing design. The following is a comparison of the total annual costs of the two scenarios:

- **1st Scenario**
  Total annual cost = $323,746,979.95
  Additional costs = $87,627,797.30

- **2nd Scenario**
  Total annual cost = $327,227,363.03
  Additional charges = $91,108,180.38
  Total loss = $-68,590.10

Where the additional cost is the difference between the total annual cost combined design with the existing design and the total loss is the cost that is borne by not using pipe number 16. Based on the total annual cost, it can be seen that scenario 1 is the best scenario which is then used as a combined design with the model, as follows:

**Table 7. Comparison of each design.**

| Facilities       | Grassroots | Existing          | Combined         |
|------------------|------------|-------------------|------------------|
|                  | Terminal + | Teluk Lamong LNG  | Terminal + Storage LNG |
|                  | Storage LNG| Terminal (3rd year)| LNG               |
| Distributed      | 198902.37  | 147327.26         | 198902.37         |
| Gas              | BBTU/Year  | BBTU/Year         | BBTU/Year        |
5. Conclusion
From the results obtained, the specific TAC which is the TAC divided by annual gas supply capacity from the grassroots, existing, and combined models are US$ 1.52/MMbtu, US$ 1.50/MMbtu, and US$ 1.44/MMbtu, respectively. Therefore, the combined model is the most optimal based on specific TAC.

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