IV. RESULTS AND DISCUSSIONS

4.1. Need Analysis

Based on previous study conducted by PT. Perusahaan Gas Negara (PGN) on 2004, there were six stakeholders (DKI government, BP TransJakarta, gas supplier, pipeline constructor, and compressor provider) who involved in the pipeline project. Furthermore, by conducting a series of interview, discussion, also questioning the stakeholders (PT. Perusahaan Gas Negara, BP TransJakarta, and DKI Government) and some respondents from residence and public services, the criteria of pipeline path have been identified as follows:

1. The length of the pipe
2. Installing the pipe under the shoulder of existing roadways
3. Installing the pipe beside the existing utilities
4. Considering 25 meter site plan proximity to residential (housing and building).
5. Considering 25 meter site plan proximity to public services (hospital, industrial, institutional, commercial, and business).
7. Minimizing area of disruption that caused by construction

In addition, there were some existing conditions should be taken into consideration such as:

1. Existing gas main pipe 6” under the shoulder of Jagorawi Toll road up to Bypass Jakarta City Toll road.
2. Existing PPD Bus Depot at Cililitan and Kramat Jati that either would be taken over by BP Transjakarta for Busway pool and there would be installed CNG Station called SPBG (Stasiun Pengisian Bahan Bakar Gas).
3. Bus station at Kampung Rambutan, Cililitan, and Kampung Melayu which part of their area would be used by the BP Transjakarta as their becoming Busway Pool and also where the CNG station would be installed.
4.2. Goal and Objective

The output resulted from interview and discussion with the stakeholders defined the goal that was to determine the best route for CNG pipeline network around the area of Transjakarta Busway Corridor VII based on criteria and additional information below:

- The site was urban area with a complex social problem.
- Engineering specification that should be considered were as follows:
  - Standard Design : ASME B 31,8
  - Line Pipe Standard : API 5 L Grade B SCH 40 STD 6” NPS
  - Fitting Standard : ANSI B 16.9
  - Pipeline Valve Standard : API 6 D
  - Welding Standard : API 1104
  - Pipe Coating : AWWA C.20386
- The pipeline would be installed along the main roads and utilities (phone line, power line, water line).
- Existing condition such as the position of bus terminal, bus depot, and existing main gas pipe.
4.3. Conceptual Design

The result of conceptual design was a framework to do the analysis based on required data, methodology, and tools. The data required were as follows:

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Area</td>
<td>Raster dataset displaying study area of busway corridor VII</td>
</tr>
<tr>
<td>Existing of Public Roads</td>
<td>Feature dataset displaying linear road network over the area</td>
</tr>
<tr>
<td>CNG Station Candidate</td>
<td>Feature dataset displaying destination point location used when finding the best route for a CNG Pipeline</td>
</tr>
<tr>
<td>Existing Gas Main</td>
<td>Feature dataset displaying linear CNG pipeline network</td>
</tr>
<tr>
<td>Gas Source Candidate</td>
<td>Feature dataset displaying source point location from SPBG</td>
</tr>
<tr>
<td>Existing Busway Corridor</td>
<td>Feature dataset displaying linear route network for busway corridor VII</td>
</tr>
<tr>
<td>Existing Public Services</td>
<td>Feature dataset displaying vector digital polygon representing mosques, school, hospital, market, shopping centre, gas station, district office</td>
</tr>
<tr>
<td>Existing Buildings</td>
<td>Feature dataset displaying vector digital polygon representing houses, and office buildings</td>
</tr>
<tr>
<td>Existing Utilities</td>
<td>Feature dataset displaying linear utility network of powerline, phoneline, waterline over the area</td>
</tr>
</tbody>
</table>

Figure 7 shows data required in the analysis which were the study area, roads network, rivers, area of interest SPBG, existing main gas pipe, gas source, busway corridor, public services, buildings, and utilities to do the spatial analysis, while Figure 9 shows overlaid data.
Figure 8. Data Required for Analysis
a. Overlay with IKONOS

b. Overlay without IKONOS
The dataset was processed in spatial analysis to perform proximity analysis. Then, the result was analyzed to certain alternative by scoring criteria for each alternative from interpolated data. The whole process was performed using ArcGIS 9.1 for spatial analysis, Microsoft Excel 2003 for data interpolation, and Criterium Decision Plus 3.0 for full pairwise comparison. Figure 4010 shows conceptual model framework.
4.4. Data Processing

Data processing was the technical detail of conceptual design which consists of map projection, data formatting and editing, proximity analysis, data interpolation, scoring, and Analytical Hierarchy Process through full pairwise comparison.

4.4.1. Map Projection

First of all, the entire data input should be registered into georeference to WGS 1984 UTM Zone 48 south as in Figure 1 below. These geographic data has a scale of 1:5000, due to limited area with detail features.

![Horizontal coordinate system](image)

Figure 1. Geographic data coordinate system

4.4.2. Proximity Analysis

By means of using proximity analysis, Figure 2 describe 50 meter of buffering area through pipeline route. There are some properties such as buildings, public services and public roadways along the pipeline route. Each alternative has different amount of properties for each criteria.
4.5. Decision Making

Defining the best route for CNG Pipeline by considering the SPBG and the gas source, it is concluded that there are 5 possible alternatives in which the CNG Station (SPBG) will be established, there are 3 bus terminals (Kampung Rambutan, Cililitan, and Kampung Melayu) and 2 PPD Depot which will be replaced by the Busway Transjakarta pool which are Cawang and Kramat Jati.
In this phase, the possible alternatives were compared and scored based on economic, social, legal aspects, and risk exposure. Economic aspect concerns in three main issues. First is the pipe length where the shortest route will be chosen. The second and last are that it should be in line with the road and utility network to reduce land cost release. In social aspect there are public services that consist of industrial area, hospital, shopping centre, school, university, hotel, tourism, and other building such as houses, offices, institutional, and worship facilities. Establishing pipeline route should avoid high density of the entire social aspect. In legal aspect, we consider the land ownership status such as there are some lands owned by government or other institution within the area of pipeline route which is difficult to release or should spend more cost to release it. And for risk exposure, we consider the areas which are sensitive to construction hazard such as the impact of digging in market area, toll road, etc.

Each criterion were compared to each alternative as described in Figure 13, while Table 4 shows the information of each alternative and Table 5 shows description of criteria.

![Figure 13. CNG Pipeline Network Criteria](image)

Alternative of pipeline route is obtained by considering the existing condition to field data. Alternative 1, Alternative 3, and Alternative 5 are bus stations where the busway pool is to be established and the CNG station (SPBG) will be also installed there. While, Alternative 2, and Alternative 3 are PPD Bus Depots which will be transformed into Busway pool and the CNG station is to be
installed there, too. Table 4 shows the alternative of the pipeline routes, while Figure 14 illustrates the possible alternative routes.

Table 4. Alternatives of Pipeline Routes

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Location</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>Kampung Rambutan</td>
<td>Starting from existing main gas to Kampung Rambutan bus terminal</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Kramat Jati</td>
<td>Starting from existing main gas to Kramat Jati bus depot</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>Cililitan</td>
<td>Starting from existing main gas to Cililitan bus terminal</td>
</tr>
<tr>
<td>Alternative 4</td>
<td>Cawang</td>
<td>Starting from existing main gas to Cawang bus depot</td>
</tr>
<tr>
<td>Alternative 5</td>
<td>Kampung Melayu</td>
<td>Starting from existing main gas to Kampung Melayu bus terminal</td>
</tr>
</tbody>
</table>
Table 5 shows the description of each criterion. These criteria were compiled through some interviews with the stakeholders, in this case are PT. Perusahaan Gas Negara, BP Transjakarta, and DKI Government.
Table 5. Description of Criteria

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Criteria</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>Criteria 1</td>
<td>Pipe Length</td>
<td>Pipe length between source to CNG Station (SPBG)</td>
</tr>
<tr>
<td></td>
<td>Criteria 2</td>
<td>The pipe align with the public roadways</td>
<td>Pipeline route should be arranged in line with the roadways network</td>
</tr>
<tr>
<td></td>
<td>Criteria 3</td>
<td>The pipe align with the utilities</td>
<td>Pipeline route should be arranged in line with the utilities network</td>
</tr>
<tr>
<td>Social</td>
<td>Criteria 4</td>
<td>Public Services</td>
<td>Number of public services along the pipeline route</td>
</tr>
<tr>
<td></td>
<td>Criteria 5</td>
<td>Buildings</td>
<td>Number of building along the pipeline route</td>
</tr>
<tr>
<td>Legal Aspect</td>
<td>Criteria 6</td>
<td>Area of Land Ownership Status by Government</td>
<td>Area of land owned by government ownership within pipeline route</td>
</tr>
<tr>
<td>Risk Exposure</td>
<td>Criteria 7</td>
<td>Area of Construction Impact</td>
<td>Area of disruption that caused by construction process</td>
</tr>
</tbody>
</table>

4.5.1. Criteria Weighting

Preference level of each criteria is obtained from questionnaires (Appendix 1) that are collected from stakeholders. The preference of criteria was averaged and consensus from the expert within the scale of nine units as shown in matrix Table 6.

Table 6. Criteria Preferences

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Criteria 1</th>
<th>Criteria 2</th>
<th>Criteria 3</th>
<th>Criteria 4</th>
<th>Criteria 5</th>
<th>Criteria 6</th>
<th>Criteria 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria 1</td>
<td>1</td>
<td>1/3</td>
<td>1/2</td>
<td>1/2</td>
<td>1</td>
<td>1/2</td>
<td>1/2</td>
</tr>
<tr>
<td>Criteria 2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Criteria 3</td>
<td>2</td>
<td>1/2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Criteria 4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Criteria 5</td>
<td>1</td>
<td>1/3</td>
<td>1/2</td>
<td>1/2</td>
<td>1</td>
<td>1/2</td>
<td>1/2</td>
</tr>
<tr>
<td>Criteria 6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Criteria 7</td>
<td>2</td>
<td>1/2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Then the weight resulted from the preferences were 0.077 for Criteria 1, 0.224 for Criteria 2, 0.148 for Criteria 3, 0.163 for Criteria 4, 0.077 for Criteria 5, 0.163 for Criteria 6, and 0.148 for Criteria 7 (Appendix 2).
4.5.2. Alternative Scoring

In this step we use interpolation with minimum and maximum value of each criteria as shown in Table 7:

Table 7. Range of the criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Units</th>
<th>Min Value</th>
<th>Max Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria 1: Length of Pipe</td>
<td>meters</td>
<td>100</td>
<td>3000</td>
</tr>
<tr>
<td>Criteria 2: Align with the Existing Roads</td>
<td>Yes/no</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Criteria 3: Align with the Existing Utilities</td>
<td>Yes/no</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Criteria 4: Number of Public Services</td>
<td>Unit</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Criteria 5: Number of Buildings</td>
<td>Unit</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Criteria 6: Area of Land Owned by</td>
<td>m²</td>
<td>0</td>
<td>1209.24</td>
</tr>
<tr>
<td>Ownership Status</td>
<td>m²</td>
<td>500</td>
<td>5000</td>
</tr>
</tbody>
</table>

As shown in Table 8, for example the value of Criteria 1 in Alternative 1 is 250. It means the length of the pipe is 250 m in Alternative 1. For Criteria 2, the entire value is 1, meaning that all alternatives align with the roadways. Also for Criteria 3 with an index 0 or 1 show Alternative 1, and Alternative 5 are in 0 indexes that means not align with the utilities. Criteria 4 and Criteria 5 shows density number of public services and buildings. It is determined from the amount of buildings divided by the buffer area of pipeline routes. And both of Criteria 6 and Criteria 7 show private ownership area and construction area within the pipeline route.

Table 8. Value of Each Criteria toward to Each Alternative

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Cr 1</th>
<th>Cr 2</th>
<th>Cr 3</th>
<th>Cr 4</th>
<th>Cr 5</th>
<th>Cr 6</th>
<th>Cr 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>250</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>1171</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>852</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>34</td>
<td>0</td>
<td>1285</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>889</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>43</td>
<td>0</td>
<td>1978</td>
</tr>
<tr>
<td>Alternative 4</td>
<td>545</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>0</td>
<td>1645</td>
</tr>
</tbody>
</table>
Table 9 shows direct scoring of each criteria to each alternative. The score is produced from linear interpolation by considering the minimum and maximum value to the scale of the score within the range of 0 to 100.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Score of Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cr 1</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>95</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>74</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>73</td>
</tr>
<tr>
<td>Alternative 4</td>
<td>85</td>
</tr>
<tr>
<td>Alternative 5</td>
<td>70</td>
</tr>
</tbody>
</table>

These scores were determined by considering field data collection, and then generate to get the normalized weight of alternative as shown at Table 10.

Table 10. Normalized Weight of Alternative

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Normalized Weight of Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cr 1</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>0.239</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>0.186</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>0.184</td>
</tr>
<tr>
<td>Alternative 4</td>
<td>0.214</td>
</tr>
<tr>
<td>Alternative 5</td>
<td>0.176</td>
</tr>
</tbody>
</table>
Figure 15 and Table 11 shows decision score for overall weight. The weight of Criteria 1 is 0.08, Criteria 2 is 0.22, Criteria 3 is Criteria 0.15, Criteria 4 is 0.16, Criteria 5 is 0.08, Criteria 6 is 0.16, and Criteria 7 is 0.15.

Table 11. Decision Score After Steady Condition of Weight Criteria

<table>
<thead>
<tr>
<th>Criteria 1</th>
<th>Criteria 2</th>
<th>Criteria 3</th>
<th>Criteria 4</th>
<th>Criteria 5</th>
<th>Criteria 6</th>
<th>Criteria 7</th>
<th>Decision Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.08)</td>
<td>(0.22)</td>
<td>(0.15)</td>
<td>(0.16)</td>
<td>(0.08)</td>
<td>(0.16)</td>
<td>(0.15)</td>
<td></td>
</tr>
<tr>
<td>Alt 1</td>
<td>0.239</td>
<td>0.200</td>
<td>0.000</td>
<td>0.217</td>
<td>0.217391</td>
<td>0.217</td>
<td>0.207842</td>
</tr>
<tr>
<td>Alt 2</td>
<td>0.186</td>
<td>0.200</td>
<td>0.333</td>
<td>0.174</td>
<td>0.161616</td>
<td>0.217</td>
<td>0.222486</td>
</tr>
</tbody>
</table>
Finally, by considering the weight of steady criteria, then we get the optimal route for CNG Pipeline is Alternative 3-2 which is Cililitan-Kramat Jati with value 0.2242 in decision score, followed by Alternative 23 (0.2154), Alternative 1 (0.2028), Alternative 4 (0.1843), and Alternative 5 (0.18071).

Figure 16 shows the best alternative of CNG Pipeline network which is Cililitan-Kramat Jati (Alternative 32). Although it was not the shortest route (with 88952 meter of length) as criteria 1, however it meets criteria 2 and criteria 3 which align with existing public roads and existing utilities. For criteria 4, there is no significant public services density around there; however it has the highest of residential density in 0.001317 for criteria 5. And another strong point is criteria 6 and criteria 5 with lees of land ownership status and area of construction impact that cause disruption.

<table>
<thead>
<tr>
<th>Alt 3</th>
<th>0.184</th>
<th>0.200</th>
<th>0.333</th>
<th>0.2170-217341</th>
<th>0.0710-070707</th>
<th>0.217</th>
<th>0.206</th>
<th>0.21510</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt 4</td>
<td>0.214</td>
<td>0.200</td>
<td>0.000</td>
<td>0.2170-217391</td>
<td>0.2220-222222</td>
<td>0.217</td>
<td>0.231</td>
<td>0.18345</td>
</tr>
<tr>
<td>Alt 5</td>
<td>0.176</td>
<td>0.200</td>
<td>0.333</td>
<td>0.1740-173913</td>
<td>0.0910-090909</td>
<td>0.130</td>
<td>0.046</td>
<td>0.17111</td>
</tr>
</tbody>
</table>
4.6. Sensitivity Analysis

By using sensitivity analysis in terms of weight it can determine the sensitivity of the preferred alternative to change the criteria weight in 0 – 1 range. Critical changes in the weights are those that cause a change in the preferred alternative and are those with which should be most concerned. For Example in pipe length (Criteria 1), although Kampung Rambutan was the shortest path, but
Cililitan was chosen for the best route in 0.08 of weight by considering all criteria. If the pipe length was the most important criteria in 1 of weight, thus Kampung Rambutan should be the preferred route. In this case, for the most sensitive criteria were Criteria 2 with the highest weight (0.224) that influencing preferred alternatives. Figure 17 shows sensitivity analysis graph for criteria 1, while another criteria was in Appendix 3.

Figure 17. Sensitivity Analysis for Criteria 1

Figure 18 shows contribution to goal of each criteria, it means weight of criteria for each alternatives. From the graph for Alternative 1 and Alternative 4, there were no contribution in Criteria 3 which is the pipe should align with existing utilities, while another criteria have varied contribution.
4.7. Potential Problem in Model Implementation

Similar model has been applied in “East Java – West Java Gas Transmission Project”. Since there is only a few of building, residential and social problem, the criteria is more accurate to the decision making and does not need advance analysis for land suitability. The problem which occurs is only construction impact or disruption in certain area.

For Jakarta City Pipeline project, in this case is gas transmission for busway corridor VII, the analysis is more advance due to Jakarta is well complex established city. Even though the study area is small, but it has complex problem that required detail data availability. In order to define where is the gas sourced and the pipeline should align with existing utilities network, it is recommended that existing gas main pipe and utilities network should available in a precise position with the field to pertain the accuracy in advance analysis.