Setting the natural gas selling price through pipeline network optimization and project feasibility study

Filscha Nurprihatin¹, Johanes Fernandes Andry², Hendy Tannady³
¹ Department of Industrial Engineering, Faculty of Technology and Design, Universitas Bunda Mulia, Jakarta, Indonesia
² Department of Information System, Faculty of Technology and Design, Universitas Bunda Mulia, Jakarta, Indonesia
³ Department of Management, Faculty of Management, Universitas Pembangunan Jaya, Jakarta, Indonesia

fnurprihatin@bundamulia.ac.id

Abstract. Natural gas will play an important role in the energy revolution, but its construction is still costly. Natural gas transport pipeline network shoulders the task of gas supply, which plays a significant role in improving the overall socio-economic benefits for the region. Pipeline network optimization design is a complex problem, involving many variables. In this study, the location of the Distribution Center is considered and was obtained from the previous study. This study also considers the distance between locations of households. The Minimum Spanning Tree (MST) is applied to obtain the pipeline network length. Then, the calculation is proceeded through the Benefit-cost Ratio in determining whether this project is feasible or not. Although the MST result shows the pipeline is longer than the previous work, studies have shown that the project is still feasible to run. The study also explains that the government can still sell gas at a lower price in the break-even condition.

1. Introduction

The natural gas will play an important role in the energy revolution, but its construction is still costly [1,2]. Transportation in the form of networked infrastructure is one of the key or important units and could not be ignored in managerial decision making[3,4]. This infrastructure aims to provide essential utilities, services[5] and reaching society as a new marketplace [6]. A previous study discussed transportation effectiveness through route optimization[7]. The gas has to be made available at a cheaper cost to all consumers and can only be done when it is transmitted via pipelines at a minimum cost[2,8]. To achieve these goals, natural gas transportation requires a continuous pipeline network from the source of gas across long distances to the various destinations[2]. Pipeline network construction costs can be greatly saved by planning the network comprehensively [8]. Furthermore, it is of great theoretical and practical significance to study layout methods of transport pipeline network[1].

Natural gas transport pipeline network shoulders the task of gas supply, which plays a significant role in improving the overall socio-economic benefits for the region[1]. The transmission segment of the gas industry is responsible for transporting natural gas from the producer to the market areas via
pipelines[2]. The pipelines used in these network systems are ranging from 6 to 48 inches in diameter, although certain component pipe section can consist of small-diameter pipe that is as small as 0.5 inch in diameter[2]. In this research, a 3.5 to 5 inches pipeline is used as the previous work suggested [9].

Previous study pointed out the order fulfillment process in an oil company which is a complicated activity when it comes to the demand integration and coordination [10]. Many attributes have been generated to highlight the importance of quick response to the customer demand [11]. This paper considers the demand should be fulfilled by the pipeline networks length. Previous research approximated the total pipeline network length based on the existing road networks [2]. The existing roads linking the regional capital towns are being used to provide access to the pipelines' construction[2]. The street interchanges must be considered because the pipelines must along the street to lay[12].

With the growth of demand and the development of natural gas infrastructures, the economy of project construction will become increasingly important[1,8]. Consequently, the system parameters and investments are decided by the design scheme of the pipeline network[8]. One important design variable in the design of networked systems is the topology of the network[5]. For a given topological form, different options which combining lots of variables, such as facility number, location, pipeline length lead to different cost required for each aspect[8]. Due to differences in location, economy, and geographical conditions, transport pipeline projects have made a tremendous impact on social and economic benefits and influence the dominance degree of network layout[1]. Previous research approximated the cost by travel time [13]. When the pipeline network is constructed, the market supply and demand, benefit, and construction costs of pipeline projects’ investments should be considered to determine a reasonable layout scheme[1]. The investment cost and operation cost per unit length of the pipeline are calculated by using the net present value of real project[14]. In this paper, the annual worth principle is utilized. Pipeline projects’ investment is large and the payback period is long, which cannot be easily recovered or expanded [15]. Natural gas transport pipeline projects have a certain service life[1]. The more construction costs, the longer the payback period, and the weaker profitability it will be[1]. In this paper, the service life is 25 years as the previous work suggested[9]. This research responds to the previous study which suggested in determining the location and quantity of natural gas stations and valve chests reasonably along with their construction costs comprehensively [1].

2. Problem formulation
Pipeline network optimization design is a complex problem, involving many variables[8]. In this study, the location of the Distribution Centers (DCs) is considered and was suggested from the previous studies. This study also considers the distance between locations of households.

The optimization design can not only reduce investment but also improve the operational efficiency of the system[16]. Good or optimal planning is unavoidable or necessary to minimize the cost of transportation and to maximize the profit for the organization consequently [3]. The investment and operation costs of natural gas pipelines networks are commonly considered important aspects of the total investment[14]. In this paper, the investment cost and operation cost per unit length of the pipeline include material, labor, installation, purchase, and transportation costs, which depend on the pipe length, pipe diameter, and electricity used by the compressor stations[9,14]. This paper applies the Benefit-cost Ratio (BCR) in determining whether this project is feasible or not.

3. Methodology
Figure 1 shows the methodology in this paper. Figure 1 explains that this study utilizes input from previous research, which is the capacity of each DC using Weymouth Formula, and the location of each DC [9]. Each DC has also been determined to work under K-Means Clustering calculations. In this study, the pipeline network is determined through the calculation of the Minimum Spanning Tree (MST) to then proceed to the project feasibility stage using BCR. In the end, the results of the calculation will be compared to see the minimum selling price that can be set by the government as the
operator on breakeven point conditions.

| Previous Research [8] | This Research |
|-----------------------|---------------|
| Capacity Calculation: Weymouth Formula | |
| K-Means Clustering | |
| Heuristics Algorithm: a. Clarke and Wright’s Savings Algorithm b. Nearest Neighbor | |
| Feasibility Study: Benefit-cost Ratio | |
| Minimum Spanning Tree | |
| Feasibility Study: Benefit-cost Ratio | |
| Comparison, conclusion, and recommendation | |

Figure 1. Research Methodology

4. Results and discussion

Five clusters are formed and represents the distribution centers as shown in Figure 2. The distribution network from DC 1 only serve the demand in that particular node. There are six nodes are directly supplied from DC 2 because DC 2 is located between them. The gas network in DC 3 is different from DC 2 because not all nodes are served directly but must pass another node first. DC 4 only serves 2 nodes so it is located between them. DC 5 has similar properties to DC 3 because not all nodes are served directly.

Table 1 explains the differences in the results of calculations using the heuristics method in previous studies with MST in this study. MST provides a longer pipeline, which is 7443 m. With this length, the feasibility study can be carried out using BCR.

It is beneficial to see the previous work in calculating BCR extensively[9]. The BCR calculation results show an index more than 1(1.8547) which indicates that the project is still feasible even though the pipeline is longer than the heuristics method. By still considering depreciation using the straight-line method for 25 years and the selling value of the government of IDR (Indonesian Rupiah) 2790/m³, a minimum selling value in breakeven conditions of IDR 1538.0720/m³ is obtained.

Break-even conditions should aware that the assigned numeric value or weight of an edge (link) might be a function of other relevant things of the pipeline [16]. In other words, the topology of networked systems, under uncertainty and in the context of many actors [5]. They could be the corrosion prevention cost, corrosion risk loss cost, leakage risk loss cost, and total investment cost are used in the corrosion risk cost [14]. Therefore, it is very possible to perform the Total Performance Maintenance (TPM) as the extension analysis [18].

After the natural gas network project is built, further research can also examine service quality [19], health and safety [20] so that continuous improvement goes on [21]. Besides, further research can also discuss operator operations on the gas network in terms of work motivation, so that it remains in a safe and comfortable condition [22].
Figure 2. Minimum Spanning Tree Results

| Cluster | Total distance using Heuristics Methods (m) [8] | Total Distance using Minimum Spanning Tree (m) |
|---------|-----------------------------------------------|-----------------------------------------------|
| 1       | 0                                             | 0                                             |
| 2       | 2659                                          | 3219                                          |
| 3       | 1529                                          | 2239                                          |
| 4       | 421                                           | 366                                           |
| 5       | 1804                                          | 1619                                          |
| Grand Total Distance | 6413                                        | 7443                                          |

5. Conclusion
Although the pipeline is longer than the previous work, this study has shown that the project is still in good condition. The study also explains that the government can still sell gas with a minimum price of IDR 1538/m$^3$ in breakeven conditions, rather than IDR 2790/m$^3$ today. This paper suggests the government in constructing a gas network using the heuristics method because it has a shorter distance.

References
[1] Zhu Z, Sun C, Zeng J and Chen G 2018 Optimization of natural gas transport pipeline network layout: a new methodology based on dominance degree model Transport33 143–50
[2] Gborgenu A K, Twenefour F B K and Gyamfi M 2016 Achieving efficiency in gas pipeline connection: evidence from Ghana Int. J. Bus. Soc. Res. 06 28–42

[3] Akpan N P and Iwok I A 2017 A minimum spanning tree approach of solving a transportation problem Int. J. Math. Stat. Invent. 5 9–18

[4] Nurprihatin F and Tannady H 2018 An integrated transportation models and savings algorithm to minimize distribution costs Proceeding of the 1st Asia Pacific Conference on Research in Industrial and Systems Engineering (Depok: Department of Industrial Engineering Universitas Indonesia) pp 216–21

[5] Heijnen P W, Chappin E J L and Herder P M 2019 A method for designing minimum-cost multisource multisink network layouts Syst. Eng. 1–22

[6] Nurprihatin F, Jayadi E L and Tannady H 2020 Comparing heuristic methods’ performance for pure flow shop scheduling under certain and uncertain demand Manag. Prod. Eng. Rev. 11 50–61

[7] Nurprihatin F and Lestari A 2020 Waste collection vehicle routing problem model with multiple trips, time windows, split delivery, heterogeneous fleet and intermediate facility Eng. J. 24

[8] Zhou J, Peng J, Liang G and Deng T 2019 Layout optimization of tree-tree gas pipeline network J. Pet. Sci. Eng. 173 666–80

[9] Nurprihatin F, Octa A, Regina T, Wijaya T, Luin J and Tannady H 2019 The extension analysis of natural gas network location-routing design through the feasibility study J. Appl. Res. Ind. Eng. 6 108–24

[10] Andry J F, Tannady H and Nurprihatin F 2020 Eliciting requirements of order fulfilment in a company IOP Conference Series: Materials Science and Engineering vol 771 pp 1–6

[11] Gunawan F E, Wilujeng F R, Rembulan G D and Tannady H 2020 Service quality analysis of smes tempe in province of Jakarta, Indonesia Technol. Reports Kansai Univ. 62 3827–33

[12] Cong F and Zhao Y 2015 The application of minimum spanning tree algorithm in the water supply network Proceedings of the 2015 International Industrial Informatics and Computer Engineering Conference (Xi’an: Atlantis Press) pp 52–5

[13] Nurprihatin F, Elnathan R, Rumawan R E and Regina T 2019 A distribution strategy using a two-step optimization to maximize blood services considering stochastic travel times IOP Conference Series: Materials Science and Engineering vol 650 (IOP Publishing Ltd)

[14] An J and Peng S 2016 Layout optimization of natural gas network planning: synchronizing minimum risk loss with total cost J. Nat. Gas Sci. Eng. 33 255–63

[15] Glumglomchit P, Rajagukguk J, Kaewkhao J, Kirdsiri K. A novel radiation shielding material for gamma-ray: The development of lutetium lithium borate glasses. InKey Engineering Materials 2018 (Vol. 766, pp. 246-251). Trans Tech Publications Ltd.

[16] Li F, Liu Q, Guo X and Xiao J 2015 A survey of optimization method for oil-gas pipeline network layout Proceedings of the 2015 International Conference on Mechatronics, Electronic, Industrial and Control Engineering (Shenyang: Atlantis Press) pp 257–60

[17] Garciano A, Garciano L E, Tanhueco R M and Abubo T J 2018 Optimal restoration strategy of a water pipeline network in Surigao City, Philippines Int. J. GEOMATE 14 25–9

[18] Nurprihatin F, Angely M and Tannady H 2019 Total productive maintenance policy to increase effectiveness and maintenance performance using overall equipment effectiveness J. Appl. Res. Ind. Eng. 6 184–99

[19] Tannady H, Nurprihatin F and Kartono H 2018 Service quality analysis of two of the largest retail chains with minimart concept in Indonesia Bus. Theory Pract. 19 177–85

[20] Tannady H, Andry J F and Nurprihatin F 2020 Determinants factors toward the performance of the employee in the crude palm oil industry in West Sumatera, Indonesia. IOP Conference Series: Materials Science and Engineering pp 1–5

[21] Tannady H, Gunawan E, Nurprihatin F and Wilujeng F R 2019 Process improvement to reduce waste in the biggest instant noodle manufacturing company J. Appl. Eng. Sci. 17 203–12
[22] Tannady H, Erlyana Y and Nurprihatin F 2019 Effects of work environment and self-efficacy toward motivation of workers in creative sector in Province of Jakarta, Indonesia *Qual. - Access to Success* **20** 165–8