Design of a Supply Chain Network for Electricity Distribution Stations for Waste Treatment

Intan Pratiwi
Master Program of Industrial Engineering Department, Faculty of Engineering
Universitas Sebelas Maret
Surakarta, Indonesia
intan_pratiwi@student.uns.ac.id

Wahyudi Sutopo
Professor, Department of Industrial Engineering
Past Head of Department of Industrial Engineering
Head of Industrial Engineering and Techno-Economics Research Group
Vice Dean for Human Resources, Finance, and Logistics
Faculty of Engineering
Universitas Sebelas Maret (UNS), Surakarta, Indonesia
President, IEOM Indonesia Chapter
wahyudisutopo@staff.uns.ac.id

Muhammad Hisjam
Industrial Engineering Department, Faculty of Engineering
Universitas Sebelas Maret
Surakarta, Indonesia
hisjam@staff.uns.ac.id

Abstract

Electrical energy or electric power is one of the main types of energy needed for electrical equipment or energy stored in electric current with units of amperes (A) and electrical voltage in units of volts (V) with the provisions of the need for electrical power consumption in units of Watts (W). to drive motors, lighting, heating, cooling or re-activating a mechanical device to produce other forms of energy. As a way to provide alternative solutions to improve the electricity distribution network from waste treatment equipment to consumers, the business of organic waste processing equipment needs to be run. A good supply chain network design (SCND) can reduce factory costs. The results of this study will be the establishment of one distribution station, namely in Sukoharjo Village, Margorejo District, Pati Regency, Indonesia.

Keywords
Opening of locations, distribution stations, supply chain networks design.

1. Introduction
Electrical energy or electric power is one of the main types of energy needed for electrical equipment or energy stored in electric current with units of amperes (A) and electrical voltage in units of volts (V) with the provisions of the need for electrical power consumption in units of Watts (W). to drive motors, lighting, heating, cooling or re-activating a mechanical device to produce other forms of energy. National electricity consumption continues to increase. In 2015, consumption was only 910 kilowatt hours (kWh) per capita. Then it increased to 1,084 kWh/capita in 2019. This increase is in line with the electrification ratio which also shows an increase. The ratio is from 84.35% in 2014 to 98.89% in 2019 (Ministry of Energy and Mineral Resources, 2020).

The estimation of the need for electrical energy consumption aims to estimate the amount of electrical energy consumption from various sectors to serve as an illustration in the coming year about the amount of electrical energy consumption at PLN (Persero) Rayon Pati. Population growth can affect the estimated demand for electrical energy consumption, as the region develops, the need for electrical energy consumption also increases. Estimated results from historical data obtained from 2013 – 2016 for calculations in 2017 to 2026 are increasing. The results of the calculation of the estimated consumption of electrical energy get the results of the population growth rate of 0.48%, the number of households 0.49%, the number of household customers 2.2%, the number of business customers 6.7%, the number of general customers 1.09% , the number of industrial customers is 4.9%, and the connectivity from all sectors is 7.6% (Dini, 2018).

Regional Regulation of Pati Regency Number 7 of 2010 concerning waste management, the population of Pati Regency which continues to increase from year to year with a high growth rate results in an increase in the volume of waste. In addition, people's consumption patterns contribute to the creation of increasingly diverse types of waste, including packaging waste that is dangerous and/or difficult to decompose by natural processes. So far, most people still view waste as useless waste, not as a resource that needs to be utilized. The community in managing waste still relies on the end-of-pipe approach, namely waste is collected, transported, and disposed of in a waste landfill. In fact, heaps of waste with a large volume at the landfill site have the potential to release methane gas (CH4) which can increase greenhouse gas emissions and contribute to global warming.

1.1 Objectives

As a way to provide alternative solutions to improve the electricity distribution network from waste treatment equipment to consumers, the business of organic waste processing equipment needs to be run. A good supply chain network design (SCND) can reduce factory costs.

2. Literature Review

Supply chain management is becoming increasingly important because of its primary role for companies to survive in today's rapidly changing market. Managing the supply chain efficiently and effectively will maximize the profitability and sustainability of the company in it. Supply chain network design (SCND) is one of the most important strategic decisions in supply chain management and therefore has never lost its appeal to researchers and practitioners. This paper presents new research on the network design of a simplified single-product, multi-source, multi-source supply chain. The proposed optimization model combines supplier selection with SCND, which is rarely referenced in the previous literature, and aims to determine the optimal supply chain network configuration in terms of number and location of facilities, material flow, and supplier selection. Furthermore, numerical experiments and discussions for future development are also presented to provide deep insights from this paper (Yu H et al, 2014). SCND is the design and planning of the physical network structure of the supply chain (R.Z.Farahani et al,2014). Due to its significant influence on long-term profitability and sustainability, SCND has never lost its appeal to researchers and practitioners, and rich literature is provided by previous studies to decide on the optimal number and location of facilities, material flow and environmental impact of the supply chain network.

Archilass et al (2010) demonstrated that the MILP model for reverse logistics network design and demonstrated its application by solving a real case study of WEEE in Central Macedonia. The model considers a two-level network in which location decisions are related to two different intermediary storage facilities. Furthermore, different transportation modes with predetermined capacities are also considered in the model.

The gravity location model is used to determine the location of a facility (such as a warehouse or factory) which is the link between supply sources or consumers (Pujawan & Mahendrawati, 2017). This model uses several assumptions. First, transportation costs are assumed to increase linearly with the volume moved. Second, sources of supply or consumers can be located on a map with clear x and y coordinates. Some of the data required in this model is denoted as follows:

Ci = Transportation costs per unit per kilometer
Vi = Transferred load
(xi,yi) = The x and y coordinates for the location
ji = Distance between locations

The distance between locations in this model is calculated as the geometric distance between two locations calculated by the following formula : $ji = \sqrt{(x0-xi)(x0-xi)+(y0-yi)(y0-yi)}$

$(x0, y0)$ are the candidate coordinates of the facility being considered. The purpose of this model is to minimize shipping costs which are formulated as follows:

TC = $\Sigma CiViji$

To get the optimal value $(x0, y0)$, three steps are needed as follows:

1. Calculating distance ji for all i.
2. Determine the coordinates of the location with the formula:

$$x_o = \frac{\frac{\sum c_i v_i x_i}{j_i}}{\frac{\sum c_i v_i}{j_i}} \qquad y_o = \frac{\frac{\sum c_i v_i y_i}{j_i}}{\frac{\sum c_i v_i}{j_i}}$$

3. If two successive iterations produce nearly the same coordinates, stop the iteration and select the coordinates as the facility location. If not, repeat the iteration starting from step 1.

3. Methods

In this study using several stages of research which can be seen in Figure 1, starting with the study of the object of study, literature review, analyzing the problems that occur, collecting data and processing data so that analysis and conclusions can be carried out. Data collection was carried out on a secondary and primary basis. Secondary data obtained from google searches, journals and websites. Primary data obtained from interviews.

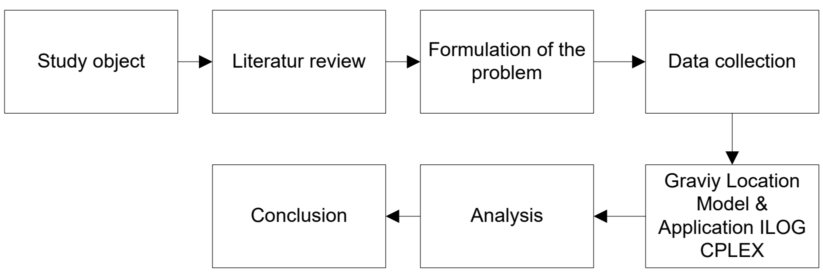

Figure 1. The research method used

4. Data Collection

Table 1 shows the data needed to conduct research and sources of data acquisition, both primary and secondary data.

Table 1. Data Source

Data Needs	Source
The resulting battery capacity	Primary
Population Data	BPS Pati
Coordinate point data	BPS Pati
Margorejo Kecamatan District Map	BPS Pati
Transportation costs	Secondary
Investment Fee	Secondary

One sewage treatment plant located in Langse Village, Margorejo District can be used for electricity in three villages in Margorejo District, namely Sukoharjo Village, Langse Village and Metaraman Village. Figure 2 shows the village of Margorejo sub-district and table 2 shows the population of the three villages.

Figure 2 Map of Margorejo Kecamatan District
Source: BPS Pati

Table 2. Population Data

village	Total population
Sukoharjo	6621
Langse	1100
Metaraman	1893

Source : BPS Pati

5. Results and Discussion

The gravity location model is used to determine the location of a facility (such as a warehouse or factory) which is the link between supply sources or consumers.

Table 3. Iteration 1 selection of villages for distribution stations

Desa	Xi	Yi	Vi	Cn	Dn	Xn	Yn	XnYn/Dn		
Sukoharjo	-6,7517	111,0147	6621	600	111,2198232	-241160,3	3965273,3	35718,5	x	-6,7500372
Langse	-6,7452	110,9992	1100	100	111,2039573	-6672,2	109797,5	989,2	y	111,01193
Metaraman	-6,734	110,9866	1893	200	111,1907017	-22929,0	377905,0	3405,0		
						-270761,5	4452975,8	40112,6		

Table 4. Iteration 2 selection of villages for distribution stations

Desa	Xi	Yi	Vi	Cn	Dn	Xn	Yn	XnYn/Dn		
Sukoharjo	-6,7517	111,0147	6621	600	0,003228593	-8307582234,1	136597264309,9	1230443034,2	x	-6,7514794
Langse	-6,7452	110,9992	1100	100	0,013620407	-54475024,6	896442529,7	8076117,0	y	111,01432
Metaraman	-6,734	110,9866	1893	200	0,029982141	-85033701,9	1401485218,9	12627517,4		
						-8447090960,6	138895192058,6	1251146668,6		

Table 5. Iteration 3 selection of villages for distribution stations

Desa	Xi	Yi	Vi	Cn	Dn	Xn	Yn	XnYn/Dn		
Sukoharjo	-6,7517	111,0147	6621	600	0,000442558	-60606267259,6	996517407163,9	8976445526,3	x	-6,7516724
Langse	-6,7452	110,9992	1100	100	0,01636871	-45328679,8	745930024,3	6720138,7	y	111,01465
Metaraman	-6,734	110,9866	1893	200	0,032767744	-77804941,5	1282344211,7	11554045,4		
						-60729400881,0	998545681399,8	8994719710,4		

Table 6. Iteration 4 selection of villages for distribution stations

Desa	Xi	Yi	Vi	Cn	Dn	Xn	Yn	XnYn/Dn		
Sukoharjo	-6,7517	111,0147	6621	600	5,50848E-05	-486918335877,7	8006145560668,4	72117886736,3	x	-6,7516966
Langse	-6,7452	110,9992	1100	100	0,016753101	-44288637,5	728815058,8	6565948,8	y	111,01469
Metaraman	-6,734	110,9866	1893	200	0,033154892	-76896416,6	1267370333,9	11419129,3		
						-487039520931,8	8008141746061,1	72135871814,4		

Iteration(table 3-6) is carried out 4 times because the next iteration the value of x, y for the next iteration is the same or stable. The results of the last iteration show that the selected x, y is the village of Sukoharjo. Furthermore, the mathematical model formulation is carried out which will then be input to the ILOG CPLEX application.

Problem formulation
i = submarine bioreactor resource, where i =1,...I
j = distribution station potential, where j = 1,..J
k = consumer, where s = 1,...S

parameter
u = production capacity/product capacity i
v = storage capacity j
d = demand
fj = investment or fixed cost to open j
ajk = transportation cost from i to j
bjk = transportation cost from j to k
Decision variables
Pij = Number of batteries sent from i to j
Qjk = Number of batteries to be sent from j to k
Xj = distribution station opened, Xj = 1 if station j is open and 0 if not

Minimize P = $\left(\sum_{i=1}^{N}\sum_{j=1}^{M} a_{ij}P_{ij} + \sum_{j=1}^{M}\sum_{k=1}^{K} b_{jk}Q_{jk} + \sum_{j=1}^{M} f_j X_j\right)$
Subject to
$\sum_{j=1}^{2} Pij < Ui\ , \forall i$, for i the number of goods sent to j does not exceed the capacity
$\sum_{j=1}^{2} Pij < VjXj\ , \forall j$, for j opened the number of goods received from i does not exceed the storage capacity
$\sum_{i=1}^{2} Pij = \sum_{k=1}^{j} Qij\ , \forall j$, for j the number of goods received from all factories is the same as the total amount sent to the customer
$\sum_{j=1}^{2} Qjk = dk, \forall k$, for k customers the total number of goods received from all distributors is the same as the number of requests
$\sum_{j=1}^{2} Qjk = VjXj, \forall j$, j opened the total number of goods sent to k does not exceed capacity

After that, input the ILOG CPLEX, so that it produces the output in Figure 3.

```
P = [[11
             0 0]];
Q = [[7 2 2]
             [0 0 0]
             [0 0 0]];
x = [1 0 0];
```

Figure 3. Output ILOG CPLEX

6. Conclusion

The opening of the distribution station for waste treatment is to be opened in the village of Sukoharjo with the coordinates of -6.7516966 111.01469. The number of batteries that will be sent from the distribution station to the customer is seven for the first consumer, two for the second consumer and two for the third customer.

References

Achillas, C., Vlachokostas, C., Aidonis, D., Moussiopoulos, Iakovou, E., Banias, G. Optimising reverse logistics network to support policy-making in the case of electrical and electronic equipment. *Waste Management*,vol.12,pp.2592–2600.2010

Aki Incoe. https://aki.incoe-astra.com/Media/Default/PriceList/PdfPriceList/Katalog%20INCOE%202016-1.pdf Accesed on December 02,2021.

BPS Pati. https://patikab.bps.go.id/publication/2020/09/28/34465262dc72447f5263af80/kecamatan-margorejo-dalam-angka-2020.html Accesed on December 02,2021.

Gomes MI, Barbosa-Povoa AP, Novais AQ. Modelling a recovery network for WEEE: a case study in Portugal. *Waste Manag* Vol.31 No. 7, pp 1645–60. 2011

KementrianESDM,2020.https://databoks.katadata.co.id/datapublish/2020/01/10/konsumsi-listrik-nasional-terus-meningkat . Accesed on November 03,2021

Pujawan IN & Mahendrawathi E. 2017. *Supply Chain Management.* Surabaya: Andi.

R. Z. Farahani, S. Rezapour, T. Drezner and S. Fallah.Competitive supply chain network design: An overview of classification, models,solution techniques and applications. *Omega*, vol. 45, pp92-118.2014

SiaranPers,2021. https://web.pln.co.id/media/siaran-pers/2021/09/ekonomi-mulai-menggeliat-pln-jalankan-4-strategi-untuk-dorong-konsumsi-listrik . Accesed on November 03, 2021

Tatang A.Taufik.2005. Konsep dan Metode Pengukuran Tingkat Kesiapan Teknologi/TKT (Technology Readiness Level/TRL)

Yu H, Solvang DW and Li S. *An Integrated Optimization Model for Single-product Supply Chain Network Design Considering Supplier Selection*. CogInfoCom 2014 • 5th IEEE International Conference on Cognitive Infocommunications • November 5-7, 2014, Vietri sul Mare, Italy.2014

Biographies

Intan Pratiwi is an understudy at the Master Program of Industrial Engineering Department, Sebelas Maret University, Surakarta, Indonesia. She accepted her Bachelor of Engineering degree from Ahmad Dahlan University. Her examination advantages are in the supply chain, logistics, business, techno economy, and sustainability.

Wahyudi Sutopo is a professor in Industrial Engineering and Head of Industrial Engineering and Techno-Economics Research Group (RG-RITE) of Faculty Engineering, Universitas Sebelas Maret (UNS), Indonesia. He earned his Ph.D. in Industrial Engineering & Management from Institut Teknologi Bandung in 2011. He has distributed in excess of 160 articles ordered Scopus, and his exploration advantages incorporate coordinations and production network the board, designing economy, cost investigation and assessment, and innovation commercialization.

Muhammad Hisjam is a lecturer at the Department of Industrial Engineering, Faculty of Engineering, Universitas Sebelas Maret since 1998. He earned Bachelor in Agroindustrial Technology from Universitas Gadjah Mada, a Master in Industrial Engineering & Management from Institut Teknologi Bandung, and Ph. D in Environmental Science from Universitas Gadjah Mada. He holds an Accredited Supply Chain Analyst from the American Academy of Project Management.