Supply Chain Network Design Integration Model for Opening-Closing Decision Allocation Terminal Salt Warehouse Facility

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Abstract

Pati Regency is one of the leading producers of raw salt in Indonesia and still have some potential in the future. However, the salt quality did not fulfill the specifications, resulting an unstable demand for the material stock. Causing raw salt prices to fluctuate greatly, allowing salt farmers in Pati to get little compensation. Various breakthroughs that can give greater incentives to salt producers by enhancing their quality must be sought. This case study discusses how to use optimal terminal facility allocation, as well as decisions on opening and shutting terminal facilities. To maximize the advantage of all stakeholders, the linear programming approach is utilized to connect supply chain network design with warehouse receipt systems. The findings show that utilizing the model that was used, the decision was made to keep terminal 1 open.

Keywords
Supply Chain Network Design, Optimization, Facility Location, Mixed Integer Linear Programming

1. Introduction
Pati Regency, being one of the salt-producing hubs in Central Java, has a big future salt potential. However, the quality of salt that does not match domestic industry criteria generates an imbalance in demand with the quantity of raw materials, causing the price of salt to be highly unpredictable, and salt farmers in Pati have not earned adequate welfare payments.

The Pati Regency government made various efforts to improve the quality of salt in accordance with the Indonesian National Standard (SNI), including through the people's salt business development program (PUGAR) by employing four approaches, such as productivity, quality, continuity, and institutions through the salt pond integration assistance program, geomembrane, and washing plant. (Department of Maritime Affairs and Fisheries of Pati Regency, 2020)

The warehouse receipt system is an alternate method of avoiding declining commodity prices induced by harvesting so that salt producers do not suffer big losses (Suryati et al., 2020). A warehouse receipt is essentially a payment document that is used as evidence of the quality of the commodity that the warehouse manager has selected to be deposited and held in a particular place on behalf of the depositor (the party who keeps).

It is possible to minimize transportation costs and speed up distribution routes by integrating supply chain network design. The second item that must be planned to maximize material flow is optimal supply chain network design integration. The placement of a facility is one of the most critical factors in supply chain network design, and it has a significant impact on the overall success of the supply chain network (Babazadeh, 2013). The government and salt farmers can optimize the economic value of salt by using supply chain network design.

In Indonesia, whether salt can be produced or not is highly reliant on the weather, leading the supply of salt to become unpredictable and farmers' salt prices to fluctuate. Through enforcing existing laws, such as Warehouse Receipt System Law No. 9 of 2011. Previous research has shown that the warehouse receipt system (WRS) can maintain commodity price stability when used in conjunction with various distribution strategies such as monopoly distribution schemes and regulated wholesale distribution schemes.

This study combines a model in closing options derived from prior research (Suryati et al, 2020). By using the mathematical model developed by (Nagasawa et al, 2017) for the mathematical model of shutting warehouse facilities.

1.1 Objectives

The goal of this study is to use the mixed integer linear programming approach to build a supply chain network model that takes into account investment costs, transportation expenses, and terminal closing costs.

2. Literature Review

Supply Chain Network Design has been the subject of several research. Supply Chain Network Design (SCND) is a sophisticated modeling method that has the ability to reduce SC costs and improve service levels by bringing SCM strategies closer together (Hasani & Khosrojerdi, 2016). Supply Chain Network Design (SCND), also known as supply chain network design, is a type of physical structure found inside the SC that has a significant impact on the SC's overall performance (Wang et al., 2020).

Supply chain management (SCM) is a systemic and strategic coordination of traditional business functions, as well as strategic functions of these business functions, in certain supply chain organizations, with the goal of improving each organization's long-term performance and the supply chain's overall performance. As a result, for the establishment of appropriate implementation in each section of the SC entity, an integrated behavior is required (Mentzer et al., 2001).

Linear programming is a technique for distributing limited resources among several competing activities. Integer linear programming refers to linear programming that uses numbers or integers. Mixed-Integer Linear Programming (MILP) is an ILP with non-discrete variables (Hillier & Lieberman, 2001).

The research model (Suryati et al, 2020) is developed by adding what is required to get the warehouse closing decision variable for a certain time. Adding facility closure parameters in the form of warehouse facility closing costs j and a decision variable to determine whether the warehouse should be closed or not.

3. Methods

3.1 Problem Description

The supply chain network model of the warehouse/terminal facility allocation system is discussed in this paper, which is based on the warehouse receipt system and mixed integer linear programming. Suryati, et al. (2020) evaluated and studied investment choices related to the opening of warehousing facilities in various regions. In prior research, the opening of a salt storage warehouse facility did not take into account the warehouse's shut down for a period of time. ILOG CPLEX will be used as the software for optimizing the output according to the model.

This situation creates a significant question how to come up with a model for opening and shutting a salt warehouse based on a warehouse receipt system that maximizes advantages for salt producers and the government before being offered to customers, by allocating the amount from each salt farmer to the available warehouse. which had to avoid falling commodity costs while still ensuring the salt's purity.

3.1 Influence Diagram

The influence diagram in the following graphic depicts the entity components present in the model for model development. (Figure 1):

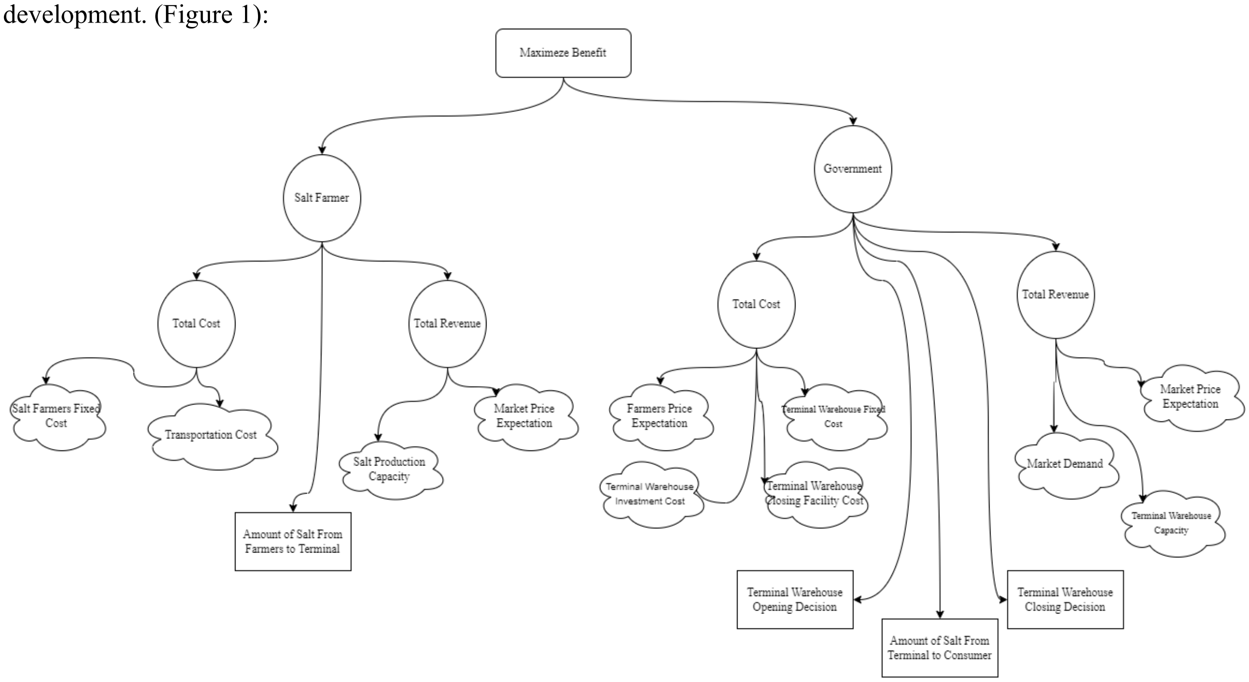

Figure 1. Influence Diagram

The total warehouse closing costs are one of four categories of charges to evaluate. There are also three more parameters from prior study, as well as the addition of a decision variable, which determines whether warehouse facilities should be closed or not.

4. Data Collection

All of the cost parameters used to complete the modeling are included in the table below to show how the suggested model evolved (Table 1, Table 2, Table 3, Table 4 and Table 5).

Table 1 Salt Total Production

No	Years	Production Capacity (Ton)	Demand (Ton)	
			Consumption	Industry
1	2016	166.380	141.696	-
2	2017	115.836	100.584	5.520
3	2018	320.288	115.453	7.200
4	2019	350.228	57.017	9.600
5	2020	375.800	59.032	9.000

Table 2. Distance of Farmers to Warehouse

Terminal/Warehouse	Bumimulyo	Genengmulyo	Tluwuk	Kertomulyo
Salt Farmer	T1	T2	T3	T4

Pecangaan	SF1	7	17.9	18.2	24.9
Mangunlegi	SF2	5.2	16.4	16.7	23.3
Lengkong	SF3	4.7	15.8	16.2	22.8

Table 3. Distance of Farmers to Warehouse

Jembangan	SF4	2.9	14.8	15.1	21.8
Bumimulyo	SF5	1	14.7	15	21.6
KetitangWetan	SF6	3	13.4	13.7	20.4
Raci	SF7	3	14.9	15.2	21.9
Bakaran Kulon	SF8	11	3.4	3.7	10.3
Langgenharjo	SF9	11.9	2.6	3.2	9.5
Agungmulyo	SF10	15.4	1.1	4.6	11.3
Genengmulyo	SF11	14.3	1	3.6	10.2
Tluwuk	SF12	14.6	3.6	1	7.8
Kepoh	SF13	16.9	5.8	3.4	7.9
Tlogoharum	SF14	17.8	6.7	3.3	8.2
Asempapan	SF15	18.7	7.6	5.1	7.4
Sambilawang	SF16	19.9	8.8	6.4	6.2
Guyangan	SF17	19.6	8.5	6.1	4.5
Kertomulyo	SF18	21.3	10.2	7.8	1
Kadilangu	SF19	21.8	10.8	8.3	6.7
Tlutup	SF20	21.6	10.5	8.1	6.4

Table 4. Transport Cost from Farmers to Warehouse

Terminal/Warehouse		Bumimulyo	Genengmulyo	Tluwuk	Kertomulyo
Salt Farmer		T1	T2	T3	T4
Pecangaan	SF1	893	2282	2321	3175
Mangunlegi	SF2	663	2091	2129	2971
Lengkong	SF3	599	2015	2066	2907
Jembangan	SF4	370	1887	1925	2780
Bumimulyo	SF5	128	1874	1913	2754
KetitangWetan	SF6	383	1709	1747	2601
Raci	SF7	383	1900	1938	2792
Bakaran Kulon	SF8	1403	434	472	1313
Langgenharjo	SF9	1517	332	408	1211
Agungmulyo	SF10	1964	140	587	1441
Genengmulyo	SF11	1823	128	459	1301
Tluwuk	SF12	1862	459	128	995
Kepoh	SF13	2155	740	434	1007
Tlogoharum	SF14	2270	854	421	1046
Asempapan	SF15	2384	969	650	944
Sambilawang	SF16	2537	1122	816	791
Guyangan	SF17	2499	1084	778	574

Kertomulyo	SF18	2716	1301	995	128
Kadilangu	SF19	2780	1377	1058	854
Tlutup	SF20	2754	1339	1033	816

Table 5. Salt Capacity for 5 Periods

Salt Farmer	Period (Ton)				
	P1	P2	P3	P4	P5
SF1	1612	2149	3277	4298	5373
SF2	4164	5552	8466	11103	13879
SF3	3975	5300	8082	10600	13249
SF4	2825	3767	5744	7533	9417
SF5	13857	18476	28176	36953	46191
SF6	11664	15551	23716	31103	38879
SF7	12727	16969	25877	33938	42422
SF8	2063	2750	4194	5501	6876
SF9	3632	4843	7385	9685	12106
SF10	5690	7587	11.57	15173	18966
SF11	14177	18902	28826	37804	47255
SF12	10344	13792	21033	27584	34480
SF13	2592	3456	5271	6912	8640
SF14	4732	6309	9622	12619	15773
SF15	1783	7377	3626	4755	5944
SF16	2892	3856	5881	7713	9641
SF17	1424	1899	2896	3798	4747
SF18	10421	13894	21189	27788	34735
SF19	1264	1685	2569	3370	4212
SF20	904	1206	1839	2412	3014

Table 6. Farmer Cost

Item	Cost
Production Cost	Rp 50/kg
Administration Cost	Rp 75/kg
Transportation Cost	Rp 128/km

Table 7. Warehouse Cost

Item	Cost
Warehouse closing cost	IDR 250,000,000
Warehouse operational cost	IDR 381,009,800
Warehouse investment cost	IDR 2,85,.000,000

Table 1 shows the overall production and demand for each annual period. Table 2 and table 3 shows the distance in kilometers between the salt producers and the proposed warehouse. The transportation cost for each distance may be computed by multiplying the distance by the transportation per kilometer rate, which is Rp 128/km, shown in table

4. In table 5, each salt farmer's production is indicated for each period. Tables 6 and 7 indicate the costs of the farmer and the warehouse, respectively.
According to the information above, the cost of opening a warehouse is IDR 2857000,000, the cost of operating a warehouse is IDR 381008800 per year, and the cost of closing a single warehouse is IDR 250000000. The above information will be used in the modeling.

5. Results and Discussion

5.1 Mathematical Modelling

Based on the above description of the problem, the goal of this article is to design a model that uses the mixed integer linear programming approach to minimize the overall cost of opening and closing warehouse or terminal facilities. The following is the nomenclature for the model's parameters, decision variables, and objective functions:
Index:

i	: Farmer
j	: Warehouse (Terminal)
k	: Consumer
t	: Index that shows time period (t =1…T)

Parameter:

CAPit	: Salt production capacity of farmer i in period t
CAPjt	: Storage capacity of terminal/warehouse j in period t
TCij	: Transportation costs from salt farmers i to the terminal/warehouse j
TCjk	: Transportation costs from terminal j to consumer k
Dk	: Demand consumer k
EPk	: Consumer k price expectation
EPi	: Farmer i price expectation
FCi	: Fixed costs salt farmer i
ICj	: Investment cost terminal/warehouse j
FCj	: Fixed Cost terminal/warehouse j
CCj	: Closing facility Cost terminal/warehouse j
CIjt	: Inventory Cost terminal/warehouse j in period t

Decision Variables

Uj	: Binary for warehouse j Value 1, if the warehouse opened Value 0, if the opposite
Vj	: Binary for terminal/warehouse j Value 1, if warehouse *j* closed Value 0, if the opposite
Xijt	: Amount of salt shipped from farmer i to terminal/warehouse j in period t
Yjkt	: Amount of salt shipped from terminal/warehouse j to consumer k in period *t*

Objective Funtion:
Maximaztion benefit with closing terminal

$[[\Sigma EPkTt=5*Xijt]- [\Sigma FCiTt=5]]+[[\Sigma EPkTt=5*Yjkt]- [\Sigma EPiTt=5+ Xijt]-$

$[\Sigma ICjTt=5*Uj]+FCj*Uj]+[\ \Sigma Vj=CCj\text{-}CIjt]+5*Vj]]\ Tt=5$ (2)

Limit Function:

$\Sigma Xijt \leq CAPit$ (3)

$\Sigma Xijt \leq \Sigma Yjkt$ (4)

$\Sigma Xijt \leq CAPjt*Vj$ (5)

$\Sigma Yjkt \leq Dk$ (6)

Equation (1) is the purpose of implementing the model, namely maximizing benefits by opening warehouse facilities. (1) is a calculation of the total benefits of salt farmers and the government while the total benefits are the total revenue minus the total cost. Equation (2) is the benefit maximization which was developed from previous research, namely the maximization of the benefit of closing terminal facilities. Equations (3) and (4) are limiting functions of the amount of salt production sent from farmers to warehouses or terminals.

5.2 Numerical Result

The SCND model is used in this study to discover which design model is the most optimal utilizing the Ilog Cplex Optimization Studio, which begins by mentioning the parameters, decision variables, and objective functions before producing the following results (Table 8-Table 10).

Table 8. Warehouse Capacity

	P1	P2	P3	P4	P5
Warehouse capacity	112740	120000	120000	120000	120000

Table 9. Closing Decision

Terminal	Initial status	After modelling
T1	Opened	Still open
T2	Closed	Close
T3	Closed	Close
T4	Closed	Close

Table 10. Allocation from Salt Farmers to Warehouse

Salt Farmer	Warehouse				
	p1	p2	p3	p4	p5
Pecangaan	1.612	2.149	3.277	4.298	5.373
Mangunlegi	4.164	5.552	8.466	11.103	13.879
Lengkong	3.975	5.300	8.082	10.600	13.249
Jembangan	2.825	3.767	5.744	7.533	9.417
Bumimulyo	13.857	18.476	28.176		32.646
KetitangWetan	11.664	15.551	23.716		
Raci	12.727	12.207	21.504	33.938	42.422
Bakaran Kulon	2.063	2.750	4.194		
Langgenharjo	3.632	4.843		9.685	
Agungmulyo	5.690	7.587	11.570	15.173	
Genengmulyo	14.177	18.902		4.514	
Tluwuk	10.344	13.792			
Kepoh	2.592		5.271		
Tlogoharum	4.732			12.619	
Asempapan	1.783	2.377		4.755	
Sambilawang	2.892	3.856			
Guyangan	1.424				

Kertomulyo	10.421				
Kadilangu	1.264	1.685		3.370	
Tlutup	904	1.206		2.412	3.014
Total	112.742	120.000	120.000	120.000	120.000

The MILP model's results show that only Terminal 1 should be open, and the capacity warehouse for each period, as well as the allocation from salt farmers, are shown above. The model results show that the opened warehouse model is T1 and remains open for up to 5 periods, while the other warehouses are not. Despite the fact that the T1 warehouse is full, the model's output does not open a second warehouse since the opening and closure expenses are too excessive, resulting in inadequate benefit.

The warehouse will be opened in Bumimulyo according the result of the model that shown in table 9. And the allocation of each salt farmers to the warehouse in Bumimulyo are shown in table 10 showing how many tons on each salt farmers should deliver to the warehouse.

6. Conclusion

The objectives of this paper is to construct a model that has been used in earlier studies to allocate warehouses/terminals with Supply Chain Network Design utilizing the Mixed-Integer Linear Programming (MILP) method (SCND). Following the development of the model, it was decided to maintain terminal 1 open while closing terminals 2,3, and 4. It could also be due to the high cost of building a single terminal/warehouse, therefore it's possible that opening a single terminal would be more beneficial, even if salt farmers can produce more, it's also because demand is relatively decreasing with each passing period. This decision indicates that having a terminal warehouse is beneficial and helpful to all parties involved.

This is due to the high cost of opening and/or shutting warehouses, which makes the government as the warehouse provider incur losses if more warehouses are opened or closed. Thus, all party benefits and the price of the commodity will be less volatile, and the quality of the salt will be assured due to the warehouse receipt system.

It is believed that this research would assist the government in making judgments on whether or not to close warehouses that have been shown to be ineffective. Salt farmers can also benefit from improved prosperity, which was formerly hampered by the variable salt selling price. The study's weakness is that some of the parameters are dependent on assumptions from reference articles that cannot be used as precise parameters. Future study ideas include collecting data directly at the site so that further results can be obtained.

References

Babazadeh, R, Facility location in responsive and flexible supply chain network design (SCND) considering outsourcing Reza Babazadeh *, Jafar Razmi and Reza Ghodsi. Vol. 17, no. 3, 2013.

Department of Maritime Affairs and Fisheries of Pati Regency, Final Report on Preparation of Masterplant for the Development of People's Salt for Pati Regency, 2019-2023

Fang, Y., Xiao, L., Chen, Z., Ai, X., Cao, Y., & Yang, H. Recent Advances in Sodium-Ion Battery Materials. Electrochemical Energy Reviews, pp. 294–323, 2018.

Gokilakrishnan, G., Ganeshkumar, S., Anandakumar, H., & Vigneshkumar, M. A Critical Review of Production Distribution Planning Models. 2021 7th International Conference on Advanced Computing and Communication Systems, ICACCS 2021, pp. 2047–2051, 2021

Hasani, A., & Khosrojerdi, A. Robust global supply chain network design under disruption and uncertainty considering resilience strategies : A parallel memetic algorithm for a real-life case study. TRANSPORTATION RESEARCH PART E, vol. 87, pp. 20–52, 2016.

Hidayat, Y. A., Sutandi, & Joelianto, E. Integrated supply chain model of distribution regionalization and network optimization of white crystal sugar traditional market. Engineering Letters, vol. 29, no. 1, pp. 302–311, 2021.

Hillier, F. S., & Lieberman, G. J. ADVANCE PRAISE FOR INTRODUCTION TO OPERATIONS RESEARCH., 2001.

Irfan, S. M., Khan, S. A., & Brahimi, N. Distribution network design for an oil blending company. Proceedings of the International Conference on Industrial Engineering and Operations Management, 2018-March, pp. 1187–1188, 2018.

Irfan, S. M., Khan, S. A., & Brahimi, N. Distribution network design for an oil blending company. Proceedings of the International Conference on Industrial Engineering and Operations Management, 2018-March, 1187–1188, 2018.

Mentzer, J. T., Keebler, J. S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. *Journal Of Business Logistics*,. Vol. 22, no. 2, pp. 1–25, 2001.

Nagasawa, K., Saito, T., Irohara, T., Deguchi, Y., Hanada, K., Abe, K., Kishi, M., & Shimizu, T. Redesigning an existing recovery logistics network in closed loop supply chain. Journal of Japan Industrial Management Association, vol. 67(4E), pp. 348–357, 2017.

Saungmuang, W., Suthammanon, S., Penchamrat, P., & Sirivongpaisal, N. Design and Model of Supply Chain Network for the Biodiesel Refinery Industry in the Southern Region of Thailand. Vol. 3, no. 4, pp. 6–20, 2013.

Shmatko, A., Barykin, S., Sergeev, S., & Thirakulwanich, A. , Modeling a Logistics Hub Using the Digital Footprint Method — *The Implication for Open Innovation Engineering*, 2021.

Suryati, Sutopo, W., & Hisjam, M. Optimization Model Supply Chain Network Design Determine Location-Allocation the Terminal Cathode Factory. *Proceedings of the International Conference on Engineering and Information Technology for Sustainable Industry,* 2020.

Wang, J., Wang, X., & Yu, M. Multi-Period Multi-Product Supply Chain Network Design in the Competitive Environment, 2020.

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