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Integrated Supply Chain Network Model for Allocating LPG in a Closed Distribution System

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Abstract: This paper proposes a model of integrated supply chain network for allocating subsidized Liquefied Petroleum Gas (LPG) in a closed distribution system. Subsidized LPG is selected as a case study due to its specific product in Indonesia. Since 2007, the Indonesian government makes policy, namely energy conversion from kerosene to LPG. The main purpose of converting kerosene to LPG is to reduce subsidies on fuel oil. The distribution system consists of several filling stations, distributors and retailers. Currently, the distribution of subsidized LPG, does not flow smoothly because there will be a shortage or excess tubes in retailers mainly because it uses a closed distribution system. A closed distribution means that people who are eligible to buy subsidized LPG will be given a card for identifying them as a legal receiver of the LPG. The model is developed using mathematical approach with reference to previous transshipment study. Based on the developed model and by using a numerical example as a case study, the allocation of LPG from filling station to the distributors and from the distributor to the retailers with minimum distribution costs can be determined. LPG in some specific retailers is supplied by only one distributor which is authorized to distribute subsidized LPG on the retailers. However, this model has limitations to arrange the route filling and distribution route.

Keywords: Supply Chain Network, Subsidized LPG, Closed Distribution System

1. Introduction

Since 2007, the Indonesian government makes policy, namely energy conversion from kerosene to LPG. The main purpose of converting kerosene to LPG is to reduce subsidies on fuel oil. During this time, kerosene, which has a high production cost is consumed by the majority of low-income communities which are concentrated in rural areas. Therefore government provides subsidies to ease the burden of their energy costs.

LPG starter pack in the form of a gas stove, a tube with its accessories has been distributed in total of more than 56 million packs in 29 provinces in Indonesia. The problem faced now is when and where we doing the refill.

Smoothing material flow is one of the goals in the concept of supply chain, which consists of several echelons [1]. Likewise in the distribution system, if the flow of LPG distribution does not go smoothly, there will be a shortage or excess in retailers mainly because it uses a closed distribution system. A closed distribution means that people who are eligible to buy subsidized LPG will be given a card for identifying them as a legal receiver of the LPG [2].

The lack of proper LPG's distribution can be caused by faulty allocation of LPG's distribution under the authority and responsibility of filling depots or distributors. Hence, in order to overcome the problems, it is necessary to redesign distribution network system. This distribution network design serves as an input to the government in making policy on LPG distribution system based on the real conditions of the field. In other words, we need the concept of distribution network design to manage the allocation of multi LPG filling depot to distributor and from distributor to retailers.

Figure 1 below shows the current down-stream LPG supply chain (distribution). Government applies closed distribution system for distributing subsidized LPG tubes or canisters in order to ensure the subsidized LPG would reach the proper targets.

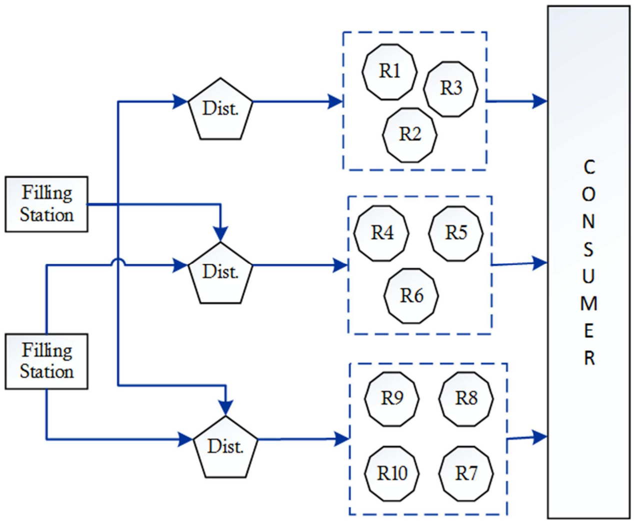

Figure 1. *LPG supply chain (distribution).*

2. Related Work

There are many distribution network designs in the literatures which concern with interaction among member of supply chain. Most of the interaction treats each member of the supply chain as a separate system. As a result, many of the problems solved with minimum integrated [3]. Here, we present previous study which is associated with the main objective of the research.

The main objective of this closed distribution network design is to minimize the total distribution cost. The total distribution cost per year consists of total distribution cost from filling stations to distributors and from distributors to retailers. Generally, network design covers supply allocation, and selecting location of supply chain members in the public and private economic sectors. Distribution network design relates to real situations where an organization needs to get the most effective and efficient distribution facilities [4]. According to Meng, Huang, and Cheu, the integration of location decisions with other relevant decisions is a basic feature that distribution design has to capture in order to support decision-making involvement in strategic supply chain planning [5].

According to Melo *et al*, [6] a company's distribution network must meet service goals at the lowest possible cost. In some instances, a company may be able to save millions of dollars in logistics costs and simultaneously improve service levels by redesigning its distribution network. To achieve this, an ideal network must have the optimum number, size, and location of facilities.

As already presented in the introduction, that because of the LPG distribution system does not run smoothly; it is necessary to redesign the distribution network of LPG. Distribution Networks is needed to be redesigned for the purpose of allocations from filling station to the distributor and from the distributor to the retailer. One of the main models that can be used is the transshipment models. Transshipment problem which was first introduced by Orden [7] refers to a development of the transportation problem by considering the possibility of transshipment. The point is that any shipping or receiving point is permitted as an intermediate point. At the transshipment problem, an origin or destination can transport subsidized LPG to another origin or destination [8].

Development models will take into consideration the concept of transshipment [9] the model uses the concept of fixed and variable costs that proposed by Chopra and Meindl. The design of this network distribution aims to produce low distribution costs as proposed by Watson et al. [10]. The model developed is composed of 1). LPG allocations from filling station to the distributor and from the distributor to the retailer. 2) the size of the vehicle and the number of orders by distributors to the filling station.

The next part will present the development model based on this transshipment problem.

3. Research Methodology

This research using analytical based methodology to answer the questions: how to allocate, and what are the number of allocation of filled tubes from multi filling station to certain multi distributor and from each distributor to certain retailers in order to minimize total distribution cost per year.

Method of building model is as follows: Firstly, previous related work namely transshipment is analyzed and then developed with mathematical approach to create a new mathematical model. Secondly, the new distribution network design is tested using numerical example with real data as single case study problem. Based on this approach, the research can make a conclusion about model and giving several suggestions for future research.

4. Development Model

The integrated supply chain network model is developed for distributing subsidized 3-kg LPG tubes from filling stations to distributors and from distributors to retailers. This model determines number of allocation from multi filling station to certain multi distributor and from each distributor to certain retailers.

In this model, a filling station supplies multi distributor and a distributor can be supplied by more than one filling station. A distributor supplies multi retailer but only a certain distributor can supply a retailer.

Each distributor has a number of trucks with a number of empty tubes in the truck that will be filled by a filling station according to quota. After all empty tubes in a truck are filled, the truck directly distributes the LPG tubes to multi certain retailers of the distributor.

4.1. Mathematical Notations

The mathematical notations are used in developing model as follows:

Indices

s: Filling station s=1..S

a: Distributor a=1..A

p: Retailer p=1..P

Decision Variables

Q_{sa}^{fd}: Number of LPG tubes that are supplied by filling station s to distributor a

Q_{ap}^{dr}: Number of LPG tubes that are supplied by distributor a to retailer p

Z_{sa}^{fd}: 1 if filling station s supplies distributor a, and 0 otherwise

Z_{ap}^{dr}: 1 if distributor a supplies retailer p, and 0 otherwise

JHT_{sa}: Number of day-trucks of subsidized LPG that are supplied from filling station s to distributor a

Variables/Parameters

K_s: Capacity of filling station s

JT_a: Number of trucks owned by distributor a

D_p: Monthly LPG demand of retailer p

FC_{sa}^{fd}: Fixed cost of distributing LPG from filling station s to distributor a

VC_{sa}^{fd}: Variable cost of distributing LPG per tubes from filling station s to distributor a

FC_{ap}^{dr}: fixed cost of distributing LPG from distributor a to retailer p

VC_{ap}^{dr}: Variable cost of distributing LPG per tubes from distributor a to retailer p

LO: the order size contract of subsidized LPG per day between certain distributor and specific filling station

JMLH: number of days per month

MINJHT: minimum number of day-trucks that are used from filling station to distributor

4.2. Mathematic Formulation

The objective function is to minimize total cost of LPG supply chain. The total cost consists of fixed cost and variable cost at fulfilling station, distributor and retailer.

$$\min \begin{aligned} TC = \textstyle\sum_s \sum_a FC_{sa}^{fd} Z_{sa}^{fd} + \sum_s \sum_a VC_{sa}^{fd}\, Q_{sa}^{fd} \\ + \textstyle\sum_a \sum_p FC_{ap}^{dr}\, Z_{ap}^{dr} + \sum_a \sum_p VC_{ap}^{dr}\, Q_{ap}^{dr} \end{aligned} \quad (1)$$

This model was developed by considering some constraints to ensure the model according to the condition of the distribution of subsidized LPG.

$$\textstyle\sum_a Q_{sa}^{fd} \le K_s \quad ;\forall s \quad (2)$$

$$Q_{sa}^{fd} \le LO\, JMLH\, JT_a Z_{sa}^{fd} \quad ;\forall s,a \quad (3)$$

$$Q_{sa}^{fd} = LO\, JHT_{sa} \quad ;\forall s,a \quad (4)$$

$$JHT_{sa} \ge MINJHT\, Z_{sa}^{fd} \quad ;\forall s,a \quad (5)$$

$$JHT_{sa} \le JMLH\, JT_a \quad ;\forall s,a \quad (6)$$

$$\textstyle\sum_s Q_{sa}^{fd} \ge \sum_p Q_{ap}^{dr} \quad ;\forall a \quad (7)$$

$$Q_{ap}^{dr} \le LO\, JMLH\, Z_{ap}^{dr} \quad ;\forall a,p \quad (8)$$

$$\textstyle\sum_a Z_{ap}^{dr} = 1 \quad ;\forall p \quad (9)$$

$$Q_{ap}^{dr} = D_p\, Z_{ap}^{dr} \quad \forall a,p \quad (10)$$

$$\textstyle\sum_p Q_{ap}^{dr} \le LO\, JMLH\ JT_a \quad ;\forall a \quad (11)$$

$$Z_{sa}^{fd} \in \{0,1\} \quad \forall s,a \quad (12)$$

$$Z_{ap}^{dr} \in \{0,1\} \quad \forall a,p \quad (13)$$

$$Q_{sa}^{fd} \ge 0\ \&\ integer \quad ;\forall s,a \quad (14)$$

$$Q_{ap}^{dr} \ge 0\ \&\ integer \quad ;\forall a,p \quad (15)$$

$$JHT_{sa} \ge 0\ \&\ integer \quad ;\forall s,a \quad (16)$$

Constraint (2) ensures each filling station never distributes subsidized LPG tubes to their distributor more than its capacity. Constraint (3) ensures there is never a supply from the filling station to the distributor exceeds the capacity of all truck owned by the distributor. The next constraint (4) guarantees number of LPG tubes are filled and supplied from a filling station to a distributor must be a multiple of the vehicle capacity in accordance with their contracts (LO). Constraint (5) deals with the contract between a filling station and a distributor has to be equal to or greater than minimum day-trucks are used. Number of day-trucks is guaranteed not to be greater than total trucks per month that owned by each distributor (constraint 6). Constraint (7) guarantees the supply balance so that the distributor has no inventory. Constraint (8) ensures a retailer can only be supplied by a distributor that has been decided as suppliers while constraint (9) guarantees each retailer is only supplied by one certain distributor. Constraint (10) and (11) ensure the amount of allocation from a distributor to a retailer is equal to demand of the retailer and total of all allocation from a distributor to all retailer do not greater than its all vehicle capacity. Constraint (12) and (13) guarantee two decision variables are binary while constraint (14), (15) and (16) guarantee the last three decision variables have to be integer and always greater than zero.

5. Numerical Example

Supply chain structure of 3-kg subsidized LPG consists of two filling station, four distributors and 77 retailers. The capacity of filling stations and distributors can be seen in the following Table.

Table 1. *Capacity of filling.*

filling station	capacity	distributor	number of trucks	capacity of truck
F1	84,000	D1	2	28,000
F2	67,200	D2	3	42,000
		D3	2	28,000
		D4	3	42,000

Table 2. *Demand of each retailer.*

retailer	demand	retailer	demand	retailer	demand
P1	2995	P26	2643	P51	2163
P2	2085	P27	3199	P52	827
P3	2228	P28	2776	P53	1514

retailer	demand	retailer	demand	retailer	demand
P4	2497	P29	2758	P54	1020
P5	885	P30	761	P55	1610
P6	1931	P31	3093	P56	1441
P7	2683	P32	3093	P57	2378
P8	100	P33	2115	P58	763
P9	891	P34	3343	P59	1372
P10	943	P35	979	P60	2364
P11	113	P36	3040	P61	2450
P12	2189	P37	179	P62	2032
P13	1690	P38	1680	P63	1793
P14	2097	P39	850	P64	2623
P15	1442	P40	246	P65	2772
P16	2123	P41	425	P66	648
P17	1861	P42	1988	P67	2388
P18	2655	P43	1777	P68	1778
P19	1396	P44	2887	P69	3245
P20	2485	P45	334	P70	2254
P21	3061	P46	702	P71	2643
P22	1254	P47	2875	P72	1036
P23	1640	P48	2841	P73	189
P24	1346	P49	3113	P74	917
P25	2523	P50	100	P75	1223
				P76	1734
				P77	1517

Table 3. *Fixed cost of distribution from filling station to distributor.*

	D1	D2	D3	D4
F1	144,000,000	142,000,000	129,000,000	143,000,000
F2	145,000,000	141,000,000	143,000,000	127,000,000

Table 4. *Fixed cost of distribution from filling station to distributor.*

	D1	D2	D3	D4
F1	78,000	77,000	57,000	52,000
F2	51,000	58,000	59,000	69,000

With fixed and variable cost from distributor to retailer, the following result is obtained.

Table 5. *Distribution allocation from filling station to distributor.*

	D1	D2	D3	D4
F1	0	11200	28000	42000
F2	28000	30800	0	0
TOTAL	28000	42000	28000	42000

Table 6. *Number of day-trucks of subsidized LPG that are supplied from filling station to distributor.*

JHT	Distributor			
	1	2	3	4
F1	0	20	50	75
F2	50	55	0	0
TOTAL	50	75	50	75

Table 7. *Detail distribution allocation from filling station to distributor and distributor to retailer.*

Filling station	QSA	Distributor	QAP	retailer
F1	42000	Dist 4	2189	P12
			1442	P15
			2123	P16
			1861	P17
			3093	P31
			3093	P32
			3040	P36
			179	P37
			1777	P43
			334	P45
			2841	P48
			100	P50
			1514	P53
			1020	P54
			1441	P56
			2032	P62
			1793	P63
			2772	P65
			3245	P69
			2254	P70
			917	P74
			1223	P75
			1517	P77
		TOTAL	41800	23
F 1	28000	Dist 3	2085	P2
			100	P8
			891	P9
			113	P11
			2097	P14
			1396	P19
			2776	P28
			761	P30
			3343	P34
			425	P41
			2887	P44
			3113	P49
			1372	P59
			2364	P60
			648	P66
			1778	P68
			1734	P76
		TOTAL	27883	17
F 1	11200	dist 2	2497	P4
			2683	P7
			943	P10
			1690	P13
			3061	P21
F 2	30800	Dist 2	1254	P22
			2643	P26
			3199	P27
			2115	P33
			979	P35
			850	P39
			246	P40
			702	P46
			2875	P47
			2163	P51
			827	P52
			2378	P57
			763	P58
			2450	P61
			2623	P64
			2388	P67

Filling station	QSA	Distributor	QAP	retailer
			2643	P71
	42000	TOTAL	41972	22
F 2	28000	Dist 1	2995	P1
			2228	P3
			885	P5
			1931	P6
			2655	P18
			2485	P20
			1640	P23
			1346	P24
			2523	P25
			2758	P29
			1680	P38
			1988	P42
			1610	P55
			1036	P72
			189	P73
		TOTAL	27949	15

6. Conclusion

Based on the developed model, and by using a numerical example as a case study, the allocation of LPG from filling station to the distributor and from the distributor to the retailer with minimum distribution costs can be determined. Every retailer can be supplied by only one distributor which is authorized to distribute subsidized LPG on the retailer. It means retailers cannot be supplied by other distributors. Distributors can only fill an empty tube on the filling station that is authorized to supply distributor.

The developed model has been able to establish the allocation of filling stations that will supply a particular distributor. The model has also been able to establish which distributor that will supply a particular retailer. Based on the developed model, and by using a numerical example as a case study, the allocation of LPG from filling station to the distributor and from the distributor to the retailer with minimum distribution costs can be determined. LPG in some specific retailers is supplied by only one distributor which is authorized to distribute subsidized LPG on the retailers.

The model has been able to establish the allocation of filling stations that will supply a particular distributor. The model has also been able to establish which distributor that will supply particular retailers. However, this model has limitations to arrange the route filling and distribution route. This initial model will be developed in further research to establish the fleet distributors' route.

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