Determining Supply Chain Network Using Location, Inventory, Routing Problem (LIRP) Approaches

Sri Meutia, Khairul Anshar*, Subhan
Industrial Engineering Department, Universitas Malikussaleh

*khairul.anshar@unimal.ac.id

Abstract. This research is motivated by the large number of complaints of the poor and micro-scale industries that have to buy 3 kg of LPG gas above the highest retail price set by the Aceh Government, Rp. 18,000. There are several cases where people have been forced to buy at almost double the price (> Rp. 30,000). One of the main causes of this spike is the unavailability. To ensure the availability of these goods, it is deemed necessary to establish a goods management policy (logistics system) which includes decisions on the allocation of goods distribution, inventory policies of all entities in the system being observed, and their delivery routes. With the formulation of an optimal goods management policy, it is considered to ensure the availability of goods which will lead to an appropriate selling price and, no less important, to reduce the management cost which has the effect of reducing the need for subsidies that must be issued by the government. The model used as a problem solving tool for the integration model of determining the location, inventory policy, and allocation delivery routes is classified as a Location-Inventory-Routing Problem (LIRP). The LIRP model is then performed optimization to determine which agents should operate, inventory policies at agents and bases, and delivery routes. From the model developed, it was concluded that only one operating agent was needed to supply 3 kg LPG gas, which served all bases operating in six villages in Muara Dua District, Lhokseumawe City.

Keywords: Elpiji 3 kg, LIRP, location determination, inventory policy, route.

1. Introduction

Oil fuel is an energy source whose existence is very much needed by the Indonesian people. This need is used in the industrial, transportation and household sectors, where most of the fuel consumed by the public is subsidized. The high dependence of the community on BBM and the large amount of subsidies provided have forced the government to take strategic steps. One solution that the government has taken is to diversify energy by converting from kerosene to Liquefied Petroleum Gas (LPG). With the implementation of this conversion program, the government has provided savings of around IDR 25 Trillion. Apart from being cheaper, LPG is also able to provide benefits such as more environmentally friendly energy use. In 2007, The Government has made an energy diversification policy where LPG gas is distributed by Pertamina under the Eliji trademark. The policy is stated in the guidelines for enumeration and distribution of LPG 3 kg No.1688/F10000/2007-S3. Important entities that play a role in the LPG gas distribution process are SPBE (LPG Bulk Filling Station), agents, bases, and end users. The study that often becomes polemic is the selling price policy of LPG at the retail level. the highest retail price (HET) which applies only at the base level not at the retail level. The LPG distribution pattern also still follows the
kerosene distribution pattern so that the LPG transportation costs for a radius of 60 km above the agent's delivery point by SPBE are not borne by the government. Product availability is still a major problem. Inventory management at bases is managed by agents but agents cannot monitor the condition of goods at each base. This often results in product shortages or product unavailability at base. This condition causes consumers to buy 3 kg LPG gas at a price above the HET.

Research related to determining the location and allocation of distributors in distribution network problems has been widely studied. Kamal (2007) developed a LPG gas distribution model in West Java for three levels of distribution, namely refineries, SPBE, and agent distribution areas. In 2009 Pertamina implemented a closed distribution of 3 kg LPG so that the model developed by Kamal (2007) was irrelevant to current conditions. Zhalechian, Tavakkoli-Moghaddam, Zahiri, & Mohammadi (2016) resolves supply chain problems consisting of suppliers, distribution centers (DC), and retail with a heuristic method approach where inventory policy decisions are calculated on DC. Hiassat, Diabat, & Rahwan (2017) developed a heuristic method based on GA (genetic algorithm) for supply chain problems consisting of warehouses and retail where the inventory policy is calculated only on retail. Saragih, Bahagia, Suprayogi, & Syabri (2019) developed a location-inventory-routing problem (LIRP) model for multi-echelon systems by applying the concepts of single cycle time, coordinated planning, and stock echelon concepts. The application of these three concepts makes the model incompatible with the observed conditions.

Ahmadi Javid & Azad (2010) examines a two-echelon location-route-inventory model (incorporating location, routing, and inventory decision) namely suppliers, distribution centers (DC), and retailers. This model raises a problem that is almost similar to the research proposed where the author assumes that demand is probabilistic and normally distributed, facilities have capacity, determines vehicle routes and inventory policies so that this model becomes the main reference model. Some aspects that have not been considered in this model are the inventory policy that is calculated only at the distribution center, there is no integration of inventory between entities, and has not guaranteed the suitability of product selling prices in the market. Based on the brief description of the problems and related research above, there is still a research gap where there is no research on determining the integrated location, allocation, inventory policy and distribution center routes by optimizing not only the total annual costs but also ensuring the selling price of the product in the market.

2. Methodology
There are three main stages to solve the problem in this research, namely the system and problem analysis stage, the model development stage, and the model trial stage. These stages can be seen in Figure 1.
The System and Problem Analysis
The first stage is the analysis of the system and problems that have been discussed in the introduction and review of the literature that explain and describe the problems both in terms of the real system, namely the unreachable selling price to the product availability or problems in terms of conceptual models, there is no research that can be used directly to solve these problems. The undertaken literature study is within the scope of the location-allocation determination model of the old and new facilities.

The Model Development
The second stage is the development of a model using the Ahmadi Javid & Azad (2010) model as the main reference or basic structure enhanced by the Aras, Aksen, & Tuğrul Tekin (2011) model related to vehicle capacity for the distribution process and consideration of product selling price aspects in determining the location of distribution centers, Bahagia (1999) model Bahagia model (1999) related to the multi-echelon concept, namely the suitability of inventory at the retailer and supplier level and calculating the inventory cost at retailers. The mathematical model that has been developed is verified through unit verification to check the logic of mathematical relations and behavior verification to see the response of the model regarding changes that occur both in terms of the problem structure or simply the extreme value of some parameters.

The Model Implementation
The third stage is the testing phase of the developed model. Basically, this stage aims to validate the proposed model by using it to solve problems in real cases. The trial process itself was carried out in Muara Dua District, Lhokseumawe City with single product, 3 kg LPG.

3. Result and Discussion
The system being studied is part of the 3 kg LPG subsidized gas distribution system with more attention to the allocation subsystem and inventory policy involving several entities (gas filling stations, agents, bases, and end consumers). This study itself focuses on the process of determining the location of the agent to meet the demand for bases in its working area. This research does not determine the product selling price or change the distribution policy. Determination of the location and allocation of agents for 3 kg LPG is an important issue because products shortage often occurs, where the product itself has become a basic needs for the community which results the selling price no longer affordable. The selling price is considered very important seeing that this product is intended for poor people and micro-scale industries.

Assumption
The assumptions used in this study:
1. Every consumer has a demand that is normally distributed and mutually independent.
2. the lead time is constant and known for all entities in the system
3. Each base can only be supplied by one agent
4. Every possible capacity level of the distribution center is known.
5. The company pays a fixed cost for placing each order and a cost for holding inventory at each agent and base.
6. Gas filling station (SPBE) is able to fulfill all agent demands.
7. Each agent j and base k assumed to follows (Q, ROP) inventory policy and has a back-up supply (safety stock).
8. The vehicle capacity is the same and the vehicle type is homogeneous.

Indeks
The complete index used in this study can be seen in Table 1.

| Index | Definition |
|-------|------------|
| K     | Set of bases / sub-agents |
| J     | Set of potential agents |
| N_j   | Set of capacity levels available to agents (j ∈ J) |
| V     | Set of vehicles |
| M     | merged set of bases and potential agents (K ∪ J) |
Parameters
In the developed model, parameters are built with a maximum of three indexes. The parameters used in this study can be seen in Table 2.

| Parameter | Definition |
|-----------|------------|
| B         | number of bases contained in set K |
| $\mu_k$  | mean of demand at base k |
| $\sigma^2_k$ | variance of demand at base k |
| $f_j^n$  | fixed cost for operating agent j with capacity level n |
| $b_j^n$  | capacity with level n for agent j |
| $d_{kl}$ | distance between node k and node l |
| $V_c$    | capacity of vehicle |
| $h_j$    | inventory cost of agent j |
| $A_j$    | ordering cost of agent j |
| $L_j$    | lead time of agent j |
| $h_k$    | inventory cost of base k |
| $A_k$    | ordering cost of base k |
| $L_k$    | lead time of base k |
| $B_t$    | transportation cost |
| $\alpha$ | The percentage of customer orders that should be satisfied |
| $z_\alpha$ | left a-percentile of standard normal random variable Z |

Decision Variable
The decision variables of this model are the location of the agent, the allocation of agents that are decided to be established, delivery route from agent to all bases, and the inventory policy which is stated in Table 3.

| Variable | Definition |
|----------|------------|
| $R_{kiv}$ | 1 if k precedes l in route of vehicle v |
| $Y_{jk}$ | 1 if base k is assigned to agent j |
| $U_j^n$ | 1 if agent j is opened with capacity level n |
| $Q_j$   | order size at agent j |
| $Q_k$   | order size at base k |
| $ROP_j$ | reorder point at agent j |
| $ROP_k$ | reorder point at base k |
| $SS_j$  | safety stock at agent j |
| $SS_k$  | safety stock at base k |

Objective Function
The objective function of this model is to minimize the total cost of distributing 3 kg LPG gas from agent to base in one cycle. In the developed model, the total distribution costs consist of facility operational costs (agents), inventory costs, and transportation costs. Based on this formula, the objective function of the model can be stated as equation (1) below:

$$
\text{min} = \sum_{j \in J} \sum_{n \in N} f_j^n u_j^n + \sum_{k \in K} \left[ h_k \left( \frac{Q_k}{2} + SS_k \right) + A_k \frac{\mu_k}{Q_k} \right] + \sum_{j \in J} \left[ h_j \left( \frac{Q_j}{2} + SS_j \right) + \frac{\sum_{k \in K} \frac{b_j^n}{Q_j}}{Q_j} (A_j) \right] + \\
\left( \sum_{v \in V} \sum_{k \in M} \sum_{l \in m} d_{kl} R_{klv} \right) B_t \\
\text{Subject to:} \\
\sum_{v \in V} \sum_{l \in M} R_{klv} = 1; \forall k \in K
$$

(2)
\[ \sum_{ik} \mu_k \sum_{j} R_{ikj} \leq \nu \forall \nu \in V \] (3)

\[ M_{lv} - M_{tv} + (B \times R_{lvy}) \leq B - 1; \forall k, l \in K; \forall v \in V \] (4)

\[ \sum_{ik} R_{ikj} - \sum_{j} R_{ikj} = 0; \forall k \in K; \forall v \in V \] (5)

\[ \sum_{ik} R_{ikj} + \sum_{j} R_{ikj} - Y_{ik} \leq 1; \forall j \in J, \forall k \in K; \forall v \in V \] (6)

\[ \sum_{ik} R_{ikj} - \sum_{j} R_{ikj} + Y_{ikj} - Y_{ik} \leq 1; \forall k, l \in K; \forall v \in V \] (7)

\[ \sum_{ik} R_{ikj} - \sum_{j} R_{ikj} + Y_{ij} \leq 1; \forall j \in J \] (8)

Constrain (2) make sure that each base is placed on exactly one vehicle route. Constrain (3) vehicle capacity constraints. Constrain (4) is subtour elimination constraints which guarantee each tour must contain a agent from which it originates. Constrain (5) is flow conservation constraints saying that whenever a vehicle enters a base or agent node, it must leave again and ensuring that the routes remain circular. Constrain (6) states that there is only one agent in each route. Constrain (7) The allocation and the routing components of the model: the base k is assigned to the agent j if the vehicle v, which visits the base k, starts its trip from the agent j. Constrain (8) ensure that each agent can be assigned to only one capacity level. Constrain (9) is the capacity constraints associated with the agent. Constrain (10) the distance between the agent and the base does not exceed 60 km, ensure the product selling price. Constrain (11)-(13) enforce the integrality restrictions on the binary variables. Constrain (14)-(17) Enforce the non-negativity restrictions on the other decision variables.

Object Description
Lhokseumawe City is a city in the province of Aceh, Indonesia. This city is right in the middle of the eastern route of Sumatra. Located between Banda Aceh and Medan, this city is a vital route of distribution and trade in Aceh. Lhokseumawe City has an area of 181.06 Km² which is divided into 4 districts namely Blang Mangat, Muara Dua, Muara Satu and Banda Sakti District. These four districts consist of 9 settlements and 68 villages. Muara Dua is one of the districts in Lhokseumawe city and consists of 17 villages. Muara Dua has a population of around 55,375 residents or about more than 25%. The estimated number of poor people living in this sub-district is 6,650 residents[8].

Structural aspects are all relatively stable components of the observed system in the time period considered. Some things that are classified as structural aspects are physical, logical, functional, or intellectual aspects[9]. The structural aspects that considered in this study were the LPG Bulk Filling Station (SPBE), agents and bases (sub-agents). The following are explanations of these structural aspects.

1. **LPG Bulk Filling Station (SPBE)**
   SPBE is the main actor in the 3 kg LPG distribution system with the task of filling gas into the cylinder. gas filling at SPBE according to the agent's production plan. Lhokseumawe city only has 1 SPBE, namely SPPBE Kuta Kandang Gas which is located at Cut Gireh, Cot Girek Village, Muara Dua District, Lhokseumawe City, Aceh 24355. This SPPBE serves all LPG gas agents in Lhokseumawe City and its surroundings.

2. **Agent**
The LPG agent is a legal entity distributing LPG gas. The agent is only assigned and authorized to sell gas received from SPBE at a price determined by Pertamina. Elpiji agents buy LPG in cash from Pertamina, with the location for collection at SPBE. In this study, the agent data taken is a certain LPG agent, which means that this agent only serves 3 kg LPG which is intended for poor people and micro-scale industries.
Table 5. Certain LPG agents in Lhokseumawe City

| No. | Code | Agent Name          | Address                                                                 |
|-----|------|---------------------|-------------------------------------------------------------------------|
| 1.  | A1   | PT Kaneubi Rahmat  | Jl. Panglima Kaom, Lorong Sakti, Desa Uteun Bayi, Kecamatan Banda Sakti, Kota Lhokseumawe, Aceh |
| 2.  | A2   | PT Myco Yudzuana   | Jl. Bangdes Ujung, Desa Hagu Barat Laut, Kec.Banda Sakti, Kota Lhokseumawe, Aceh |
| 3.  | A3   | PT Prima Gas Atjeh | Jl. Cut Meutia No.29 Gampong Pusong Lhokseumawe, Kec. Banda Sakti, Kota Lhokseumawe, Aceh |

3. Base (sub-agent)

Base is an LPG gas distribution agency where people can buy directly subsidized 3 kg LPG gas whose selling price is in accordance with the price set by the local government or the Highest Retail Price (HET).

Table 6. A certain LPG base in Lhokseumawe City

| No. | Code | Base Name          | Address                                                                 |
|-----|------|---------------------|-------------------------------------------------------------------------|
| 1   | P1   | Marzuki             | Meunasah Manyang                                                       |
| 2   | P2   | UD. Mahliga Putra   | Jl. Medan-Banda Aceh, Lorong Poska No.2b                                |
| 3   | P3   | UD. Panteu Aron Gas | Jl. PT Sandi Wijaya                                                     |
| 4   | P4   | UD. Mahdy Rasyid    | Jl. Cot Sabong                                                          |
| 5   | P5   | UD. Brnz Gas        | Jl. Cot Sabong, Gang Ali Burak                                          |
| 6   | P6   | UD. Ibm Elpji       | Jl. Cot Sabong Dusun C Eteun Kot                                       |
| 7   | P7   | UD. Ahandri Gas     | Jl. Merdeka Timur No.227                                                |
| 8   | P8   | UD. Harum Manis     | Jl. Merdeka Timur                                                       |
| 9   | P9   | UD. Given Elpji     | Jl. Dusun Syahbanda Baroe                                               |
| 10  | P10  | UD. Bumg Persika    | Jl. Patih Rani                                                         |
| 11  | P11  | Abdul Rahman        | Dusun Kumbang                                                           |
| 12  | P12  | UD. Nurhayati Z     | Jl. Tgk. Ahmad Kandang                                                  |

From Table 6, there are several bases that are located too close between these bases, therefore these bases will be merged because they are deemed irrelevant to be separated but demands from each bases are combined. In Lhokseumawe City, there is a gas filling station (SPBE) which is tasked with supplying gas to three agents that have been established and operating to supply all bases in Lhokseumawe City. Of the four existing districts, the research was carried out in Muara Dua district, especially Meunasah Manyang Village, Cot Girek Kandang Village, Uteun Kot Village, Keude Cunda Village, Meunasah Mee Village, and Meunasah Blang Village, where 12 (twelve) bases have been operating. The distribution of SPBE, agents, and bases will be illustrated in Figure 3 below. The names of gas filling stations, agents, and bases in Figure 3 below are adjusted to the order of these entities as summarized in Tables 5 and 6.

Figure 3. The position of gas filling station, agent, and 3 kg LPG bases in Muara Dua District, Lhokseumawe City
Result

The model developed is categorized as MINLP (Mix Integer Non Linear Programming) and it takes a very long time to find a global optimal solution, so that the completion of the model is limited to 12 hours and produces a local optimal solution. The developed model is executed using Lingo 12 software. In this section, we describe the final solutions produced for real systems. The results of the final solution can be seen in Figures 4 and 5 as follows.

\[
\begin{align*}
\text{P1} & : Q = 216, SS = 7 \\
\text{P2} & : Q = 244, SS = 8 \\
\text{P3} & : Q = 244, SS = 8 \\
\text{P6} & : Q = 244, SS = 8 \\
\text{P8} & : Q = 216, SS = 7 \\
\text{P9} & : Q = 244, SS = 8 \\
\text{P10} & : Q = 244, SS = 8 \\
\text{P11} & : Q = 230, SS = 8 \\
\text{P7} & : Q = 365, SS = 19 \\
\text{P12} & : Q = 244, SS = 8
\end{align*}
\]

\[
\begin{align*}
\text{A3} & : \text{Kapasitas} = 1.000, Q = 693, SS = 91
\end{align*}
\]

Referring to Figure 4, it was decided that agent 3 was operating to fulfill the demand for 12 bases. The inventory policy in the form of the number of 3 kg LPG that must be ordered every time an order is made (Q) and the amount of safety stock that must be available at each agent and base (SS) is clearly shown in Figure 4. At Agent 3, the number of units of LPG gas which is economical for each order (Q) is 693 units and Agent 3 must provide 91 units of 3 kg LPG gas in the warehouse to reduce the demand that may rise during the order period to avoid unfulfilled demand (lost sale). The same explanation applies to the inventory policy on bases.

Comparison of Initial Conditions and Improvement Solutions

As previously explained, in Muara Dua District, there are three active agents who are assigned to serve 12 3 kg LPG bases in six villages. From the initial data obtained, improvements were made using the developed model and the change in agent needs and allocations was obtained. From Figure 7, it can be seen that there are differences in the number of operating agents. Changes also occurred in the distribution network (allocation of each operating agent), capacity, and inventory policy. From the best solution obtained, agent 3 is able to serve all bases operating in 6 observation villages. This distribution network is better from costs point of view. Agent 3 allocation solution and inventory management (inventory policy) for agents and bases can be seen in Figure 4. From the developed model, a delivery route solution is also determined related to the allocation solution from agent 3 that has been determined to operate. Two routes were formed that started and ended at agent 3. The route to deliver 3 kg LPG gas by agent 3 can be seen in Figure 5.

\[
\begin{align*}
\text{Figure 4. Final solution of operating agents, their allocations, and inventory policies}
\end{align*}
\]

\[
\begin{align*}
\text{Figure 5. Transportation route from agent to bases}
\end{align*}
\]

\[
\begin{align*}
\text{Figure 7. Improvement condition illustration of the agents location and allocation}
\end{align*}
\]

4. Conclusion

The model generated from this research is a Non-Linear Integer Mix Program (MINLP) model using the Ahmadi Javid & Azad (2010) as the main reference. The model developed has considered the integration of inventory between echelons by implementing a multi-echelon inventory system, and guarantees that the selling price of products in the market does not exceed the HET. The solution cannot produce a global optimal solution due to the high level of complexity of the problem. The model developed in this study was applied in Muara Dua District, Lhokseumawe City, by including one gas filling station, three agents, and twelve 3 kg LPG bases that have been operating. Based on the calculation results, the best solution obtained from data processing using lingo 12 software is the operation of one out of three agents to serve twelve bases in six villages in Muara Dua District. Based
on the best solution, the operating agent is agent 3 with a small capacity (1,000 tubes/cycle). In the end, this study succeeded in integrating inventory management with location and route determination which was initially carried out partially by implementing a multi-echelon inventory system that had never been done in previous studies.

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