ITS Institut Teknologi Sepuluh Nopember

MAHIDOL UNIVERSITY
*Wisdom of the Land*

# OSCM 2016

## Proceedings of the 7th International Conference on Operations and Supply Chain Management (OSCM)

December 18-21, 2016 Phuket Thailand

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| **December 21th, 2016 (Wed)** | | | |
| **End** | | | |

# DEVELOPING MODEL OF CLOSED LOOP SUPPLY CHAIN NETWORK FOR SUBSIDIZED LPG 3-KGS IN EAST JAVA-INDONESIA

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## ABSTRACT

Demand of subsidized LPG 3-kgs in Indonesia has been increasing since the Indonesian government imposed a conversion program from kerosene to Liquefied Petroleum Gas (LPG) in 2007. The high increase in demand for subsidized LPG 3-kgs led to the scarcity of products availability. The design of a closed distribution system is required to ensure the availability of subsidized LPG 3-kgs. In this research, the development model of the integration of closed loop supply chain network and vehicle routing problem with simultaneous deliveries and pick-ups with time windows has been proposed. The mechanism of closed distribution system starts from the distributors send LPG empty tubes to filling stations. After filling station inspected and filled the LPG tubes, distributors delivered LPG 3-kgs subsidized from the filling station to some retailers. At the same time, the distributors take back the empty tubes from these retailers by considering the limitations of operational time in each retailers. The proposed model was tested on numerical example and analyzed the results.

**Keywords**: Liquefied Petroleum Gas, Closed Loop Supply Chain Network Design (CLSCND), Vehicle Routing Problem Simultaneous Deliveries and Pick-up with Time Windows (VRPSDPTW)

## 1. INTRODUCTION

Since 2007, the Indonesian government has made policy of the fuel conversion from kerosene to Liquefied Petroleum Gas (LPG) and provide subsidies for the weak economy society. Gas fuel conversion program has sparked a significant increase in demand of subsidized LPG 3-kgs. This was compounded by the existence of irregularities distribution of subsidized LPG 3-kg ineffective. This led to a scarcity of subsidized LPG 3-kgs availability, so the government adopted a policy through a closed system distribution program in each region. It requires appropriate setting of closed distribution systems for subsidized LPG 3-kgs in order to ensure the products availability according to community needs.

Development allocation optimization model of subsidized LPG 3-kgs in closed loop supply chain in each region had been done by Santoso et al. (2015) involving entities filling stations, distributors and retailers as shown in Figure 1 .The closed distribution system 3-kgs of subsidized LPG based on the allocation of supply of filling stations to distributors in accordance quotas listed in contacts which is expressed in the number of Loading Orders (LOs) for each time period. Furthermore, distributors do a closed distribution to multiple retailers within a certain area. At the time of sending LPG distributor 3-kgs subsidized to some specific retailers once conducted an empty LPG tubes from the retailers to be brought back and refilled in the filling stations. This mechanism in closed distribution system of subsidized LPG 3-kgs requires the optimal solution of the integration of closed loop supply chain network design (CLSC) and vehicle routing problem with simultaneous deliveries and pickups (VRPSDP).

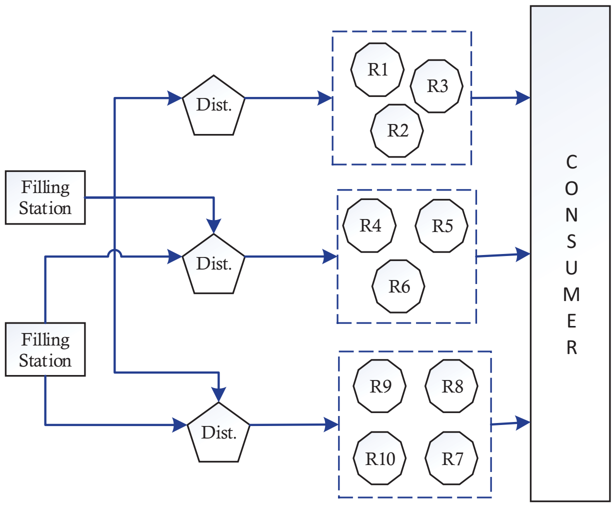


**Figure 1**. Closed distribution structure of subsidized LPG 3-kg *(Santoso et.al., 2015)*

In addition, Section 2 will be discussed literature review related to the model of closed loop supply chain network design and vehicle routing problem with simultaneous deliveries and pick-ups. The research methodology is explained in Section 3. Section 4 describes in detail the development of the proposed integration model and applied to a numerical example in section 5. In the final section, we present some conclusions and further research.

## 2. LITERATURE REVIEW

The combination of forward and reverse supply chain will construct closed loop supply chain (Govindan et al., 2015). According to Govindan et al. (2015), closed-loop supply chain management is the design, control, and operation of a system with dynamic recovery of value from different types and volumes of return products to maximize value creation over the entire life cycle of a product. In order to reducing environmental impact, many companies share their returnable transport items (RTIs) among the different partners of a closed-loop supply chain (Iassinovskaia et al., 2016). RTIs means packaging material involved in secondary and tertiary packaging such as bottle, tubes, tray, etc.

In order to minimize the distribution costs of products, the company needs to design the right vehicle routing that suitable to their distribution systems requirement. In a closed-loop supply chain systems, vehicle routing is not only required in delivering products to consumers, but it is also necessary return products, re-usable packaging and goods to be recycled or remanufactured have to be transported at the same time have to be transported (Dethloff, 2001). One type of vehicle routing problem (VRP) variants that suitable applied into closed loop supply chain network is vehicle routing problem with simultaneous deliveries and pickups – VRPSDP (Iassinovskaia et al., 2016).

Vehicle routing used in closed distribution network of the subsidized LPG 3-kgs is developed to determine the vehicle routes from a distributor to filling station and continues to deliver subsidized LPG 3-kgs to retailers and take the empty tubes from retailer locations back to the distributor. This distribution model is developed in order to minimize the total distribution costs. Retailers should return the empty tubes in according to the number of LPG tubes are delivered by their distributor. Therefore, the proposed model of the LPG 3-kgs distribution was developed based on Vehicle Routing Problem with Simultaneous Deliveries and Pick-Up (VRPSDP) model. VRPSDP model is variant of VRP model in which products need to be picked up from a certain location and dropped off at their destination (Braekers et al., 2015). Tasan and Gen, (2012) have proposed a genetic algorithm based approach as solution method for VRPSDP model (Tasan and Gen, 2012). There are several different characteristics between our proposed model and VRPSDP model that can be presented in Table 1.

**Table 1.** Comparison between VRPSDP and proposed model

| | **VRPSDP model** | **Proposed model** |
|---|---|---|
| Objective function | Minimize total transportation cost in distribution network | Minimize total transportation cost in closed loop supply chain network |
| Vehicle routing | route | Part of the vehicle routes are direct shipments. |
| Time windows | Not considered | Considered |
| Delivery & pickup | number of product deliveries and pick-ups are not always equal for all customers | Equal number of product deliveries and pick-ups in each customer locations |
| number of vehicle loads | Fluctuating among visiting locations | Vehicle load is fixed among visiting locations and as many as vehicle capacity |

## 3. RESEARCH METHODOLOGY

This study is a continuation of the research conducted by Santoso et al. (2015), which related to the development of an optimization model for the allocation of a closed distribution system of subsidized LPG 3-kgs. The results of the optimal solution based on the optimization model become the input parameters for the model proposed. The linkage between the models that have been developed by (Santoso, 2015) and designing process of the proposed model can be described in Figure 2.

The research phase of the proposed model development can be described as follows. First, conducting literature review related to the development of integration model of closed loop supply chain networks (CLSCND) and vehicle routing problem with simultaneous deliveries and pickups with time windows (VRPSDP-TW). Based on the literature overview, we developed an integration model of CLSCND and VRPSDP by taking into account the limitations of operational time in each retailers (VRPSDP-TW). The proposed models will be validated using numerical example and solved by the exact method. Furthermore, we draw some conclusions based on the results of the proposed integration model.

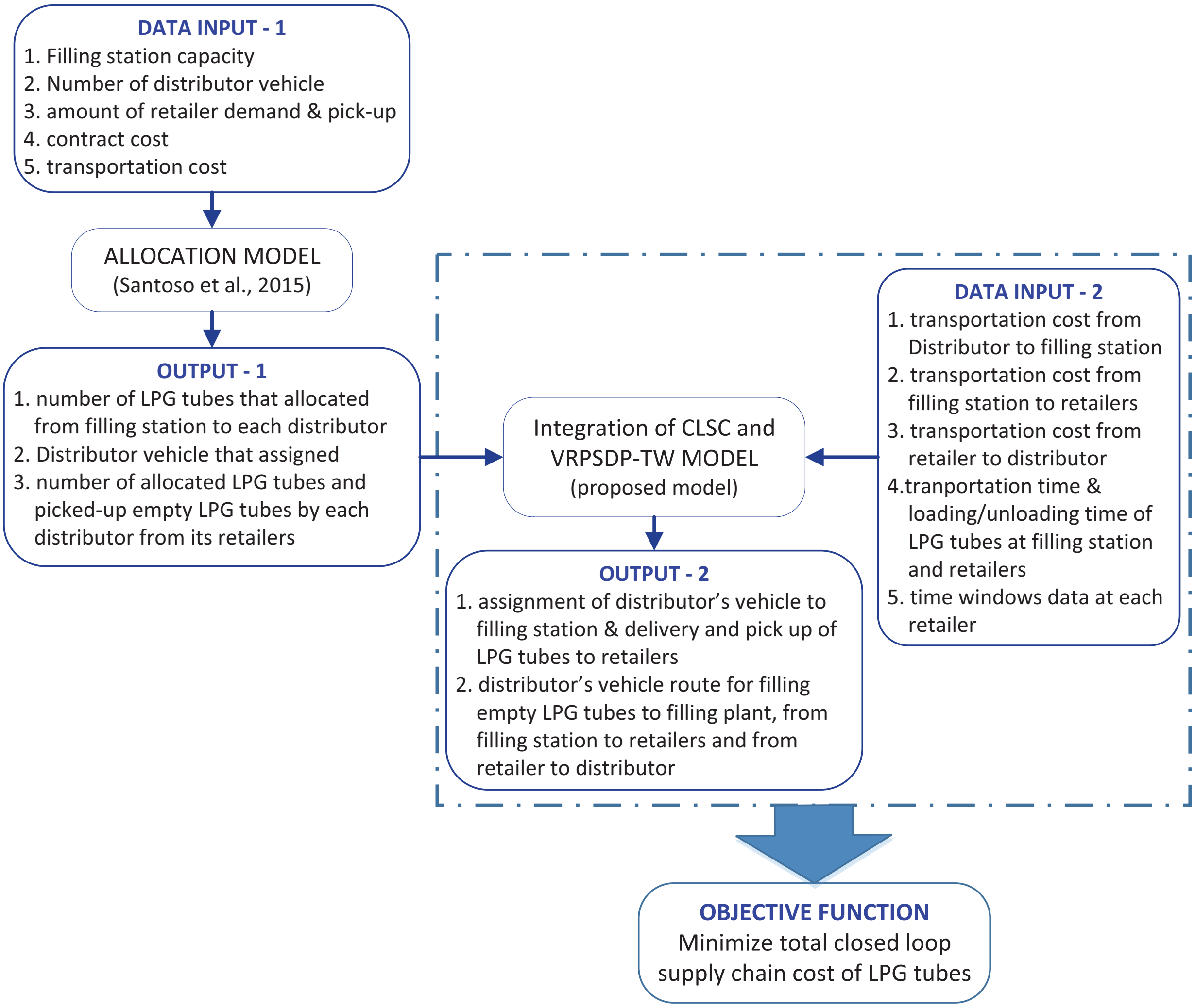


**Figure 2**. Research steps

## 4. MODEL DEVELOPMENT

The closed loop supply chain structure of LPG 3-kgs consists of multi filling station, multi distributor and multi retailer (Chopra and Meindl, 2016). A filling station supplies multi certain distributor and a distributor can be supplied by more than one certain filling station. A distributor supplies multi certain retailer but a retailer can be supplied by only a certain distributor which is authorized to distribute subsidized LPG on the retailer. Vehicle is only had by distributors and a distributor can have more than one vehicle.

Mechanism of distributing LPG 3-kgs is describe as shown in Figure 3. A distributor's vehicle brings a truck of empty LPG tubes (560 tubes) to certain filling station that are authorized to fulfill LPG to empty 3-kgs tubes according to quota. From filling station, the vehicle directly to distribute the LPG 3-kgs tubes to retailers ordered to distributor. When the distributor's vehicle delivers the LPG 3-kgs tubes to a certain retailer, the vehicle also collects the empty LPG 3-kgs tubes as number of delivered LPG 3-kgs tubes and brings it return to distributor. After delivering LPG 3-kgs tubes to the last retailer of that route, the vehicle return to the distributor.

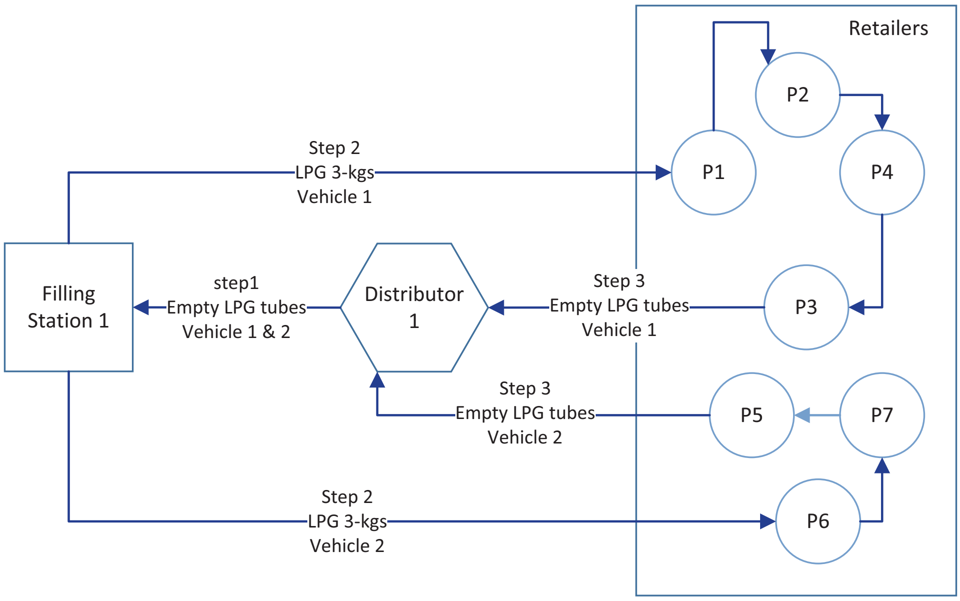


**Figure 3**. Closed distribution flow of subsidized LPG 3-kgs

The proposed model of integrated closed loop supply chain (CLSC) and vehicle routing problem with simultaneous deliveries and pickups with time windows (VRPSDPTW) is developed for distributing subsidized LPG 3-kgs from filling stations to distributors and from distributors to retailers. The objective of this model is to minimize total closed loop supply chain cost of LPG tubes. This proposed model determines the assignment of distributor's vehicle to filling station, and delivery and pick up of LPG tubes to retailers. This model also determine route of distributor's vehicle for filling empty LPG tubes to filling plant, from filling station to retailers and from retailer to distributor.

### 4.1 Mathematical Notations

The mathematic notations included sets, variables, parameters, and decision variables that are used in this developing model as follows:

**Set**

$S$ : set of filling station nodes
$A$ : set of distributor nodes
$P$ : set of retailer nodes
$N$ : set of all nodes including filling station, distributor and retailer; $N = S \cup A \cup P$
$V$ : set of vehicles

**Variables/Parameters**

$FC_s$ : Fixed (contract) cost between filling station $s$ and distributor
$C_{as}^{df}$ : Transportation cost from distributor $a$ to filling station $s$
$C_{ij}$ : Transportation cost from node $i$ to node $j$; $i, j = N \in S \cup A \cup P$
$D_j^r$ : LPG demand at retailer $j$
$P_j$ : Number of empty LPG tubes to be taken from retailer $j$
$[E_j, L_j]$ : Time window range at node $j$ ; $j = N \in S \cup A \cup P$

$JT_a$ : Number of vehicles that owned by distributor $a$
$JT_{as}^{df}$ : Number of vehicles that assigned by distributor $a$ to filling station $s$
$S_i$ : Service time at node $i$; $i \in S \cup P$
$T_{ij}$ : Travel time from node $i$ to node $j$; $i, j \in S \cup A \cup P$

**Decision Variables**

$Q_{ijv}$ : Number of LPG tubes that delivered from node $i$ to node $j$ by using vehicle $v$
$Z_{ijv}$ : Binary decision variable that indicates whether LPG tubes are delivered from node $i$ to node $j$ by using vehicle $v$
$L_{sv}$ : number of loads in vehicle $v$ when it departs from filling station $s$
$L_i$ : number of vehicle loads when it departs from node $i$
$Q_{asv}^{dfk}$ : Number of empty LPG tubes that are delivered by distributor $a$ using vehicle $v$ to filling station $s$
$Z_{asv}^{dfk}$ : Binary decision variable that indicates whether empty LPG tubes are delivered by distributor $a$ using vehicle $v$ to filling station $s$
$A_j$ : Arrival time at node $j$
$B_i$ : Departure time from node $i$
$JT_s$ : Number of vehicles that assigned to filling station $s$

**4.2 Mathematical Formulation**

The objective of closed loop supply chain model for subsidized LPG 3-kgs is minimizing the total closed loop supply chain cost of LPG. The total closed loop supply chain cost (TC) consists of total fixed cost at distributors, total transportation cost from distributor to filling station, total transportation cost among all nodes including transportation cost from filling station to the first retailer that is visited, transportation cost among retailers and from the last visited retailer to distributor. The total closed loop supply chain cost (TC) is formulated as follows:

$$Min\ TC = \sum_s \sum_v FC_s Z_{asv}^{dfk} + \sum_s \sum_v C_{as}^{df} Q_{asv}^{dfk} + \sum_{i\in S\cup P} \sum_{j\in P\cup A} \sum_v C_{ij} Q_{ijv} \quad (1)$$

Several constraints are considered to ensure the suitability of the developed model and the condition of distribution of subsidized LPG 3-kgs. Constraint (2) ensures number of LPG tubes are delivered from each distributor to filling station as the capacity of each vehicle, while constraint (3) guarantees load of each vehicle is less than vehicle capacity. Constraint (4) and (5) guarantee number of dispatched trucks by a distributor to each filling station corresponding to allocation of each filling station's supply capacity for that distributor and total number of truck that are assigned by the distributor to each filling station.

$$Q_{ajv}^{dfk} = LO\ Z_{ajv}^{dfk} \qquad ; j \in S; v \in V \quad (2)$$

$$\sum_{j\in P} D_j^r \sum_{i\in S\cup P; i\neq j} Z_{ijv} \leq LO \qquad ; \forall v \quad (3)$$

$$JT_{as}^{df} = \frac{D_{as}^{df}}{LO} \qquad ; \forall a, s \quad (4)$$

$$\sum_v Z_{asv}^{dfk} = JT_{as}^{df} \qquad ; \forall a, s \quad (5)$$

Each truck sent from distributors are guaranteed by constraint (6) go to only one SPPBE and the number of trucks sent to all SPPBE guaranteed by constraint (7) as many as the number of trucks owned by the distributor. Constraint (8) and (9) ensure that each truck owned by a distributor is sent from a filling station to only one of retailers and number of trucks that are sent from a filling station to all retailers as many as number of truck that are assigned by the distributor to the filling station.

$$\sum_s Z_{asv}^{dfk} = 1 \qquad ;\forall v \tag{6}$$

$$\sum_s JT_{as}^{df} = JT_a \qquad ;\forall a \tag{7}$$

$$\sum_{p\in a} Z_{spv} \leq 1 \qquad ;\forall s, v \tag{8}$$

$$\sum_{p\in a} \sum_v Z_{spv} = JT_{as} \qquad ; \forall a, s \tag{9}$$

Constraint (10) ensures each retailer is visited only by one truck from one of filling stations while constraints (11) guarantees the amount of load in the vehicle when it departs from the filling station equal to the total LPG tubes to be delivered to retailers. Constraint (12) guarantees number of vehicle loads when it departs from the first node *j* after filling station minimum as much as the number of loads in each vehicle when it departs from filling station reduced the number of LPG tubes that delivered and added the number of empty tubes taken from the first visited retailer.

$$\sum_s \sum_v Z_{spv} \leq 1 \qquad ;\forall p \in a \tag{10}$$

$$L_{sv} = \sum_{j\in p} D_j\, Z_{sjv} \qquad ; \forall s, v \tag{11}$$

$$L_j \geq L_{sv} - D_j + P_j - M\left(1 - Z_{sjv}\right) \qquad ; \forall s, v : j \in P \tag{12}$$

Constraint (13) ensures number of vehicle loads when it departs from the first node *j* after filling station minimum as much as the number of loads in vehicle when it departs from node *i* reduced the number of LPG tubes that delivered and added the number of empty tubes taken from node *j*. Constraint (14) and (15) Number of loads of vehicle is not exceed of vehicle capacity. Each vehicle loads only one LO (loading order), i.e.: 560 LPG tubes.

$$L_j \geq L_i - D_j + P_j - M\left(1 - \sum_v Z_{sjv}\right) \qquad ; i, j \in P \tag{13}$$

$$L_{sv} \leq LO \tag{14}$$

$$L_j \leq LO + M\left(1 - \sum_{i\in S\cup P} \sum_v Z_{ijv}\right) \qquad ; j \in P \tag{15}$$

Constraint (16) ensures each distributor's truck will visit one of retailers after visited a filling station while constraint (17) guarantees that a truck will go to another retailer or return to distributor after visiting a retailer. Each retailer is guaranteed by constraint (18) will be visited only by one truck that come from another retailer or from a filling station. Constraint (19) and (20) ensure each truck that arrived in a retailer will continue to visit another retailer or return to distributor.

$$Z_{asv} = \sum_p Z_{spv} \qquad ; \forall s, v, a \tag{16}$$

$$\sum_{j\in P\cup A} Z_{pjv} = 1 \qquad ;\forall p, v \tag{17}$$

$$\sum_{i\neq p} \sum_v Z_{ipv} = 1 \qquad ;\forall p \in a \tag{18}$$

$$\sum_{i\in s\cup p; i\neq k} \sum_v Z_{ikv} = \sum_{j\in p\cup a; j\neq k} \sum_v Z_{kjv} \qquad ;\forall p \tag{19}$$

$$\sum_{i\in s\cup p} Z_{ikv} = \sum_{j\in p\cup A} Z_{spv} \qquad ; \forall p, v \tag{20}$$

Constraint (21) and (22) guarantee amount of LPG 3-kgs that are sent to a retailer corresponding to the retailer's demand. Constraint (23) deals with number of trucks return from retailer to a distributor as many as number of trucks that are sent from the distributor to a filling station. Constraint (24) guarantees each truck that arrived at a filling station or a retailer has to continue its visiting immediately after is serviced.

$$Q_{ijv} = D_j Z_{ijv} \qquad ;i \in s \cup p \ ,j \in p \cup a \ ,i \neq j \tag{21}$$

$$\sum_{i \in s \cup p} \sum_v Q_{ijv} = D_j \qquad ;\forall p \tag{22}$$

$$\sum_{i \in p} \sum_v Z_{iav} = JT_{as} \qquad ;\forall a, s \tag{23}$$

$$A_i + S_i \leq B_i \qquad ;i \in s \cup p \tag{24}$$

Constraint (25), (26) and (27) ensure each truck start from a distributor at time=0, goes to a filling station then from the filling station, the truck goes to one of retailers. Constraint (28) ensures arrival at the distributor after the departure of the last retailer while constraint (29) ensures arrival time at a retailer after departing time from a filling station or another retailer. Constraint (30) guarantees each vehicle will arrive at node *j* in range of its time window while constraint (31) ensures the assigned vehicles must be moved to another node.

$$B_a = 0 \qquad ;\forall a \tag{25}$$

$$A_s \geq B_a + T_{as} - M(1 - Z_{asv}) \qquad ;s, v \tag{26}$$

$$A_p \geq B_s + T_{sp} - M(1 - Z_{spv}) \qquad ;s, p, v \tag{27}$$

$$A_a \geq B_p + T_{pa} - M(1 - Z_{pav}) \qquad ;p, v \tag{28}$$

$$A_j \geq B_i + T_{ij} - M(1 - Z_{ijv}) \qquad ;i \in p; j \in p \cup a; i \neq j \tag{29}$$

$$E_j \leq A_j \leq L_j \qquad ;j \in A \cup S \cup P \tag{30}$$

$$Z_{iiv} = 0 \qquad ;i \in A \cup S \cup P \tag{31}$$

Constraint (32) deals with the binary decision variables and constraint (33) deals with the integer decision variables.

$$Z_{ijv} \in \{0,1\} \qquad ;\forall i, j \in A \cup S \cup P; \ \forall v \tag{32}$$

$$Q_{ijv} \geq 0 \ \& \ integer \qquad ;\forall i, j \in A \cup S \cup P; \ \forall v \tag{33}$$

## 5. NUMERICAL EXAMPLE

Similar with Santoso et al. (2015), the supply chain structure of subsidized LPG 3-kgs consists of two filling stations, four distributors and 77 retailers. The capacity of filling stations and distributors can be seen in the Table 2 and demand of retailers are shown in the Table 3.

**Table 2**. The capacity of filling stations and distributors

| 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 3.** Demand of each retailer (tubes)

| retailer | demand | retailer | demand | retailer | demand |
|---|---|---|---|---|---|
| P1 | 2995 | P26 | 2643 | P51 | 2163 |
| P2 | 2085 | P27 | 3199 | P52 | 827 |
| P3 | 2228 | P28 | 2776 | P53 | 1514 |
| 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 4. and Table 5. show the fixed and variable cost of distribution from filling station to distributors.

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

| | 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 5.** Variable cost of distribution from filling station to distributor (rupiahs)

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

Data of distribution allocation and number of truck-day of subsidized LPG 3-kgs from filling station to distributors that are used in this model are the results of the allocation model of 3-kg LPG developed by Santoso et al. (2015). Santoso et al. (2015) obtained filling station 1 supplies distributor 2, 3 and 4; whereas filling station 2 supplies distributor 1 and 2 with details of allocation as in Table 6 and number of truck-day of Subsidized LPG 3-kgs as in Table 7.

**Table 6.** Distribution allocation from filling station to distributors

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

**Table 7.** Number of truck-day of Subsidized LPG 3-kgs from filling station to distributor

| Number truck-day | Distributor | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| F1 | 0 | 20 | 50 | 75 |
| F2 | 50 | 55 | 0 | 0 |
| TOTAL | 50 | 75 | 50 | 75 |

The fixed transportation cost from distributor to filling station as shown in Table 8, whereas Table 9 shows demand, time window, and duration time needed in each entity.

**Table 8.** Transportation cost from distributor to filling station

| Filling Station | distributor | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1 | 0 | 5.680.000 | 5.160.000 | 5.720.000 |
| 2 | 5.800.000 | 5.640.000 | 0 | 0 |

**Table 9.** Data of Filling station 2, distributor 1 and all retailers

| Location | Daily demand (tubes) | Service time in entity (minutes of all demand) | Open time | Closed time |
|---|---|---|---|---|
| F2 | 1120 | 46 | 0 | 480 |
| P1 | 119 | 24 | 0 | 480 |
| P3 | 89 | 18 | 0 | 480 |
| P5 | 35 | 7 | 0 | 480 |
| P6 | 77 | 16 | 0 | 480 |
| P18 | 106 | 22 | 0 | 480 |
| P20 | 99 | 20 | 0 | 480 |
| P23 | 65 | 13 | 0 | 480 |
| P24 | 53 | 11 | 0 | 480 |
| P25 | 100 | 20 | 0 | 480 |
| P29 | 110 | 22 | 0 | 480 |
| P38 | 67 | 14 | 0 | 480 |
| P42 | 79 | 16 | 0 | 480 |
| P55 | 64 | 13 | 0 | 480 |
| P72 | 41 | 9 | 0 | 480 |
| P73 | 7 | 2 | 0 | 480 |
| AGEN 1 | 0 | 0 | 0 | 480 |

The result of closed-loop supply chain model are optimal distribution route of subsidized LPG 3-kgs for all vehicles in distributor 1 and 2 (Table 10), whereas optimal distribution route of all vehicles in distributor 3 and 4 (Table 11)

**Table 10.** Route of all vehicles in Distributor 1 and Distributor 2

| | **Distributor 1** | | **Distributor 2** | | |
|---|---|---|---|---|---|
| | **VEHICLE 1** | **VEHICLE 2** | **VEHICLE 1** | **VEHICLE 2** | **VEHICLE 3** |
| Route | Distributor 1 | Distributor 1 | Distributor 2 | Distributor 2 | Distributor 2 |
| | Filling station 2 | Filling station 2 | Filling station 2 | Filling station 1 | Filling station 2 |
| | P72 | P01 | P22 | P67 | P64 |
| | P18 | P25 | P58 | P71 | P40 |
| | P55 | P73 | P10 | P33 | P47 |
| | P20 | P42 | P04 | P46 | P13 |
| | P29 | P06 | P39 | P07 | P61 |
| | P38 | P05 | P51 | P52 | P35 |
| | P23 | P03 | P27 | P26 | P21 |
| | Distributor 1 | P24 | P57 | Distributor 2 | Distributor 2 |
| | | Distributor 1 | Distributor 2 | | |

**Table 11.** Route of all vehicles in Distributor 3 and Distributor 4

| | **Distributor 3** | | **Distributor 4** | | |
|---|---|---|---|---|---|
| | **VEHICLE 1** | **VEHICLE 2** | **VEHICLE 1** | **VEHICLE 2** | **VEHICLE 3** |
| Route | Distributor 3 | Distributor 3 | Distributor 4 | Distributor 4 | Distributor 4 |
| | Filling station 1 | Filling station 1 | Filling station 1 | Filling station 1 | Filling station 1 |
| | P76 | P68 | P37 | P63 | P70 |
| | P30 | P59 | P48 | P50 | P53 |
| | P09 | P41 | P62 | P69 | P36 |
| | P11 | P02 | P65 | P56 | P31 |
| | P66 | P14 | P32 | P12 | P45 |
| | P34 | P28 | P75 | P74 | P16 |
| | P60 | P49 | P17 | P15 | P77 |
| | P44 | P08 | Distributor 4 | P43 | Distributor 4 |
| | P19 | Distributor 3 | | P54 | |
| | Distributor 3 | | | Distributor 4 | |

## 6. CONCLUSION

This study have developed an optimization model of integration between closed-loop supply chain network design and vehicle routing problem with simultaneous deliveries and pickups with time windows in a closed distribution system for subsidized LPG 3-kgs. The closed loop supply chain network encompasses multi filling station, multi distributor and multi retailer. The proposed model has been applied to a numerical example that illustrates a closed distribution system of subsidized LPG 3-kgs in East Java and analyzed the optimal solutions resulting from the exact method. For further research, this proposed model will be developed by considering the vehicle routing for deliveries and pick-ups of defected LPG tubes that taken form several filling stations by re-tester plants.

**AKNOWLEDGEMENT**

This study is part of research funded by the Directorate General of Higher Education. We grateful thanks for their support in this research funding.

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