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HOW HALAL TRANSPORTATION SYSTEM IMPACT THE LOCATION ROUTING PROBLEM

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Abstract. *Halal products become more popular in the world market today that increase the demand of other halal services especially in halal distribution system. These services are designed not only for profitability but its ability to serve customers to maintain the integrity of their halal products. The important decision of designing halal distribution system is determining the location of facilities. In this paper, a halal and non-halal demand constrains with vehicle flow formulation of an uncapacitated location routing model is presented. Halal and non-halal goods are not mixed on a same transportation vehicle. Its a clear difference in transportation of halal and non-halal goods. A location routing problem used to minimize total cost simultaneously. A heuristic algorithm is developed to solve minimum cost considering halal aspect. This paper conduct some numerical experiments to show the behavior of this algorithm.*

***Key Words**: halal transportation,halal, supply chain, halal product, location routing problem,*

1. Introduction

Demand for halal products is increases by moslem consumers to permitt the right of their religious. This is due to the fact that moslem consumers become more knowledgeable and aware about their religious obligations for halal products. According to Bahli [1], the increasing purchasing power among Moslems around the world also contributes to the increase demand for Halal products. Moslem consumers also understand the importance of using halal products is vital for their daily activities and for their afterlife [2]. It is affected by the behaviour of Muslim consumers nowadays are not only looking for Halal products, but also for the Halal processes [3]. This issues has created new services in the company to accomodate step by step in managing the integrity of a halal product. Several logistic industries understand to play their part in maintaining the halal integrity of products, hence they are trying to be halal transportation service providers [4].

All rules and regulations concerning the preparation of Halal products must be applied from the first step of producing the raw materials to the distribution systems, so the Halal food supply chain starts from the farm and finishes with the end customers.

However the traditional supply chain management is a series processes raw materials into final product then delivered to the end customer using transportation [5]. Tieman [6] discussed the increasing demand for Halal products should also affect the demand of other Halal services especially in Halal transportation and warehousing since all products must use these services.

Furthermore, the Halal supply chain approach is important to guarantee the Halal integrity at the point of consumption. To ensure the integrity of Halal products, managing its supply chain needs extra attention. Thus, the challenge of the Halal supply chain help to reduce the doubt of Moslem users to consume halal products. Halal industries relies on logistics service capabilities in the integrity of halal products such as transportation and warehousing that are really halal at the point of consumption [7]. Tieman [8] mentioned Halal needs a supply chain approach where the value chain and its supply chain activities totally align with the Syariah requirements.

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Therefore, it is important for Halal companies to look beyond their production and ingredients, and should extend Halal to the entire supply chain in ensuring that transportation, storage and handling are in compliance with Syariah to meet the requirements of the Muslim market [6]. The activity of halal supply chain are warehousing, sourcing, transportation, handling of products, inventory management and other managements.

Halal transportation is one of the fields of the supply chain in which Halal products are handled from non Halal products to avoid cross contamination in order to maintain their Halal integrity. As transporting Halal products, Halal and non-Halal goods are not mixed in a same load carrier or in a container/ common transportation vehicle. It is a clear difference in transportation in any vehicle. Principles pertaining to halal and non-halal is very detailed and clear since a Hadisth saying that there is clear between Halal and Haram. In order to maintain the "Halalness" of the Halal products, it must be handled by the right person using the right process [4]. All the products can't simply be put together in the same distribution system to be moved to the right destination without considering their Halal status of the products.

An important aspect of designing a distribution system is determining the locations of the facilities. Determining the locations of facilities within a distribution network is an important decision that impacts not only the profitability of an organization but its ability to serve customers [9]. Deliveries of halal and non halal product is clear difference vehicle and storage. Berger, et al, [9] discuss this activity are made along multiple stop routes visiting two or more customers. The cost of delivery depends on the other customers on the route and the sequence in which they are visited. To capture the cost of multiple stop routes accurately within a location model, the routing problem must be solved at the same time as the location problem. the location-routing problem (LRP), as cites by Berger, et al [9] is to minimize total cost by simultaneously selecting a subset of candidate facilities and constructing a set of delivery routes that satisfy the following constraints: (i) customer demands are satisfied without exceeding vehicle or facility capacities; (ii) the number of vehicles, route lengths, and route durations do not exceed the specified limits; and (iii) each route begins and ends at the same facility.

LRP is specifically discussed by several researchers. Webb [10] and Christofides et al [11] which discusses the error introduced into location modeling by the out-and-back representation of delivery costs. Laporte [12] summarizes the literature of LRP models, solution procedures, and applications of LRPs. Min, et al [13] develop and use a hierarchical taxonomy and classification scheme based on problem characteristics and solution methodology to review the LRP literature. Most research of LRP has focused on heuristic methods. The heuristics generally decompose the problem into three components—facility location, customer allocation to facilities, and vehicle routing—and solve a series of well-known problems such as p-median, location-allocation, and vehicle routing. Previous studies mainly devoted to heuristic methods ([14] [15] [16] [17] [12] [18] [19]).

Some exact methods have been developed for LRP models with vehicle-routing problem (VRP). Laporte and Nobert [20] solve a single depot model by a constraint-relaxation method. The method use branch-and-bound algorithm for the traveling salesman problem (TSP) developed by Miliotis[21]. Laporte et al [22] solve a multidepot problem in which at most p-facilities are located by adapting

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Miliotis's [21] reverse algorithm. Laporte [12] develops an equivalent model and also extends the model to the case in which the number of vehicles used is a variable in the model. Laporte, Nobert, and Taillefer[23] formulate a multidepot VRPs and LRPs as a variant of the TSP in which some of the nodes do not need to be visited by using a graph transformation. They formulate the transformed problem as an assignment problem with subtour elimination constraints and side constraints that define legal routes.

However, none of previous paper discuss LRPs with integrated halal transportation that halal and non-halal goods are not mixed on a load same transportation vehicle. Its a clear difference in transportation dan facilities of halal and non-halal goods. In this paper, a vehicle flow formulation of an uncapacitated location routing model with halal and non-halal demand constrains is presented. A set partitioning constraints is identified to reduce the total number of contraints and the heuristic algorithm is developed to solve minimum cost considering halal aspect.

2. Problem Formulation

In this section, we discuss a formulation of the LRP with distance contraints. Berger, et al [9] explain the objective of the LRP with distance constraints is to select a set of locations and construct a set of associated delivery routes in such a way to minimize facility costs plus routing costs. The set of routes must be such that each customer is visited exactly once by one route and that the length of each route does not exceed the maximum value [9]. Generally, in these models the transportation costs are assumed to be a linear function of the straight-line (also referred as radial distance) between a facility and final customers. This is based on the assumption that each customer is served by a full load truck, which performs a dedicated route, whose transportation cost is well approximated by the straight-line distance from the facility [24].

2.1 Location Routing Problem with Disance-Constraint (LRPDC)

Location Routing Problem is one of the logistics and distribution problem to integrate the depot selection (facility location) and the route of vehicle (vehicle routing problem) to supply consumer demand. Some of LRP problem assume that used vehicles have the same capacity. Routes in the LRP has the same structure with the vehicle routing problem (VRP), which started from a depot then visiting two or more customers until the load is full then back to the same depot.

The formulation of location routing problem as developed by Berger, et al [9]. The sets, parameters and variables used in the mathematical model are defined below: Let J be the set of candidate facility locations and I be the set of customer locations. We define the graph G = (N,A), where $N = I \cup J$ is the set of nodes and $A = N * N$ is the set of arcs. We let d_{ij} for all $(i,j) \in A$ be the "distance" between nodes i and j. The distance d_{ij} can be defined as the Euclidean distance. For applications in which the constraint applies to the length of the route to the last customer instead of the length of the return trip to the depot, we set d_{ij} to 0 for all (i,j) with $i \in I$ and $j \in J$. Feasible route k associated with facility j that begins at facility j then visits one or more customer nodes and return to facility j and has a total distance of at most the maximum distance and denoted by M. P_j denote the set of all feasible routes associated with facility j for all $j \in J$. The cost of a route $k \in P_j$ is the sum of the costs of arc in the route and the cost of an arc $(i,j) \in A$ is proportional to

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the distance d_{ij} to reflect distance-related operating costs. $a_{ijk} = 1$ if route k associated with facility j visits customer $i, \forall i \in I, \forall j \in J, \forall k \in P_j$, otherwise $a_{ijk} = 0$. c_{jk}= cost of route k associated with facility $j, \forall j \in J, \forall k \in P_j$. $f_j =$ fixed cost associated with selecting facility $j, \forall j \in J$. α= objective weighting factor. $X_j = 1$ if facility j is selected $\forall j \in J$ and 0 otherwise. $Y_{ijk} = 1$if route k associated with facility j is selected, $\forall j \in J, \forall k \in P_j$ and 0 otherwise.

$$miminize\ \alpha . \sum_{j \in J} f_j X_j + \sum_{j \in J} \sum_{k \in P_j} c_{ijk} Y_{jk} \quad \text{.......................................(1)}$$

subject to

$$\sum_{j \in J} \sum_{k \in P_j} a_{ijk} Y_{jk} = 1\ \forall i \in I \quad \text{.....................(2)}$$

$$X_j - Y_{jk} \geq 0\ \forall j \in J, \forall k \in P_j \quad \text{..........(3)}$$

$$X_j \in \{0,1\}\ \forall j \in J \quad \text{..........................(4)}$$

$$Y_{jk} \in \{0,1\}\ \forall j \in J, \forall k \in P_j \quad \text{...........(5)}$$

The objective function (1) seeks to minimize the weighted sum of the facility costs and the routing costs.in this study, α can be ignored because all the candidates of facilities have the same weighted factor. The constraints in the first line (2) is a set partitioning constraints that require each customer *i* be served by one selected routes. Contraint no 3 require that facility j be selected if a route k associated with facility j is selected. Constraints (4) and (5) are standard binary restrictions on the variables. In this study, integrated halal transportation means that halal and non halal goods are not mixed in a same load carrier or in a container/ common transportation vehicle to avoid cross contaminatio, so the facility and transportation of halal and non halal good will split in the difference storage and vehicle.

2.2 Nearest Neighbor method

The heuristic method that used in this study is nearest neighbor method. Nearest Neighbor method was first introduced in 1983 and is a very simple method. At each iteration, do a search nearby customers to next customers. The new route starts in the same way if there is a position that is feasible to place new customers due to capacity or distance constraints. This method insert one by one cutomer nearest unvisited into service (nearest neighbor) due to the capacity or distance limits then back to the depots. the same process for the next vehicle until all customers have visited [25].

Nearest neighbor algorithm cite by Pop [26] as follows:

1. Starting from the depot or facility, then look for customers who have not visited the location which has the shortest distance from the depot as the first location.
2. Continue to another location that has the shortest distance from the location previously selected and the distance does not exceed from maximum distances of each vehicle delivery
   a. If a location selected and there is a remaining distances of the vehicle, then back to step (2)
   b. If the vehicle does not have residual mileage, then return to depot (1)
   c. If there is no location was selected because of the demand exceeds the vehicle's total distances, then return to step (1). Then repeat step (1)start from depot and visiting nodes who have not visited and select the shortest distance.
3. When all customers have visited exactly once then the algorithm end.

The example of this algorithm is given in figure 1. In the figure A, depot searching the minimum distance of all customers and choosing them to be the first visited customers. After that, find the minimum distance and select the nearest customer from the depo which can be seen in figure B. then find the next customer

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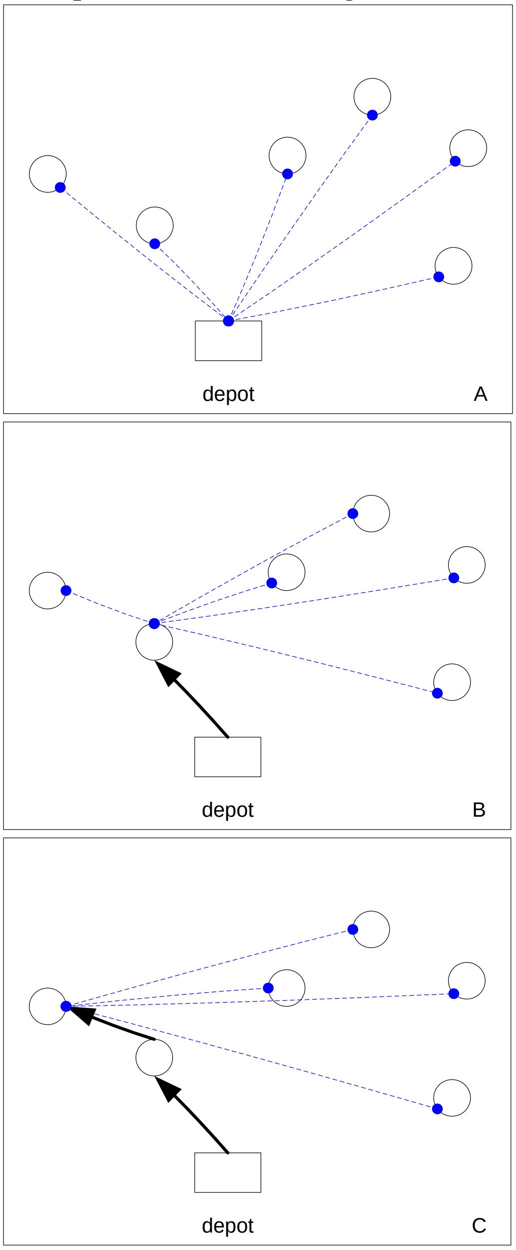
with searching the minimum distance starting from first selected customer. If the distance is smaller than distance contraints (M) then continue to select next customer which can be seen in figure C. The next step is searching and find the minimum distance from the second customer to another. then view the distance contraints M whether it can accomodate or exceed its capacity limits. If all of the customers have visited exactly once then the vehicle back to the depot as illustrates in figure D.



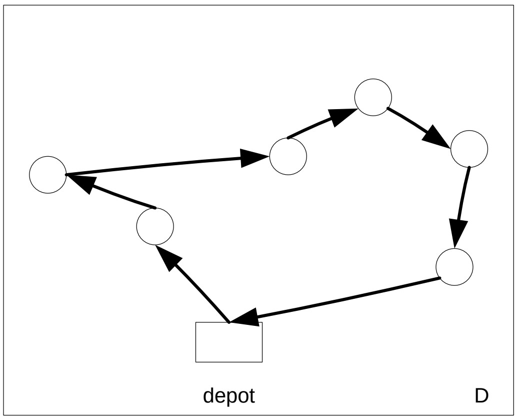


Figure 1. Example of Nearest neighbour algorithm

2.3 Halal Supply Chain

Supply chain management can be interpreted with a series of processes to transform raw material into final products. Then delivered to the customers. According to Pujawan [41], supply chain is a network of comanies that work together to create and distribute a product or services to the end customer from the upstream to downstream.

When supply chain corespond to product for moslem which is needs halal troughout the supply chain from the supplier of raw material to the end of customers.

Halal Supply Chain Management is the practical shape by delivering value and societal value chain in complete supply chain, taking care of consumers and society's long term interests simultaneously meeting company's requirements [27]. Van der Spiegel et al [28] mention that the first halal storage and warehousing in the world is in the Netherlands, which has in turn stirred the development of a worldwide Halal supply chain. Other aspects of halal supply chain that cannot be considered analytically are animal welfare, the ritual slaughter method, handling and separation of halal animals, cleaning and disinfection, separation of halal and haram food at all stages of the halal food supply chain, and low concentrations of haram contaminants.

To ensure the halal standard in the entire supply chain needs tracibility system

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to combine both halal standard and food safety system [29]. However, haram contamination can take place in the entire halal food supply chain, e.g. from breeder to livestock farmer, distributor, slaughterhouse, meat processor, retailer, and consumer ([30] [31] [32]). The activities in the Halal supply chain includes warehousing, sourcing, transportation, handling of products, inventory management and other managements.

2.4 Halal Transportation

The case of transporting product, halal and non-Halal goods are not mixed in a load carrier or pallet or in a container/ common transportation vehicle (in case of bulk shipments). There is also a clear difference in transportation in the case of ambient or reefer for example chilled or frozen ([4] [33]). The uniqueness of Halal in Islam is separate the halal and non-halal products which is very detailed and clear since there is a Hadith saying that there is clear between Halal and Haram. The previous research that adopting Halal into logistics persepctive and hold on to shariah principles during all the activities of logistics such as transportation or storage ([34] [35] [36] [37] [38]). Lodhi [38] mentions that all halal products must be separated from non-halal products in the whole stages of logistics and supply chain activities. It has been depicted by Tan et al [39] that the facility of logistics such as halal warehousing and transportation play a large part in the success story in halal industry by ensuring the integrity of halal products.

The industries which maintain "Halalness" of the Halal products must be handled by the right person using the right process. All the products can't simply be put together in the same transport to be moved to the right destination without considering their Halal status of the products. If there is any misconduct, the Halal integrity of the products could be questioned. Tieman [33] explain that for refrigerated shipments there should be no mixing in the same container/common transportation storage of Halal and severe Najis (items regarded as ritually unclean) like pork. In case of ambient transports, there should be no mixing of Halal and non-Halal goods on a pallet or load carrier, and tertiary packaging should be used to protect the Halal cargo along the supply chain.

3. Numerical Experiment

In this section, we present the result of our computation experiments with the LRP-DC formulation and nearest neighbour algorithm. We run all computational experiments on a microsoft excel with visual basic application (VBA) or macro excel as figure 2. To specify an instance of the LRP with distance constraints, we need the locations of the customers and the candidate facilities, the associated distance matrix, facility costs, routing costs, a value for the objective weighting factor α, and a value for the maximum distance M.

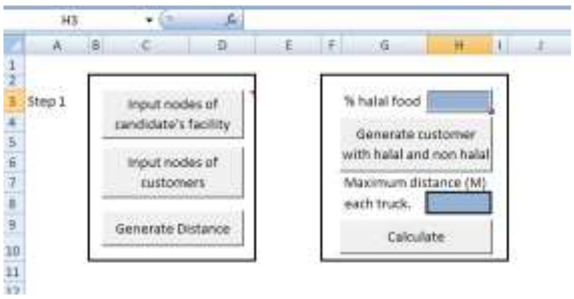

figure 2. VBA excel form

In the LRP, there is no standard set of instances for testing algorithms. We generate the location of the customer and candidate facilities from Solomon vehicle routing problem with time windows (VRPTW) instances based on Berger et al [9] and Solomon [40]. We randomly generated candidates from uniform distribution with 5 candidates facilities locations and 20 customers. The nodes can

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be seen in the figure 3. Then we continued generating candidate until each customer location could be reached by single route at most M= 30 from at least one candidate facility.

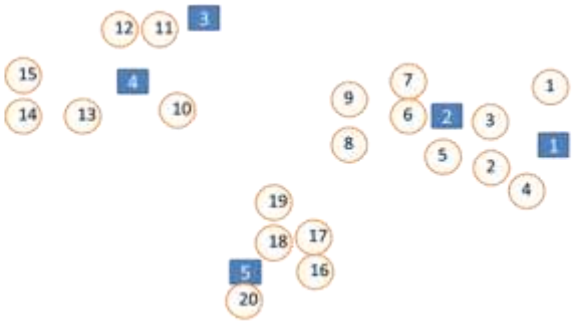
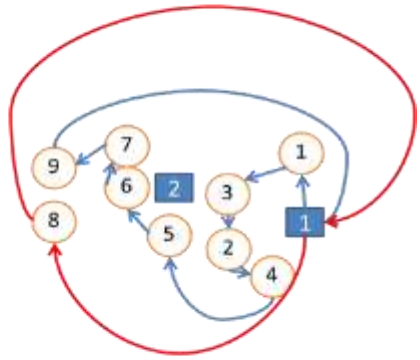


Figure 3. nodes/location of 5 candidats facilities locations and 20 customer.

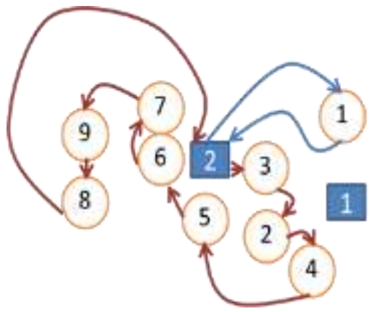
To calculate the distance matrix, we begin by calculating the Euclidean distance between all node pairs and rounding the value to the nearest integer. We assign the distance between a pair of nodes allow links between any node pair for which the distance.

According to Berger et al [9], facility costs vary widely depend on the type, location, and size of the facility. Facility cost in this case, we use the same assumption cost for all candidate facilities at $400. If one candidate selected for both halal and non halal good, the assumption costs for this candidate facility is $600. For the routing costs, we assume a cost per unit distance at $1 to cover vehicle costs which distance obtained from distance formula with x and y axis. As Berger [9] assumption that personnal costs and other related vehicle fixed costs are not considered the location-routing decision.



Node 1

Truck 1	0---1---3---2---4---5---6---7---9---0	28,9
Truck 2	0---8---0	20,4
Total		49,3



Node 2

Truck 1	0---3---2---4---5---6---7---9---8---0	26,32
Truck 2	0---1---0	4
Total		30,32

Figure 4. Route in the nodes 1 and 2, without considering "halalness".

When the routes was not considering the "halalness" as figure 4, the nodes which selected is node 2 with total cost is 30.32.

We generated the halal customers from 30%, 50% and 70% to show the behaviour of route with the same candidate facilities as can be seen in figures 5, 6 and 7. If one of the candidate facility selected for halal and non halal goods then the facility will split into two difference depot on the same location. The assumption in this case, that facilities location which selected have a different place of halal and non halal products.

As we running the first scenario (30% demand of halal) that can be shown in the figure 8. The results for this scenario, is more than costly when compare with

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"halalness". As can be shown in figure 4. The red arrow is indicated route of truck that bring halal foods to the customer 2 and 4. The blue arrow indicated routes for non halal products. For this example nodes 1 need 2 truk which is one for transporting halal products and another for non halal products.

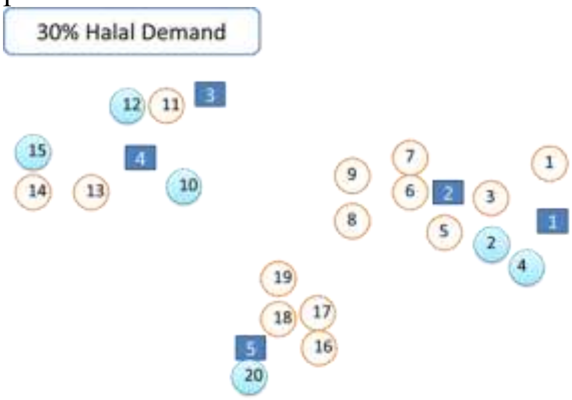


Figure 5. generated halal and non halal customers with 30% halal demand.

Figure 6. generated halal and non halal customers with 50% halal demand.

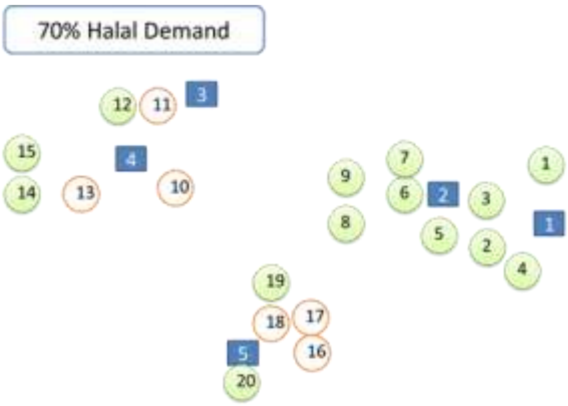
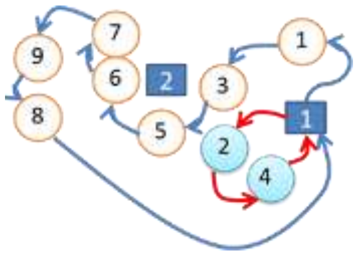
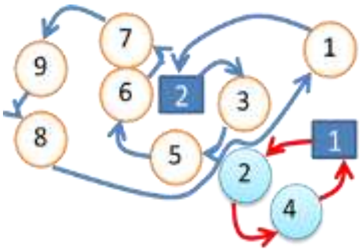


Figure 7. generated halal and non halal customers with 70% halal demand.



Node 1

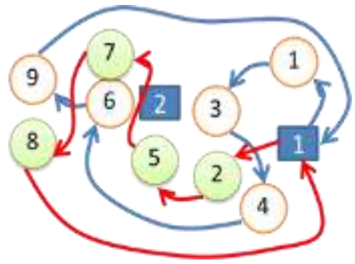
Truk 1 (n-Halal)	0---1---3---5---6---7---9---8---0	29,64
Truk 2 (Halal)	0---2---4---0	8,86
Total		38,5



Node 2

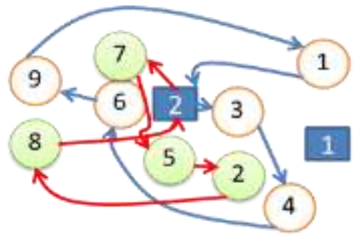
Truk 1 (n-Halal)	0---3---5---6---7---9---8---1---0	28,85
Truk 2 (Halal)	0---2---4---0	9,09
Total		37,94

Figure 8. Route in the nodes 1 and 2, with considering "halalness" (30% demand of halal product).



Node 1

Truk 1 (n-Halal)	0---1---3---4---6---9---0	26,83
Truk 2 (Halal)	0---2---5---7---8---0	25,29
Total		52,12



Node 2

Truk 1 (n-Halal)	0---3---4---6---9---1---0	28,56
Truk 2 (Halal)	0---7---5---2---8---0	21,56
Total		50,12

Figure 9. Route in the nodes 1 and 2, with

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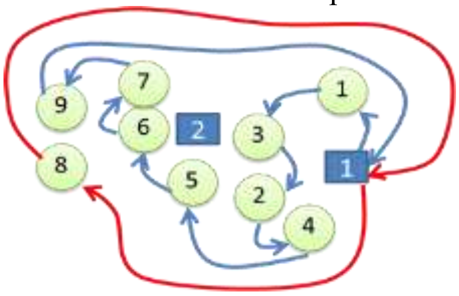
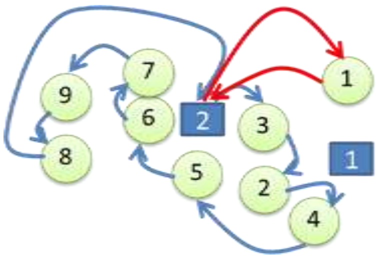
considering “halalness” (50% demand of halal product).

In the figure 9. We can see 50% demand is halal products in the halal customers. Total cost in node 1 is $52,12 and node 2 is $50,12. When we compares with figure 8 and figure 4. The trend of cost is increasingly while increase the demand of halal products. The red arrow is indicated route of truck that bring halal foods to the customer 2, 5, 7 and 8. The blue arrow indicated routes for non halal products.



Node 1

Truk 1 (Halal)	0---1---3---2---4---5---6---7---9---0	28,9
Truk 2 (Halal)	0---8---0	20,4
Total		49,3



Node 2

Truk 1 (Halal)	0---3---2---4---5---6---7---9---8---0	24,32
Truk 2 (Halal)	0---1---0	10,2
Total		34,52

Figure 10. Route in the nodes 1 and 2, with considering “halalness” (70% demand of halal product).

Figures 10 shows the 70% of the halal demand. For the case that shown in figure 7, that node 1 dan node 2 serve 100% of halal customers. This is similary with initial case which is serve customer without sparate halal and non halal products and also similar routes for this node 1 and nodes 2. The differences is the costs attendent on halal and non halal handling for the facilities of warehouses and truk.

Table 1 shows the result of total distance with all candidate facilities. The computation shows that candidate1 dan 2 is one cluster and serve customer no 1 until customer 9 but not feasible to cover other customer because of limitation distance constraint M=30. In other words, if candidate 1 will opened, then candidate 2 is close and otherwise.

Candidate 3 and 4 have the same condition that a group of another cluster in which serve customer 10 until 15. Different from candidate 5 and serve customer number 16 until 20. These cluster are separated by color as in table 1.

Table 1. Total distance

	mixed	30% halal food	50% halal food	70% halal food
candidate1	49,3	38,5	52,12	49,3
candidate2	30,32	37,94	50,12	34,52
candidate3	78,23	77,56	99,41	80,78
candidate4	39,78	43,07	53,76	49,72
candidate5	19,25	20,64	24,48	20,23

Table 2. total cost selected candidate facilities

	mixed	30% halal food	50% halal food	70% halal food
candidate2	430,32	637,94	650,12	634,52
candidate4	439,78	643,07	653,76	649,72
candidate5	419,25	620,64	624,48	620,23
Total cost	**1.289,35**	**1.901,65**	**1.928,36**	**1.904,47**

LRP is used for minimize cost, so we select candidate which have minimum

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distance. Candidate 2 has a shorter distance than candidate 1. Likewise candidate 4 is shorter than candidate 3. The result from these numerical experiment we select candidate 2, candidate 4 and candidate 5. The total cost of the selected candidate facilities can be seen in table 2.

Based on table 1, we can conclude when there is a request on halal demand then increase the total distance and add to the transportation costs and facility costs but not necessarily reduce profit, instead it can increase the customer satisfaction of halal goods requirement.

4. Conclusion

This research has developed a facility location problem with halal and non halal demand constraints. LRPs arise in many application contexts in which deliveries are made along multiple stop routes. This study we presented a location routing problem with a set partitioning based formulation to find the minimize cost and which depot will be opened. We also deal with distance contraints to limit the models and can be used as a capacity limitation. We presented the nearest neighbor method to search the nearest customer and insert one by one to the route due to the distance contraints.

The result of numerical experiment, we obtained some candidate facilities are clustered on groups that can reduce the number of constraints. Computation of LRP with distance constraints has differ significantly when applied the halal and non halal food products. This difference occurs because the facilities and transportation of halal and non halal goods must be distinguished. The calculation can be used for all halal and non halal product which have perishable goods caracteristics.

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