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Two stages of halal food distribution model for perishable food products

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Abstract:

Two stages of halal food distribution model for perishable food products are a mixed integer linear program (MILP) model proposed to solve the distribution problem of halal food, especially for perishable food products. The model can simultaneously minimize overstock, shortage, transportation, and deterioration costs. The model is developed into two stages. The first stage is the location-allocation model to determine the halal cluster and the number of suppliers in each cluster. The second stage is the vehicle routing model to determine the routing at each cluster. Numerical experiments are done using CPLEX Solver and the proposed model is applied to solve a real case of halal meat distribution in Yogyakarta. The results show that the proposed model can be used as a decision tool for supply chain and distribution managers to determine the strategy for distributing halal food products with the least total logistics cost for daily application.

Key words:

Halal food distribution, MILP, deterioration, overstock, shortage, transportation.

1. Introduction

Halal is increasingly becoming an eminent market not just in Moslem but also non-Moslem countries. The trend for halal industry is increasing, and it becomes a promising business. According to the second edition of the Halal Guidebook report, the global halal economy is estimated to be worth $3.2 trillion by 2024, ranking first is the food and beverage industry. Furthermore, the State of the Global Islamic Economy Report 2020/21 also reveals that Moslems' spending on food and beverage is expected to reach $1.38 trillion by 2024.

Moreover, the halal industry will become more promising since the number of Moslem population is projected to increase in the future. The world's Moslem population is expected to increase to 2.2 billion by 2030, according to new population projections by the Pew Research Center. Thus, the market of the halal industry will also increase accordingly. This is supported by the study of Kurniawati and Savitry (2020) which found that Moslem consumers of halal food products are loyal customers. They found that halal awareness of Moslem consumers for halal products is very high.

According to Islamic rules, sourced from the Quran, Moslems are required to consume only halal and toyyib (wholesome) food product and forbidden to consume besides it. For example, even though a type of food is considered halal, but if it is spoiled, it cannot be consumed because it can be harmful to the body and bad for health. Moslems need a guaranteehat they only consume food product that is halal and toyyib, which means wholesome and good to be consumed, as a manifestation of the Islamic rules.

With the fact that Moslem consumers are loyal and have high awareness of halal products (Kurniawati and Savitry, 2020), if the demand for halal products cannot be fulfilled by suppliers, there will be a shortage of halal products for customers. In addition, if halal stock in the suppliers cannot be well distributed to the right market and right demand,

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this may lead to overstocking within the suppliers. Kurniawati (2018) defines it as an unbalanced halal product distribution.

In the unbalanced halal product distribution, there are unreasonable overstock and shortage of products (Kurniawati, 2018). The overstock and shortage of products can reduce the company's profit, resulting in loss of sales and customer dissatisfaction. One example of unbalanced halal food distribution is a case study conducted by Aisyah and Kurniawati (2019). They found that in 2017 there was an unbalanced distribution of halal meat in the Province of Daerah Istimewa Yogyakarta, Indonesia with high shortage and overstock costs. Both studies point out that it is important to implement a balanced halal food distribution for sustainability purposes and to reduce overstock and shortage costs.

Balanced distribution strategy is important, especially for perishable food that deteriorates quickly. Some examples are meat, beef, fish, vegetables, fruits, etc. If the distribution of these products is not well-managed, shortage and overstock may occur and the products may become spoiled. The spoiled products could turn into food waste and it is estimated that around 30% of food during the distribution that become waste (Lee and Dye, 2012; Huang et al., 2018; Beullens and Ghiami, 2021). Therefore, it is necessary to manage the effect of food spoilage so that the food product can be consumed for its greatest benefit and food waste can be minimized.

Literature on balanced halal food product distribution is in general scarce, and there are only two that discuss it: Kurniawati (2018) and Aisyah and Kurniawati (2019). Although both references consider overstock, shortage, and transportation costs, they do not consider the deteriorating factor of food products. Therefore, to the best of the author's knowledge, this study is the first study that formulates a model to determine halal food product distribution that considers overstock, shortage, transportation costs, and the deterioration factor of the food product simultaneously.

Considering this background, it is important to consider overstock, shortage, and transportation costs, and the deteriorating factor of the halal products simultaneously so that the product can be distributed and arrive to customers in good quality with minimum logistics costs. The objective of this study is to develop a strategy for balancing halal food product distribution which can minimize shortage, overstock, and transportation costs of halal products and the deteriorating factor of food products.

Finally, by proposing a mixed integer linear program (MILP) model as a decision planning tool, this study may be useful to supply chain managers, warehouse supervisors, and any person in charge of distribution to determine the halal food product distribution that minimizes the overstock, shortage, and transportation costs, and the deterioration factor of the product simultaneously. In addition, the study could contribute to the existing literature and research on halal product distribution which are still limited, particularly in the area of optimizing the distribution of halal food products.

2. Literature review

The characteristic of halal food product, which makes it different from other products such as diet food, Japanese food, Korean food, etc., is its possibility for cross-contamination with non-halal food which turns the halal food into non-halal. As a consequence, the contaminated halal food is forbidden to be consumed by Moslem since its state now becomes non-halal. In their study, Soon et al. (2017) reported that many cross contaminations of halal food with porcine DNA, pork, and others occurred from 2000 to 2016.

According to Bonne and Verbeke (2008) Moslem consumers lack information on supply chain and cannot be reassured that no cross-contamination has taken place. In particular, halal logistics capabilities are critical in ensuring the halal integrity of the supply chain from farm to fork Tieman (2007). Therefore, it is important for halal-certified companies to look beyond their production and ingredients and extend halal to the entire supply chain in ensuring that their transportation, storage and handling are in compliance with Islamic rules and meet the requirements of their Moslem market.

Some previous research have studied halal supply chain. In 2014, Ab Talib and Abdul Hamid (2014) conducted a Strength Weakness Opportunity Threat (SWOT) analysis for halal logistics. In 2020, Ab Talib (2020) identified halal logistics constraints. Shahijan et al. (2014) have identified retailers' behavior in managing critical points in halal meat handling. In 2015, Ngah et al. (2015) identified the barriers and enablers in the adoption of halal warehousing and its relationship. Haleem and Khan (2017) have studied the critical success factor (CSF) adoption of halal logistics. Tan et al. (2017) have studied the impact of external integration on halal food integrity. Ali et al. (2017) have proposed a supply chain integrity framework for halal food. Maman et al. (2018) have identified halal risk events, halal risk agents, measured halal risk levels and formulated a halal risk control model (mitigation) in all stages in the beef supply chain from Australia to Indonesia.

Poniman et al. (2015) have explored the emergence and implementation of traceability systems in Western Australian halal food industry. Tieman et al. (2012) have proposed new framework to optimise the design of halal food supply chains, called the "Halal Supply Chain Model". Tieman (2011) has described the basic requirements of halal food supply chains in order to ensure the integrity of halal food at the point of consumption. Azmi et al. (2020) have studied the perception of food manufacturers towards the adoption of halal food supply chain in Malaysia. Zailani et al. (2017) have investigated challenges and opportunities for logistics companies in Malaysia to adopt halal logistics. Zulfakar et al. (2018) have investigated the role of institutional forces in shaping the operations of halal meat supply chain in Australia.

In 2017, Ngah et al. (2017) identified the contributing factors to the adoption of halal warehousing services among Malaysian halal manufacturers. Manzouri et al. (2013) have conducted a survey for halal food industries implementing lean practices in the halal food supply chain and the barriers to their implementation. Abdul Rahman et al. (2018) have challenged the implementation of halal warehouse in air cargo context along with the standard of handling process for the storage of halal product for import and export purposes. Bashir et al. (2019) have investigated the current and future status of overseas halal food marketing and developed strategies for improving the competitiveness of Korean seafood companies in the global halal food market.

Mohamed et al. (2020) have studied the effect of halal supply chain management on halal integrity assurance. Susanty et al. (2021) have identified and ranked the barriers to halal logistics implementation and identified the relationship among the identified barriers of halal logistics implementation. Khan et al. (2021) have identified and analysed the elements of Halal Supply Chain Management (HSCM) and their significant risk dimensions. Khan et al. (2022b) have identified the risk elements associated with halal food supply chains and prioritized them appropriately towards better management. Khan et al. (2022a) have analysed and mitigated barriers towards management of halal supply chain. Hendayani and Febrianta (2020) have studied about the relationship between technology and performance of family businesses supply chain. Ab Rashid et al. (2020) have studied the relationship between halal traceability system adoption and environmental factors on halal food supply chain integrity in Malaysia.

Fathi et al. (2016) have investigated factors that motivate consumers in Malaysia to pay for halal logistics and its consequences on their demand for halal logistics certification. Haleem et al. (2021) have conceptualized a framework linking halal supply chain management with sustainability. Ngah et al. (2020) have identified factors influencing the decision about halal transportation adoption among pharmaceuticals and cosmetics manufacturers. Selim et al. (2022) have modelled halal logistic services and its positive impact on manufacturers' trust and satisfaction. Ag Majid et al. (2021) have investigated the factors that influence consumers' willingness to pay (WTP) for halal logistics among young non-Moslem adults. Kristanto and Kurniawati (2023) proposed the general framework for halal supply chain risk management in frozen food industries.

Kurniawati and Cakravastia (2023) conducted literature review in halal supply chain and found that there is still a lack research in the area of optimization of halal supply chain, especially using Operations Research (OR) model. There are four articles related to halal supply chain research using OR method. Mohammed et al. (2017) have proposed MILP and stochastic programming model for an RFID-enabled HSCM network design using cost-effective decision-making algorithm. Kurniawati (2018) has developed a MILP model for sustainable halal food supply chain for balancing halal food supply chain to minimize the shortage, overstock, and transportation costs. Kwag and Ko (2019) have formulated a MILP model for optimal location and allocation problem of halal food logistics network, including farms, butcheries and food plants that follow Islamic rule. In 2022, Kurniawati et al. proposed a MILP and Tabu search algorithm to minimize the vehicle route dedicated to halal product and non-halal product distributions.

There are two references that propose balanced halal food products distribution model, but they do not consider the deteriorating factor of the food products. Kurniawati (2018) has proposed balanced halal supply chain (BHSC) model to balance the halal food products distribution which consider only the overstock costs and distribution cost, while the shortage cost is assumed to be zero because it is assumed that the shortage cost is setting as hard time constraint which means that the shortage cannot happen. In addition, in this model, the transportation cost is calculated as a function of distance between supplier to the market supplied. Then in 2019, the BHSC was improved by Aisyah and Kurniawati (2019) by proposing improved and balanced halal supply chain (IBHSC) model in which the transportation cost considers the routing from suppliers to several destinations (markets) and the shortage cost is not setting as hard-time constraint. Thus, in IBHSC, the model minimizes the overstock, shortage and transportation costs as the function of vehicle routing for distribution.

Based on the literature review, there is no model for halal food product distribution that considers overstock, shortage, and transportation costs, and the deteriorating factor of the halal food product simultaneously. For perishable halal food product distribution, it is important to minimize the factor of deterioration in order to ensure that the product is distributed as halal and good quality product.

3. Model description

The model proposed in this study is titled "Two Stages of Halal Food Distribution Model for Perishable Food Products". It is a development of two previous models, BHSC model in Kurniawati (2018) and IBHSC model in Aisyah and Kurniawati (2019). The difference between the two previous models and the model in this paper is that the proposed model does not only consider the shortage, overstock, and transportation costs of the halal product distribution, but also the deterioration factor of the halal product.

In the case of perishable food product, the decay and expiration time of the product is short. In this condition, it is important to consider the deterioration rate of the halal product to avoid the product becomes spoiled, decays and breaks during the distribution process. If the halal food product decays during transportation or distribution, the product may reach the customer in low quality to be consumed and thus it can be harmful for the body and bad for health. To tackle this problem, this study proposes a model that considers the deterioration factor of the halal food product in order to successfully distribute halal and good quality product to the customer. The model is developed especially for perishable halal food products, which spoil fast such as fresh meat and fish, and others. The proposed model considers two levels of supply chain: halal production houses and halal markets. The objective of the proposed model is to minimize the total logistics costs that consist of overstock cost, shortage cost, transportation cost and the cost to compensate the deterioration factor of the product. Based on the above description, the conceptual model of the proposed model is depicted in Figure 1.

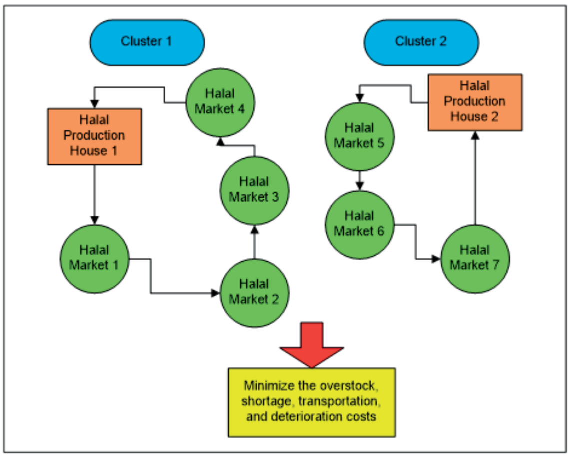

Figure 1. Conceptual Model of two stages halal food distribution model for perishable food products.

Based on the conceptual model and to achieve the objective of the model, the proposed model is developed into two stages. The first stage is to determine the location-allocation decision and the second stage is to determine the optimal vehicle routing. The flowchart of the model is depicted in Figure 2, which is the first stage determines which halal production house that supplies the halal market and how much that must be supplied. The first stage determines the location-allocation decision by minimizing the overstock, shortage and transportation costs between the halal production house and the halal market supplied. The detailed explanation for the costs is as follows.

- The overstock cost calculates the number of overstocks at halal production house. Overstock occurs when the production or stock is more than the total number of supplies in the halal production house. Therefore, the overstock represents the food waste.
- The shortage cost calculates the number of shortages at the halal market. The shortage occurs

when the total number of supplies received by the market are less than the demand of the market. Therefore, the shortage represents customer dissatisfaction and loss of sales.

- The transportation cost in this stage is the cost that only calculates the distance between the halal production house to each halal market but does not consider (ignores) the routing of the vehicles.

This stage will determine the cluster of the halal markets. The cluster of halal market is determined by the solution that gives minimum overstock cost, shortage cost, and transportation cost which is based on the distance between the halal production house and the halal market.

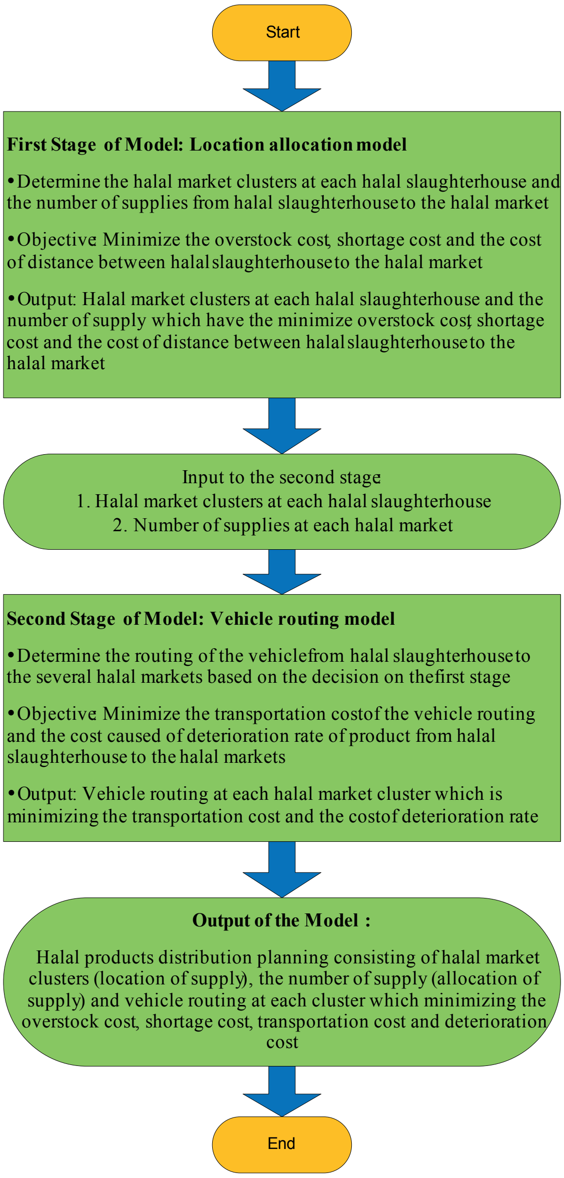

Figure 2. Flowchart of the Proposed Model.

The second stage of the model minimizes the transportation cost by considering the vehicle routing and the cost compensated for the deterioration of the product. The determination of the vehicle routing is based on the location-allocation decision obtained in the first stage, while in the second stage, the quantities supplied, and the cluster of halal market decisions obtained from the first stage are inputted. For example, if the outcome of the first stage is four halal market clusters, each cluster is then inputted in the second stage of the model. The outcome of the second stages model is the vehicle routing and the number of vehicles required to distribute the products from the halal production house to the halal market at each cluster. Thus, the transportation cost and deterioration cost could be minimized.

In summary, the outcomes of the first stage are the halal market cluster in each halal production house and the number of supplies from the halal production house to each halal market that belongs to its cluster. In the second stage of the model, the outcomes are the vehicle routing in each halal market cluster and the number of vehicles required. The route starts from the halal production house, then to the halal markets, and finally to the halal production house again. Therefore, implementing the whole model could help determine the distribution strategy that could minimize the total logistics costs (overstock cost and shortage cost) as the result of the first stage and the transportation and deterioration costs as the result of the second stage.

4. Model formulation

As described in Section 3, the proposed model is developed into two stages. The first stage describes the location-allocation problem, and the second stage describes the vehicle routing problem.

4.1. The First Stage of The Model

The assumptions used in the first stage of the model are as follows.

1) The model is deterministic.
2) Every halal market can be supplied by more than one halal production house.
3) Every production house can supply more than 1 halal market.
4) The transportation cost is based on the distance travelled between the halal production house and

the halal market, and it does not consider (ignore) the route.

The notations, variables, and parameters used in the first stage of the model are as follow:

- A set of halal production houses i, i = 1,…, I
- A set of halal markets j, j = 1,…, J

The parameters used in the first stage model are as follow:

- P_i: production quantity of halal production house (kg)
- D_j: halal market demand for halal food (kg)
- TT_{ij}: travel time between halal production house i and halal market j (minute)
- α : the constant for shortage cost ($/kg)
- β : the constant for overstock cost ($/kg)
- γ : the constant for transportation cost ($/minute)

The decision variables in the first stage model are as follow:

- S_{ij}: the quantity of supply from halal production house i to halal market j (kg)
- O_i: the quantity of overstock at halal production house i (kg)
- R_j: the quantity of shortage at halal market j (kg)
- X_{ij}: the boolean variable, X_{ij} =1 if the halal production house i supplies the halal market demand j, and 0 otherwise

The objective function of the first stage of the proposed model is to minimize the shortage cost, overstock cost, and the transportation cost between the halal production house and the halal market. The shortage cost is formulated as $\alpha\left(\sum_{j=1}^{J} R_j\right)$, while the overstock cost is formulated as $\beta\left(\sum_{i=1}^{I} O_i\right)$. The transportation cost between the halal production house i and the halal market j is formulated as $\gamma\left(\sum_{j=1}^{J}\sum_{i=1}^{I} X_{ij}TT_{ij}\right)$. Constraint 2 is the formula to determine the shortage cost at every halal market j. Constraint 3 is the formula to determine the overstock cost at every halal production house i. Constraint 4 determines that the total quantities of the supplies in every halal production house i must not exceed its production quantities. Constraint 5 states that total number of supplies from all production houses i must be less than or equal to the demand quantities of the halal market j. Constraint 6 enforces the decision variable X_{ij}. X_{ij} must be valued as 1 if the halal production house i supplies the halal market j, and vice versa. Constraint 7 is the constraint to enforce that every halal market j can be supplied by one up to all halal production houses i. Constraint 8 and constraint 9 are the nonnegativity constraints for decision variables S_{ij}, O_i, R_j, and X_{ij}.

4.2. The Second Stage of the Model

The following assumptions are used in the development of the second stage of the model.

1) The model is deterministic.
2) Vehicle can deliver halal food products to multiple destinations.
3) All vehicles are available at the beginning of the planning horizon.
4) All vehicles have the same and fixed capacity.
5) The vehicle's speed is assumed to be constant, and no traffic jam happens.
6) Split delivery is not allowed.
7) Deterioration rate is a linear function of time.
8) The distribution starts from the halal production house to the halal markets and returns to the halal production house.

The following notation is used in the formulation of the second stage of the model:

- A set of nodes i, i = 0, 1,…,I+1. The nodes for halal production house are denoted as node 0 and node I+1 (i = 0 and i = I+1).
- A set of vehicles k, k = 1…K

Parameters and input used in the second stage of the model are:

- TT_{ij} : Travel time from node i to node j (minute)
- S_i: Quantities of supplies from halal production house to halal market j (kg)
- Det : Deterioration rate of the product, dependent on time ($/minute)
- γ : The constant for transportation cost ($/minute)
- T: Time planning horizon (minute)

- Q : Vehicle capacity (kg)

The decision variables in the second stage of the model are:

- Z_{ijk} : binary variables. Z_{ijk} = 1 if there is a route from node i to node j using vehicle k, 0 otherwise, for i = 0,1,…,I; j = 1,…,I+1; i ≠ j, k = 1,…,K.
- V_{ik} : binary variables. V_{ik} = 1 if the supply of node i is distributed using vehicle k, and 0 otherwise, for i = 1,…,I; k = 1,…,K.
- AT_{ik} : time at which vehicle k completes the delivery at node i, for i = 1,…, n; k = 1,…,K.

Because it is assumed that all vehicles are available at the beginning of the planning horizon, it means that each vehicle is departed from the production house at time = 0 (vehicle departure time is 0).

The model formulation of the second stage of the model is described as follows. The objective function of the second stage of the model is to minimize the transportation cost of the route at each cluster and the deteriorating cost caused the deterioration rate. The transportation cost function is formulated as $\gamma\left(\sum_{i=0,i\neq j}^{I}\sum_{j=1}^{I+1}\sum_{k=1}^{K} Z_{ijk}TT_{ij}\right)$ and the deteriorating cost caused the deterioration rate of halal product is formulated as: $\left(\sum_{i=1}^{I}\sum_{k=1}^{K} DetAT_{ik}\right)$. Therefore, the objective function of the second stage of the model is Minimize $Z_2 = \gamma\left(\sum_{i=0,i\neq j}^{I}\sum_{j=1}^{I+1}\sum_{k=1}^{K} Z_{ijk}TT_{ij}\right) + \left(\sum_{i=1}^{I}\sum_{k=1}^{K} DetAT_{ik}\right)$.

Constraint 11 specifies that each node (order) *i* is visited exactly once by a vehicle. Constraint 12 ensures that each delivery route starts at the production house, while constraint 13 ensures that each delivery route ends at the production house. Constraint 14 restricts the sequence of the vehicle's route of distribution. Constraint 15 ensures that each distribution must be completed within the planning horizon. Constraint 16 computes the completion time of distribution to each halal market. M is a sufficiently large number so that the condition always remains true. Constraint 17 forces V_{jk} to be *1* if the vehicle k distributes to node *j*; this constraint captures the relation between Z_{ijk} and V_{jk}. Constraint 18 restricts the vehicle's load, as a vehicle's load (total number of products that are loaded onto the vehicle) cannot exceed its capacity. Constraints 19-21 are the nonnegativity constraints for the decision variables.

The summary table with all the indices, parameters, and decision variables both at the first stage and the second stage of the model are presented in Table A in the Appendix.

5. Numerical experiment result

In this study, model validation was performed using numerical experiments with artificial data generated with Microsoft Excel. The model was coded in CPLEX Solver version 20.1. and the experiment was performed using computer platform with processor AMD Ryzen3 2.10 GHz. To understand the performance and the behaviour of the model, numerical experiment was conducted for three data sets: small, medium, and large data sets. The data sets and the parameter values used in the numerical experiment are presented in Table 1. The results of the experiment for the small, medium, and large data sets are shown in Tables B-H in the Appendix, while for the run time for the numerical experiment is presented in Table 2. The existing condition for the small data set and the result for the first and second stages of the model is depicted in Figures A-C in the Appendix.

Table 1. Data Sets for Numerical Experiment.

Data set	Number of PH	Number of HM
Small set	4	8
Medium set	8	20
Large set	4	40

Parameter	Value
α	Rp 12,000/kg
β	Rp 45,000/kg
γ	Rp 600/minute
Det	Rp 31.25/minute
T	1,440 minute
Q	500 kg
M	10

Note: PH is halal production house; HM is halal market.

Based on the results of the experiment, the proposed model was able to optimize the distribution strategy for halal products. The model was able to determine the optimized number of supplies from the halal production houses to the halal markets with vehicle routing by minimizing the overstock, shortage, transportation, and deterioration costs simultaneously. In addition, based on the three data sets, the run time increased exponentially with increasing size of data sets.

Table 2. Run Time for Numerical Experiments.

Data Set	1st Stage Run time (second)	2nd Stage Run time (second)	
Small Data Set	0,51	Cluster 1	0,17
		Cluster 2	0,18
		Cluster 3	0,18
		Cluster 4	0,17
Medium Data Set	2,35	Cluster 1	0,2
		Cluster 2	0,34
		Cluster 3	0,17
		luster 4	0,23
		Cluster 5	0,17
		Cluster 6	0,17
		Cluster 7	0,17
		Cluster 8	0,26
Large Data Set	58	Cluster 1	17,49
		Cluster 2	23,7
		Cluster 3	33,8
		Cluster 4	5,51

6. Case study

based on the numerical experiment, the two stages of halal food distribution model for perishable food products have been validated and can be used to determine the strategy for distributing halal products, so the shortage, overstock, transportation, and deterioration costs can be minimized simultaneously. Therefore, the proposed model can be used to solve real-world problems.

The model has been used to solve a problem faced by the province Y in Indonesia. The province has a problem in distributing halal meat product from halal slaughterhouses (HS) to halal markets (HM), resulting in high overstock and shortage costs. The province has 10 halal slaughterhouse (10 HS) and 12 halal market (12 HM). Their problem in distributing the halal meat is because the demand of each halal market in the region can only be supplied by the halal slaughterhouse in that region also. This is because each halal market in the region is only supplied by the halal slaughterhouses in that region. In fact, the province has halal slaughterhouses that produce halal meat much more than the demand of the local halal market, while in other regions the halal slaughterhouses' productions are less than the demand of the halal market in that region. This creates an un-balanced distribution in that province and the high overstock and shortage costs. The existing production and demand quantities at five regions in Province Y is shown in Table 3.

Table 3. The existing production and demand quantities at five regions of province Y, Indonesia.

Region	HS	Production quantities (kg)	HM	Demand quantities (kg)
SLM	HS6	258,86	HM6	221,78
	HS7	258,86	HM7	140,91
	HS8	258,86	HM8	196,31
	HS9	258, 86	-	-
BNT	HS1	307,25	HM3	182,91
	HS2	307,25	HM4	491,1
	HS3	307,25	HM5	360,72
	HS4	307,25	-	-
	HS5	307,25	-	-
YGY	HS10	514,82	HM11	218,5
	-	-	HM12	188,44
GK	-	-	HM9	235,25
	-	-	HM10	209,88
KP	-	-	HM1	278,67
	-	-	HM2	222,36

Based on Table 3, in region SLM, they have 4 halal slaughterhouses (HS6, HS7, HS8, and HS9) and 3 halal markets (HM6, HM7, and HM8). The regions BNT and YGY also have halal slaughterhouses and halal markets. But in regions GK and KP they do not have any halal slaughterhouse but there are halal markets. Since the distribution is based on region, so since regions GK and KP do not have any halal slaughterhouse, so the demand of halal meat at the halal market in regions GK and KP can not be fulfilled at all. While the rest regions can. The existing distribution are shown in Table 4. The existing distribution results in high shortage cost in region GK and KP. The costs result from the existing distribution are presented in Table I in the Appendix.

Table 4. The existing halal meat distribution route of Province Y.

Region	Distribution route
SLM	HS9→HM 8→HS9
	HS7→HM 7→HS 7
	HS6→HM6→HS 6
	HS 8→HM6→HS 8
BNT	HS1→HM5 →HM4→HS1
	HS3→HM 4→HS3
	HS 4→HM5 →HM 4
	HS2→HM4→HM3→HS2
	HS 5→HM3→HS 5
YGY	HS10→HM 12→HM 11→HS 10
KP	N/A
GK	N/A

Given the situation, it is necessary to optimize the distribution planning so that the shortage, overstock, and transportation costs can be minimized. In addition, as halal meat belongs to a perishable product, it is also important to minimize the deterioration factor of the product. Therefore, the problem can be solved by implementing the proposed model.

The data for parameter values, the matrix for distance between HS and HM and the matrix for distance between HM are presented in the Appendix (Table J-L). The problem is solved using the two stages of halal food distribution model for perishable food products and coded in CPLEX Solver with the same platform in the numerical experiments. The result and the solution proposed by the model are presented in Tables M-0 in the Appendix, while for the total logistics costs after implement the model in presented in Table 5.

Table 5. Total logistics costs after implement the model.

No	Cost	Rupiah (Rp)
1	Overstock cost	Rp6.107.500
2	Shortage cost	Rp0
3	Transportation cost	Rp110.163
4	Deterioration cost	Rp2.409.385
Total logistics Cost		Rp8.627.048

Based on the results, the proposed model can build distribution planning with much lower cost than the existing distribution. The existing total logistics cost is Rp 151,783,185, while the proposed total logistics cost is Rp 8,627,048. The proposed distribution planning can reduce many costs because in the proposed model the halal markets in a region can be supplied by halal slaughterhouses from other regions (cross-region) as long as the production quantities are enough. This strategy can reduce shortage and overstock. In addition, the proposed model can also determine the vehicle routing that eventually results in minimized transportation cost and deterioration factor of the halal meat simultaneously.

7. Discussion

Based on the results of the numerical experiment, there is a positive relationship between the transportation cost and the deterioration cost. Higher the transportation cost (meaning the travel distance is longer), so higher the deterioration cost since the deterioration rate is also a linear function and equally depends on travel time. This phenomenon is shown in Figure 3.

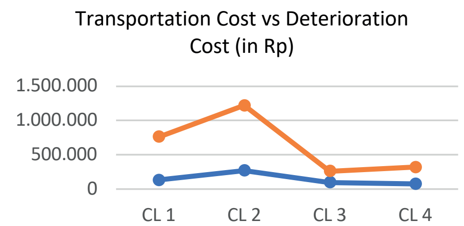

Figure 3. Transportation Cost (blue line) vs Deterioration Cost (orange line) for Small Data Set.

In addition, the deterioration cost is always higher than the transportation cost because in this study the deterioration cost is considered to have higher value than the transportation cost. The deterioration cost is directly related to the product itself and direct contact with customers. If the product is spoiled when it reaches the customer, it cannot be consumed, could be harmful, and causes customer dissatisfaction. Thus, the deterioration factor has a greater impact than the transportation cost and represents the supplier's guarantee of the product quality.

Of the four components in logistics cost, the shortage cost is the highest cost as it represents the loss of sales and customer dissatisfaction, which are detrimental not only for the customer but also the supplier. The second highest component is the overstock cost. When the product is not distributed elsewhere, it becomes food waste, and it must be avoided. The third highest component is the deterioration cost. The quality of food is represented in the deterioration cost. The higher the deterioration cost, the worse the quality of the product that the customer will receive. Higher deterioration cost represents higher spoilage probability of the product and vice versa. Therefore, spoilage must be eliminated to avoid high deterioration cost. The last component is the transportation cost which is the least of all costs since the supplier will bear the transport charges. In other words, the transportation cost risk is only exposed to the supplier.

Based on the results of the numerical experiment of the three data sets in Table 2, the run time for the first stage of the experiment increases exponentially from small to large data sets. It can be seen that in the first stage when the number of halal production house and the number of halal market increase, the run time increases exponentially. The two stages of halal food distribution model for perishable food products belong to the combinatorial problem, in which larger data set will require more time for computation. The higher the data set, the higher the run time will increase, which requires another approach, such as meta heuristics approach, to solve the problem in a fast and acceptable run time.

Based on the case study, if the result is compared with the two previous works of Kurniawati (2018) and Aisyah and Kurniawati (2019), the proposed model does not only propose the distribution strategy that considers the shortage, overstock, and transportation costs, but also the deterioration factor. Therefore, the proposed model is more suitable for perishable food products or products that spoil quickly because the total logistics cost in the proposed model also considers the distribution strategy that can minimize the deterioration factor of the product. In addition, compared with Kurniawati (2018), the proposed model includes the transportation cost that considers the vehicle routing, while Kurniawati (2018) only considered the distance between halal slaughterhouses to halal markets.

As the managerial implication of the proposed model, the model can help supply chain or logistics managers and decision makers in the company decide which halal market must be supplied, the amount of the supply, which route must be taken, and the number of vehicles that should be used to distribute the products. Thus, the overstock, shortage, transportation, and deterioration costs can be minimized and eventually this could improve sustainable supply chain.

8. Conclusion

The two stages of halal food distribution model for perishable food products is a MILP model proposed to solve halal food product distribution problem, especially for perishable food products. The proposed model can be used as a decision tool for logistics or supply chain managers, and anyone in charge to determine the strategy for distributing halal food products with the least total logistics cost. The model can minimize overstock, shortage, transportation and deterioration costs simultaneously. The implementation of the model may not only minimize the transportation and overstock costs the supplier has to pay, but also the shortage and deterioration costs the customer has to pay. In addition, the overstock cost and the deterioration cost can be an indicator for sustainability. Less overstock cost and deterioration cost mean that the distribution is more sustainable because the amount of food waste and spoiled food have been minimized.

The proposed model is developed into two stages. The first stage is about location and allocation model. This stage determines the halal cluster and the number of suppliers to minimize the overstock cost, the shortage cost and the distance between the halal production house and the halal market that belongs to its cluster. The second stage is about vehicle routing model, which determines the routing at each cluster to minimize the transportation cost and the deterioration cost. The results of the numerical experiment and the case study show that the proposed model can be used as the decision tool for supply chain and distribution managers to determine the strategy for distributing the halal food product with the least logistics cost for daily application. For future work, meta-heuristics approach could be proposed to solve the large problem. Since based on the numerical experiment result of the model, the running time for solving the problem increases exponentially for larger number of halal production houses and halal markets.

when technical systems offer unlimited possibilities. Therefore, the future goal of the authors is to take advantage of the new data in the field of ontology technology and create from scratch a new ontology of Supply Chain that will take into account the conclusions drawn from the present literature review and will aim at the integration of all Supply Chain systems.

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Appendix

Table A. Summary of indices, parameters, and decision variables of the model

Stage 1		
Indices	$i = 1,\dots,I$	A set of halal production houses i
	$j = 1,\dots, J$	A set of halal markets j
Parameter	P_i	production quantity of halal production house (kg)
	D_j	halal market demand for halal food (kg)
	TT_{ij}	travel time between halal production house i to halal market j (minute)
	α	the constant for shortage cost ($/kg)
	β	the constant for overstock cost ($/kg)
	γ	the constant for transportation cost ($/minute)
Decision variables	S_{ij}	the quantity of supply from halal production house i to halal market j (kg)
	O_i	the quantity of overstock at halal production house i (kg)
	R_j	the quantity of shortage at halal market j (kg)
	X_{ij}	the boolean variables, X_{ij} =1 if the halal production house i supply the halal market demand j, and 0 otherwise.
Stage 2		
Indices	$i = 0, 1,\dots,I+1$	A set of nodes i. The nodes for halal production house/depot are denoted as node 0 and node I+1.
	$k = 1\dots K$	A set of vehicles k
Parameter	TT_{ij}	Travel time from node i to node j (minute)
	S_i	Quantities of supplied from halal production house to halal market j (kg)
	Det	Deterioration rate of the product, dependent on time ($/minute)
	γ	the constant for transportation cost ($/minute)
	T	Time planning horizon (minute)
	Q	vehicle capacity (kg)
Decision variables	Z_{ijk}	binary variables. Z_{ijk} = 1 if there is a route from node i to node j using vehicle k, 0 otherwise
	V_{ik}	binary variables. V_{ik} = 1 if the supply of node i is distributed using vehicle k, and 0 otherwise
	AT_{ik}	time at which vehicle k completes the delivery at node i

Table B. Result for the first stage in small data set.

Cluster	Halal Market (Number of Supply, in kg)			Overstock cost	Shortage cost	Cost of distance between HP to HMs	Total Cost
Cluster 1 at PH 1	HM6 (248)	HM7 (184)		Rp675,000	Rp0	Rp285,600	Rp960,600
Cluster 2 at PH 2	HM3 (197)	HM5 (151)					
Cluster 3 at PH 3	HM3 (20)	HM4 (270)	HM7 (96)				
Cluster 4 at PH 4	HM1 (193)	HM2 (118)	HM8 (116)				

Note: PH is halal production house; HM is halal market.

Table C. Result for the second stage in small data set.

Cluster	# of Vehicle	Vehicle Routing	Deterioration Cost (Rp)	Transportation Cost (Rp)	Total Cost of 2nd Stage (Rp)
Cluster 1	2	PH 1→HM 7→PH 1 PH 1→HM 6→PH 1	762,500	132,000	894,500
Cluster 2	2	PH 2→HM 2→PH 2 PH 2→HM 1→ PH 2	1,222,700	269,400	1.492,100
Cluster 3	2	PH 3→HM 2→PH 3 PH 3→HM 1→HM 3→PH 3	259,370	95,400	354,770
Cluster 4	2	PH 4→HM 3→HM 2→PH 4 PH 4→HM 1→PH 4	318,560	75,600	394,160

Note: PH is halal production house; HM is halal market.

Table D. Total Logistics Cost for Small Data Set.

Overstock cost		Rp 675,000
Shortage cost		Rp 0
Deterioration Cost	Cluster 1	Rp 762,500
	Cluster 2	Rp 1,222,700
	Cluster 3	Rp 259,370
	Cluster 4	Rp 318,560
Transportation Cost	Cluster 1	Rp 132,000
	Cluster 2	Rp 269,400
	Cluster 3	Rp 95,400
	Cluster 4	Rp 75,600
Total Logistics Cost		Rp 3,810,530

Table E. Total Logistics Cost for Medium Data Set.

Overstock cost		Rp0		
Shortage cost		Rp0		
Deterioration Cost	Cluster 1	Rp471,690	Cluster 5	Rp80,906
	Cluster 2	Rp310,780	Cluster 6	Rp400,620
	Cluster 3	Rp534,810	Cluster 7	Rp157,870
	Cluster 4	Rp405,030	Cluster 8	Rp252,190
Transportation Cost	Cluster 1	Rp115,200	Cluster 5	Rp40,800
	Cluster 2	Rp99,000	Cluster 6	Rp61,200
	Cluster 3	Rp87,000	Cluster 7	Rp28,800
	Cluster 4	Rp115,800	Cluster 8	Rp69,000
Total Logistics Cost		Rp3,230,696		

Table F. Result for the first stage of large data set.

Cluster 1 at PH1	Halal Market	HM 4	HM 10	HM 14	HM 19	HM 20	HM 22	HM 27	HM 30	HM 32	HM 36	
	Number of supply (kg)	53	72	55	61	63	64	57	56	60	74	
Cluster 2 at PH2	Halal Market	HM 2	HM 9	HM 11	HM 13	HM 16	HM 17	HM 21	HM 25	HM 26	HM 28	HM 40
	Number of supply (kg)	52	57	56	54	57	73	60	41	55	50	55
Cluster 3 at PH3	Halal Market	HM 5	HM 6	HM 7	HM 8	HM 12	HM 24	HM 25	HM 29	HM 33	HM 34	HM 38
	Number of supply (kg)	76	61	59	52	56	58	31	77	59	62	54
Cluster 4 at PH4	Halal Market	HM 1	HM 3	HM 15	HM 18	HM 23	HM 31	HM 35	HM 37	HM 39		
	Number of supply (kg)	61	62	74	59	64	78	70	74	68		
Cost at 1st Stage (Rp)	Overstock cost			Shortage Cost			Cost of distance between HP to HM			Total Cost		
	0			2.400.000			1.118.400			3.518.400		

Note: PH is halal production house; HM is halal market.

Table G. Result for the second stage of large data set.

Cluster	# Of Vehicle	Vehicle Routing (Arrival Time, in minute)
Cluster 1 at PH1	2	PH 1 (0)→HM4 (16)→HM 2 (41)→HM 1 (93)→HM 10 (109)→HM 7 (149)→PH 1 (174)
		PH 1 (0)→HM 9 (18)→HM 6 (41)→HM 8 (67)→HM 3 (98)→HM 5 (178)→PH 1 (209)
Cluster 2 at PH2	2	PH 2 (0)→HM 6 (16)→HM 5 (37)→HM 2 (68)→HM 1 (113)→HM 10 (127)→HM 11 (158)→PH 2 (176)
		PH 2 (0)→HM 7 (18)→HM 4 (32)→HM 9 (45)→HM 3 (86)→HM 8 (168)→PH 2 (190)
Cluster 3 at PH3	2	PH 3 (0)→HM 4 (14)→HM 1 (55)→HM 6 (92)→HM 11 (117)→HM 8 (160)→PH 3 (197)
		PH 3 (0)→HM 5 (11)→HM 9 (35)→HM 10 (62)→HM 3 (77)→HM 7 (91)→HM 2 (113)→PH 3 (188)
Cluster 4 at PH4	2	PH 4 (0)→HM 8 (37)→HM 1 (49)→HM 2 (61)→HM 6 (138)→PH 4 (172)
		PH 4 (0)→HM 3 (46)→HM 9 (56)→HM 5 (66)→HM 7 (83)→HM 4 (176)→PH 4 (268)

Note: PH is halal production house; HM is halal market.

Table H. Total Logistics Cost for Large Data Set.

Overstock cost		Rp0
Shortage cost		Rp2.400.000
Deterioration Cost	Cluster 1	Rp1.546.100
	Cluster 2	Rp1.408.000
	Cluster 3	Rp1.552.000
	Cluster 4	Rp1.497.000
Transportation Cost	Cluster 1	Rp228.600
	Cluster 2	Rp219.600
	Cluster 3	Rp231.000
	Cluster 4	Rp263.400
Total Logistics Cost		Rp9.345.700

Table I. The existing condition of overstock, shortage and transportation costs (in Rp).

No	Region	Overstock		Shortage		Transportation cost (Rp)	Total logistics cost (Rp)
		Overstock (Kg)	Overstock cost (Rp)	Shortage (Kg)	Shortage cost (Rp)		
1	BN	501,52	21.928.962	0	0	10.047	21.939.009
2	KP	0	0	501,03	55.224.529	0	55.224.529
3	SLM	476,44	20.832.339	0	0	4.511	20.836.850
4	YGY	107,88	4.717.053	0	0	2.625	4.719.678
5	GK	0	0	445,13	49.063.119	0	49.063.119
Total		1085,84	47.478.354	946,16	104.287.648	17.183	151.783.185

Table J. Parameter for the case study.

Alpha	110,222	Rp/kg
Beta	43,725	Rp/kg
Gamma	600	Rp/minute
Deterioration rate cost	31,25	Rp/min

Table K. The matrix for distance between HS and HM (in minute).

	HS1	HS2	HS3	HS4	HS5	HS6	HS7	HS8	HS9	HS10
HM1	46,5	45	49,5	51	48	49,5	46,5	43,5	45	37,5
HM2	66	72	73,5	75	70,5	81	78	75	78	67,5
HM3	12,6	2,85	11,55	13,05	10,8	60	57	36	36	16,5
HM4	2,25	8,25	4,65	4,2	3,45	54	51	25,5	30	9,3
HM5	13,05	11,85	15	14,85	14,1	49,5	45	33	36	18
HM6	25,5	24	0,75	21	25,5	30	6,15	55,5	9,6	18
HM7	48	45	19,5	48	48	42	12,6	63	19,5	33
HM8	46,5	42	19,5	43,5	45	40,5	16,5	72	30	28,5
HM9	81	49,5	57	48	46,5	36	66	55,5	52,5	51
HM10	79,5	82,5	96	81	79,5	75	105	94,5	93	91,5
HM11	10,65	7,35	22,5	7,95	10,65	36	31,5	22,5	25,5	1,125
HM12	10,65	8,1	14,85	9,15	11,25	37,5	34,5	19,5	22,5	5,55

Table L. The matrix for distance between HM (in minute).

	HM1	HM2	HM3	HM4	HM5	HM6	HM7	HM8	HM9	HM10	HM11	HM12
HM1	0	33	45	45	39	48	58,5	43,5	87	127,5	39	43,5
HM2	33	0	61,5	70,5	60	75	87	70,5	115,5	142,5	66	70,5
HM3	45	61,5	0	11,55	14,55	34,5	57	49,5	55,5	81	34,5	18
HM4	45	70,5	11,55	0	11,55	67,5	42	42	49,5	82,5	7,5	25,5
HM5	39	60	14,55	11,55	0	67,5	52,5	36	57	96	8,7	13,05
HM6	48	75	34,5	67,5	67,5	0	19,5	18	58,5	97,5	22,5	19,5
HM7	58,5	87	57	42	52,5	19,5	0	37,5	69	108	39	36
HM8	43,5	70,5	49,5	42	36	18	37,5	0	76,5	117	36	37,5
HM9	87	115,5	55,5	49,5	57	58,5	69	76,5	0	52,5	49,5	46,5
HM10	127,5	142,5	81	82,5	96	97,5	108	117	52,5	0	90	85,5
HM11	39	66	34,5	7,5	8,7	22,5	39	36	49,5	90	0	4,65
HM12	43,5	70,5	18	25,5	13,05	19,5	36	37,5	46,5	85,5	4,65	0

Table M. Result for the first stage of the case study.

Cluster	Halal Market (Number of Supply, in kg)		Overstock cost (Rp)	Shortage cost (Rp)	Cost of distance between HP to HMs (Rp)	Total Cost (Rp)
Cluster 1 at HS 1	HM4 (70.87)	HM5 (236.38)	6.107.500	0	54.488	6.161.988
Cluster 2 at HS 2	HM3 (182.91)	HM5 (124.34)				
Cluster 3 at HS 3	HM6 (103.83)	HM8 (196.31)				
Cluster 4 at HS 4	HM4 (112.98)	HM12 (188.44)				
Cluster 5 at HS 5	HM4 (307.25)					
Cluster 6 at HS 6	HM10 (209.88)					
Cluster 7 at HS 7	HM6 (117.95)	HM7 (140.91)				
Cluster 8 at HS 8	HM2 (222.36)					
Cluster 9 at HS 9	HM9 (235.25)					
Cluster 10 at HS 10	HM1 (278.67)	HM11 (218.5)				

Table N. Result for the second stage of the case study.

Cluster	# of Vehicle	Vehicle Routing	Costs	
Cluster 1	1	HS 1→HM 4→HM 5→HS 1	Deterioration Cost	Rp106.920
			Transportation Cost	Rp4.475
			Total Cost for Second Stage	Rp111.395
Cluster 2	1	HS 2→HM 3→HM 5→HS 2	Deterioration Cost	Rp83.900
			Transportation Cost	Rp4.875
			Total Cost for Second Stage	Rp88.775
Cluster 3	1	HS 3→HM 6→HM 8→HS 3	Deterioration Cost	Rp117.460
			Transportation Cost	Rp6.375
			Total Cost for Second Stage	Rp123.835
Cluster 4	1	HS 4→HM 12→HM 4→HS 4	Deterioration Cost	Rp176.220
			Transportation Cost	Rp6.475
			Total Cost for Second Stage	Rp182.695
Cluster 5	1	HS 5→HM 4→HS 5	Deterioration Cost	Rp33.125
			Transportation Cost	Rp1.150
			Total Cost for Second Stage	Rp34.275
Cluster 6	1	HS 6→HM 10→HS 6	Deterioration Cost	Rp491.910
			Transportation Cost	Rp25.000
			Total Cost for Second Stage	Rp516.910
Cluster 7	1	HS 7→HM 6→HM 7→HS 7	Deterioration Cost	Rp135.620
			Transportation Cost	Rp6.375
			Total Cost for Second Stage	Rp141.995
Cluster 8	1	HS 8→HM 2→HS 8	Deterioration Cost	Rp521.160
			Transportation Cost	Rp25.000
			Total Cost for Second Stage	Rp546.160
Cluster 9	1	HS 9→HM 9→HS 9	Deterioration Cost	Rp385.960
			Transportation Cost	Rp17.500
			Total Cost for Second Stage	Rp403.460
Cluster 10	1	HS 10→HM 11→HM 1→HS 10	Deterioration Cost	Rp357.110
			Transportation Cost	Rp12.938
			Total Cost for Second Stage	Rp370.048

Table O. Distribution route of halal meat before and after implement the model.

Before		After	
Region	Distribution route	Cluster	Distribution Route
	HS1→HM5→HM4→HS1	Cluster 1	PH 1→HM 4→HM 5→PH 1
	HS2→HM4→HM3→HS2	Cluster 2	PH 2→HM 3→HM 5→PH 2
BNT	HS 4→HM5→HM 4	Cluster 3	PH 3→HM 6→HM 8→PH 3
	HS3→HM 4→HS3	Cluster 4	PH 4→HM 12→HM 4→PH 4
	HS 5→HM3→HS 5	Cluster 5	PH 5→ HM 4→PH 5
	HS9→HM 8→ HS9	Cluster 6	PH 6→HM 10→PH 6
SLM	HS7→HM 7→HS 7	Cluster 7	PH 7→HM 6→HM 7→PH 7
	HS6→HM6→HS 6	Cluster 8	PH 8→HM 2→PH 8
	HS 8→HM6→HS 8	Cluster 9	PH 9→HM 9→PH 9
YGY	HS10→HM 12→HM 11→HS 10	Cluster 10	PH 10→HM 11→HM 1→PH 10
KP	N/A		
GK	N/A		

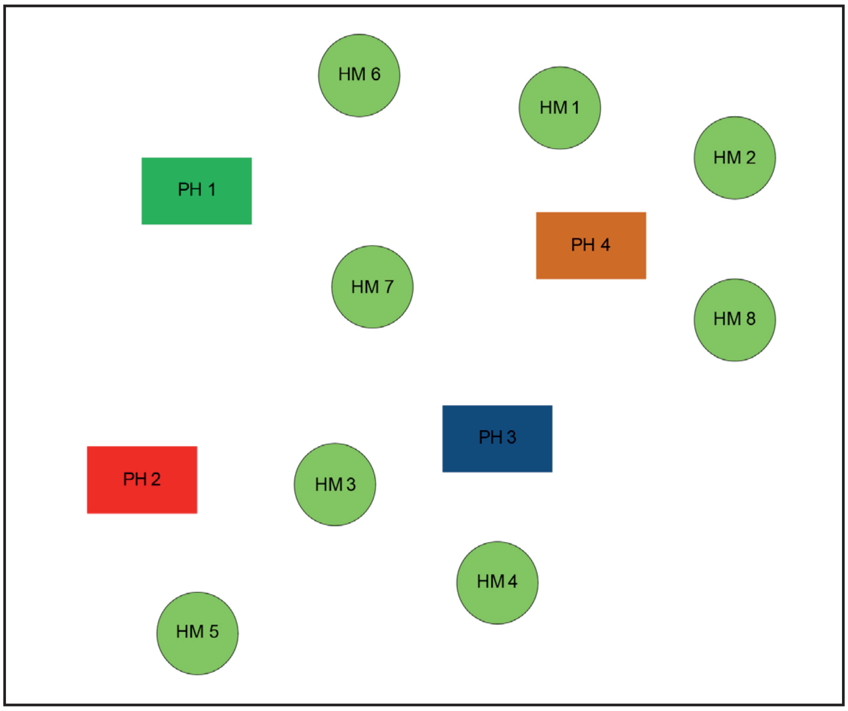

Figure A. System Under Study for Small Data Set.

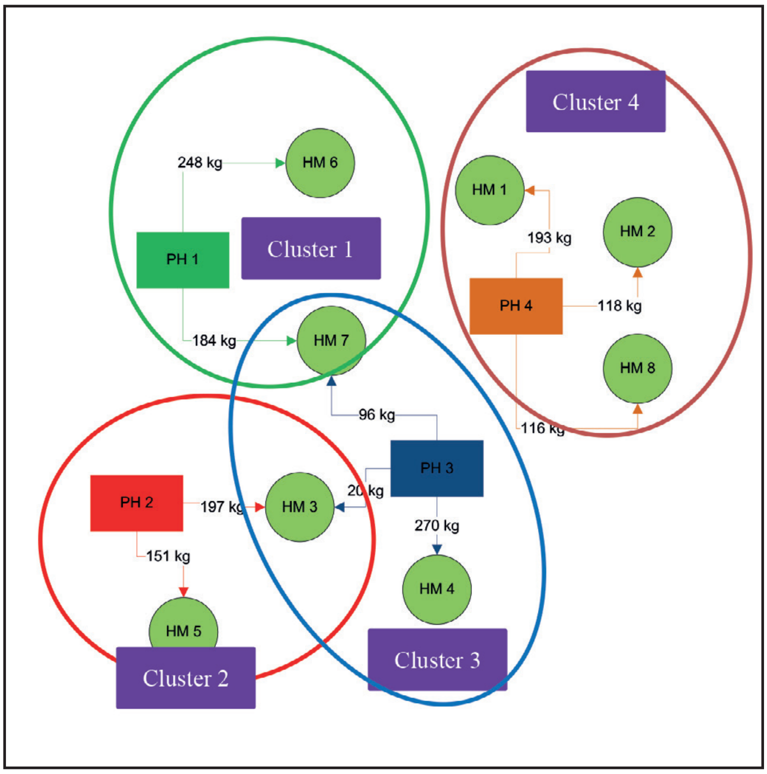

Figure B. The first stage of small data sets.

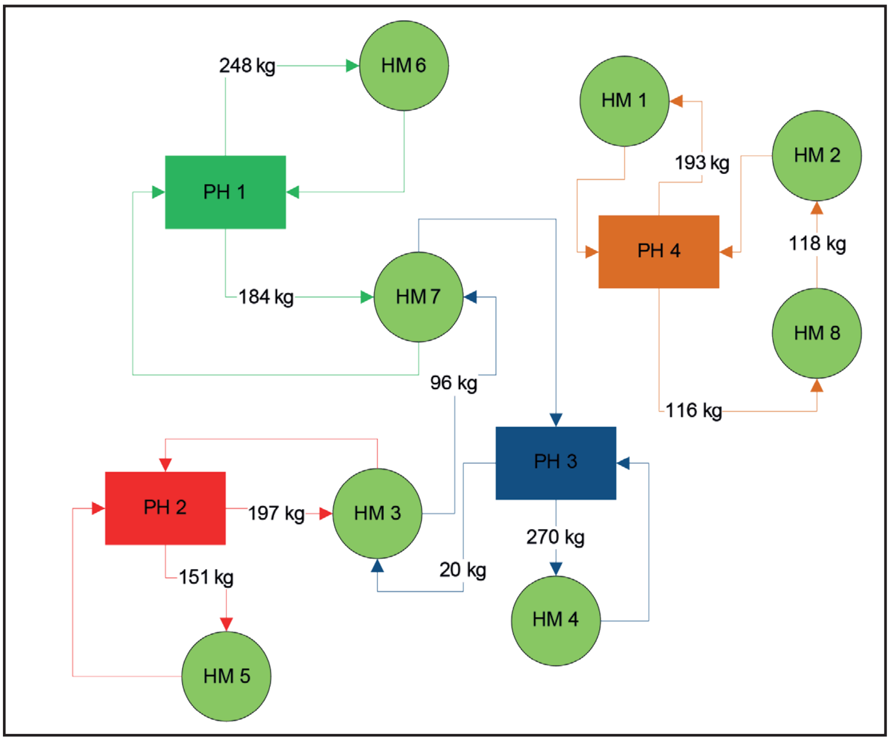

Figure C. The second stage of small data set (the solution proposed).