Balance Halal Food Supply Chain: A mathematical Model Appoach for Halal Food Supply Chain Sustainability

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ABSTRAK

Ketika permintaan makanan halal meningkat dan pasokan makanan halal terbatas, diperlukan strategi untuk mengoptimalkan rantai pasokan makanan halal. Optimalisasi rantai pasokan makanan halal dapat mendukung keberlanjutannya. Oleh karena itu, diperlukan studi tentang optimalisasi rantai pasokan makanan halal. Makalah ini mencoba mengembangkan model matematika, yang disebut model Balance Halal Supply Chain (BHSC). Model ini mengusulkan strategi distribusi untuk rantai pasokan makanan halal dari rumah jagal halal terbatas ke beberapa pasar halal sehingga total biaya distribusi menjadi minimal. Diasumsikan bahwa semua tuntutan pasar halal harus dipenuhi, sehingga kekurangan biaya menjadi nol. Model ini mencoba memenuhi semua permintaan pasar halal dan meminimalkan kelebihan pasokan dan biaya transportasi. BHSC dimodelkan sebagai MILP. Eksperimen numerik dilakukan untuk memvalidasi model dan diselesaikan oleh CPLEX Solver Versi 12.6.3. Berdasarkan hasil percobaan, ditunjukkan bahwa model dapat digunakan oleh pengambil keputusan rantai pasokan halal sebagai alat pengambilan keputusan untuk merancang strategi terbaik untuk mendistribusikan jumlah daging halal terbatas ke banyak pasar halal untuk keberlanjutan rantai pasokannya. Model BHSC dapat meminimalkan total biaya distribusi yang terdiri dari kelebihan pasokan dan biaya transportasi, dalam hal semua permintaan pasar halal harus dipenuhi. Kesimpulannya, model yang diusulkan menjadi metode alternatif untuk mendukung keberlanjutan rantai pasokan makanan halal.

Kata Kunci: Rantai pasokan, Keberlanjutan, Makanan halal, Keseimbangan, Distribusi, MILP.

ABSTRACT

As the demand for halal food becomes raising and the supply of halal food is limited, it is required a strategy to optimize the halal food supply chain. The optimization of halal food supply chain can support its sustainability. Therefore, study about halal food supply chain optimization is required. This paper try to develop a mathematical model, entitled as Balance Halal Supply Chain (BHSC) model. This model propose a distribution strategy for halal food supply chain from limited halal slaughterhouses to several halal markets so as the total cost of distribution becomes minimize. It is assumed that all halal market demands must be fulfilled, so the lack ness cost becomes zero. The model try to fulfill all the halal market demands and minimize the oversupply and transportation costs. BHSC is modeled as MILP. Numerical experiment is performed to validate the model and it is solved by CPLEX Solver Version 12.6.3. Based on the experiment result, it is shown that the model can be used by halal supply chain decision maker as the decision making tool to design the best strategy for distributing the limited number of halal meat to many halal markets for its supply chain sustainability. The BHSC model can minimize the total cost of distribution that consists of oversupply and transportation costs, in the case of all halal market demands must be fulfilled. In conclusion, the proposed model becomes an alternative method to support the halal food supply chain sustainability.

Keywords: Supply chain, Sustainability, Halal food, Balance, Distribution, MILP

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Introduction

As the Quran has stresses heavily on the consumption of halal foods through numerous verses, Muslim people are strict to consume only halal food. One of them is translated as "O mankind, eat from whatever is on earth (that is) lawful and pure" (Al-Quran 2: 168). Halal food must be free of any components that Muslims are prohibited from consuming (haram). All foods are halal except those that are specifically mentioned as haram. Haram foods include any products derived from or contaminated with these prohibited materials, such as, carrion, blood, pig, permitted animals slaughtered incorrectly, and intoxicants.

Apart from above description, nowadays, the demand for halal food is not just coming from Muslim people. Now, the demand for halal food also comes from non-Muslim people, since halal food is not just a symbol for Islamic terms, but it also represents food with more hygienic, higher quality, healthier, and clean (Mohamad and Backhouse, 2014). So now there is an increasing trend for halal food demand and halal food market.

In 2010, Pew Forum census found that number of Muslim in Indonesia were 204,847,000 people. In addition, Pew Forum predicted that in 2030 the number of Muslim population in Indonesia will be 238,833,000 people (www.pewforum.org). With this figure, Indonesia is in the first rank as the country with the biggest Muslim people (Riaz dan Chaudry, 2004). As reported by Pew Forum also, in 2010, Muslim population were 1.6 billion people, or 23% from people around the world. (www.pewforum.org).

Based on the figure above, it is shown that there are big number and growth of Muslim population, not just in Indonesia, but also the whole world. The figure shows that Muslim becomes big market, both in Indonesia and the whole world. The big number of Muslim, both in Indonesia and the world, has created a big potential for halal market consumer not just for food and beverages, but also for cosmetics, drugs, fashion, tourism, banking, etc.

Considering the big potential of halal food demand, as represented by the big number of Muslim population (even though the consumer of halal food is not limited just for Muslim; but non-Muslim also can demand it), so it is important to maintain and ensure the sustainability of halal food supply chain. If the sustainability of halal food supply chain cannot be maintained, it can harm not just the customer itself but also the whole members of the halal food supply chain, such as producer, distributor, etc.

There are previous research studied the halal food supply chain. Mohamad and Backhouse (2014)

proposed a framework for development of halal food products in Malaysia. Ngah et al. (2014) performed an exploratory study about adoption of halal supply chain among Malaysian halal manufacturers. Zulfakar et al. (2014) proposed a conceptual framework on halal food supply chain integrity enhancement. Henderson (2016) studied and compared about halal food certification and halal tourism in Malaysia and Singapore. Ismail et al. (2016) studied about the hidden gap between halal logo and brand in Malaysia. Soon et al. (2017) studied about halal integrity in the food supply chain.

On the other hand, there is a lack of research done in the area of mathematical model development that help to determine the successful operation of halal food supply chain, especially the halal supply chain mathematical model that support the sustainability of halal supply chain. To the best of author's knowledge, there is only one paper that propose mathematical model for halal supply chain. Mohammed et al. (2015) proposed a multi-objective mathematical model to design a three-echelon Halal meat supply chain (HMSC) network. The model maximize the integrity of halal meats, return of capital investment and minimizing costs in implementation of the system. Therefore, there is no halal supply chain model that propose to minimize the unbalance of halal supply chain (the lack and over of supply) for supporting the sustainability of halal supply chain. This paper tries to propose a mathematical model for halal food supply chain to support the sustainability of halal food supply chain, entitled as Balance Halal Supply Chain (BHSC) Model.

The balance halal supply chain is important since it can support the sustainability of halal supply chain. If there is a lack ness or over of halal food supply, it can threat the sustainability of halal food supply chain. The lack ness of halal food supply chain can happen if the number of supply is less than the number of demand, while over supply can happen when the number of supply is more than the number of demand. These conditions, lack ness and over supply both will threat the sustainability of halal food supply chain.

The lack ness of supply can harm the customer, make the customer dissatisfaction, and loss of sale. On the other hand, the oversupply can make the supply becomes waste then makes the cost becomes higher because of the un-useful supply). Therefore, the lack ness and over supply must be minimized to have a sustainable halal food supply chain. One way to minimize the lack ness and over supply is through proposing BHSC model. This paper propose a mathematical model, entitled as Balance Halal Supply Chain (BHSC) model. The

BHSC model determines the best allocation and distribution from halal food production to halal market of customer, so that any lack of supply or oversupply can be minimized, while each halal market can be fulfilled for its halal food demand.

In this paper, the proposed model focus on halal meat as the kind of halal food (even though the model can be replaced by other halal food, such as bakery, milk, fish, etc.). The paper consider the halal meat since meat is the most sensitive product than other halal food. Halal meat must be slaughtered in a proper and halal way, such as before slaughtering must say 'Bismillah' (the meaning is "In the name of God"). Otherwise, the meat become non-halal meat. So halal meat must be produced by halal certified slaughterhouse. The BHSC model is proposed to minimize any unbalance supply (any lack and over of supply) of halal meat from the halal slaughterhouse to the halal market. Therefore the proposed model can optimize the distribution of halal meat to the halal market.

Nowadays many scholars study about halal related issue. Now, halal related issue becomes a new research area. This research area becomes a broader area since many scholars study from many point of view. Some scholars study about halal certification issue. For example Ismail et al. (2016) study about the hidden gap between the halal logo and brand in Malaysia. Henderson (2016) studies about halal certification and halal tourism in Malaysia and Singapore. Noordin et al. (2014) propose a strategic approach for Halal certification system, by considering the ecosystem perspective. Ab Talib et al. (2016) propose an institutional theory to implement Halal food certification. They mention that highly institutionalized Halal industry comprising government regulations, Muslim demands for Halal foods and intense industry competition instigate Halal food certificate implementation.

Another scholars study about the halal awareness. Krishnan et al. (2017) study about halal awareness toward halal food industry in Malaysia. Ambali and Bakar (2014) also study about people's awareness on halal foods and products and found that the religious belief, exposure, certification logo, and health reason are potential sources of Muslim awareness about halal consumption. However, health reason is the most contributing predictor of level of halal awareness.

Another scholar, Mohamad and Backhouse (2014) propose a framework for the development of halal food products in Malaysia. Ngah et al. (2014) do an exploratory study about adoption of halal supply chain among Malaysian Halal Manufacturers. Nakyinsige et al. (2012) state that the production of halal meat consists of many critical control points from farm to table in order to ensure that the meat is produced in the acceptable manner and there is no cross contamination with non-halal materials at all unit operations. Halal certifying authorities need robust analytical techniques in areas where fraud is most likely to occur. Their paper highlight the requirements of the halal food chain and overview of the methods used to authenticate the halal meat products. Ali and Suleiman (2016) explore and evaluate the relationships between standard food production practices and the principles of sustainable production. One of their research objective is to clarify whether halal food production is capturing aspects of sustainable development.

The current topic of halal related issue is halal integrity. Soon et al. (2017) study about halal integrity in the food supply chain. Zulfakar et al. (2012) propose a conceptual framework for halal food supply chain integrity based on the literature review have been done. Zulfakar et al. (2014) study about the conceptual framework on halal food supply chain integrity enhancement. Bahrudin et al. (2011) study about tracking and tracing technology for halal product integrity over the supply chain.

Apart of the halal food issue, there are many scholars have studied about the sustainability of food supply chain. Govindan (2017) studies about sustainable consumption and production in the food supply chain and proposes a conceptual framework for it. Sgarbossa and Russo (2017) proposes a proactive model in sustainable food supply chain based on the case study they done. Grimm et al. (2014) investigate the critical factors for sub-supplier management based on the sustainable food supply chains perspective. Validi et al. (2014) analyze the sustainable food supply chain distribution system using multi-objective approach. A robust solution approach is proposed for the design of a capacitated distribution network for a two-layer supply chain of milk distribution. In addition, Validi et al. (2014) propose a green multi-objective optimization model which minimizes CO_2 emissions from transportation and total costs in the distribution chain. Govindan et al. (2014) study about two-echelon multiple-vehicle location–routing problem. The problem considers the time windows for optimization of sustainable supply chain network for perishable food. Agustina et al. (2014) propose mathematical model for food supply chain using cross dock warehouse. The problem is modeled as MILP to solve the vehicle routing and scheduling for the perishable food supply chain. The proposed model try to minimize the earliness, tardiness, inventory and transportation costs. Ting et al. (2014) study about mining logistics data to assure the quality in a sustainable food supply chain and take a case in the red wine industry. Zanoni and

Zavanella (2012) propose a decision strategies for sustainable food supply chains, between chilled or frozen.

On the other hand, based on the author's knowledge, there is a lack of study related with mathematical model development to improve the halal supply chain operation. Based on the literature review that have been done, there is only one paper that propose mathematical model for halal supply chain. Mohammed et al. (2015) proposed a multi-objective mathematical model to design a three-echelon Halal meat supply chain (HMSC) network. The model maximize the integrity of halal meats, return of capital investment and minimizing costs in implementation of the system. The system is monitored by an integrated RFID-based management system. Therefore, it is still required more studies about mathematical model development to optimize the halal food supply chain sustainability.

Balance Halal Supply Chain Model

The proposing of BHSC model is motivated by the fact that there is still any lack ness and oversupply for the halal product (meat) to the Muslim consumers, especially in a country with Muslim majority. So this model is proposed to help the halal food supply chain decision maker to determine and estimate the right number of halal food supplies to the Muslim consumers (region). Otherwise, many Muslim consumers will lack of the halal food product, since they can't consume non-halal food product. Therefore, BHSC model is proposed to ensure the sustainability of halal meat distribution from the halal certified slaughterhouse to the halal meat market, so that any lack ness or over supply to any halal market can be minimized.
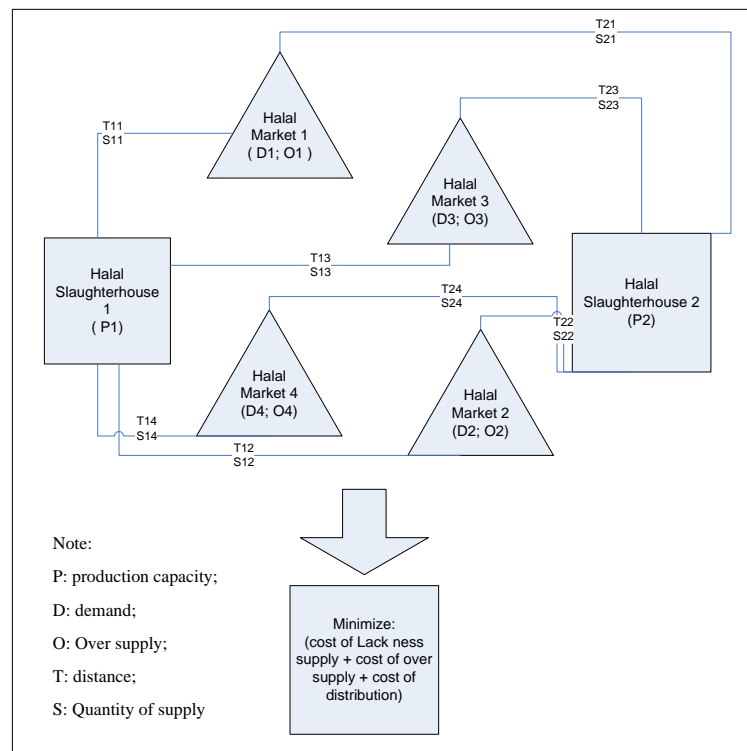
Mathematical Model Development

In BHSC model, the problem is how to distribute and allocate the halal meat from limited halal certified slaughterhouses to many customers (halal market) that demand for halal meat. If the distribution of halal meat is done only in arbitrarily without any good planning, so the distribution of halal meat can results in unbalanced supply of halal meat, and affect the unsustainability of halal meat distribution from halal slaughterhouses to the consumers (markets).

If it happens every day, it will affect the customer satisfaction, since Muslim consumers cannot consume non-halal meat. So the unbalanced halal food supply chain can make the customer dissatisfaction and loss of sales. Moreover it can make the unsustainable halal food supply chain.

In this paper, the BHSC model is proposed in its basic form. There are some assumptions applied in the model. These assumptions are used to formulate the model. In this model, the system has limited numbers of halal certified slaughterhouses and many halal markets. Every slaughterhouse has its own production capacity. The capacity represents the number of animals (i.e. cow, sheep, or chicken) that are slaughtered every day. Every halal market has its own demand per day for the halal meat. The proposed model is not a routing problem, but it is an allocation and distribution problem. So the transportation cost is calculated as the cost between the slaughterhouse to the halal market multiplied by the quantity of delivery.

The objective of BHSC model is to minimize the lack ness, the over supply and the transportation costs. In this paper, the BHSC model uses lack ness hard constraint which means that in BHSC model it is not allowed to occur any lack ness of supply. By implementing lack ness hard constraint, the number of lack ness becomes zero.

In addition, in BHSC model, the transportation cost is a function of variable cost, which means that it depends on the distance and total number of supplied or delivered ($/km.kg). By minimizing the cost of lack ness, over supply and transportation cost, the proposed model can support the sustainability of halal food (meat) supply chain and distribution between halal slaughterhouses to the halal markets in the halal food supply chain. The proposed model is represented in Figure 1.

Gambar 1. Balance Halal Food Supply Chain System

Mathematical Model Formulation

Based on the description above, BHSC model is developed based on some assumptions. The assumptions used in BHSC model are:

1) The model is a deterministic model.
2) Halal market can be supplied by more than 1 halal slaughterhouse (halal food producer).
3) Every halal slaughterhouse (halal food producer) can deliver (supply) more than 1 halal market as long as it is not exceed its production capacity.
4) The transportation cost only considers the travel distance between the halal slaughterhouse i to the halal market j. So this model does not take into consideration about routing and Vehicle Routing Problem (VRP) model.
5) This model does not take into consideration about truck capacity.
6) The BHSC model only considers the allocation problem.
7) The transportation cost is a function of variable cost, means that the cost is a function of distance between Halal slaughterhouse to halal market and the quantity of delivery from the halal slaughterhouse to the halal market.

8) The basic BHSC use hard constraint of lack ness. It means that it is assumed that there is no lack ness. In this model it is not allowed any lack ness, so the number of lack ness and the lack ness cost must be zero.

Based on the assumptions above, since the model already used lack ness hard constraint (which means that the lack ness cost becomes zero), so the objective of BHSC model is to minimize the cost of oversupply and the transportation cost of halal meat. The model try to fulfill all halal food demand with the most economical way. For example, halal market A is near to slaughterhouse 1 and slaughterhouse 2. Through the BHSC model, it will be determined the best strategy to supply the halal meat demand in minimize cost (cost of oversupply and cost of transportation). The solution can be fulfilling the demand of halal market A by delivering from slaughterhouse 1, or slaughterhouse 2, or both slaughterhouses. The decision is based on the strategy that results in the most economical way (the minimize cost of over supply and transportation cost).

The BHSC model is developed using some notations, variables and parameters. The notation used in BHSC model are as follows:

- A set of halal certified slaughterhouse, indexed by i, $i = 1,…I$.

- A set of halal meat market, indexed by j, $j = 1,...,J$.

Parameters used in BHSC model are:

- P_i : Halal slaughterhouse's production capacity, indexed by P_i (kg).
- D_j : Halal market's demand for halal food, indexed by d_j (kg).
- T_{ij} : Travel distance between Slaughterhouse i to Halal market j (km).
- β : the constant for oversupply cost of halal meat ($/kg).
- γ : the constant for transportation cost of halal meat ($/kg.km).

The decision variables in BHSC model are:

- S_{ij} : the quantity of supply from Slaughterhouse i to halal market j (kg).
- O_j : the quantity of oversupply at halal market j (kg).

Based on the assumptions, parameters, and the decision variables of the model, the problem is formulated as a mixed-integer linear program (MILP). Since the BHSC model uses lack ness hard constraint, so the cost of lack ness becomes zero. The objective function of BHSC model now only consists of two components, these are cost of oversupply and cost of transportation.

1. Cost of oversupply. The cost of over supply is the sum of oversupply in each halal market multiplied by the constant for oversupply of halal meat. This formulation is notated as:

$$\beta(\sum_{j=1}^{J} O_j)$$

2. Cost of transportation from slaughterhouse i to halal market j. The cost of transportation is the summation of supplied quantity multiplied by travel distance of Slaughterhouse i to Halal market j, then the summation is multiplied by the constant for travel distance. The formulation is notated as:

$$\gamma(\sum_{j=1}^{J}\sum_{i=1}^{I} S_{ij}.T_{ij})$$

So the objective function of BHSC model, which consists of cost of oversupply and cost of transportation, can be written as below.

$$Minimize: \beta(\sum_{j=1}^{J} O_j) + \gamma(\sum_{j=1}^{J}\sum_{i=1}^{I} X_{ij}.D_{ij}) \quad (1)$$

The constraints of BHSC model are as follows:

1. The total quantities of halal food supplied to the halal markets cannot be more than the halal slaughterhouse's production capacity.

$$\sum_{j=1}^{J} S_{ij} \leq P_i \; ; \; i = 1,...,I \quad (2)$$

2. The total quantities of halal food supplied to each halal market must fulfill the halal market's demand (as the consequence of applying zero lackness hard constraint).

$$\sum_{i=1}^{I} S_{ij} \geq D_j \; ; \; j = 1,...,J \quad (3)$$

3. Oversupply of each halal market is deviation between the total quantities of halal food supplied to the halal market minus its demand.

$$O_j = \sum_{i=1}^{I} S_{ij} - D_j \; ; \; j = 1,...,J \quad (4)$$

4. Non negativity constraints for O_j

$$O_j \geq 0 \; ; \; j = 1,...,J \quad (5)$$

5. Non negativity constraints for S_{ij}

$$S_{ij} \geq 0 \; ; \; i = 1,...,I; j = 1,...,J \quad (6)$$

The whole mathematical model formulation of BHSC is presented below:

$$Minimize: \beta(\sum_{j=1}^{J} O_j) + \gamma(\sum_{j=1}^{J}\sum_{i=1}^{I} X_{ij}.D_{ij})$$

Subject to:

$$\sum_{j=1}^{J} S_{ij} \leq P_i \; ; \; i = 1,...,I$$

$$\sum_{i=1}^{I} S_{ij} \geq D_j \; ; \; j = 1,...,J$$

$$O_j = \sum_{i=1}^{I} S_{ij} - D_j \; ; \; j = 1,...,J$$

$$O_j \geq 0 \; ; \; j = 1,...,J$$

$$S_{ij} \geq 0 \; ; \; i = 1, ..., I; \; j = 1, ..., J$$

Based on the BHSC that modeled as MILP, the proposed model would minimize the oversupply cost and the transportation cost, since the default of lack ness cost is already zero. The BHSC model also consists of three constraints as the explanation for the constraints already given above.

Numerical Example Experiments

In order to validate the BHSC model, it is performed numerical experiment. The data for numerical experiment is drawn from the artificial data. For example, city X consists of region A, B and C. Then at each region, there are several halal slaughterhouses and halal markets. Halal market represents the Muslim demand of halal meat. So the data for the halal slaughterhouses and halal markets are shown in the Table 1.

Based on Table 1, it is shown that at city X, in region A, the halal slaughterhouses HS1, HS2, and HS3 produce 120 kg, 80 kg, and 210 kg halal meats respectively. While the halal market in region A, these are Halal market HM1, HM2, and HM3 demand for 70 kg, 90 kg, and 140 kg, and 115 kg halal meats, respectively. The rest regions (region B and C) follow the same illustration with illustration of region A.

Table 1. Data for Halal Meat Production and Demand of City X

Region	Production capacity (kg)	
Region A	Production capacity (kg)	
	Halal Slaughterhouse HS1	120
	Halal Slaughterhouse HS2	80
	Halal Slaughterhouse HS3	210
	Demand (kg)	
	Halal Market HM1	70
	Halal Market HM2	90
	Halal Market HM3	140
	Halal Market HM4	115

Region	Production capacity (kg)	
Region B	Production capacity (kg)	
	Halal Slaughterhouse HS4	210
	Halal Slaughterhouse HS5	190
	Demand (kg)	
	Halal Market HM 5	130
	Halal Market HM 6	150
	Halal Market HM 7	180
Region C	Production capacity (kg)	
	Halal Slaughterhouse HS6	90
	Halal Slaughterhouse HS7	120
	Halal Slaughterhouse HS8	70
	Demand (kg)	
	Halal Market HM 8	80
	Halal Market HM 9	70
	Halal Market HM 10	90

Since this model use hard constraint of lackness (Lackness of supply is not allowed), means that the demand of halal meat from all halal market of city X must be fulfilled, and in the case of production of halal slaughterhouse from city X has not yet fulfilled all the demand of city X, so the unfulfilled demand of city X must be fulfilled by another city (better if the nearest city from city X). So to avoid any lackness of supply, it is required additional data, this is the production of nearest halal slaughterhouse of city X. For example, the nearest halal slaughterhouse from city X is halal slaughterhouse of city Y. The data of halal meat production of halal slaughterhouse in city Y is shown in Table 2. In addition, the data of travel distance between Slaughterhouse i to Halal Market j is shown in Table 3.

Table 2. Data for Halal meat production of city Y

City	Production capacity (kg)	
City Y	Production capacity (kg)	
	Halal Slaughterhouse HS9	210
	Halal Slaughterhouse HS10	170

Table 3. Travel distance between Slaughterhouse i to Halal market j (km)

	HM1	HM2	HM3	HM4	HM5	HM6	HM7	HM8	HM9	HM10
HS1	2	6	9	10	15	18	19	21	24	26
HS2	7	8	4	3	18	19	17	22	26	28
HS3	10	12	9	11	16	14	18	24	23	27
HS4	12	13	15	17	3	5	8	21	24	26
HS5	14	15	11	12	7	8	2	24	26	22
HS6	24	26	21	22	13	15	17	6	9	10

HS7	23	21	27	21	15	18	19	5	8	9
HS8	22	24	27	29	11	13	12	4	6	7
HS9	41	44	48	51	61	63	67	71	72	74
HS10	50	53	56	67	73	75	77	81	83	85

Based on Table 3, it is shown that the travel distance between HS1 and HM1 is 2 km, while the distance between HS1 to HM10 is 26 km. The rest distances, follows the same illustration. For the constant of oversupply cost of halal meat (β) is specified as $15/kg and the constant of distribution cost of halal meat (γ) is specified as $2/kg.km. Based on the data above, the experiment is performed on an Intel® Core™ i7 M620 2.67 GHz computer. Then the BHSC model is coded and solved using CPLEX Solver Version 12.6.3. The result of experiment is presented in Table 4.

Table 4. Halal meat allocation from Halal Slaughterhouses to Halal Markets (*kg*)

Halal Slaughterhouse	Halal Market										Total
	HM1	HM2	HM3	HM4	HM5	HM6	HM7	HM8	HM9	HM10	
HS1	70	50	0	0	0	0	0	0	0	0	120
HS2	0	0	0	80	0	0	0	0	0	0	80
HS3	0	15	140	35	0	20	0	0	0	0	210
HS4	0	0	0	0	90	120	0	0	0	0	210
HS5	0	0	0	0	0	10	180	0	0	0	190
HS6	0	0	0	0	40	0	0	30	0	20	90
HS7	0	0	0	0	0	0	0	50	70	0	120
HS8	0	0	0	0	0	0	0	0	0	70	70
HS9	0	25	0	0	0	0	0	0	0	0	25
HS10	0	0	0	0	0	0	0	0	0	0	0
Total	70	90	140	115	130	150	180	80	70	90	

As the result of experiment, Table 4 shows the solution of the problem. Table 4 shows the distribution strategy proposed by BHSC model. Table 4 shows that all halal market demands are fulfilled as they requested. For example, the demand of HM1 is 70, and it is supplied by HS1 as much 70 kg meat. The demand of HM2 is 90 kg meat and it is supplied by HS1, HS3, and HS9 as much 50 kg, 15 kg, and 25 kg, respectively. The demand of HM3 is 140 kg, all is fulfilled by HS3 as much 140 kg. HM4's demand is fulfilled by HS2 and HS3 as much 80 kg and 35 kg. HM5's demand is fulfilled by HS4 and HS6 as much as 90 kg and 40 kg. The demand of HM6 is 150 kg meat and it is supplied by HS3, HS4, and HS5 as much 20 kg, 120 kg, and 10 kg respectively The demand of HM7 is 180 kg and it is supplied by HS5 as much 180 kg meat. The demand of HM8 is 80 kg and it is supplied by HS6 and HS7 as much 30 kg and 50 kg. The demand of HM9 is 70 kg and it is supplied by HS7 as much 70 kg. Lastly, the demand of HM10 is 90 kg and it is supplied by HS6 and HS8 as much 20 kg and 70 kg.

In addition, as shown in the table above, based on the experiment result, it is shown that the total quantities of halal meat supplied from each halal slaughterhouse to the halal markets are not exceed each halal slaughterhouse's production capacity. As shown in the table above, HS1 supplies HM1 and HM2 as much 70 kg and 50 kg. So the total meat supplied by HS1 is 120 kg and it is not exceed its production capacity. HS2 supplies HM4 as much 80 kg and it is still under HS2 capacity. HS3 supplies HM2, HM3, HM4, and HM6 as much 15 kg, 140 kg, 35 kg, and 20 kg respectively. HS4 supplies HM5 and HM6 as much 90 kg and 120 kg. HS5 supplies HM6 and HM7 as much 10 kg and 180 kg. HS6 supplies HM5, HM8, and HM10 as much 40 kg, 30 kg, and 20 kg respectively. HS7 supplies HM8 and HM9 as much 50 kg and 70 kg. HS8 supplies HM10 supplies 70 kg meat. HS9 supplies HM2 as much 25 kg. Lastly HS10 does not supplies

anything since all halal market's demand already fulfilled by HS1 to HS9. Based on these results, these are shown that all meats supplied by each halal slaughterhouse do not exceed the halal slaughterhouse's capacity.

Table 5. The solution of BHSC model

Solution proposed by BHSC model	
Cost of over supply	$0
Cost of transportation	$14,790
Total cost of distribution	$14,790

Based on those results, the cost solution proposed by BHSC model is shown in table 5. The distribution strategy proposed by BHSC model results in over supply cost is $ 0 and transportation cost is $ 14,790. Therefore the total cost of halal meat distribution is $ 14, 790.

Conclusion and Future Work

As the demand for halal food becomes raising and the supply of halal food is limited, it is required a strategy to optimize the halal food supply chain. The optimization of halal food supply chain can support the sustainability of halal food supply chain itself. Therefore study about halal food supply chain optimization is required to drive the sustainability of halal food supply chain.

This paper try to develop a mathematical model, entitled as Balance Halal Supply Chain model. This model proposes a distribution strategy for halal food supply chain from limited halal slaughterhouses to several halal markets, therefore the total cost of distribution becomes minimize and satisfied some constraints. In this model, it is assumed that all halal markets demand must be fulfilled. There is no lack ness cost. Therefore, the model try to fulfill all the halal market demands in minimize cost of oversupply and transportation cost. The BHSC is modeled as MILP.

In order to validate the model, it is performed the numerical experiment. The experiment is performed using Intel® Core™ i7 M620 2.67 GHz computer. Then the BHSC model is coded and solved using CPLEX Solver Version 12.6.3. The experiment results shows that all halal markets' demand can be fulfilled by the halal slaughterhouse HS1 to HS9. The total cost of halal meat distribution is $ 14,790 that consists of cost of oversupply is $ 0 and the transportation cost is $ 14,790. Based on the experiment result it is shown that the BHSC model can be used by the halal supply chain decision maker as the decision making tool to help them designing the best strategy to distribute the limited number of halal meat supply to many halal markets demand for its supply chain

sustainability. The BHSC model can minimize the total cost of distribution that consists of cost of oversupply and cost of transportation, in the case of all halal market demands must be fulfilled so as the model can be an alternative method to support the halal supply chain sustainability.

By minimizing the oversupply, the un-used supply can be minimized, so the rest product can be distributed to other Halal market that still need it or Halal market which the demand has not been yet fulfilled. By minimizing the oversupply, all production capacity can be used to fulfill all halal markets' demand. So this strategy can support the sustainability of halal supply chain.

Do so with minimizing the transportation cost. By minimizing the transportation cost, so it can save the money, while the saved money can be used by the supplier for other activities. So minimizing the transportation cost, also can support the sustainability of halal food supply chain.

As the future work of the basic BHSC model, there are many studies can be done to improve the current model and approach. For example, it is possible to relax the current constraints then study its effects. It can be such as applying soft constraint for the lack ness and considering the container capacity. Another possible future work is through considering the routing in the BHSC problem, so the problem will be not just an allocation problem, but a routing problem also. It is possible also to investigate another method and approach of problem solving, not just MILP mathematical model, such as developing meta-heuristics method or another exact methods.

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