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INTERVAL MODEL OF FOOD SUPPLY CHAIN NETWORK AT THE MULTI STAGE DISTRIBUTION SYSTEMS

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ABSTRACT: The main purpose of this paper is to design a comprehensive decision-making model, includes all parts of the supply that make up the food supply chain. The research method is divided into two parts. The first part is designing a comprehensive configuration of singles product multi stage FSCN model, which consists of multi farmers, multi factories, multi distribution central, and multi-consumer retail. This section also examines supply chain design problems with various uncertainty conditions of the parameters and propose a mathematical modeling framework to optimize FSCN problem. The second part complements the optimization of the single product multi stage FSCN model using interval programming method. The optimal optimization is minimization the total costs incurred to operate a multi-stage distribution system. FSCN configuration is formed based on the case of salt distribution system, consisting of 9 salt farmer groups, 3 warehouses, 2 factories, 3 distribution centers (DC) and 6 consumer retail points. This configuration explains about the structure that forms the network and its role in the food supply chain network interval model. Interval Coefficient method used effectively and usefully can solve FSCN optimization problems in real life. This interval method uses matrix data input of costs in the form of intervals. The efficiency of the proposed method is illustrated by a numerical example where it is proven optimization problem of FSCN model can be solved with the Interval Method.

Keywords: Programming Interval, Uncertainty, Food Supply Chain

1. INTRODUCTION

Supply Chain Network (SCN) is a network that describes the flow of material, money, and information from the beginning of the raw material enter into the network until the products in consumer's hands. This network is usually started with suppliers, factories, distribution centers, retail, and ended with consumers. Shankar *et. al.,* defines a complete supply chain structure consists of suppliers, producers, distributors, and customers [1]. A typical supply chain consists of the stage levels as follows: suppliers, factoriess, distribution centers (DC) and customer markets [2]. Braziotis (2013) SCN has emerged as a key concept in recent years because of the increased complexity of supply chain structure and relationship interconnectedness among the supply chain members [3]. SCN structure develops according to the globalization demand to become Food Supply Chain Network (FSCN). FSCN structure consists of multi farmers, factoriess (processing), multi distribution centers (DC) and multi consumers (retail/customers).

Research about supply chain (SC) management is carried out by Soysall *et. al.*, concluded that SC is increasingly developing and transforming become Food Supply Chain (FSC) suitable for the food industry needs. However, the characteristics of food products and processes and relationships among supply chain members have not been well identified. The quantitative model's details are needed to meet the requirements of the FSCN model as consideration to support the company business decisions [4]. Company business decision on the food industry is more oriented to customer satisfaction and needs, faster response time to minimize food distribution [5].

In the real world the FSCN problems, it is usually difficult to estimate the actual value of parameters or constants (eg. number of harvests, transportation costs, delivery time, number of items sent, below capacity usage, demands, etc.). To overcome uncertainty, Sopranino *et. al.*, has modified simplex method so can be used in the real interval. For example, linear programming intervals can be solved by executing real intervals directly [6].

The paper aims to design multi stage FSCN structures configuration consists of Multi Farmers, Multi processor/factories, Multi distributor and Multi customers. This paper too studies supply chain network design problems with various uncertainty conditions from parameters and propose mathematical modeling framework to optimize FSCN problems. The second goal is to solve the optimization of the interval model of multi stage single product FSCN by using interval programming method. The optimization completed is the minimization of total costs incurred to operate a multi-stage distribution system.

Considering the FSCN design importance, because the results will be very decisive for the next supply chain, it needs an optimization method that can help to solve this problem. So that if the FSCN design is optimal will be able to reduce supply chain costs and ultimately increases the company profitability. Therefore the results obtained will greatly assist the company management in making decisions related to the FSCN.

2. METHOD

FSCN is a network that consists of Farmers (F), Processor (P), Distribution Center (DC) and Retailer (R) (Figure 2 .1). All parts of the FSCN (F, P, DC, and R) are often referred to as Echelons. Echelon one another forms network and works together to meet customer demand (consumer, retailer or end user).

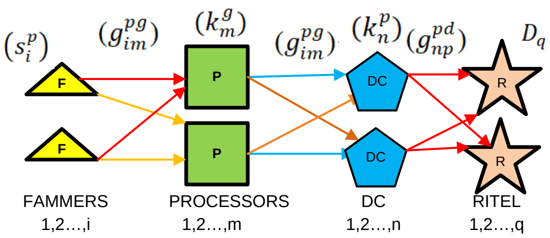

Fig. 1 Food Supply Chain Network

2.1 Data Collection

The data collected to design the FSCN model in this paper is a case example of salt distribution system network. To compile the FSCN model, the following data is needed: Location of Retail/ retailers/ consumers, the location of Distribution Centers, the location of Processing/ Factories/ Factory, and the location of Farmers / salt farmer groups. The number and types of salt required by customers, the amount of salt harvest produced. The transportation used for distribution. Annual demand for each salt type distributed to each consumer location. Transportation costs tariff for transportation used. Inventory storage costs and operational fixed costs. Capacity of transportation used and a delivery frequency to consumers. Capacity of Farmers (F), Processors (P), Distribution Centers (DC) and Retailers (R)

2.2 Interval Arithmetic

The definition and nature of arithmetic intervals can be seen in Alefeld and Herzberger, Mohd [7], [8].

Definition 1. Number of intervals on the number line $\mathfrak{R}$ is the set of all points between two specific end points (lower limit and upper limit) on the number line $\mathfrak{R}$

Definition 2. An interval X that has a lower limit (minimum value) $\underline{\mathbf{x}}$ and upper limit (maximum value) $\overline{\mathbf{x}}$ we write: X = $[\underline{\mathbf{x}};\overline{\mathbf{x}}]$

Definition 3. The width of an interval X is real number: w (X) = $\overline{\mathbf{x}}$ - $\underline{\mathbf{x}}$

Definition 4. Two intervals are said to be the same if and only if they have the same limits. If X = $[\underline{\mathbf{x}},\overline{\mathbf{x}}]$ and Y = $[\underline{\mathbf{y}},\overline{\mathbf{y}}]$, Then: X = Y if and only if $\underline{\mathbf{x}} = \underline{\mathbf{y}}$ and $\overline{\mathbf{x}} = \overline{\mathbf{y}}$

Definition 5. The X interval is said to be smaller than Y if and only if the maximum X limit is smaller than the minimum Y limit. $\overline{\mathbf{x}}$<$\underline{\mathbf{y}}$

Definition 6. **If X =** $[\underline{\mathbf{x}},\overline{\mathbf{x}}]$ **and Y =** $[\underline{\mathbf{y}},\overline{\mathbf{y}}]$ **then** $\mathbf{X}+\mathbf{Y} = [\underline{\mathbf{x}}+\underline{\mathbf{y}}, \overline{\mathbf{x}}+\overline{\mathbf{y}}]$

Definition 7. Two-interval multiplication X and Y are defined as: X•Y = {xy: x€X, y€Y}, which can be written X•Y = [min{ $\underline{\mathbf{x}}\underline{\mathbf{y}}, \underline{\mathbf{x}}\overline{\mathbf{y}}, \overline{\mathbf{x}}\underline{\mathbf{y}}, \overline{\mathbf{x}}\overline{\mathbf{y}}$} , max{$\underline{\mathbf{x}}\underline{\mathbf{y}}, \underline{\mathbf{x}}\overline{\mathbf{y}}, \overline{\mathbf{x}}\underline{\mathbf{y}}, \overline{\mathbf{x}}\overline{\mathbf{y}}$}

Below will be presented some related theorems with a linear programming problem with interval coefficient. These theorems can be seen in (Chinneck and Ramadan) and (Suprajitno and Mohd) [9], [10].

Theorem 1. If there is an interval inequality constraint $\sum_{j=1}^{n}[\underline{\mathbf{a}}_j,\overline{\mathbf{a}}_j]\mathbf{x}_j \le [\underline{\mathbf{b}},\overline{\mathbf{b}}]$ with $x_j \ge 0$, then $\sum_{j=1}^{n}\underline{\mathbf{a}}_j\mathbf{x}_j \le \overline{\mathbf{b}}$ is the range of maximum feasible settlement areas and $\sum_{j=1}^{n}\overline{\mathbf{a}}_j\mathbf{x}_j \le \underline{\mathbf{b}}$ is the range of minimum feasible settlement areas

Theorem 2. If there is an interval inequality constraint $\sum_{j=1}^{n}[\underline{\mathbf{a}}_j,\overline{\mathbf{a}}_j]\mathbf{x}_j \ge [\underline{\mathbf{b}},\overline{\mathbf{b}}]$ with $x_j \ge 0$, then $\sum_{j=1}^{n}\overline{\mathbf{a}}_j\mathbf{x}_j \ge \underline{\mathbf{b}}$ is the range of maximum feasible settlement areas and $\sum_{j=1}^{n}\underline{\mathbf{a}}_j\mathbf{x}_j \ge \overline{\mathbf{b}}$ is the range of minimum feasible settlement areas

Theorem 3. If there is an interval inequality constraint $\sum_{j=1}^{n}[\underline{\mathbf{a}}_j,\overline{\mathbf{a}}_j]\mathbf{x}_j \le [\underline{\mathbf{b}},\overline{\mathbf{b}}]$ with $x_j \ge 0$, then $\sum_{j=1}^{n}\overline{\mathbf{a}}_j\mathbf{x}_j \le \overline{\mathbf{b}}$ is the range of maximum feasible settlement areas $\sum_{j=1}^{n} \underline{a}_j x_j \leq \underline{b}$ is the range of minimum feasible settlement areas

Theorem 4. If Z = $\sum_{j=1}^{n}[\underline{c}_j, \overline{c}_j] x_j$ is the destination function with $x_j \geq 0$, then $\sum_{j=1}^{n} \overline{c}_j x_j \geq \sum_{j=1}^{n} \underline{c}_j x_j$ for any solution x = ($x_1, x_2, \ldots, x_n$) , with $x_j \geq 0$, (j = 1,2, ..., n)

Theorem 5. In the equation constraints in the intervals form $\sum_{j=1}^{n}[\underline{a}_j, \overline{a}_j] x_j = [\underline{b}, \overline{b}]$, then the following pair of inequality constraints: $\sum_{j=1}^{n} \underline{a}_j x_j \leq \overline{b}$, $\sum_{j=1}^{n} \overline{a}_j x_j \geq \underline{b}$, where for each point it fulfills all possible shapes in the constraints of the interval equation.

FSCN model problem that has interval coefficient, either at goal function or constraints can be solved with following steps:

Step 1: Change model of FSCN Interval Coefficient becomes linear programming model. Change all constraint functions of interval equation form into a pair of inequalities. Determine the area range of maximum and minimum values in all constraint functions. Determine the smallest upper limit and lower limit of the Purpose Function. The linear programming model form is based on the values range and limits area.

Step 2: By using the simplex method to solve linear programming models

Step 3: Check the solution. If the value of the Goal Function is limited, the solution is one of the linear programming models. If both models have found a solution, continue to step 4, if you haven't returned to step 2 to complete the next model. If the model does not have regular areas range, stop, because there is no solution. If the value of the Goal function is unlimited. Stop, if you have already get additional constraints. If not, add another model constraint to the current model, so the new linear programming model is formed. Then proceed to step 2

Step 4: Forms an interval solution. Determine the supremum value for solving the smallest upper limit problem to the supremum interval solution that is formed. Determine the infimum value for solving the biggest lower limit problem to the minimum interval that is formed. If the solution formed is an interval, then stop. If not, then the non-interval solution section is given the infimum value of the biggest corresponding lower limit solution so an interval is formed.

3. RESULTS AND DISCUSSION

The structure of the FSCN coefficient interval model that is formed from the example case of the salt distribution system network is:

$$
\begin{aligned}
MIN &= \sum_{i=1}^{a}\sum_{m=1}^{b}\left[\underline{c}_{im}^{pg}, \overline{c}_{im}^{pg}\right] g_{im}^{pg} \\
&+ \sum_{j=1}^{c}\sum_{m1}^{b}\left[\underline{c}_{jm}^{lg}, \overline{c}_{jm}^{lg}\right] g_{jm}^{lg} \\
&+ \sum_{k=1}^{e}\sum_{m=1}^{b}\left[\underline{c}_{km}^{ig}, \overline{c}_{km}^{ig}\right] g_{km}^{ig} \\
&+ \sum_{m=1}^{b}\left[\underline{c}_{m}^{g}, \overline{c}_{m}^{g}\right] i_{m}^{g} \\
&+ \sum_{m=1}^{b}\sum_{n=1}^{f}\left[\underline{c}_{mn}^{gp}, \overline{c}_{mn}^{gp}\right] g_{mn}^{gp} \\
&+ \sum_{n=1}^{f}\sum_{p=1}^{h}\left[\underline{c}_{np}^{pd}, \overline{c}_{np}^{pd}\right] g_{np}^{pd} + \sum_{p=1}^{h}\left[\underline{c}_{p}^{d}, \overline{c}_{p}^{d}\right] i_{p}^{d} \\
&+ \sum_{p=1}^{h}\sum_{q=1}^{z}\left[\underline{c}_{pq}^{dp}, \overline{c}_{pq}^{dp}\right] g_{pq}^{dp} \qquad (1)
\end{aligned}
$$

3.1 Input Model

a = Number of salt farmer groups

c = Number of salt fields of PT. Garam

e = Total Frequency of salt import

(s_i^p) = Capacity (number of harvests) from a group of salt farmers *i*.
The amount of salt harvest from a group of salt farmers cannot be known certainly or cannot be determined precisely so it needs to be changed in the intervals form $s_i^p = [\underline{s}_i^p, \overline{s}_i^p]$. $[\underline{s}_i^p, \overline{s}_i^p]$ = Capacity (number of harvest) from group of farmera a s salts *i*.
This means that the number of harvest on the salt farmers *i* the value between and $\underline{s}_i^p$ and $\overline{s}_i^p$

(s_j^l) = Capacity (number of harvests) from the salt fields of PT. Garam *j*.
The amount of salt harvested from the salt fields of PT. Garam cannot be known certainly or cannot be determined precisely so that it needs to be changed in the form of intervals $s_j^l = [\underline{s}_j^l, \overline{s}_j^l]$. $[\underline{s}_j^l, \overline{s}_j^l]$ = Capacity (number of quantities) of the salt fields of PT. Garam - *j*.
This means that the number of harvest from PT.Garam salt fiel ds - *j* value between $\underline{s}_j^l$ and $\overline{s}_j^l$.

(s_k^i) = Capacity (amount of imported salt) from salt import *k*.

b = Number of potential warehouse locations

(g_{im}^{pg}) = number of salt supply channeled from salt farmers i to warehouse the m.

(g_{jm}^{lg}) = number of salt supply channeled from salt field i the warehouse m.

(g_{km}^{ig}) = number of salt supply channeled from imported salt i to warehouse m .

(k_m^g) = Warehouse capacity m .
The capacity of the warehouse to be operated is not yet determined its area so it needs to be estimated (k_m^g) = $\left[\underline{k}_m^g, \overline{k}_m^g\right]$ This means that the warehouse that will be operated has an area between $\underline{c}_m^g$ and $\overline{c}_m^g$.

(c_{im}^{pg}) = Shipping cost per ton salt from group of salt farmers i to the warehouse m .
Shipping costs per ton of salt farmer groups i to the warehouse m cannot be known certainly or cannot be determined precisely so it needs to be changed in the intervals form c_{im}^{pg} = $\left[\underline{c}_{im}^{pg}, \overline{c}_{im}^{pg}\right]$ This means the shipping cost per ton from group of salt farmers i to warehouse m the value between $\underline{c}_{im}^{pg}$ and $\overline{g}_{im}^{pg}$.

(c_{jm}^{lg}) = Shipping cost per ton of salt fields j to the warehouse m.
Shipping costs per ton from salt field j to warehouse m cannot be known certainly or can not be determined precisely so that needs to be changed in the intervals form c_{jm}^{lg} = $\left[\underline{c}_{jm}^{lg}, \overline{c}_{jm}^{lg}\right]$ This means the shipping cost per ton from salt fields j to warehouse m value between $\underline{c}_{jm}^{lg}$ and $\overline{c}_{jm}^{lg}$.

(c_{km}^{ig}) = Shipping cost per ton of import salt k to the warehouse m.
Shipping costs per ton of import salt k to the warehouse m cannot be known certainly or cannot be determined precisely so it needs to be changed into interval form c_{km}^{ig} = $\left[\underline{c}_{km}^{ig}, \overline{c}_{km}^{ig}\right]$. This means that the shipping cost per ton of import salt k to the warehouse m value between $\underline{c}_{km}^{ig}$ and $\overline{c}_{km}^{ig}$.

(c_m^g) = Storage cost per ton salt stock / inventory at warehouse - m
Storage costs per ton salt stock/inventory at the warehouse- m cannot be known certainly or cannot be determined precisely so that needs to be changed into interval form (c_m^g) = $\left[\underline{c}_m^g, \overline{c}_m^g\right]$.

(i_m^g) = amount of provision / inventory at warehouse-m.

f = Number of iodized salt factories.

$\left[\underline{k}_n^p, \overline{k}_n^p\right]$ = Capacity of iodized salt factories n

(g_{mn}^{gp}) = amount of salt channeled from warehouse the the – m to iodized salt factories – n .

(c_{mn}^{gp}) = Shipping per unit from the warehouse m to iodized salt factories n.
Shipping costs per ton from the warehouse m to iodized salt factories - n cannot be known certainly or cannot be determined precisely so it needs to be changed into interval form c_{mn}^{gp} = $\left[\underline{c}_{mn}^{gp}, \overline{c}_{mn}^{gp}\right]$ This means that the shipping cost per ton from the warehouse m to iodized salt factories - n value between $\underline{c}_{mn}^{gp}$ and $\overline{c}_{mn}^{gp}$.

h = Number of potential locations for distribution centers .

g_{np}^{pd} = amount of salt channeled from factory-n ke distribution center-p

c_{np}^{pd} = Shipping cost per ton from iodized salt factories - n to distribution center - p
Shipping costs per ton of iodized salt factories - n to distribution center - p cannot be known certainly or cannot be determined precisely so it needs to be changed into interval form c_{np}^{pd} = $\left[\underline{c}_{np}^{pd}, \overline{c}_{np}^{pd}\right]$ This means that shipping costs per ton of iodized salt factories - n to distribution center - p value between $\underline{c}_{np}^{pd}$ and $\overline{c}_{np}^{pd}$

c_p^d = Storage cost per ton stock / inventory salt at distribution center - p
Storage costs per ton salt stostock/inventory distribution center - p cannot be known certainly or cannot be determined precisely so it needs to be changed into interval form. (c_p^d) = $\left[\underline{c}_p^d, \overline{c}_p^d\right]$

i_p^d = Amount of stock / inventory at distribution center p.

(k_p^d) = Distribution Center Capacity p

z = Number of retailers or demand point

g_{pq}^{dp} = amount of salt will be channeled from distribution center p to retailer q.

c_{pq}^{dp} = Shipping cost per unit from the distribution center p to retailer q.
Shipping cost per unit from distribution center p to retailer q cannot be known certainly or cannot be determined precisely so it needs to be changed into interval form c_{pq}^{dp} = $\left[\underline{c}_{pq}^{dp}, \overline{c}_{pq}^{dp}\right]$. This means that shipping cost per unit from distribution center p to retailer q value is between $\underline{c}_{pq}^{dp}$ and $\overline{c}_{pq}^{dp}$.

D_q = annual demand from retailers q.
Annual demand from retailers - q cannot be known certainly or cannot be determined precisely so it needs to be changed into interval form. D_q = $\left[\underline{D}_q, \overline{D}_q\right]$. This means that annual demand from retailers - q value between $\underline{D}_q$ and $\overline{D}_q$.

3.2 Constraint Identification

The capacity constraint of salt farmer harvest

$$\sum_{i=1}^{a}\sum_{m=1}^{b}(g_{im}^{pg}) \le \sum_{i=1}^{a}\left[\underline{s}_i^{\,p},\ \overline{s}_i^{\,p}\right] \tag{2}$$

1. for each $i = 1, 2, 3, \ldots a$
2. for each $m = 1, 2, 3, \ldots b$

Capacity constraint of salt field harvest

$$\sum_{j=1}^{c}\sum_{m=1}^{b}(g_{jm}^{lg}) \le \sum_{j=1}^{c}\left[\underline{s}_j^{\,l},\overline{s}_j^{\,l}\right] \tag{3}$$

1. for each $j = 1, 2, 3, \ldots c$
2. for each $m = 1, 2, 3, \ldots b$

Capacity constraint of salt import

$$\sum_{k=1}^{e}\sum_{m=1}^{b}(g_{km}^{ig}) \le \sum_{k=1}^{e}\left[\underline{s}_k^{\,i},\overline{s}_{lk}^{\,i}\right] \tag{4}$$

1. for each $k = 1, 2, 3, \ldots e$
2. for each $m = 1, 2, 3, \ldots b$

Capacity constraint of warehouse

$$\sum_{i=1}^{a}\sum_{m=1}^{b}(g_{im}^{pg}) + \sum_{j=1}^{c}\sum_{m=1}^{b}(g_{jm}^{lg}) + \sum_{k=1}^{e}\sum_{m=1}^{b}(g_{km}^{ig}) \le \sum_{m=1}^{b}\left[\underline{k}_m^g,\overline{k}_m^g\right] \tag{5}$$

1. for each $i = 1, 2, 3, \ldots a$
2. for each $j = 1, 2, 3, \ldots c$
3. for each $k = 1, 2, 3, \ldots e$
4. for each $m = 1, 2, 3, \ldots b$

Capacity constraint of warehouse inventory

$$\sum_{m=1}^{b} i_m^g = \sum_{m=1}^{b}\left[\underline{k}_m^g,\overline{k}_m^g\right] - \sum_{m=1}^{b}\sum_{n=1}^{f} g_{mn}^{gp} \tag{6}$$

1. for each $m = 1, 2, 3, \ldots b$
2. for each $n = 1, 2, 3, \ldots f$

Capacity constraint of warehouse

$$\sum_{m=1}^{b}\sum_{n=1}^{f} g_{mn}^{gp} \le \sum_{m=1}^{b}\left[\underline{k}_m^g,k_m^g\right] \tag{7}$$

1. for each $m = 1, 2, 3, \ldots b$
2. for each $n = 1, 2, 3, \ldots f$

Capacity constraint of factory

$$\sum_{m=1}^{b}\sum_{n=1}^{f} g_{mn}^{gp} \le \sum_{n=1}^{f}\left[\underline{k}_n^p,\overline{k}_n^p\right] \tag{8}$$

1. for each $m = 1, 2, 3, \ldots b$
2. for each $n = 1, 2, 3, \ldots f$

Inventory constraints of factory

$$\sum_{n=1}^{f} i_n^p = \sum_{n=1}^{f}\left[\underline{k}_n^p,\overline{k}_n^p\right] - \sum_{n=1}^{f}\sum_{p=1}^{h} g_{np}^{pd} \tag{9}$$

1. for each $n = 1, 2, 3, \ldots f$
2. for each $p = 1, 2, 3, \ldots h$

Capacity constraint of factory

$$\sum_{n=1}^{f}\sum_{p=1}^{h} g_{np}^{pd} \le \sum_{n=1}^{f}\left[\underline{k}_n^p,\overline{k}_n^p\right] \tag{10}$$

1. for each $n = 1, 2, 3, \ldots f$
2. for each $p = 1, 2, 3, \ldots h$

Capacity constraint of distribution center

$$\sum_{n=1}^{f}\sum_{p=1}^{h} g_{np}^{pd} \le \sum_{p=1}^{h}\left[k_p^d,\overline{k}_p^d\right] \tag{11}$$

1. for each $n = 1, 2, 3, \ldots f$
2. for each $p = 1, 2, 3, \ldots h$

Inventory constraint of distribution center

$$\sum_{p=1}^{h} i_p^d = \sum_{p=1}^{h}\left[\underline{k}_p^d,\overline{k}_p^d\right] - \sum_{p=1}^{h}\sum_{q=1}^{z} g_{pq}^{dp} \tag{12}$$

1. for each $p = 1, 2, 3, \ldots h$
2. for each $q = 1, 2, 3, \ldots z$

Capacity constraint of distribution center

$$\sum_{p=1}^{h}\sum_{q=1}^{z} g_{pq}^{dp} \le \sum_{p=1}^{h}\left[\underline{k}_p^d,\overline{k}_p^d\right] \tag{13}$$

1. for each $p = 1, 2, 3, \ldots h$
2. for each $q = 1, 2, 3, \ldots z$

Constraints of demand needs

$$\sum_{p=1}^{h}\sum_{q=1}^{z} g_{pq}^{dp} \le \sum_{q=1}^{z}\left[\underline{D}_q,\overline{D}_q\right] \tag{14}$$

1. for each $p = 1, 2, 3, \ldots h$
2. for each $q = 1, 2, 3, \ldots z$

Constraint

$$(g_{im}^{pg}), (g_{jm}^{lg}), (g_{km}^{ig}), (i_m^g), (g_{mn}^{gp}), (g_{np}^{pd}), (i_p^d), (g_{pq}^{dp}) \ge 0 \tag{15}$$

3.3 Numerical examples

To solve the optimization problem, the FSCN model used a real case of salt distribution system.

Table 1. Annual Salt Harvest Results (1000 tons)

Salt farmer	Number of harvests	Salt field	Number of harvests	Imported salt	Number of harvests
1	[70,120]	1	[90,110]	1	[50,70]
2	[80,110]	2	[85,105]	2	[50,70]
3	[75,105]	3	[90,115]		
4	[70,110]				

3.3.1 The salt shipping cost to warehouse

Table 2. Matrix of salt shipping cost to warehouse (1000 rupiah)

Cost to warehouse		Warehouse		
PG	1	[270,320]	[290,330]	[290,340]
	2	[290,330]	[270,320]	[280,330]
	3	[290,340]	[290,330]	[280,330]
	4	[310,350]	[290,340]	[290,330]
LG	1	[240,280]	[250,340]	[260,290]
	2	[260,320]	[240,270]	[260,310]
	3	[250,320]	[320,340]	[220,250]
IG	1	[380,410]	[400,450]	[390,430]
	2	[410,450]	[390,410]	[420,450]

3.3.2 The amount of salt distributed to warehouse

Based on the data collected from the salt distribution system, processed by using definitions, theorems and arithmetic interval resolution steps obtained the solution by simplex method as table 4.

Table 3. Salt distribution to warehouses

The salt transported to the warehouse		Warehouse			Capacity
PG	1	X1	X2	X3	[70,120]
	2	X4	X5	X6	[80,110]
	3	X7	X8	X9	[75,105]
	4	X10	X11	X12	[70,110]
LG	1	X13	X14	X15	[90,110]
	2	X16	X17	X18	[85,105]
	3	X19	X20	X21	[90,115]
IG	1	X22	X23	X24	[50,70]
	2	X25	X26	X27	[50,70]
Demand		[230,260]	[240,265]	[270,310]	

Results interpretation based on table 2 and solution in table 4, salt farmer group 1 distributes salt to warehouse 1 with transportation costs of [270, 320] rupiah as much as [70,120] tons of salt. Salt farmer group 2 distributes salt to warehouse 2 with transportation costs of [270, 320] rupiah as much as [0,110] tons of salt. This means that if transportation cost to distribute salt from salt farmer group 1 to warehouse 1 is between 270 thousand and 320 thousand rupiahs, the minimum cost occurs if the amount salt delivered is 70-120 tons of salt.

Table 4 Solution of Salt FSCN Interval Models

Variable	Model 1	Model 2	Model Interval
X1	120	70	[70,120]
X2	0	0	[0,0]
X3	0	0	[0,0]
X4	0	0	[0,0]
X5	110	0	[0,110]
X6	0	80	[0,80]
X7	5	0	[0,5]
X8	60	0	[0,60]
X9	40	75	[40,75]
X10	0	0	[0,0]
X11	0	45	[0,45]
X12	115	25	[25,115]
X13	70	50	[50,70]
……	……	……	……
……	……	……	……
……	……	……	……
X59	120	0	[120,0]
X60	140	250	[140,250]
X61	0	30	[0,30]
X62	20	30	[20,30]

4. CONCLUSION

FSCN Interval Model which is formed from the salt distribution system as the research object is 9 farmers/land or salt farmer groups, 3 warehouses, 2 factories/processors, 3 distribution centers (DC) and 6 retails/consumer points. The configuration describes the structure that makes up the network and its role in the food supply chain network interval model. Interval coefficient method that is used effectively and usefully can solve the FSCN optimization problem from the salt distribution system which is the research object. This interval method uses matrix data input of costs into interval form.

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