Journal of Theoretical and Applied Information Technology
31st January 2021. Vol.99. No 2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

ROBUST OPTIMIZATION APPROACH FOR AGRICULTURAL COMMODITY SUPPLY CHAIN PLANNINGG

[1]NURDIN, [2]BUSTAMI, [3]MARYANA

[1,2] Department of Informatics, Universitas Malikussaleh, Lhokseumawe, Aceh, Indonesia.

[3] Department of Mathematics Education, Universitas Malikussaleh, Lhokseumawe, Aceh, Indonesia.

E-mail: [1]nurdin@unimal.ac.id, [2]busabiel@gmail.com, [3]maryana_jalil@yahoo.co.id

ABSTRACT

North Aceh is one of the districts that has great potential in agriculture and plantations. Many agricultural resources have become superior commodities, because most of North Aceh is a commodity producer from the agricultural sector. However, there are several subdistricts in Aceh Utara district that experience a shortage of agricultural commodity supplies, due to the location of their areas along the coast. Therefore, it is necessary to plan management and supply chain management of agricultural resources. The purpose of this study is to create a robust optimization model that is integrated based on artificial intelligence for the distribution network of agricultural commodity supply chains. The stages carried out in this study started from literature review, data collection and analysis, determining parameters and model decision variables, formulating objective functions and model constraints functions, algorithms and model design, implementation and model testing. The results of this study are a mathematical method or model that can be used for the distribution network of agricultural commodity supply chains, so as to minimize supply chain operating costs from suppliers to consumers. This research is expected to assist decision makers and stakeholders in planning and managing agricultural commodities.

Keywords: *Optimization, Supply chain, Agricultural commodities, Decisions, Robust.*

1. INTRODUCTION

Intelligent decision making is very important for every individual, government, manager, organization leader or anyone. Decisions can be on a daily basis or even happen for a moment. Decisions can be important and many are mediocre. Many important decisions come from the information available and the treatment of that information. Essentially, the more relevant the information required is, the higher the level of knowledge can be made of a person and the smarter the decisions can be made. The decisions that need to be taken regarding the planning and management of agricultural commodities require the role of an intelligent decision-making system, especially since this decision-making process contains large amounts of data [1], [2].

The agricultural sector is the mainstay of the economy in Aceh province. In each period this sector always gives the largest contribution to economic growth (Gross Regional Domestic Product). This illustrates that Aceh is a potential agribusiness area. Agriculture in the Aceh region produces rice, soybeans, cassava, sweet potatoes, maize, soybeans, vegetables and fruits. Meanwhile, in the plantation sector, the Aceh region produces cocoa, candlenut, rubber, oil palm, coconut, coffee, cloves, nutmeg, patchouli, pepper, areca nut, sugar cane, tobacco and randu. The agricultural sector is also the business sector that absorbs the most labor. This sector also plays the most important role in driving Aceh's economic growth. Each year the contribution of this sector to Aceh's Gross Regional Domestic Product reaches 30 percent, far more than other sectors [3].

Based on the description above, it is necessary to plan and manage agricultural commodity resources as one of the main factors in increasing economic development, especially in the districts of North Aceh and Aceh province in general. With the existence of global challenges, parties related to the management of agricultural and fishery products are organized in a network that includes various processes and activities to produce final products and distribute them to the community. The main

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

objective is to improve the quality of the right product at the right place and at the right time with minimum costs [4], [5], [6]. This network is known as the supply chain.

Supply chain management is defined as the logistical and production processes of a company network for a particular industry [7], [8]. Thus the supply chain can be viewed as a connected network between organizational units operating in a coordinated way to manage, control and improve the flow of materials and information from suppliers to society. The aim is to combine and evaluate from a systems perspective the decisions and policies taken cover the various sub-processes that make up the logistic system of the company [9]. This process integrates the operations of the supply chain, even for parts that are outside of management. Integrated logistics processes are used to achieve supply chain optimization [10].

The proposed optimization model explicitly contains uncertain parameters, namely parameters of the availability of agricultural resources and market demand. In the literature, optimization problems with uncertainty arise on the topic of stochastic programs [11], [12]. In such a model, the objective function is generally the minimization of expected costs or maximizing profit expectations (linear or nonlinear). With the calculation of this expectation value, uncertain parameters which are often termed random parameters need to have a probability distribution function. This condition is the main weakness of the stochastic program model. The optimization model that can also handle uncertain parameters is robust optimization [13].

Robust optimization is a modeling methodology combined with computational tools, to process optimization problems where the available data is uncertain and only a few sets of uncertainties are known [14]. Robust is defined as insensitivity to small changes in a system. The robust counterpart (RC) methodology presented by Ben-Tal and Nemirovskii is one of the existing methodologies for dealing with data uncertainty over an optimization problem. Robust optimization has become popular recently as a robust methodology for solving optimization models in the presence of uncertainty in the feasibility of a solution and its objective value. This approach is to optimize mathematical uncertainty and maintain the tractability of the model as proposed by [14], [15]. The Robust Optimization Model has been used to address decision making in a dynamic environment where future decisions depend on the realization of current data such as inventory problems [16], supply contracts [15].

As for the problem of this study, because there are several areas in North Aceh Regency that experience a shortage of agricultural commodity supply, because some of the areas are located on the coastline, a robust optimization model is needed for integrated supply chain planning from suppliers to consumers. The process of distributing agricultural resource commodity resources from suppliers to consumers takes a long time, so it requires a distribution system that is smart and timely so that the quality of agricultural resources is maintained at a minimum cost. With this model, it is hoped that it can help solve problems in smart decision making related to policies for planning and managing agricultural commodities.

The data to be processed in the research on the distribution network optimization problem in the supply chain of agricultural commodities is large-scale data, so that the model discussed earlier is still not suitable for large-scale management. One of the optimization models that includes large-scale data and contains uncertainty on parameters is to use robust optimization or a data driven optimization approach [1], [2]. The results of the implementation of this robust optimization model are expected to produce a mathematical model for planning the supply chain network for agricultural commodities in North Aceh Regency. This supply chain network optimization model can also be implemented in determining the shortest route using the ant colony algorithm approach [17].

2. ROBUST OPTIMIZATION

The term Robust Optimization has been used as an approach to decision making related to the presence of ambiguity and stochastic uncertainty parameters. The main paradigm depends on the worst case analysis where the solution is evaluated using actual unexpected uncertainty realization [18]. Robust optimization is a modeling methodology that is combined with computing, to process optimization problems where available data is uncertain and only a few sets of uncertainty are known [14].

Robust optimization has become popular lately as a robust methodology for completing the optimization model with the existence of uncertainty in the feasibility of solutions and their objective values. This approach is to optimize mathematical uncertainty and maintain the

Journal of Theoretical and Applied Information Technology
31st January 2021. Vol.99. No 2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

tractability of the model as stated by [19], [20]. Robust Optimization Models have been used to overcome decision making in dynamic environments where future decisions depend on the realization of current data such as in inventory problems [16].

2.1 Robust Optimization Approach

(Bertsimas and Thiele, 2004) stated that the interesting features of the robust optimization approach include: (a) this approach combines many phenomena, such as requests that are not distributed over time and capacity in echelons and relationships; (b) using limited information related to distribution of requests; (c) provide optimal policies such as dynamic programs; (d) numerically can be solved for large supply chain problems even in networks, where dynamic program methods face serious problems related to dimensionality; (e) in the calculation experiment is often faster than dynamic program-based solutions for a large number of parameters.

(Bertsimas and Sim, 2004) provide linear program solutions using robust oprimization in the form of:

$$\min c'x : Ax \leq b, l \leq x \leq u \qquad (1)$$

Assuming a matrix A is a matrix expressing uncertainty, assuming:

$$A = \left\{ A \in \mathbb{R}^{mxn} \middle| aij \in [\bar{a}ij - \hat{a}ij, ij + \hat{a}ij]\ \forall i.j, \textstyle\sum_{(i,j)} \in j\ \frac{|aij - \bar{a}ij|}{\hat{a}ij} \leq \Gamma \right\}$$

(2)

Where Γ is a parameter that controls conservative degrees. Robust problems can be formulated as follows:

$$\begin{aligned} &\text{minimize } c'x \\ &\text{subject to :} \\ &Ax \leq b, \forall i \in A \\ &l \leq x \leq u \end{aligned} \qquad (3)$$

The uncertain linear problem has a robust linear program pair with the following formulations:

$$\begin{aligned} &\textit{minimize } :c'x \\ &\text{subject to : } \sum_j \bar{a}_{ij} x_j + q_i \Gamma + \sum_{j:(i,j)\epsilon J} r_{ij} \leq b_i ;\ \forall_i \\ &q_i + r_{ij} \geq \hat{a}_{ij} y_i \qquad \forall_{(i,j)} \in J \qquad (4) \\ &-y \leq x \leq y \\ &l \leq x \leq u \\ &q \geq 0, r \geq 0, y \geq 0 \end{aligned}$$

Problems in the form of robust are the same class as nominal problems, namely linear program problems. This provides an interesting feature, because linear program problems can easily be solved with a standard application package. Then, if in the original problem equation (1) some variables in the constraint function are integers, while the problem of solid round equation (3) is a problem of integer round by itself.

2.2 Robust Optimization Paradigm

The linear programming problem is defined as follows [21], [22]:

$$min_x\{c^T x : Ax \leq d\} \qquad (4)$$

If the parameters *c, A* and *d* are assumed to be of indefinite value, where *c, A, d*∈*U* with *U* are the set of all data uncertainties, then from the linear programming problem, an indefinite linear programming problem can be obtained as follows:

$$min_x\{c^T x : Ax \leq d, x \geq 0\ \forall c, A, d \in \mathcal{U}\} \qquad (5)$$

(Ben-Tal et al, 2009) stated that in order for robust optimization to produce a feasible solution, a "decision environment" must be defined which has the following characteristics: (A1) All decision variables represent the here and now decision, and certain numerical values must be obtained as the result of solving the problem before the actual data shows its true value. (A2) The decision maker is fully responsible for the decisions to be made if and only if the actual data has been specified in the uncertainty set *U*. (A3) Constraints on indeterminate Linear Programming problems are difficult constraints, meaning that violations of the constraints cannot be tolerated, even though No matter how small, when the data is at *U*. Using the conditions A1, A2 and A3 above, the robust optimization approach converts the indefinite problem family (5) into a deterministic problem with the following single variable function, which is called a robust counterpart.

$$\pi * = min_x\{c^T x : Ax \leq d, x \geq 0\ \forall (c, A, d) \in \mathcal{U}\} \qquad (6)$$

The vector x^* is called the optimal robust solution if for all realizations ∀ *(c, A, d)* ∈*U*, x^* is a feasible solution and the value of the objective function is guaranteed to be at most π *. According to (Gorisen et al, 2015) and (Hertog et al, 2015), problem (5) can be expressed equivalently as a problem with a fixed linear objective function and indeterminate constraints as follows:

$min_{x,t}\{t: c^T x - t \le 0, a_i^T x - d_i \le 0, i = 1, \dots, m\}, (c, A, d) \in \mathcal{U}$ (7)

Apart from these basic assumptions, it can be assumed that the objective function is fixed and the constraints on the right side are fixed (Gorissen et al, 2015). These assumptions are not limiting because of the following reasons: (B1) Suppose the coefficients on the objective function, c, are indefinite, and the coefficients are put together in terms of c:

$min_x max_{c\in C}\{c^T x: Ax \le d, \forall A \in \mathcal{U}\}$ (8)

The uncertainty of the objective function of the optimization problem can be reformulated equivalently into the following objective function [21].

$min_{x,t}\{t: c^T x - t \le 0, \forall c \in c, Ax \le d, \forall A \in \mathcal{U}\}$ (9)

With the additional variable $t \in R$.

(B2) If the vector of the right-hand side is indefinite, it can always be formed into a definite coefficient by introducing the additional variable $x\_0 = 1$, so that it is obtained (Hertog et al, 2015):

$min_x\{c^T x: a_i^T x - d_i x_0 \le 0, i = 1, \dots, m, x_0 = 1, \forall A, d \in \mathcal{U}\}$ (10)

(B2) Robustness over an indefinite set U can be formulated constraints-wise. According to (Hertog et al, 2015) the constraints-wise notion of an indefinite set $U\_ (i)$ is a projection of the set U on the plane of the indefinite component of constraint i [21].

3. ALGORITHM

The procedure for finding a suboptimal but integer viable solution of the optimal continuous solution can be described as follows [23]:

For example:

$$x = [x] + f, 0 \le f \le 1$$

being the (continuous) solution of the relaxation problem, $[x]$ is the integer component of the non-integer variable x and f is the fractional component.

Step 1. Get a line i^* infeasibility of the smallest integer, like $\delta_{i^*} = \min\{f_i, 1 - f_i\}$

Step 2. Count

$$v_{i^*}^T = e_{i^*}^T B^{-1}$$ this is a pricing operation

Step 3. Count $\sigma_{ij} = v_{i^*}^T \alpha_j$ with j corresponds to

$$\min_j \left\{\left|\frac{d_j}{\sigma_{ij}}\right|\right\}$$

a. For nonbasic j at the lower bound

$If\ \sigma_{ij} < 0\ and\ \delta_{i^*} = f_i\ count\ \Delta = \frac{(1-\delta_{i^*})}{-\sigma_{ij}}$

$If\ \sigma_{ij} > 0\ and\ \delta_{i^*} = 1 - f_i\ count\ \Delta = \frac{(1-\delta_{i^*})}{\sigma_{ij}}$

$If\ \sigma_{ij} < 0\ and\ \delta_{i^*} = 1 - f_i\ count\ \Delta = \frac{\delta_{i^*}}{-\sigma_{ij}}$

$If\ \sigma_{ij} > 0\ and\ \delta_{i^*} = f_i\ count\ \Delta = \frac{\delta_{i^*}}{\sigma_{ij}}$

b. For nonbasic j at the upper bound

$If\ \sigma_{ij} < 0\ and\ \delta_{i^*} = 1 - f_i\ count\ \Delta = \frac{(1-\delta_{i^*})}{-\sigma_{ij}}$

$If\ \sigma_{ij} > 0\ and\ \delta_{i^*} = f_i\ count\ \Delta = \frac{(1-\delta_{i^*})}{\sigma_{ij}}$

$If\ \sigma_{ij} > 0\ and\ \delta_{i^*} = 1 - f_i\ count\ \Delta = \frac{\delta_{i^*}}{\sigma_{ij}}$

$If\ \sigma_{ij} < 0\ and\ \delta_{i^*} = f_i\ count\ \Delta = \frac{\delta_{i^*}}{-\sigma_{ij}}$

Step 4. Count $\alpha_{j^*} = B^{-1}\alpha_{j^*}$ solve $B\alpha_{j^*} = \alpha_{j^*}$ for α_{j^*}

Step 5. Test the ratio, there will be three possibilities for the base variable to remain viable due to release nonbasic j^* from the limit.

If j^* the lower limit, leave it

$$A = \min_{i' \ne i^* | \alpha_{ij^*} > 0} \left\{\frac{x_{B_{i'}} - I_{i'}}{\alpha_{ij^*}}\right\}$$

$$B = \min_{i' \ne i^* | \alpha_{ij^*} < 0} \left\{\frac{u_{i'} - x_{B_{i'}}}{-\alpha_{ij^*}}\right\}$$

$$C = \Delta z$$

the maximum movement j^* depends on: $\theta^* = \min (A', B', C)$.

If j^* the upper limit, leave it

$$A' = \min_{i' \ne i^* | \alpha_{ij^*} < 0} \left\{\frac{x_{B_{i'}} - I_{i'}}{\alpha_{ij^*}}\right\}$$

$$B' = \min_{i' \ne i^* | \alpha_{ij^*} > 0} \left\{\frac{u_{i'} - x_{B_{i'}}}{-\alpha_{ij^*}}\right\}$$

$$C' = \Delta$$

If j^* the upper limit

Let the maximum movement j^* depend on: $\theta^* = \min (A', B', C')$

Step 6. Interchange the bases for the three possibilities

a. If A or A'

$x_{B_{i'}}$ becomes nonbasic at the lower bound of $l_{i'}$

x_{j^*} become the basis (replace $x_{B_{i'}}$)

x_{i^*} fixed base (non-integer)

b. If B or B'

$x_{B_{i'}}$ to be nonbasic at the upper limit $u_{i'}$

x_{j^*} become the basis (replace $x_{B_{i'}}$)

x_{i^*} fixed base (non-integer)

c. If C or C'

Journal of Theoretical and Applied Information Technology
31st January 2021. Vol.99. No 2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

x_{j^*} become the basis (replace x_{i^*})

x_{i^*} becomes a superbasic in integer-valued

Step 7. If the line $i^* = \{\emptyset\}$ stop, otherwise repeat from step 1.

4. RESEARCH METHODOLOGY

4.1 Description of Problem Formulation

North Aceh is one of the regencies that produce commodities from the agricultural sector. However, there are several subdistricts in Aceh Utara district that experience a shortage of agricultural commodity supplies, due to the location of their areas along the coast. Therefore, planning management and supply chain management of agricultural commodity resources are needed. The agricultural commodities in this study are limited to foodstuffs only. The food ingredients used as research objects consist of five commodities, namely: rice, corn, soybeans, peanuts and green beans. Food availability is very important to ensure food supply to meet consumer needs.

The process of distributing food from suppliers to consumers takes a long time. So we need a good distribution system. Supply chain management is a production process from activities for processing, distribution, so that the desired product reaches consumers by minimizing operational costs. To minimize the total operational costs in the supply chain for agricultural resources, a robust optimization approach is needed, because of the uncertainty parameter, namely the parameter of food availability to suppliers and market demand by consumers.

Establishment of an optimization model for planning and managing food commodities using a supply chain distribution network. The supply chain network proposed in this study includes three levels of distribution networks, namely suppliers, distribution centers and consumers, as shown in Figure 2, to anticipate uncertainty in supply, this problem also adds to inventory problems. To produce an optimal solution in minimizing the cost of the food supply chain distribution network using a robust optimization approach.

4.2 Stages and Research Procedures

The steps taken in the research on a robust optimization approach for supply chain planning for agricultural commodity products are as follows:

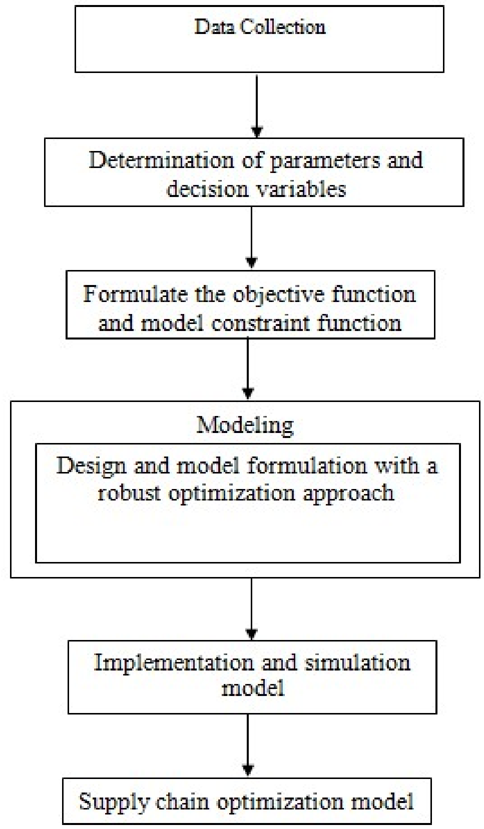


Figure 1: Stages and Research Procedures

1. Data collection

   The research data used is numerical data in the form of a matrix to support the modeling process and provide clarity on the objective function of the model mathematically.

2. Formulate the objective function of the model

   The objective function of the model built is to minimize transportation costs from suppliers to distribution centers and from distribution centers to consumers, minimize the cost of stockpiling food products at suppliers and distribution centers, and minimize other costs related to the distribution of food products, so that all maximally fulfilled consumer demand. The objective of the objective function model is to minimize the cost of selecting a food supplier *(p)* from several existing suppliers, minimize transportation costs to the food supplier *(p)* by using route *(v)*, minimize transportation costs from the food supplier *(p)* to the distribution center *(d)*, minimize transportation costs from the distribution center *(d)* to consumers *(k)*, minimize the cost of food product inventory *(m)* at the supplier's

Journal of Theoretical and Applied Information Technology
31st January 2021. Vol.99. No 2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

place *(p)* minimize the cost of stocking food products (m) at the distribution center *(d)*. Equation (14).

3. Formulate model constraints

Formulating model constraints is done by determining the initial value of the problem and the limitations of the model to be built. The following is an explanation of the constraints that need to be met on the model:

a. Each food supplier *(p)* uses route *(v)* to visit the selected consumer *(k)* only once. Equation (15)

b. Each food supplier *(p)* selected using route *(v)* to visit a facility greater than or equal to zero. Equation (16)

c. The number of foodstuff products *(m)* sent from the foodstuff supplier *(p)* to the distribution center *(d)* must not exceed the capacity of the foodstuff supplier *(p)*. Equation (17)

d. The number of foodstuff products *(m)* sent from the foodstuff supplier (p) to the distribution center *(d)* must not be greater than the number of foodstuff products sent from the distribution center *(d)* to the consumer *(k)*. Equation (18)

e. The number of foodstuff products *(m)* sent from the distribution center *(d)* to consumers *(k)* must not exceed the distribution center capacity *(d)*. Equation (19).

f. The number of foodstuff products *(m)* sent from the distribution center *(d)* to consumers *(k)* must be able to meet the demand for food products *(m)* by consumers *(k)*. Equation (20)

g. The total initial inventory of food products (m) at the foodstuff supplier *(p)* consists of the initial inventory of food products (m) at the distribution center *(d)* added by the amount of production at the foodstuff supplier *(p)* and subtracting the number of food products (m) to be sent from the food supplier *(p)* to the distribution center *(d)*. Equation (21)

h. The total initial inventory of food products *(m)* in the distribution center *(d)* consists of the initial inventory of the distribution center *(d)* added by the number of food products *(m)* to be sent from the food supplier *(p)* to the distribution center *(d)* reduced number of foodstuff products *(m)* sent from distribution center *(d)* to consumers *(k)*. Equation (22)

i. The range of values for binary variables uses binary integer numbers, namely 0 and 1. Equation (23)

4. Modeling

The formulation of an optimization model for planning and managing the distribution network of the supply chain for foodstuffs from agricultural commodities used for optimal planning and decision making, the model structure is in the form of a mathematical program model, which in general can be formulated as:

Minimum $$v = w(x) \qquad (11)$$

with constraints $$h(x) = J \qquad (12)$$

$$x \geq 0 \qquad (13)$$

The expression (11) states an objective function which in this case will minimize the function $w(x)$ Usually in reality there are always limitations to the decision variables x Equation (12) expresses these limitations. Meanwhile, statement (13) is to limit that all values of the decision variable must be non-negative. In this condition variable x also called a continuous variable, which is a variable that can take all the values in the *n* dimensional real number space (written R^n).

In the matter of planning and managing the distribution network of the fish resources supply chain to be resolved in addition to continuous variables, there are also binary variables, namely variables that can be 1 (yes) or 0 (no). At the beginning of modeling the objective function is formulated first, then the constraint function.

5. Model implementation and simulation

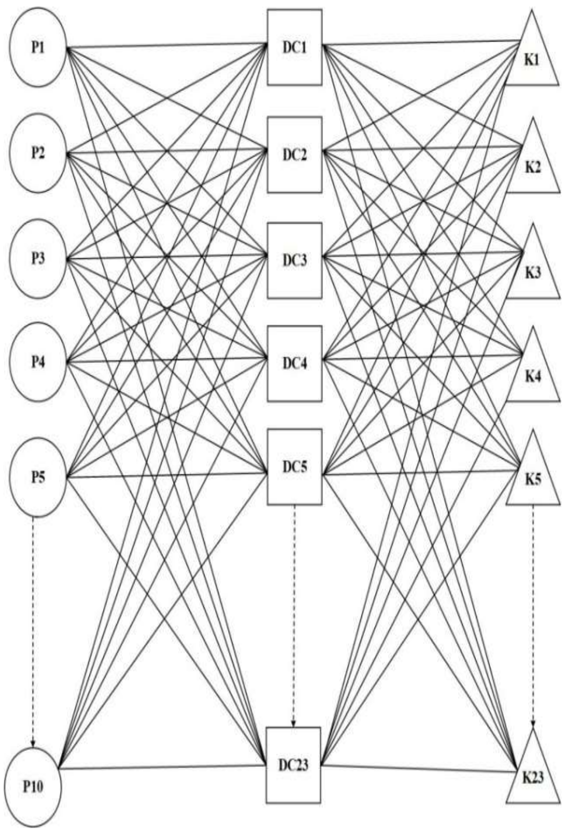
Implementation or testing of this model to find out that the model is good as desired. The goal is to provide information if there is an error in the model so that you can immediately find a solution which parts need to be repaired. Model simulation using the Linear Interactive and Discreate Optimizer (LINDO) application.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

5. RESULT AND DISCUSSION

5.1 Model Formulation

The mathematical formulation model built is based on the agricultural commodity supply chain planning model which consists of 10 food supply places, for distribution centers and consumers consisting of 23 sub-districts in North Aceh district, as shown in Figure 2.



P1..P10 :Supplier
DC1..DC23: Distribution Center
K1..K23: Consumer

Figure 2: Food supply chain network

There are several types of foodstuffs that will be distributed to sub-districts in North Aceh district, namely: rice, corn, soybeans, peanuts and green beans. This type of foodstuff is stated in the form of an index $|\ell = \in 1, .., M|$. Each type of foodstuff is assumed to take the supply chain diagram as shown in the picture above. The formulations used in modeling the optimization of supply chain networks in the distribution of agricultural foodstuffs are as follows:

1) Set

P Set of Supplier, with index p
D Set of Distribution Centers, with index d
K Set of Consumer, with index k
M Set of Product (Type of food), with index m
V Set of Vehicle Routes, with index v

2) Parameter

BT_{pd}^{vm} Cost of transporting the product using the route $v \in V$ from the supplier $p \in P$ to the distribution center $d \in D$.
BT_{vm}^{dk} Cost of transportation The product uses the route $v \in V$ from the distribution center $d \in D$ to consumers $k \in K$.
C_{pm} Operating costs for product storage at suppliers $p \in P$.
C_{md} Costs for operational storage of products at Distribution Centers $d \in D$.
BT_p Costs associated with supplier selection $p \in P$
BT_{pv} Transportation costs associated with suppliers $p \in P$ through the route $v \in V$
KP_p Supplier capacity $p \in P$ (Ton)
KD_d Distribution center capacity $d \in D$ (Ton)
JP_p^m Product production amount $m \in M$ by the supplier$p \in P$
PP_k^m Product request $m \in M$ by consumers $k \in K$

3) Decision variable

R_{pd}^{vm} Product Amount $m \in M$ will be sent from the supplier $p \in P$ to the distribution center $d \in D$ through the route $v \in V$
S_{vm}^{dk} Product Amount $m \in M$ will be sent from the distribution center $d \in D$ to consumers $k \in K$ through the route $v \in V$
PA_{pm} Initial product inventory $m \in M$ at the supplier $p \in P$
PA_{md} Initial product inventory $m \in M$ at the distribution center $d \in D$

4) Binary variable

a_{kpv} Binary variable worth 1, if consumers $k \in K$ visited from suppliers $p \in P$ use the route $v \in$ V, is worth 0 if not.
X_p Binary variable worth 1, if a supplier $p \in P$ selected, is worth 0 if not.
Y_{pv} Binary variable worth 1, if route $v \in V$ used to visit suppliers $p \in P$, is worth 0 if not.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

5.2 Data Collection

The research data used are numerical data in the form of a matrix to support the process of making the model and provide a mathematical objective function of the objective model. Data is taken from the minimum set of function matrices as follows:

Table 1: The Function $\sum_{P\in P} Bt_P X_P$ States The Cost For Selecting Suppliers

BT- Xp	p=1	p=2	p=3	p=4	p=5
x = 1	2	2	2	1	4
x = 2	2	3	5	5	2
x = 3	2	5	1	5	1
x = 4	1	2	5	1	5
x = 5	1	3	5	5	4
In units of 10.000					

Table 2: The Function $\sum_{P\in P}\sum_{V\in V} Bt_{Pv} Y_{Pv}$ States The Transportation Costs To Suppliers By Route

BT- pv	v=1	v=2	v=3	v=4	v=5
p =1	3	3	3	3	2
p =2	3	4	1	4	5
p =3	4	3	5	1	5
p =4	3	4	3	5	5
p =5	3	3	3	4	5
In units of 10,000					

Table 3: The Function $\sum_{P\in P}\sum_{D\in D}\sum_{M\in M}\sum_{V\in V} Bt_{Pd}^{Vm} R_{Pd}^{Vm}$ States The Transportation Costs From Suppliers To The Distribution Center

BT- pd	d=1	d=2	d=3	d=4	d=5
p =1	4	4	4	1	2
p =2	5	5	5	4	5
p =3	5	1	3	2	2
p =4	3	5	4	2	5
p =5	3	1	5	3	5
In units of 10,000					

Table 4: The Function $\sum_{D\in D}\sum_{K\in K}\sum_{M\in M}\sum_{V\in V} Bt_{Vm}^{Dk} S_{Vm}^{Dk}$ States The Transportation Costs From Distribution Center To Consumers

BT- dk	k=1	k=2	k=3	k=4	k=5
d =1	4	4	5	1	5
d =2	3	2	1	1	2
d =3	5	5	1	2	1
d =4	3	3	2	5	4
d =5	4	2	1	4	3
In units of 10,000					

Table 5: The Function $\sum_{P\in P}\sum_{M\in M} C_{Pm} Pa_{Pm}$ States The Product Inventory Operational Costs To The Supplier

BT- pm	m=1	m=2	m=3	m=4	m=5
p = 1	3	3	4	1	3
p = 2	4	5	2	5	2
p = 3	5	5	3	3	5
p = 4	4	2	3	3	2
p = 5	1	3	1	4	4
In units of 10,000					

Table 6: The Function $\sum_{D\in D}\sum_{M\in M} C_{Md} Pa_{Md}$ States The Product Inventory Operational Costs To The Distribution Center

BT- dm	m=1	m=2	m=3	m=4	m=5
d = 1	2	2	4	5	3
d = 2	1	1	5	1	2
d = 3	5	2	4	2	1
d = 4	1	1	2	2	2
d = 5	3	5	2	3	4
In units of 10,000					

5.3 Optimization Model

The following is the objective model function and the model constraint function for the distribution network of the food supply chain from agricultural commodities.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

$$Minimum \sum_{p\in P} BT_p X_p + \sum_{p\in P}\sum_{v\in V} BT_{pv} Y_{pv} + \sum_{p\in P}\sum_{d\in D}\sum_{m\in M}\sum_{v\in V} BT_{pd}^{vm} R_{pd}^{vm} + \sum_{d\in D}\sum_{k\in K}\sum_{m\in M}\sum_{v\in V} BT_{vm}^{dk} S_{vm}^{dk} + \sum_{p\in P}\sum_{m\in M} C_{pm} PA_{pm} + \sum_{m\in M}\sum_{d\in D} C_{md} PA_{md} \quad (14)$$

$$\sum_{p\in P}\sum_{v\in V} a_{kpv} Y_{kpv} = 1 \ \forall k \in K \quad (15)$$

$$X_p - Y_{pv} \geq 0 \ \ \forall p \in P, v \in V \quad (16)$$

$$\sum_{p\in P}\sum_{m\in M} R_{pd}^{m} \leq \sum_{p\in P}\sum_{m\in M} KP_{pd}^{m} \qquad \forall d \in D \quad (17)$$

$$\sum_{p\in P}\sum_{m\in M} R_{pd}^{m} \geq \sum_{d\in D}\sum_{m\in M} S_{dk}^{m} \qquad \forall_k \in K \quad (18)$$

$$\sum_{d\in D}\sum_{m\in M} S_{m}^{dk} \leq \sum_{d\in D}\sum_{m\in M} KD_{m}^{d} \qquad \forall k \in K \quad (19)$$

$$\sum_{k\in K}\sum_{m\in M} S_{m}^{dk} = \sum_{k\in K}\sum_{m\in M} PP_{m}^{k} \qquad \forall d \in D \quad (20)$$

$$\sum_{p\in P}\sum_{m\in M} PA_{p}^{m} = \sum_{d\in D}\sum_{m\in M} PA_{d}^{m} + \sum_{p\in P}\sum_{m\in M} JP_{p}^{m} - \sum_{p\in P}\sum_{m\in M} R_{pd}^{m} \ \ \forall_d \in D \quad (21)$$

$$\sum_{d\in D}\sum_{m\in M} PA_{d}^{m} = \sum_{d\in D}\sum_{m\in M} PA_{d}^{m} + \sum_{p\in P}\sum_{m\in M} R_{pd}^{m} - \sum_{d\in D}\sum_{m\in M} S_{m}^{dk} \ \ \forall_k \in K \quad (22)$$

$$R_{pd}^{vm}, S_{\leq dk}^{vm}, PA_{pm}, PA_{pd} \geq 0 \qquad \forall p \in P, d \in D, m \in M, v \in V \quad (23)$$

Equations (14) to equation (23) are an optimization model for the food supply chain distribution network.

5.4 Mathematical Computation Model

To perform mathematical modeling calculations in this study using the Linear Interactive and Discrete Optimizer (LINDO) modeling application. The following is attached a mathematical calculation model to minimize the cost of selecting supplier locations from several existing suppliers, minimizing transportation costs to the supplier's place by using the chosen route, minimizing transportation costs from the chosen supplier's place to the distribution center by using the route, minimizing transportation costs from distribution center to consumers by using the route, minimizing product inventory costs at selected supplier locations, minimizing product inventory costs at selected distribution center locations.

Supplier (p) selection costs
2xp10 + 2xp11 + 2xp12 + 1xp13 + 4xp14
+ 2xp20 + 3xp21 + 5xp22 + 5xp23 + 2xp24
+ 2xp30 + 5xp31 + 1xp32 + 5xp33 + 1xp34
+ 1xp40 + 2xp41 + 5xp42 + 1xp43 + 5xp44
+ 1xp50 + 3xp51 + 5xp52 + 5xp53 + 4xp54

Transportation costs to suppliers (p) by route (v)
+ 3pv10 + 3pv11 + 3pv12 + 3pv13 + 2pv14
+ 3pv20 + 4pv21 + 1pv22 + 4pv23 + 5pv24
+ 4pv30 + 3pv31 + 5pv32 + 1pv33 + 5pv34
+ 3pv40 + 4pv41 + 3pv42 + 5pv43 + 5pv44
+ 3pv50 + 3pv51 + 3pv52 + 4pv53 + 5pv54

Transportation costs from suppliers (p) to distribution center (d)
+ 4pd10 + 4pd11 + 4pd12 + 1pd13 + 2pd14
+ 5pd20 + 5pd21 + 5pd22 + 4pd23 + 5pd24
+ 5pd30 + 1pd31 + 3pd32 + 2pd33 + 2pd34
+ 3pd40 + 5pd41 + 4pd42 + 2pd43 + 5pd44
+ 3pd50 + 1pd51 + 5pd52 + 3pd53 + 5pd54

Transportation costs from distribution center (d) to consumer (k)
+ 4pk10 + 4pk11 + 5pk12 + 1pk13 + 5pk14
+ 5pk20 + 2pk21 + 1pk22 + 1pk23 + 2pk24
+ 5pk30 + 5pk31 + 1pk32 + 2pk33 + 1pk34
+ 3pk40 + 3pk41 + 2pk42 + 5pk43 + 4pk44
+ 3pk50 + 2pk51 + 1pk52 + 4pk53 + 3pk54

Product inventory operating costs (m) to suppliers (p)
+ 3pm10 + 3pm11 + 4pm12 + 1pm13 + 3pm14
+ 4pm20 + 5pm21 + 2pm22 + 5pm23 + 2pm24
+ 5pm30 + 5pm31 + 3pm32 + 3pm33 + 5pm34
+ 4pm40 + 2pm41 + 3pm42 + 3pm43 + 2pm44
+ 1pm50 + 3pm51 + 1pm52 + 4pm53 + 4pm54

Product inventory operating costs (m) at the distribution center (d)
+ 2dm10 + 2dm11 + 4dm12 + 5dm13 + 3dm14
+ 1dm20 + 1dm21 + 5dm22 + 1dm23 + 2dm24
+ 5dm30 + 2dm31 + 4dm32 + 2dm33 + 1dm34
+ 1 dm40 + 1dm41 + 2dm42 + 2dm43 + 2dm44
+ 3dm50 + 5dm51 + 2dm52 + 3dm53 + 4dm54

State that each supplier (p) using route (v) visit the selected consumer (k)
pv10 + pv11 + pv12 + pv13 + pv14 =1
pv20 + pv21 + pv22 + pv23 + pv24 =1
pv30 + pv31 + pv32 + pv33 + pv34 =1
pv40 + pv41 + pv42 + pv43 + pv44 =1
pv50 + pv51 + pv52 + pv53 + pv54 =1

Journal of Theoretical and Applied Information Technology
31st January 2021. Vol.99. No 2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

State that each supplier (p) using route (v) to visit the facility must be greater or equal zero
pv10 + pv11 + pv12 + pv13 + pv14 - pv10 - pv11 - pv12 - pv13 - pv14 <= 0
pv20 + pv21 + pv22 + pv23 + pv24 - pv20 - pv21 - pv22 - pv23 - pv24 <= 0
pv30 + pv31 + pv32 + pv33 + pv34 - pv30 - pv31 - pv32 - pv33 - pv34 <= 0
pv40 + pv41 + pv42 + pv43 + pv44 - pv40 - pv41 - pv42 - pv43 - pv44 <= 0
pv50 + pv51 + pv52 + pv53 + pv54 - pv50 - pv51 - pv52 - pv53 - pv54 <= 0

States that the number of products (m) sent from suppliers (p) to distribution center (d) must not be greater that the number of products (m) sent from distribution center (d) to consumer (k)
4 pd10 >= 2 dm10
4 pd11 >= 2 dm11
4 pd12 >= 4 dm12
1 pd13 >= 5 dm13
2 pd14 >= 3 dm14

From the results of model testing with LINDO software, information is obtained that the maximum value of the objective function is 36.00000 in the 15th iteration step.

LP OPTIMUM FOUND AT STEP 15
OBJECTIVE FUNCTION VALUE
1) 36.00000

Table 7: Value of Optimal Decision Variable

VARIABLE	VALUE	REDUCED COST
XP11	0.000000	2.000000
XP12	0.000000	2.000000
XP13	0.000000	2.000000
XP14	0.000000	1.000000
XP15	0.000000	4.000000
XP21	0.000000	2.000000
XP22	0.000000	3.000000
XP23	0.000000	5.000000
XP24	0.000000	5.000000
XP25	0.000000	2.000000
XP31	0.000000	2.000000
XP32	0.000000	5.000000
XP33	0.000000	1.000000
XP34	0.000000	5.000000
XP35	0.000000	1.000000
PV11	0.000000	1.000000
PV12	0.000000	1.000000
PV13	0.000000	1.000000
PV14	0.000000	1.000000
PV15	1.000000	0.000000
PV21	0.000000	2.000000
PV22	0.000000	3.000000
PV23	1.000000	0.000000
PV24	0.000000	3.000000
PV25	0.000000	4.000000
PV31	0.000000	3.000000
PV32	0.000000	2.000000
PV33	0.000000	4.000000
PV34	1.000000	0.000000
PV35	0.000000	4.000000
PD11	0.500000	0.000000
PD12	0.500000	0.000000
PD13	1.000000	0.000000
PD14	5.000000	0.000000
PD15	1.500000	0.000000
PD21	0.000000	5.000000
PD22	0.000000	5.000000
PD23	0.000000	5.000000
PD24	0.000000	4.000000
PD25	0.000000	5.000000
PD31	0.000000	5.000000
PD32	0.000000	1.000000
PD33	0.000000	3.000000
PD34	0.000000	2.000000
PD35	0.000000	2.000000
PK11	0.000000	4.000000
PK12	0.000000	4.000000
PK13	0.000000	5.000000
PK14	0.000000	1.000000
PK15	0.000000	5.000000
PK21	0.000000	5.000000
PK22	0.000000	2.000000
PK23	0.000000	1.000000
PK24	0.000000	1.000000
PK25	0.000000	2.000000
PK31	0.000000	5.000000
PK32	0.000000	5.000000
PK33	0.000000	1.000000
PK34	0.000000	2.000000
PK35	0.000000	1.000000
PK45	0.000000	4.000000
PK51	0.000000	3.000000
PM11	0.000000	3.000000
PM12	0.000000	3.000000
PM13	0.000000	4.000000
PM14	0.000000	1.000000
PM15	0.000000	3.000000
PM21	0.000000	4.000000
PM22	0.000000	5.000000
PM23	0.000000	2.000000
PM24	0.000000	5.000000

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

PM25	0.000000	2.000000
PM31	0.000000	5.000000
PM32	0.000000	5.000000
PM33	0.000000	3.000000
PM34	0.000000	3.000000
PM35	0.000000	5.000000
DM11	0.000000	2.000000
DM12	0.000000	2.000000
DM13	0.000000	4.000000
DM14	0.000000	5.000000
DM15	0.000000	3.000000
DM21	0.000000	1.000000
DM22	0.000000	1.000000
DM23	0.000000	5.000000
DM24	0.000000	1.000000
DM25	0.000000	2.000000
DM31	0.000000	5.000000
DM32	0.000000	2.000000
DM33	0.000000	4.000000
DM34	0.000000	2.000000
DM35	0.000000	1.000000

6. CONCLUSIONS

This study produces an optimization model for planning and managing the supply chain for agricultural commodities, particularly foodstuffs. The supply chain network proposed in this study includes three levels of distribution networks, namely suppliers, distribution centers and consumers. to anticipate uncertainty in supply, this problem also adds inventory problems. The new model produced is a model for minimizing transportation costs to suppliers, minimizing transportation costs from suppliers to distribution centers and minimizing transportation costs from distribution centers to consumers, as well as minimizing product supply costs at suppliers and distribution centers. the resulting model is part of the mixed integer linear programming form with a robust optimization approach. The form of this number is found in supplier selection and route selection using binary variables (0,1). From the results of model testing with LINDO software, information is obtained that the maximum value of the objective function is 36.00000 in the 15th iteration step.

REFRENCES:

[1] Nurdin, M. Zarlis, Tulus and S. Efendi, "Mixed Integer Linear Programming Model for Integrated Fish Supply Chain Planning" *Journal of Theoretical and Applied Information Technolog.*, Vol.98, No.12, 2020, pp. 2017-2028.

[2] Nurdin, M. Zarlis, Tulus and S. Efendi, "Data Driven Optimization Approach to Fish Resources Supply Chain Planning in Aceh Province", *IOP Conf. Series: Journal of Physics: Conf. Series* 1255 (2019) 012081, 2019.

[3] BPS Aceh., Aceh Dalam Angka., Propinsi Aceh, 2016.

[4] C. Shepherd, and H. Günter, " supply chain performance: current research and future directions". *International Journal of Productivity and Performance Management,* Vol.55, No.3, 2005, pp. 242-258.

[5] J. Xu, Y. He, and M. Gen., "A class of random fuzzy programming and its application to supply chain design". *Computers and Industrial Engineering*, Vol. 56, No. 3, 2009, pp. 937-950.

[6] V. F. N. Yu., M. E. Normasari., and H. T. Luong, Integrated location-production-distribution planning in a multiproducts supply chain network design model, *Mathematical Problems in Engineering,* 2015, Article ID 473172, pp. 1-13.

[7] L. A. S. Santa-Eulalia, J. M. Damours, C. C. Frayret, R. C. Menegusso, and Azevedo., "Advanced Supply Chain Planning Systems (APS) Today and Tomorrow". *In Supply Chain Management– Pathways for Research and Practice (D. ONKAL, ED.), InTech, Croatia.,* 2011.

[8] T. Schoenmeyr, "Strategic inventory placement in multi-echelon supply chains: Three essays". PhD. Thesis, Massachusetts Institute of Technology, United States, 2008.

[9] C. Vercellis. "Business Intelligence: Data Mining and Optimization for Decision Making". John Wiley and Sons, United Kingdom, 2009.

[10] D. M. Carlsson, and Ronnqvist., "Supply chain management in forestry – Case studies at Sodra Cell AB". *European Journal of Operational Research*, Vol. 163, 2005, pp. 589–616.

[11] A. Ruszczynski, and A. Shapiro, "Stochastic programming". *Handbooks in operations research and management science*, Vol. 10, 2003.

[12] S. Sen, and J. Higle, "Introductory tutorial on stochastic linear programming models". *Interfaces*, Vol.29, No.2,1999, pp.33-61.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[13] J. M. Mulvey, R. J. Vanderbei, and S. A. Zenios, "Robust Optimization of large-scale system". *Operations Research*, Vol. 43, No.2, 1995, pp. 264-281.

[14] A. Ben-Tal, and A. Nemirovski, "Robust Optimization Methodolog yand Applications". *Mathematical Programming,* Vol. 92, No. 3, 2002, pp. 453-480.

[15] D. Bertsimas, and M. Sim, "The price of robustness". *Operations Research*, Vol. 52, No.1, 2004, pp. 35–53.

[16] D. Bertsimas, and A. Tiele, "A Robust Optimization Approach to Supply chain management". *Operations Research*, Vol. 52, No. 1, 2004, pp. 86–100.

[17] Nurdin, Taufiq, and Fajriana. "Searching the shortest route for distribution of LPG in Medan City using ant colony algorithm". IOP Conf. Series: Materials Science and Engineering, 725 (2020) 012121, 2020.

[18] V. Gabrel, C. Murat, and A. Thiele, "Recent Advances in Robust Optimization, an Overview". *European Jornal of Operations Research*, Vol. 235, No.3, 2014, pp. 471-483.

[19] D. Bertsimas, and M. Sim, "Robust Discrete Optimization and Network Flows". *Mathematical Programming,* Vol. 98, No1, 2003, pp. 49–71.

[20] A. Ben-Tal, and A. Nemirovski, "Robust Solutions of Linear Programming Problems Contaminated with Uncertain Data". *Mathematical Programming*, Vol. 88, No. 3, 2000, pp. 411-424.

[21] A. Ben-Tal, L. El Ghaoui, and A. Nemirovski, "Robust Optimization, Princeton University Press", Princeton Series in Applied Mathematics, 2009.

[22] D. Chaerani, and C. Roos, "Handling Optimization under Uncertainty Problem Using Robust Counterpart Methodology". *Jurnal Teknik Industri,* Vol. 15, No.2 , 2013, pp. 111-118.

[23] Firmansyah and H. Mawengkang " Fish Processed Production Planning Using in teger stochastic progamming model". *Procedings of the fourth Global Conference on power control and optimization. American Institute of physics*, 2011