Integrated Supply Chain Model of Distribution Regionalization and Network Optimization of White Crystal Sugar Traditional Market

Yosi A. Hidayat, Sutandi, and Endra Joelianto

Abstract—**White sugar is a strategic commodity that is distributed within traditional market in Indonesia. We propose an integrated supply chain model of regionalization distribution and network optimization of traditional market white crystal sugar commodity. The supply chain total cost is defined as the performance criteria for the developed Mixed-Integer Linear Programming (MILP) model. From the experimental result, our proposed model successfully reduces the total supply chain costs by 31% compared with the existing condition of the traditional market distribution network after considering 11% increase of warehouse capacity This even lower or more competitive than the existing modern markets distribution network. From the sensitivity analysis, it is found that fixed cost and the increase of demand are insensitive to model solution. On the other hand, handling cost and the decrease of demand are sensitive with moderate degree of influence, to change the decision to close existing facilities, where transportation cost is sensitive with moderate degree of influence, to change the decision to open a new facility. On extreme condition, the increase in warehouse capacity is very sensitive, to change the decision to close existing facilities. With a 67% increase in distributor warehouse capacity, it will dramatically eliminate sub distributors in all regions.**

Index Terms— **supply chain, network modeling, traditional market, white crystal sugar, facility-location planning.**

I. Introduction

THE retail industry is a strategic industry in its contribution to the economy of Indonesia. Based on the structure of Gross Domestic Product (GDP) according to the business field of 2008-2020, the trade sector contributes to GDP of about 13% and based on employment data, the trade sector contributes 24 million workers (21.30%) of 112.8 million working people [1]. The traditional markets employ 12.625 million traders spreading across 13,540 units of traditional markets. Currently, the growth of modern markets in various major cities in Indonesia has penetrated remote areas. Within these 4 years, the number of traditional markets dropped dramatically from 13,540 to 9,950, indicating that 3,800 of them have disappeared. These data reflect that the position of traditional markets in people's lives is increasingly worrying for small traders, plus currently traditional markets are growing slowly by 8.1% while modern markets are growing by 31.4% [2]. During the Covid-19 pandemic, the turnover of traders in traditional markets fell by 40% on average and followed by decrease in the number of traders by 29%.

The traditional market is physically close to the life of the community and depicts a thick and harmonious social life between buyers and sellers due to repeated and deep interactions with natural competitive advantages. The role of this traditional market is very beneficial for the lives of mid-lower income society, especially in rural area who depend on their life in trading activities.

The eradication of large-scale retail trade business and large trade from negative list for foreign investment makes the growth of modern market to increase rapidly and to start giving negative impacts to the existence of traditional markets [2]. These can be seen from the share of fast-moving consumer goods (FMCG) product trading in modern retail and traditional market during the last 10 years. Modern retail share increased from 25% in 2002 to 41% in 2010. As for the traditional markets, there was a decline in trading share from 75% in 2002 to 59% in 2010, or a decrease of about 2% per year [3].

Various government programs have been undertaken to improve the performance since 2003 through the Ministry of Trade and Ministry of Cooperative, Small and Medium Enterprises. In 2007 and 2008, the government issued Presidential Regulation No. 112 of 2007 and Regulation of Minister of Trade No. 53 of 2008 which regulate traditional and modern retails, especially related to zoning which limits modern market development and reduces its impact on traditional markets, and also discusses about opening hours, licensing up to trading terms.

Traditional markets have a long supply chain network system that reaches 6 (six) echelons that impacts on several stages of commodity transfer of ownership. With the commodity transfer of ownership, there are costs incurred for each movement of goods occurring in the supply chain,

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such as distribution cost and profit margin on each distribution actor. These results in the inefficiency of the distribution channel and the selling price of goods will increase in the final level.

Traditional market supply chain system is related to accessibility, infrastructure, and network of distribution facilities, supply chains through markets, stability and price disparities. By improving the performance, the traditional market supply chain is expected to compete with the modern market.

Sugar is one of the important commodities that are used in agricultural sector. In 2001, Indonesia's government transformed the sugar's industry from a regulated industry to an open industry that caused the misleading of sugar's distribution and pricing. Based on that fact, sugar is becoming the strategic consumption commodity for the Indonesia. Nowadays, Indonesia's government is giving large attention and focusing in subsidized factor and the arrangement of distribution system of sugar commodity.

In 2003, according to the Industrial and Trading Minister Policy No. 70/MPP/KEP//2003 [4] about the procurement and distribution of subsidized fertilizer, the government made a rearrangement to the pattern of those core activities. The used pattern is the regionalization distribution for each sugar's producer. The impact of this pattern is to the marketing, sales, and distribution activities that are done independently by each of the sugar's producer in Indonesia. The producers are distributing their products via warehouses in various areas that have been allocated to serve independent sugar's wholesalers.

Subsequently, these distributors will distribute the products to the retailers, and finally, the retailers distribute them to the end customers. The outcome from this decentralized regionalization is the fluctuated distribution that causes the sugar shortage and eventually admitting the high price of this important commodity to the end consumers.

Sugar commodity is one of the basic necessities where the dynamics of the price directly affect the inflation rate. The impact of scarcity of supply and inefficiency of domestic sugar distribution network cause an upsurge in domestic sugar prices. According to Indonesian Statistics Bureau, during the period of 2006-2020, the sugar price has increased by an average of 10-21.28% each year.

The mechanism of forming the final price to the consumer cannot be separated from the activities carried out to distribute goods from the production place to the sales location in order to reach consumers. Since each distribution actor expects profit from the activities performed, the final sale price of an item is the total cost incurred during the procurement and distribution process. For that purpose, it is necessary to make improvements in the process of business trading activities. Improvement can be made by structuring the network structure of the supply chains which involved actors, infrastructure, trade and governance systems, to produce an efficient supply chain system at an affordable cost to the community consisting of consumers and business actors. The purpose of supply chain improvement is to provide an affordable price for consumers and to increase profit margins for business actors.

II. Literature Study

Supply chain is a series of activities in transferring raw materials from the initial or upstream supplier to the end customer [5]. Supply chain management includes the activities of providing raw materials, production scheduling, and distribution systems supported by the flow of information [6]. As is known, the supply chain is divided into two structures, namely upstream and downstream. Each structure has many stakeholders, whether as an organizations, groups, or individuals [5]. The biggest challenge in managing supply chains is the management of information flow to uphold collaboration between stakeholders [7][8]. Then integration is needed to reduce supply costs and increase customer satisfaction [9].

A successful arrangement of supply chain management is to integrate material procurement activities, intermediate goods and final products transformation, and delivery to customers [10]. Procurement, production, and distribution are three fundamental processes involved in supply chain management [11]. A supply chain network shows a group of facilities that are geographically dispersed and linked by transportation modes in connecting these facilities [12]. In many cases, manufacturers as focal companies face some problems to coordinate directly with their distributors as the intermediaries to link the manufacturers to their customers. While, the design of co-ordination processes of suppliers-manufacturer-distributors-retailers-customers is important for successful supply chain management [13][14], it is vital for the company and its suppliers to live up to new logistics system.

Logistics system is related to a group of activities that repeated in one path where the raw materials have been changed into finished products that give added value from customer's point of view. The rearrangement that results more efficiency in logistics system impacts to the production cost reduction, product quality improvement, and higher customer service level. A company's product is seen by customer as a combination of price, quality, and services [15]. Price is the function of production and distribution process efficiency. Later on, it is stated that the tremendous technology development has reduced the manufacturing cost until 40% compared with 30 years ago [16]. Logistics system's efficiency improvement can be done by the time the increased integration between functions that involved in the creation of product and or services. This approach is known as integrated logistics. Next, the flow of product and or service creation from raw material until its end customer will involve several echelons such as producers, distributors, depots, retailers, and others. The integrated outbound activities model development related to goods shipment from producers to end customers for three echelons case has been developed in [17]. The model consists of one production unit, one depot, and multi retailers. Hidayat *et. al.* in [18] developed this model for situation where producers are possible to deliver products directly to their retailers using flexible ordering system. Yurisulhikmah and Hidayat in [19] has also developed model for multi-producers, multi-warehouses, and multi retailers. Next, Han in [20] has developed multi sourcing inventory model of two echelons for company which has multi depots and multi retailers. Vidal and Goetschalckx in [21] integrate internal/inbound and outbound logistics activities. The proposed research is a part of analytical approach taxonomy for production-distribution system, according to the mapping of this type of system done with the work in [22].

Research on the improvement of distribution channel is related to the determination of depot location/warehouse on the three echelons of chain system conducted in [23], and further, Hidayat *et al.* [24] conducted a research by developing mathematical model for the determination of the facility location and transportation fleet.

The previous studies do not facilitate the condition of the traditional market distribution channels for sugar commodity. This is because: first, the number of echelons in the distribution channel of white crystal sugar reaches 5 (five) echelons. Second, the system connectivity is present in each entity of channeling agency. The third is a constraint related to the distribution range of an entity of channeling agency. A distribution range constraint is also required because the ability of each entity of the channeling agency is different and each will choose the most rational choice based on its own ability. This is in accordance with the concept of last mile delivery because it only serves consumers in a certain radius. The paper considers the increasing efficiency in white crystal sugar supply chain in West Java Province by developing a model of supply chain network to minimize the total cost of white crystal sugar distribution from producer/factory to traditional market.

III. System Analysis

A. System description

The object of this research is the supply chain system in the traditional market for white crystal sugar commodity in West Java Province. At present, the supply chains in traditional markets are not well managed so that traditional market has not been able to compete with modern markets that have implemented an efficient and integrated supply chain system. The system under discussion is an open system because there is an interaction between systems, where the behavior of demand from consumers will affect the performance behavior of the system. This system is categorized as a deterministic system since the system inputs are known and predictable. Similarly, the system parameters are be given. We propose to design a traditional market supply chain system for white crystal sugar commodities ranging from sugar factory, distributors, to traditional markets.

B. Environment

Environment is the elements that are outside the system but have an influence on the performance of the system studied. Factors of consumers that may affect system performance consist of 2 (two) things. The first is the value of demand which is defined as the amount of white crystal sugar needed by every City/District in Indonesia. The second is the pattern of demand which reflects the behavior of demand from consumers. Consumer demand behavior is strongly influenced by the increasing needs of consumers at certain moments, especially during Christmas and Ied-Fitr.

C. Object of study

Objects are entities within the system that each has a particular function and purpose which are interconnected between the entities to form interactions. The objects within the system are:

a. Sugar Factory is a sugar factory owned by Indonesia Government Sugar State-Holding-Company consisting of 5 (five) factories located in City-1 (one factory), City-2 (one factory), and City-3 (three factories).

b. Distributors are sugar distributors registered in the Department of Industry and Commerce of West Java Province. In this system, each City/District is represented by one distributor. There are 8 (eight) cities/districts that have registered as distributors. They are located in such as City-1, City-2, City-3, City-6, City-7, City-8, City-10, City-14, and City-16.

c. Sub distributor is a sugar trader who buys sugar from distributor located in each city/district. It consists of 16 cities/districts.

d. Wholesaler is a sugar trader that exists in every city/district. It consists of 16 cities/districts.

e. Traditional market is retailers in traditional market in every city/district. It consists of 16 cities/districts.

Figure 1 describes the entity's relationship in the white crystal sugar commodity supply chain system.

IV. Model of Traditional market Supply Chain Network

A. Approach and model assumption

The model considered in the paper is a model of combining between transshipment model and facility planning model. Adjustment is made in the distribution network and cost component. The distribution network consists of 5 (five) echelons which are made based on the connections among all entities of channeling agencies and distribution range limits. The cost components consider the costs that affect the model, namely fixed cost to establish facilities, and transportation costs which include handling cost.

The assumptions used in the model are:

a. Each sugar factory is assumed to have one warehouse.
b. Each distributor is assumed to have one warehouse. Each city/district is represented by one distributor.
c. Each sub distributor is assumed to have one warehouse. Each city/district is represented by one sub distributor.
d. Each wholesaler is assumed to have one warehouse. Each city/district is represented by one wholesaler.
e. Transportation cost is the same between cities/districts.
f. Handling cost is the same between cities/districts.

B. Mathematical notation

The mathematical notations used in the model are:

Index Notation

i Notation for sugar factory, where i is the member I

j Notation for distributor, where j is the member of J
k Notation for sub distributor, where k is the member of K
l Notation for wholesaler, where l is the member of L
m Notation for traditional market, where m is the member of M
p Total warehouses at sugar factory
q Number of alternative areas of distributor warehouse
r Number of alternative areas of sub distributor warehouse
s Number of alternative areas of wholesaler warehouse
t Planning period
u Number of traditional market areas

Variable Notation

β_j Distributor warehouse capacity (j) [ton]
δ_l Wholesaler warehouse capacity (k) [ton]
γ_k Sub distributor warehouse capacity (k) [ton]
C_h Handling cost of goods [USD/ton]
C_t Transportation cost of goods from sugar factory warehouse (i) through distributor warehouse (j), sub distributor warehouse (k), wholesaler warehouse (l) to traditional market traders (m) [USD/Km/ton]
F_j Fixed cost of distributor [USD]
F_k Fixed cost of sub distributor [USD]
F_l Fixed cost of wholesaler [USD]
R_{ij} Land distance from sugar factory warehouse *(i)* to distributor warehouse *(j)* [Km]
R_{jk} Land distance from distributor warehouse *(j)* to sub distributor's warehouse *(k)* [Km]
R_{jl} Land distance from distributor warehouse *(j)* to wholesale warehouse *(l)* [Km]
R_{jm} Land distance from distributor warehouse *(j)* to traditional market trader warehouse *(m)* [Km]
R_{kl} Land distance from sub distributor's warehouse *(k)* to wholesaler's warehouse *(l)* [Km]
R_{km} Land distance from sub distributor warehouse *(k)* to traditional market trader warehouse *(m)* [Km]
R_{lm} Land distance from wholesaler warehouse *(l)* to traditional market trader's warehouse *(m)* [Km]

Variable Notation

D_{tm} Demand of each city/district on the traditional market in period (t)
S_i Maximum production capacity of white crystal sugar per year at sugar factory warehouse (i) [ton]

Decision Variable Notation

b_{jm} is a binary variable showing the relationship between distributor and traditional market. It has a value of 1 if the determined distance is near and zero if it is far.
b_{km} is a binary variable showing the relationship between sub distributor and traditional market. It has a value of 1 if the determined distance is near and zero if it is far.
b_{lm} is a binary variable showing the relationship between wholesale and traditional market. It has a value of 1 if the determined distance is near and zero if it is far.
W_j is a binary variable of decision to open a distributor j if it has a value of 1 and zero if it is not to open a distributor.
W_k is a binary variable of decision to open a sub distributor if it has a value of 1 and zero if it is not to open a sub distributor.
W_l is a binary variable of decision to open wholesale if it has a value of 1 and zero if it is not to open a wholesale.
x_{tij} Number of white crystal sugar units distributed over the time interval (t) from sugar factory warehouse (i) to distributor warehouse (j) [ton/period]
x_{tjk} Number of white crystal sugar units distributed over the time interval t from distributor warehouse (j) to sub distributor warehouse (k) [ton/period]
x_{tjl} Number of white crystal sugar units distributed over the time interval t from distributor warehouse (j) to wholesaler (l) [ton/period]
x_{tjm} Number of white crystal sugar units distributed over the time interval t from distributor warehouse (j) to traditional market trader (m) [ton/period]
x_{tkl} Number of white crystal sugar units distributed over the time interval (t) from sub distributor warehouse (k) to wholesaler warehouse (l) [ton/period]
x_{tkm} Number of white crystal sugar units distributed over the time interval (t) from sub distributor warehouse (k) to traditional market trader (m) [ton/period]
x_{tlm} Number of white crystal sugar units distributed over the time interval t from wholesaler warehouse (l) to traditional market trader (m) [ton/period]

C. Purpose Function

This mathematical model has a purpose function to minimize the total cost of logistics incurred on white crystal sugar supply chain to the traditional market traders, this total cost is represented by Z. This Z function [USD/year] minimizes the total cost for 1 (one) year consisting of fixed cost, distribution cost and handling cost on each echelon. The function is described in the following:

Z = Total Cost of Factory (TCa) + Total Cost of Distributor (TCb) + Total Cost of Sub distributor (TCc) + Total Cost of Wholesale (TCd)

Total cost of factory is handling cost of factory plus transportation cost of factory to distributor. Handling cost is the cost of handling/unit multiplied by the amount distributed. Transportation cost is the cost of transportation/km/ton multiplied by distance and multiplied by amount of ton of sugar distributed. Total cost of distributor consists of fixed cost, handling cost and transportation cost from distributor to sub distributor, from distributor to wholesaler, and from distributor to traditional market. Fixed cost is the cost to open and run a distribution business derived from investment cost within a certain time horizon.

Total cost of sub distributor consists of fixed cost, handling cost and transportation cost from sub distributor to wholesaler and from sub distributor to traditional market trader. The last is total cost of wholesale consisting of fixed cost, handling cost and transportation cost from wholesaler to traditional market traders.

D. Constraints

The followings are the new constraints acquired in the proposed model:

a. Constraint of conservation of the number of deliveries on each echelon.
b. Constraint of warehouse capacity on each echelon.
c. Constraint of Binary Number:
    1) Network constraint, there is a flow of products from supplier to retailer when there is a link between supplier and retailer.
    2) Binary constraint to determine whether a facility is opened or not.
    3) Binary constraint for regionalization.
d. All variables are non negative.

E. Final Model:

After performing model formulation, the model solution is searched through software. To be able to accommodate existing modeling problems and the amount of data involved, the LINGO 9 extended version software is used. Thus, the details of the traditional market supply chain model for a complete white crystal sugar commodity are shown as follow:

Minimize $\boldsymbol{Z = TC_a + TC_b + TC_c + TC_d}$ (1)

$$Z = \sum_{t=1}^{h}\sum_{i=1}^{p}\sum_{j=1}^{q} Ch_{ij}x_{tij} + \sum_{t=1}^{h}\sum_{i=1}^{p}\sum_{j=1}^{q} Ct_{ij}x_{tij}R_{tij} +$$

$$\left(\begin{array}{l}\sum_{t=1}^{h}\sum_{j=1}^{q} F_{tj}W_j + \sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{k=1}^{r} Ch_{jk}x_{tjk} + \sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{k=1}^{r} Ct_{jk}x_{tjk}R_{jk} + \\ \sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{l=1}^{s} Ch_{jl}x_{tjl} + \sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{l=1}^{s} Ct_{jl}x_{tjl}R_{jl} + \sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{m=1}^{u} Ch_{jm}x_{tjm} + \sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{m=1}^{u} Ct_{jm}x_{tjm}R_{jm}\end{array}\right) +$$

$$\left(\begin{array}{l}\sum_{t=1}^{h}\sum_{k=1}^{r} F_{tk}W_k + \\ \sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{l=1}^{s} Ch_{kl}x_{tkl} + \sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{l=1}^{s} Ct_{kl}x_{tkl}R_{kl} + \sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{m=1}^{u} Ch_{km}x_{tkm} + \sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{m=1}^{u} Ct_{km}x_{tkm}R_{km}\end{array}\right) +$$

$$\left(\sum_{t=1}^{h}\sum_{l=1}^{s} F_{tl}W_l + \sum_{t=1}^{h}\sum_{l=1}^{s}\sum_{m=1}^{u} Ch_{lm}x_{tlm} + \sum_{t=1}^{h}\sum_{l=1}^{s}\sum_{m=1}^{u} Ct_{lm}x_{tlm}R_{lm}\right) \quad (2)$$

Constraints :

$$\sum_{t=1}^{h}\sum_{i=1}^{p}\sum_{j=1}^{q} x_{tij} = \sum_{t=1}^{h}\sum_{i=1}^{p} S_{ti}, \ \forall\, t \epsilon h, i \epsilon p,\ j \epsilon q \quad (3)$$

$$\sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{m=1}^{u} x_{tjm} + \sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{k=1}^{r} x_{tjk} + \sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{l=1}^{s} x_{tjl} = \sum_{t=1}^{h}\sum_{i=1}^{p}\sum_{j=1}^{q} x_{tij}, \ \forall\, t \epsilon h,\ j \epsilon q, k \epsilon r,\ l \epsilon s, m \epsilon u \quad (4)$$

$$\sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{l=1}^{s} x_{tkl} + \sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{m=1}^{u} x_{tkm} = \sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{k=1}^{r} x_{tjk}, \ \forall\, t \epsilon h,\ j \epsilon q, k \epsilon r,\ l \epsilon s, m \epsilon u \quad (5)$$

$$\sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{l=1}^{s} x_{tkl} = \sum_{t=1}^{h}\sum_{l=1}^{s}\sum_{m=1}^{u} x_{tlm}, \ \forall\, t \epsilon h,\ j \epsilon q, k \epsilon r,\ l \epsilon s, m \epsilon u \quad (6)$$

$$\sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{m=1}^{u} x_{tjm} + \sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{m=1}^{u} x_{tkm} + \sum_{t=1}^{h}\sum_{l=1}^{s}\sum_{m=1}^{u} x_{tlm} \geq \sum_{t=1}^{h}\sum_{m=1}^{u} D_{tm}, \ \forall\, t \epsilon h,\ j \epsilon q, k \epsilon r,\ l \epsilon s,\ m \epsilon u \quad (7)$$

$$\sum_{t=1}^{h}\sum_{i=1}^{p}\sum_{j=1}^{q} x_{tij} \leq \beta_j W_j, \ \forall\, t \epsilon h, i \epsilon p,\ j \epsilon q \quad (8)$$

$$\sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{k=1}^{r} x_{tjk} \leq \gamma_k W_k, \ \forall\, t \epsilon h,\ j \epsilon q,\ k \epsilon r \quad (9)$$

$$\sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{l=1}^{s} x_{tjl} + \sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{l=1}^{s} x_{tkl} \leq \delta_l W_l, \ \forall\, t \epsilon h,\ j \epsilon q,\ k \epsilon r, l \epsilon s \quad (10)$$

$$\sum_{t=1}^{h}\sum_{m=1}^{u} D_{tm} b_{jm} \leq \beta_j, \ \forall\, t \epsilon h,\ j \epsilon q, m \epsilon \quad (11)$$

$$\sum_{t=1}^{h}\sum_{m=1}^{u} D_{tm} b_{km} \leq \gamma_k, \ \forall\, t \epsilon h,\ k \epsilon r,\ m \epsilon u \quad (12)$$

$$\sum_{t=1}^{h}\sum_{m=1}^{u} D_{tm} b_{lm} \leq \delta_l, \ \forall\, t \epsilon h, l \epsilon s, m \epsilon u \quad (13)$$

$$\sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{m=1}^{u} x_{tjm} \leq M b_{jm}, \ \forall\, t \epsilon h,\ j \epsilon q, m \epsilon u \quad (14)$$

$$\sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{m=1}^{u} x_{tkm} \leq M b_{km}, \ \forall\, t \epsilon h,\ k \epsilon r, m \epsilon u \quad (15)$$

$$\sum_{t=1}^{h}\sum_{l=1}^{s}\sum_{m=1}^{u} x_{tlm} \leq M b_{lm}, \ \forall\, t \epsilon h, l \epsilon s, m \epsilon u \quad (16)$$

$$Wj \in \{0,1\} \quad (17)$$

$$Wk \in \{0,1\} \quad (18)$$

$$Wl \in \{0,1\} \quad (19)$$

$$R_{jm} <= 60, \sum_{t=1}^{h}\sum_{j=1}^{q}\sum_{m=1}^{u} x_{tjm} * b_{jm},\ b_{jm} \in \{0,1\} \quad (20)$$

$$R_{km} <= 30, \sum_{t=1}^{h}\sum_{k=1}^{r}\sum_{m=1}^{u} x_{tkm} * b_{km},\ b_{km} \in \{0,1\} \quad (21)$$

$$R_{lm} <= 20, \sum_{t=1}^{h}\sum_{l=1}^{s}\sum_{m=1}^{u} x_{tlm} * b_{lm},\ b_{lm} \in \{0,1\} \quad (22)$$

$$x_{tij}, x_{tjk}, x_{tkl}, x_{tlm}, x_{tjm}, x_{tkm} >= 0 \quad (23)$$

V. NUMERICAL EXPERIMENT AND ANALYSIS

The data taken for numerical analysis come from a case study of white crystal sugar commodity in West Java Province, Indonesia. Model is categorized as a Mixed-Integer Linear Programming (MILP). In the calculation using the proposed model without considering warehouse capacity extension (namely Model 1), we obtain the optimum result that has a total cost of logistics of USD 12,012,786 per year. On the other hand, the calculation using the existing system of traditional market is resulted at USD 15,826,581 per year.

Thus, there is an expected cost reduction of USD 3,813,795 per year compared with the existing traditional market system. The comparison is shown in Figure 2.

However, when comparing the proposed model with the existing system of modern market, it is found that the proposed model is not cheaper than the modern market network model which has a total cost of logistics of USD 10,998,926 per year as shown in Figure 2. Therefore, to generate minimal cost, it is necessary to perform further analysis to the proposed model by means of sensitivity analysis on costs parameter, demand parameter, and warehouse capacity parameter.

From parameter sensitivity analysis, it is found that:

a. Fixed cost is insensitive to model solution because it must reach 101% to be able to change the decision to close the existing facilities.
b. Transportation cost is sensitive with moderate degree of influence, because the increase of transportation cost of 49.6% will change the decision to open a new facility.
c. Handling cost is sensitive with moderate degree of influence, because the increase of handling cost of 44.7% will change the decision to close existing facilities.
d. An increase in demand up to 100% does not change the decision to open a facility. While the decline in new demand will affect the decision to close existing facilities with a decrease of 50.5%. It can be analyzed that the decrease in demand affects the decision to close existing facilities with moderate influence rate.
e. The increase in warehouse capacity is very sensitive because a 3% increase in capacity of each distributor, sub distributor, and wholesale has influenced the decision to close existing facilities. The next is an analysis to find out whether an echelon can be eliminated by increasing the warehouse capacity on one or more echelons. With a 67% increase in distributor warehouse capacity, it will eliminate sub distributors in all regions.
f. The last is capacity analysis to decrease total cost of logistics so the traditional market can compete with the modern market. An increase in each warehouse capacity of 11% will result in a cost of USD 10,971,542. The result of proposed model is a 31% decrease in cost from the existing condition of traditional market distribution network that is shown in Figure 3. Therefore, the total cost of supply chain of the proposed model is even lower than the modern market distribution network.

As managerial implications, to implement the ideal system design, there should be policies that support system performance, including:

a. Regulation on the channeling agency and the number of facilities.
b. To realize the proposed model, it is necessary to regulate the right of distribution of white crystal sugar commodities. Distribution right may be awarded to distributor through an auction system.
c. Control at the central level is carried out by the Ministry of Trade and at the regional level by the Provincial and District Trade Office.
d. There is a need for cooperation between SOEs of sugar producers and SOEs of channeling agencies.
e. Increasing warehouse capacity is an effort to improve distribution performance.
f. In the process of conducting activities at channeling agency, it is necessary to have RVA (Real Value-added Activities), for example, the packaging process.

By adjusting the warehouse capacity (namely Model 2), it is found that for the distributors in all regions, 9 (nine) distributors, 3 (three) sub distributors in 3 (three) regions, *i.e.* Kuningan, Ciamis, and Majalengka are optimized to be opened. On the other hand, wholesale is only opened in 7 (seven) regions, which are City-3, City-4, City-7, City-11, City-12, City-13, and City-15. The supply chain network model that describes the opening of distributors, sub distributors, and wholesales is shown in Figure 4.

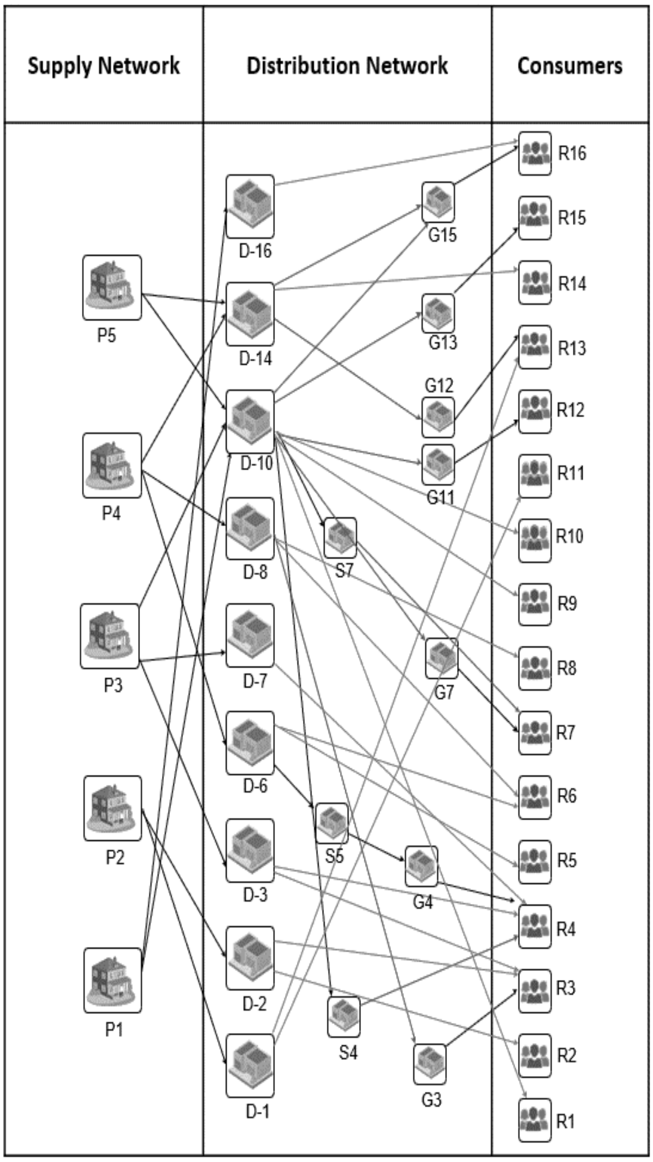


Fig. 4. Proposed Model 2 of traditional market supply chain network

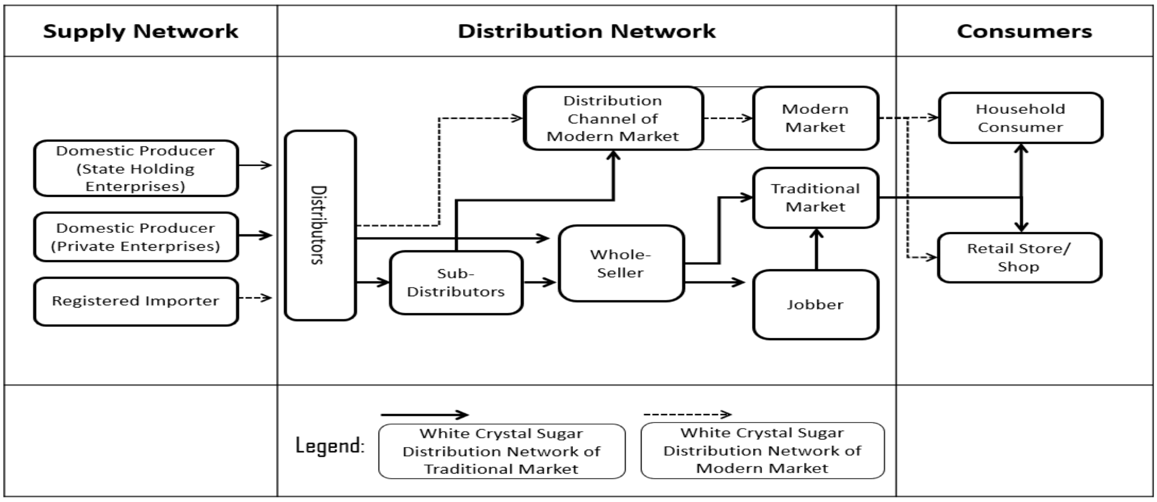
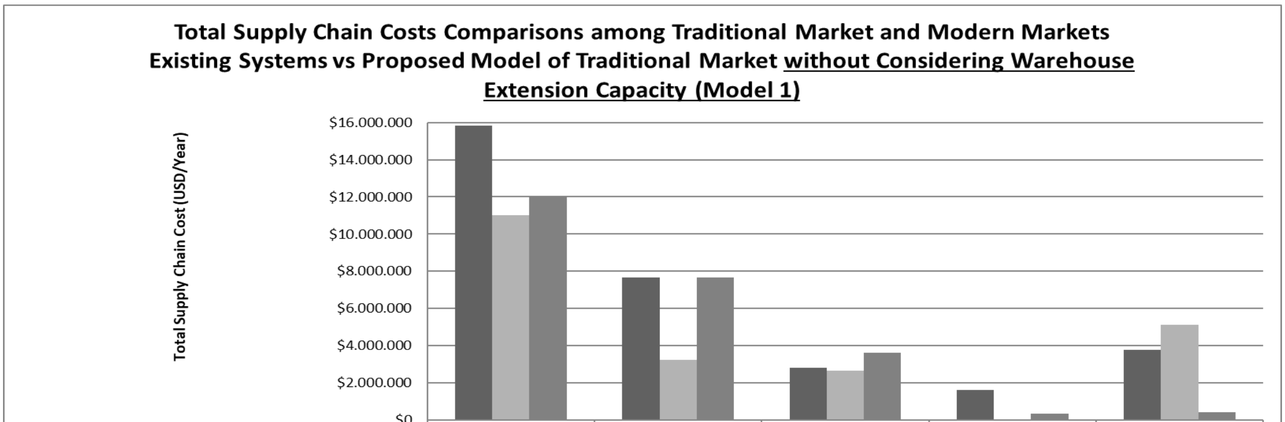
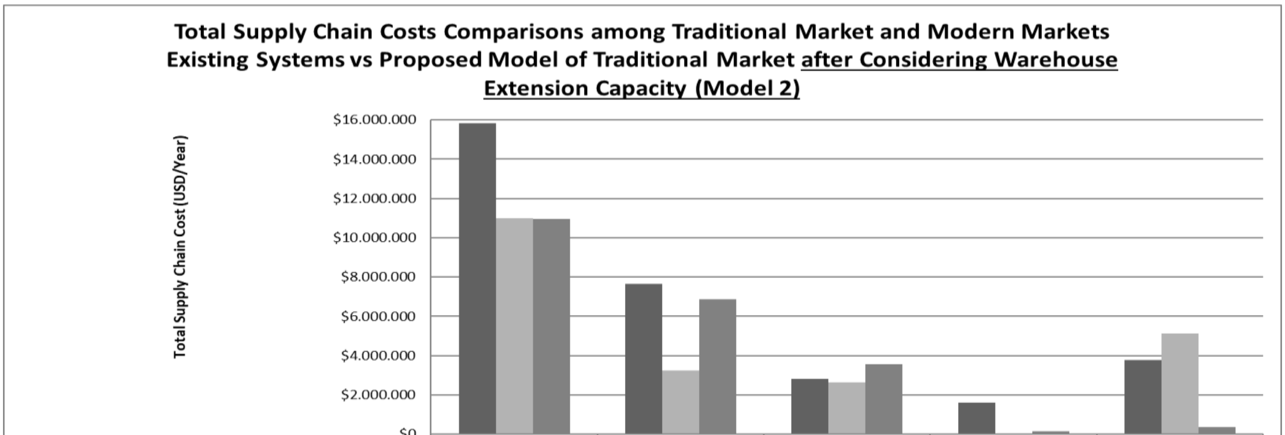


Fig. 1. Supply chain network of white crystal sugar commodity in Indonesia.



	TOTAL SUPPLY CHAIN COST	SUGAR FACTORY COST	DISTRIBUTOR COST	SUB DISTRIBUTOR COST	WHOLESELLER
TRADITIONAL MARKET EXISTING SYSTEM	15826580,71	7652790,15	2811754,62	1602536,711	3759499,227
MODERN MARKET EXISTING SYSTEM	10998926,03	3237617,647	2649406,84	0	5111901,539
PROPOSED MODEL OF TRADITIONAL MARKET (Model 1)	12012785,91	7652790,15	3602617	354180,1915	403198,5636

Fig. 2. Total Supply Chain Costs Comparisons among Traditional Market and Modern Markets Existing Systems vs Proposed Model of Traditional Market without Considering Warehouse Extension Capacity (Model 1)



	TOTAL SUPPLY CHAIN COST	SUGAR FACTORY COST	DISTRIBUTOR COST	SUB DISTRIBUTOR COST	WHOLESELLER
TRADITIONAL MARKET EXISTING SYSTEM	15826580,71	7652790,15	2811754,62	1602536,711	3759499,227
MODERN MARKET EXISTING SYSTEM	10998926,03	3237617,647	2649406,84	0	5111901,539
PROPOSED MODEL OF TRADITIONAL MARKET (Model 2)	10971541,78	6863476,471	3569662,554	163945,9781	374456,7729

Fig. 3. Total Supply Chain Costs Comparisons among Traditional Market and Modern Markets Existing Systems vs Proposed Model of Traditional Market after Warehouse Extension Capacity (Model 2)

According to Fig. 4, the proposed solution, inventory is not kept by the factory (namely, manufacture storage system), but is handled by distributors in intermediate warehouses. The distributor here can be a distributor, or a retailer who is a party that is directly related to consumers. Information and goods flow along the same route, namely factories - distributors / retailers - consumers.

In this network system, the transportation cost is lower than manufacture storage system, and this becomes larger for fast moving items, the facility and handling cost are higher than manufacture storage system but not significant for fast moving items. The increase of facility and handling costs can be compensated and replaced by warehouse capacity extension. On the other hand, related to service factor, the response time will be faster, product availability is higher; customer experience, order visibility, and return-ability are easier than manufacture storage system.

VI. MODEL VALIDATION

Validation is the process of determining whether a model, as a conceptualization or abstraction, is a meaningful and accurate representation of a real system [25]. Verification of this model shows the results that the real system model that has been created is verified correctly and there are no programming errors. Table 1 shows the comparisons of simulation output in traditional and modern markets is used to validate the model.

TABLE I
MODEL COMPARISON RESULTS

ESELON - COST COMPONENTS	TRADITIONAL MARKET EXISTING SYSTEM (USD/Year)	MODERN MARKET EXISTING SYSTEM (USD/Year)	PROPOSED MODEL TRADITIONAL MARKET (USD/Year)
TOTAL SUPPLY CHAIN COST	**15,826,581**	**10,998,926**	**10,971,542**
SUGAR FACTORY	**7,652,790**	**3,237,618**	**6,863,476**
TRANSPORTATION COST	6,720,335	2,305,162	5,931,021
HANDLING COST	932,456	932,456	932,456
DISTRIBUTOR	**2,811,755**	**2,649,407**	**3,569,663**
FIXED COST	135,776	65,515	135,776
TRANSPORTATION COST	1,743,523	1,651,436	2,501,431
HANDLING COST	932,456	932,456	932,456
SUB DISTRIBUTOR	**1,602,537**	**-**	**163,946**
FIXED COST	137,249	-	16,935
TRANSPORTATION COST	532,832	-	107,201
HANDLING COST	932.456	-	39,810
WHOLE-SELLER	**3,759,499**	**5,111,902**	**374,457**
FIXED COST	85,781	28,935	39,273
TRANSPORTATION COST	2,741,263	4,150,511	121,885
HANDLING COST	932,456	932,456	213,299

Based on Table 1, the comparison of the total costs of Traditional Market Existing System, Modern Market Existing System, and Proposed Traditional Market Model shows that the proposed traditional market model has a lower total supply chain cost than both traditional and modern market existing systems costs.

VII. SENSITIVITY ANALYSIS

Sensitivity analysis is a step of systematic inquiry to check response of optimal solution to input change. Usually checking the response of this optimal solution is done separately for each input by changing one input while the other input parameters are fixed [25]. For all the tables in sensitivity analysis, the grey highlighted cells indicate that there is an additional opened facility while the black highlighted cells indicate that there is closing or eliminating facilities.

A. Sensitivity analysis at fixed cost parameters

Fixed cost parameters are affected, among others, by the minimum wage of workers in each region and the price factor of land and buildings. Factors of labor, land and buildings tend to change due to government policy, economic development of a region, the increase of time and other factors. The result shows that a fixed cost increase will change the decision by eliminating the existing sub distributors in the C-5 and C-9 city areas starting from a fixed cost increase of 101%. It can be identified that the fixed cost assumption of the parameters is too small so that the effect on the facility opening decision is very small. This result is shown in Table 2.

TABLE II
SENSITIVITY OF FIXED COSTS TO DECISION VARIABLES

No	City Code	Sugar Factory	Distributor	Sub Distributor	Wholesaler	Traditional Market
1	C-1	P-1	D-1	-	-	R-1
2	C-2	P-2	D-2	-	-	R-2
3	C-3	P-3,P-4,P-5	D-3	-	G-3	R-3
4	C-4	-	-	S-4	G-4	R-4
5	C-5	-	-	closed	-	R-5
6	C-6	-	D-6	-	-	R-6
7	C-7	-	D-7	S-7	G-7	R-7
8	C-8	-	D-8	-		R-8
9	C-9	-	-	closed		R-9
10	C-10	-	D-10	-		R-10
11	C-11	-	-	-		R-11
12	C-12	-	-	-	G-12	R-12
13	C-13	-	-	-	G-13	R-13
14	C-14	-	D-14	-		R-14
15	C-15	-	-	-	G-15	R-15
16	C-16	-	D-16	-	G-16	R-16

B. Sensitivity analysis on transportation cost parameters

Transportation costs are costs that have a high dependency on fuel costs. Along with the fluctuation of fuel prices resulting in changes in transportation costs, the sensitivity analysis of transportation cost parameters will be carried out. The result is that the increase of transportation cost will change the decision to add one wholesaler in C-11 city area starting from the increase of transportation cost by 49.6%. It can be identified that transport costs affect the decision on opening of facilities but not significantly, (see Table 3).

TABLE III
SENSITIVITY OF TRANSPORTATION COSTS TO DECISION VARIABLES

No	City Code	Sugar Factory	Distributor	Sub Distributor	Wholesaler	Traditional Market
1	C-1	P-1	D-1	-	-	R-1
2	C-2	P-2	D-2	-	-	R-2
3	C-3	P-3,P-4,P-5	D-3	-	G-3	R-3
4	C-4	-	-	S-4	G-4	R-4
5	C-5	-	-	S-5	-	R-5
6	C-6	-	D-6	-	-	R-6
7	C-7	-	D-7	S-7	G-7	R-7
8	C-8	-	D-8	-	-	R-8
9	C-9	-	-	S-9	-	R-9
10	C-10	-	D-10	-	-	R-10
11	C-11	-	-	-	**G-11 (newly-opened)**	R-11
12	C-12	-	-	-	G-12	R-12
13	C-13	-	-	-	G-13	R-13
14	C-14	-	D-14	-	-	R-14
15	C-15	-	-	-	G-15	R-15
16	C-16	-	D-16	-	G-16	R-16

C. Sensitivity analysis on cost handling parameters

Cost sensitivity analysis of handling is used to know the effect to decision of facility opening. Sensitivity analysis is done by raising the handling cost while the other cost parameter value is fixed, unchanged. The result shows that the increase of handling cost will change the decision to eliminate the existing sub distributors in C-5 and C-9 city areas starting from 44.7% handling increase. It can be identified that the cost of handling influences the opening decision of the facility with moderate hearing rate (see Table 4).

TABLE IV
SENSITIVITY OF HANDLING COSTS TO DECISION VARIABLES

No	City Code	Sugar Factory	Distributor	Sub Distributor	Wholesaler	Traditional Market
1	C-1	P-1	D-1	-	-	R-1
2	C-2	P-2	D-2	-	-	R-2
3	C-3	P-3,P-4,P-5	D-3	-	G-3	R-3
4	C-4	-	-	S-4	G-4	R-4
5	C-5	-	-	closed	-	R-5
6	C-6	-	D-6	-	-	R-6
7	C-7	-	D-7	S-7	G-7	R-7
8	C-8	-	D-8	-	-	R-8
9	C-9	-	-	closed	-	R-9
10	C-10	-	D-10	-	-	R-10
11	C-11	-	-	-	-	R-11
12	C-12	-	-	-	G-12	R-12
13	C-13	-	-	-	G-13	R-13
14	C-14	-	D-14	-	-	R-14
15	C-15	-	-	-	G-15	R-15
16	C-16	-	D-16	-	G-16	R-16

D. Sensitivity analysis on increase and decrease demand

An analysis of the sensitivity of increase and decrease in demand is used to determine the effect on the decision to open the facility. Sensitivity analysis is done by raising and lowering the demand, while the value of other cost parameters does not change. The result shows that the increase in demand up to 100% does not change the decision to open a facility. It can be identified that the increase in demand does not affect the decision of opening of the facility. On the other hand, the decline in new demand will affect the opening decision of the facility with a decrease of 50.5%. This is shown in the Tables 5 and 6.

TABLE V
SENSITIVITY OF INCREASE IN DEMAND TO DECISION VARIABLES

No	City Code	Sugar Factory	Distributor	Sub Distributor	Wholesaler	Traditional Market
1	C-1	P-1	D-1	-	-	R-1
2	C-2	P-2	D-2	-	-	R-2
3	C-3	P-3,P-4,P-5	D-3	-	G-3	R-3
4	C-4	-	-	S-4	G-4	R-4
5	C-5	-	-	S-5	-	R-5
6	C-6	-	D-6	-	-	R-6
7	C-7	-	D-7	S-7	G-7	R-7
8	C-8	-	D-8	-	-	R-8
9	C-9	-	-	S-9	-	R-9
10	C-10	-	D-10	-	-	R-10
11	C-11	-	-	-	-	R-11
12	C-12	-	-	-	G-12	R-12
13	C-13	-	-	-	G-13	R-13
14	C-14	-	D-14	-	-	R-14
15	C-15	-	-	-	G-15	R-15
16	C-16	-	D-16	-	G-16	R-16

TABLE VI
SENSITIVITY OF DECREASE IN DEMAND TO DECISION VARIABLES

No	City Code	Sugar Factory	Distributor	Sub Distributor	Wholesaler	Traditional Market
1	C-1	P-1	D-1	-	-	R-1
2	C-2	P-2	D-2	-		R-2
3	C-3	P-3,P-4,P-5	D-3	-	G-3	R-3
4	C-4	-	-	S-4	G-4	R-4
5	C-5	-	-	closed	-	R-5
6	C-6	-	D-6	-	-	R-6
7	C-7	-	D-7	S-7	G-7	R-7
8	C-8	-	D-8	-	-	R-8
9	C-9	-	-	closed	-	R-9
10	C-10	-	D-10	-	-	R-10
11	C-11	-	-	-	-	R-11
12	C-12	-	-	-	G-12	R-12
13	C-13	-	-	-	G-13	R-13
14	C-14	-	D-14	-	-	R-14
15	C-15	-	-	-	G-15	R-15
16	C-16	-	D-16	-	G-16	R-16

E. Sensitivity analysis on warehouse capacity increase

Sensitivity analysis of warehouse capacity increase is used to determine the effect on total logistic cost and facility opening decision. Sensitivity analysis is done by increasing the warehouse capacity while the demand does not change. It was found that only by increasing the warehouse capacity of each distributor, sub-distributor and wholesaler by 3%, this has influenced the decision in opening of a facility. It can be identified that the increase of warehouse capacity greatly influences the decision of facility opening, so it has a high level of hearing. The next scenario is designed to minimize the total cost of logistics so it can be lower than the modern market. This is shown in the Table 7.

TABLE VII
SENSITIVITY OF INCREASE IN WAREHOUSE CAPACITY TO DECISION VARIABLES

No	City Code	Sugar Factory	Distributor	Sub Distributor	Wholesaler	Traditional Market
1	C-1	P-1	D-1	-	-	R-1
2	C-2	P-2	D-2	-	-	R-2
3	C-3	P-3,P-4,P-5	D-3	-	G-3	R-3
4	C-4	-	-	S-4	G-4	R-4
5	C-5	-	-	S-5	-	R-5
6	C-6	-	D-6	-	-	R-6
7	C-7	-	D-7	S-7	G-7	R-7
8	C-8	-	D-8	-	-	R-8
9	C-9	-	-	S-9	-	R-9
10	C-10	-	D-10	-	-	R-10
11	C-11	-	-	-	-	R-11
12	C-12	-	-	-	G-12	R-12
13	C-13	-	-	-	closed	R-13
14	C-14	-	D-14	-	-	R-14
15	C-15	-	-	-	G-15	R-15
16	C-16	-	D-16	-	G-16	R-16

VIII. CONCLUSION

The paper presented a development of integrated model of distribution regionalization which is part of production-distribution system problem. In this paper, it was developed using mathematical model of supply chain network modeling of white crystal sugar commodity which considers the connectivity of all channeling agencies and distribution range limits. The developed model has a lower total cost of logistics than the existing condition of traditional market supply chain network. To increase the competitiveness of traditional market supply chain network, it is necessary to increase the channeling agency warehouse capacity. The model is designed to be able to obtain decision variables, including (1) the optimum number of distributors, sub distributors, and wholesales opened to distribute white crystal sugar, (2) the number of distribution allocations per echelon, and (3) the new constraint of regionalization in the distribution of white crystal sugar.

In future, the model can be extended by considering seasonal demand, other types of supply chain network alternatives, multi-periodic model, perpetual-order-review, and transfer pricing resulted on the moving of products among the same tier warehouses owned by different producers. Government has also had to rearrange the responsibility areas and the quantum limit production for each producer in order to cover the demand from customers without increasing price. Results of this model can be implemented in commodities of industry regulated by government.

REFERENCES

[1] Indonesia Statistical Central Bureau (BPS), 2019. Available: https://bps.go.id/

[2] F. Desa, “Design of policy analysis of traditional market development in Cirebon regency,” M.S. thesis, Ind. Eng. and Mngmt. Study Program, Bandung Inst. of Tech. (ITB), Bandung, Indonesia, 2009.
[3] A. C. Nielsen, “Retail Audit Report,” 2011. Available: https://www.nielsen.com/id/en/
[4] Keputusan Menteri Perindustrian Dan Perdagangan Nomor 70/MPP/KEP/2/2003, Pengadaan Dan Penyaluran Pupuk Bersubsidi Untuk Sektor Pertanian, 2003 (Decree of the Minister of Industry and Trade Number 70/MPP/KEP/2/2003, “Procurement and Distribution of Subsidized Fertilizers for the Agricultural Sector,” 2003).
[5] D. Waters, *Logistics: An Introduction to Supply Chain Management*. 1st ed. New York: Palgrave Macmillan, 2003.
[6] M. Felea and I. Albăstroiu, “Defining the concept of supply chain management and its relevance to romanian academics and practitioners,” *Amfiteatru Economic*, vol. XV, no. 33, pp. 74-88, 2013.
[7] A. Groznika and P. Trkman, “Current issues and challenges of supply chain,” *Economic Research-Ekonomska Istraživanja,* vol. 24, no. 4, pp. 1101-1112, 2012.
[8] N. Rajah, H. Musa, V. Nipis, P. K. Krishnan, S. Suppiah, and A. F. N. Ahmad, “Global supply chain management: challenges and solution,” *Int. J. of Eng. Technol*., vol. VII, no. 4, pp. 447-454, 2018.
[9] D. Power, “Supply chain management integration and implementation,” *Supply Chain Manag*., vol. 10, no. 4, pp. 252–263, 2005.
[10] J. Heizer and B. Render, *Operations Management 6th Ed*. New Jersey: Prentice-Hall, Englewood Cliffs, 2001.
[11] D. J. Thomas and P. M. Griffin, “Invited review: Coordinated supply chain management,” *Eur. J. Oper. Res.*, vol. 94, no. 1, pp.1-15, 1996.
[12] M. Fasanghari, F. H. Roudsari, and S. K. Chaharsooghi, “Assessing the impact of information technology on supply chain management,” *World Appl. Sci. J.*, vol. 4, no. 1, pp. 87-93, 2008.
[13] F. Haghighat, “The impact of information technology on coordination mechanisms of supply chain,” *World Appl. Sci. J.*, vol. 3, no. 2, pp. 74-81, 2008.
[14] Y. A. Hidayat, Sebrina, M. N. Ardiansyah, and W. J. Sembada, “Integrated model of two-echelon inventory system considering lead time acceleration and component commonality,” *Lecture Notes in Engineering and Computer Science: Proceedings of The World Congress on Engineering 2014*, WCE 2014, 2-4 July, 2014, London, U.K., pp. 1034-1039.
[15] R. H. Ballou, *Business Logistics Management 4th ed*. New Jersey: Prentice-Hall, Inc., 1992.
[16] P. F. Drucker, *Managing in The Next Society*. New York: St. Martin’s Press, 2002.
[17] Y. A. Hidayat, and S. Nur Bahagia, “Integrated model of regionalization distribution and subsidized cost in order to reach urea fertilizer’s maximum price in Indonesia,” in *Proc. of the 2nd Operations and Supply Chain Management (OSCM) Confer*., Bangkok 2007, pp. 1049-1063.
[18] Y. A**.** Hidayat, L. Diawati, Y. Thaddeus, and S. Sumargo, “3-Echelon distribution policy with order flexibility and direct ordering system,” in *2013 IEEE Int. Conf. on Ind. Eng. and Eng. Mngmt.*, pp. 901-905.
[19] B. Yurisulhikmah and Y. A. Hidayat, **“**Product demand allocation and distribution optimization model using transshipment model (Case study: PT Pertamina Lubricants Indonesia),” in *Proc. of The Thirteenth Int. Conf. on Ind. Mngmt. (ICIM) 2016*, Hiroshima, Japan, pp. 138-147.
[20] C. Han, “Stochastic modeling of two echelon multiple sourcing supply chain system with genetic algorithm,” *J. Manuf. Technol. Manag.*, vol. 16, no. 1, pp. 87-108, 2005.
[21] C. J. Vidal and M. Goetschalckx, “A global supply chain model with transfer pricing and transportation cost allocation: theory and methodology,” *Eur. J. Oper. Res.*, vol. 129, no. 1, pp. 134-158, 2001.
[22] V. Verter and M. C. Dincer, “Facility location and capacity acquisition: an integrated approach,” *Naval Research Logistics (NRL)*, vol. 42, no. 8, pp. 1141-1160, 1995.
[23] R. H. Saragi, “Depot location determination model on the echelon three value chain system,” M.S. thesis, Ind. Eng. and Mngmt. Study Program, Bandung Inst. of Tech. (ITB), Bandung, Indonesia, 2005.
[24] Y. A. Hidayat, K. R. Widiastuti, and E. Joelianto, “Refinery scheduling for Naphta Hydrotreater unit using non-linear programming,” *J. Eng. Appl. Sci.*, vol. 12, no. 18, pp. 4606-4612, 2017.
[25] H. Daellenbach and D. McNickle, *Management Science: Decision Making through Systems Thinking*. Hampshire: Palgrave Macmillan, 2005.

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