INTEGRATED MODEL OF DISTRIBUTION REGIONALIZATION SYSTEM AND SUBSIDIZED COST IN ORDER TO REACH UREA FERTILIZER’S MAXIMUM PRICE IN INDONESIA

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ABSTRACT
Fertilizer is one of the important commodities in Indonesia on farming productivity. In 2001, Indonesia’s government transformed the fertilizer’s industry from a regulated industry to an open industry that caused the misleading of fertilizer’s distribution and pricing. The latest policy in 2006 contained the guiding principle for procurement and distribution and the amount of subsidy of fertilizer commodity for each appointed manufacturer. The arrangement process of work regions is called regionalization and the amount of subsidy is called subsidized cost.

We purpose an integrated model of regionalization which adapts characteristics of fertilizer’s procurement and distribution (distribution pattern, demand fluctuation) to organize the responsibility area of fertilizer’s manufacturer and a subsidized cost model that will result the optimal amount of cost subsidy from government to the manufacturers to guarantee the same fertilizer’s maximum pricing until its end user. The references models are from Nur Bahagia and Sofitra (2001), which have developed an optimization model for single manufacturer, single warehouse, and multi retailers and Vidal and Goetschalckx (2001), which have developed a global supply chain model with transfer pricing and transportation cost allocation. The logistics total cost will become the performance criteria for this developed model. Solution for this model uses MILP.

KEY WORDS
Distribution Regionalization, Subsidized Cost, Supply Chain

1. Introduction
Fertilizer is one of the important commodities that are used in agricultural sector. The appropriate usage of these commodities according to the dossier is proven in improving agricultural sector productivity. Based on that fact, fertilizer is becoming the strategies production support for farmers [1]. Nowadays, Indonesia’s government is giving large of attention and focusing in subsidized factor and the arrangement of distribution system of fertilizer commodity [1].

In 2003, according to the Industrial and Trading Minister Policy No. 70/MPP/KEP//2003 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 fertilizer’s producer. The impact of this pattern is to the marketing, sales, and distribution activities that are done independently by each of the fertilizer’s producer in Indonesia. The producers are distributing their products via warehouses in various areas that have been signed to serve independent fertilizer’s distributors.

Next, these distributors will distribute the products to the retailers, and finally, the retailers distribute them to the end customers (farmers). The outcome from this decentralized regionalization is the fluctuated distribution that causing the fertilizer shortage and by the end causing the high price of this important commodities to the farmers.

The pricing factor (retail price) in Indonesia is organized by the government policy. But, the changes of distribution mechanism are causing new problems in procuring fertilizer in all of the Indonesia’s area. One of the crucial problems is a large number of farmers that cannot afford the retailer’s price according to reach urea fertilizer’s maximum price stated by government (Rp. 1,200,00 / kg for urea fertilizer, Rp. 1,050,00 / kg for ZA fertilizer, Rp. 1,550,00 / kg for SP-36 fertilizer, and Rp. 1,750,00 / kg for NPK fertilizer).

The gas subsidized for subsidized urea fertilizer is given at this time with giving an order to producers to pay gas price US$ 1,3 / mmbtu from gas pricing that has been dealt with gasses supplier [2]. This gas subsidized policy
has caused many subsidized urea fertilizer’s producers that comes into deficit situation in doing their tasks for procuring and distributing subsidized urea fertilizer. This deficit condition usually caused by the high distribution cost and un-uniform responsibility areas that were arranged by government for every fertilizer’s producer in Indonesia, especially for remote areas, that can be covered from subsidized urea fertilizer sales and the giving of gas subsidy [3]. These facts will give a significant impact in the development of agricultural sector and the procurement activities of agriculture commodities in Indonesia.

According to the above explanations, one alternative solution for these problems is the need of rearrangement of national fertilizer 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 product that giving value added from customer’s point of view [4]. The rearrangement that results more efficiency in logistics system impacts to the production cost reduction, product quality improvement, and higher customer service level. Ballou [4] stated that a company’s product is seen by customer as a combination of price, quality, and services. Price is the function of production and distribution process efficiency. Drucker [5] stated that the tremendous technology development has reduced the manufacturing cost until 40% compared with 30 years ago. 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 [6]. 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, etc. The integrated outbound activities model development related to goods shipment from producers to end customers for three echelons case has been developed by Nur Bahagia [7]. The model consists of one production unit, one depot, and multi retailers. Nur Bahagia and Toruan [8] next developed this model for situation where producers can deliver products directly to their retailers. Nur Bahagia and Sofitra [9] has also developed model for one producer, one warehouse, and multi retailers. Next, Han [10] has developed multi sourcing inventory model of two echelons for company which has multi depots and multi retailers.

2. Framework

Related to regionalization-distribution system, the most relevant model for the related cost components on fertilizer distribution system in Indonesia, the references models are from Nur Bahagia and Sofitra [9], which have developed an optimization model for single manufacturer, single warehouse, and multi retailers and Vidal and Goetschalckx [10], which have developed a global supply chain model with transfer pricing and transportation cost allocation. Nur Bahagia and Sofitra [9] analyze outbound logistics activities and consider the optimal shipment route according to seasonal demand characteristics and continue production systems. Vidal and Goetschalckx [11] integrate logistics internal and logistics outbound activities. The logistics total cost will become the performance criteria for this developed model. Solution for this model uses MILP, which are mixed of integer linear programming with biner variables. Research road map can be shown in Figure 1.

![Figure 1: Research Road Map](image)

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 Verter and Dincer [12] in Appendix 1, we can conclude that the proposed research can be categorized as (1) minimize cost objective function, (2) three number echelons level in production and distribution system; (3) single number of commodity; (4) deterministic demand; (5) available capacity limitations on sites; (6) multiple number of demand periods; (7) duties, exchange rate uncertainties,
and subsidy factor as local content requirements included; and (8) available industrial application.

3. Model Development

The focused supply chain system of model development process can be shown on Figure 2.

Figure 2: Supply Chain System in Model Development

3.1 Limitation And Assumption Of The Research

The limitations of this research are:
1. The focused system is the national logistics system for subsidized urea fertilizer.
2. Product is limited for three largest appointed producers in Indonesia, which has responsibilities areas in West Java, West Nusa Tenggara, and Center Sulawesi.
3. Research object is outbound supply chain from those three producers.
4. Costumers are farmers that buy subsidized urea fertilizer from appointed retailers.
5. Distributors are the legal private companies that have been appointed by producers for buying, procuring, sale, and marketing subsidized urea fertilizer in large party to farmers via retailers.
6. Retailers are appointed people or private company that has main task to sell subsidized urea fertilizer directly to farmers.
7. Subsidy is given to the appointed producers and distributors in subsidized urea fertilizer production and procurement activities.
8. Subsidy amount is counted according to the subsidy value should be given from Indonesia’s government in subsidized urea fertilizer procurement activities at Indonesia Republic area in 2006.
9. Covering area of logistics system in this research is national and conclude three distribution tier, which are from plants (first tier) to provinces (second tier), and sub-province (third tier).
10. System performance will be measured is a logistics total cost of national fertilizer logistics systems.
12. Logistics total cost will become performance criteria in this model development. Logistics total cost consists of the cost components, they are: production cost, transportation cost, and inventory cost.
13. Fertilizer’s demand pattern that has a certain cyclic every year give impact to inventory system, specially to the average fertilizer hold in one planning horizon (a year). In order to cover this situation, we divide periods in a year, which is for every 4 months according to the similarity of fertilizer demand pattern in certain months.
14. The developed model uses successive linear programming approaches.

General assumptions that used in this research are:
1. All producers have their production based on their maximum production capacity.
2. Distribution system is in ideal condition, in which every retailer in the fourth tier has sufficient supply from distributor in the third tier.
3. There is no fertilizer’s moving unit at the same tiers.
4. Warehouse’s capacity in one area is enough in procuring the availability of subsidized urea fertilizer in that area.
5. There is a uniform demand pattern of subsidized urea fertilizer in every sub region in a sub province.

3.2 Mathematical Notation

Mathematical notation used in developing integrated model of distribution-regionalization and subsidized cost is explained as follows:
• \( i \) = plant/producer index \((i = 1, 2, \ldots, n)\).
• \( j \) = the second tier warehouse index of plant \( i \) \((j = 1, 2, \ldots, o_i)\).
• $k$ = the third tier warehouse index of plant $i$ which is part of second tier area of warehouse $j$ ($k = 1, 2, \ldots, u_{ij}$).
• $l$ = distributor’s index supplied from the third tier of producer $i$ and part of the second tier area of warehouse $j$ ($l = 1, 2, \ldots, v_{ijk}$).
• $m$ = retailer’s index which has appointed of distributor $l$ to distribute subsidized urea fertilizer produced by producer $i$ in the third tier warehouse $k$ area and the second tier warehouse $k$ area ($m = 1, 2, \ldots, r_{ijk}$).
• $t$ = demand period index (or every four months in a year).
• $f$ = number of demand period in a year (ton/year).
• $n$ = number of subsidized urea fertilizer producer’s.
• $o_{ij}$ = number of second tier warehouse for every producer $i$.
• $u_{ij}$ = number of third tier warehouse which dedicated to producer $i$ in the second tier warehouse $j$ area.
• $v_{ijk}$ = number of third tier warehouse of distributor $l$ which is supplied from the third tier warehouse of producer $i$ in the second tier warehouse $j$.
• $r_{ijkl}$ = number of retailers in the fourth tier which distribute fertilizer from distributor $l$ in corporation with producer $i$ (in the second tier area II $j$ and the third tier area III $k$).
• $w$ = frequency of delivery for subsidized urea fertilizer from the first tier to the second tier which is done in one period.
• $x$ = frequency of delivery of subsidized urea fertilizer from the second tier warehouse to the third tier warehouse of producer in one period.
• $y$ = frequency of delivery of subsidized urea fertilizer from the third tier warehouse of producer to the third tier of distributor’s warehouse which is done in one period.
• $z$ = frequency of delivery of subsidized urea fertilizer from distributors to retailers in one period.
• $h_{2ij}$ = percentage of holding cost in the second tier warehouse $j$ from producer $i$.
• $h_{3ijk}$ = percentage of holding cost in the third tier warehouse $k$ which in the second tier warehouse $j$ from producer $i$.
• $h_{3dijkl}$ = percentage of holding cost in the distributor’s $l$ warehouse in corporation with producer $i$ (in the third tier III $k$ and the second tier II $j$).
• $h_{4ijklm}$ = percentage of holding cost in the retailer $m$ at the fourth tier, supplied from distributor $l$ in the third tier area III $k$ and the second tier area II $j$ from producer $i$.
• $S_{pi}$ = total subsidy amount that is given to the producer $i$ for the procurement and distribution activities of subsidized urea fertilizer (Rp/year).
• $S_{Dijkl}$ = total subsidy amount that is given from government to distributor $l$ in corporation with the producer $i$ for procurement and distribution activities in the third tier area III $k$ supplied from the second tier area II $j$ (Rp/year).
• $P_i$ = number of urea subsidized fertilizer produced by producer $i$ in a certain year (assumed to be same with the demand of the subsidized urea fertilizer) (ton).
• $C_i$ = Cost of goods sold of producer $i$ (Rp/ton).
• $C_{max}$ = maximum cost of goods sold (COGS) that can be subsidized (Rp/ton).
• $G_i$ = general administrative expenses from the producer $i$ (Rp/ton).
• $M_i$ = marketing expenses of subsidized urea fertilizer from each of producer $i$ (Rp/ton).
• $A$ = government budget allocation for subsidizing the urea fertilizer (Rp/year).
• $D$ = demand of subsidized urea fertilizer in a year all over Indonesia (ton).
• $D_{ijklm}$ = demand of subsidized urea fertilizer in first tier region (ton).
• $K_i$ = maximum production capacity per year for each plant of producer $i$ (ton).
• $Q_{ij}$ = number of subsidized urea fertilizer that distributed from the first tier of producer $i$ to the second tier warehouse II $j$ in a year, \[ \sum_{j=1}^{Q_{ij}} Q_{ij} = P_i \] (ton/year).
• $Q_j$ = number of subsidized urea fertilizer supplied from the first tier’s warehouse of producer $i$ to the second tier warehouse II $j$ at period $t$ in a certain year (ton/period).
• $Q_{ijk}$ = number of subsidized urea fertilizer supplied from the second tier warehouse II $j$ to the third tier warehouse III $k$ owned by producer $i$ in a certain year, \[ \sum_{k=1}^{Q_{ijk}} Q_{ijk} = Q_j \] (ton/year).
• $Q_{ijk}$ = number of subsidized urea fertilizer supplied from the second tier warehouse II $j$ to the third tier warehouse III $k$ owned by producer $i$ at period $t$ in a certain year (ton/period).
\[ Q_{ijkl} = \text{number of subsidized urea fertilizer supplied from the third tier warehouse III of producer } i \text{ to distributor } l \text{ in a certain year, } \sum_{i=1}^{v_{ij}} Q_{ijkl} = Q_{ijl} \text{ (ton/year).} \]

\[ Q_{ijkl} = \text{number of subsidized urea fertilizer that distributed from the third tier warehouse III of producer } i \text{ to the distributor } l \text{ at period } t \text{ in a certain year (ton/period).} \]

\[ Q_{ijklm} = \text{number of urea subsidized fertilizer that distributed from the distributor } l \text{ 's warehouse (in corporation with producer } i \text{ in the second tier area II } j \text{ and the third tier area III } k \text{ ) to the retailer } m \text{ 's warehouse in a certain year, } \sum_{m=1}^{v_{ijkl}} Q_{ijklm} = Q_{ijkl} \text{, (ton/year).} \]

\[ \sum_{m=1}^{v_{ijkl}} \sum_{t=1}^{v_{ij}} Q_{ijklm} = f_{ijkl} \text{ (ton/period).} \]

\[ s_{3a} = \text{number of safety stock of subsidized urea fertilizer in the second tier warehouse II of producer } i \text{ (ton/period).} \]

\[ s_{3k} = \text{number of safety stock of subsidized urea fertilizer in the third tier warehouse III of producer } i \text{ (in the second tier area II } j \text{ ) (ton/period).} \]

\[ s_{dij} = \text{number of safety stock of subsidized urea fertilizer in the third tier warehouse III of producer } i \text{ (in the second tier area II } j \text{ ) (ton/period).} \]

\[ O_{TD2ij} = \text{land transportation cost per km for every one ton of subsidized urea fertilizer supplied from the first tier warehouse of producer } i \text{ to the second tier warehouse II of producer } j \text{ (Rp / ton . km).} \]

\[ O_{TL2ij} = \text{sea transportation cost per km for every one ton of subsidized urea fertilizer supplied from the first tier warehouse of producer } i \text{ to the second tier warehouse II of producer } j \text{ (Rp / ton . km).} \]

\[ O_{TD3ijk} = \text{land transportation cost per km for every one ton of subsidized urea fertilizer supplied from the second tier warehouse III of producer } i \text{ to the third tier warehouse III of producer } j \text{ (Rp / ton . km).} \]

\[ O_{TL3ijk} = \text{sea transportation cost per km for every one ton of subsidized urea fertilizer supplied from the second tier warehouse III of producer } i \text{ to the third tier warehouse III of producer } j \text{ (Rp / ton . km).} \]

\[ O_{TD4ijklm} = \text{land transportation cost per km for every one ton of subsidized urea fertilizer supplied from the distributor } l \text{ 's warehouse (in corporation with producer } i \text{ in the second tier area II } j \text{ and the third tier area III } k \text{ ) to the retailer } m \text{ 's warehouse (Rp / ton . km).} \]

\[ O_{TL4ijklm} = \text{sea transportation cost per km for every one ton of subsidized urea fertilizer supplied from the distributor } l \text{ 's warehouse (in corporation with producer } i \text{ in the second tier area II } j \text{ and the third tier area III } k \text{ ) to the retailer } m \text{ 's warehouse (Rp / ton . km).} \]

\[ d_{ij} = \text{land distances from the first tier warehouse of producer } i \text{ to the second tier warehouse II of } j \text{ (km).} \]

\[ d_{ik} = \text{land distances from the second tier warehouse II of } j \text{ to the third tier warehouse III of producer } i \text{ (km).} \]

\[ d_{ijk} = \text{land distances from the second tier warehouse III of producer } i \text{ (in the second tier area II } j \text{ ) to the distributor } l \text{ 's warehouse (km).} \]

\[ d_{iklm} = \text{land distances from the distributor } l \text{ 's warehouse (in corporation with producer } i \text{ in the second tier area II } j \text{ and the third tier area III } k \text{ ) to the retailer } m \text{ 's warehouse (km).} \]

\[ L_{ij} = \text{sea distances from the first tier warehouse of producer } i \text{ to the second tier warehouse II of } j \text{ (km).} \]

\[ L_{ij} = \text{sea distances from the second tier warehouse II of } j \text{ to the third tier warehouse III of producer } i \text{ (km).} \]

\[ L_{ijk} = \text{sea distances from the second tier warehouse III of producer } i \text{ (in the second tier area II } j \text{ ) to the distributor } l \text{ 's warehouse (km).} \]

\[ L_{iklm} = \text{sea distances from the distributor } l \text{ 's warehouse (in corporation with producer } i \text{ in the second tier area II } j \text{ and the third tier area III } k \text{ ) to the retailer } m \text{ 's warehouse (km).} \]
• $R_p$ = producer’s return on investment, used as a criteria in producer’s profit margin computation.

• $R_d$ = distributor’s return on investment, used as a criteria in distributor’s profit margin computation.

• $R_{re}$ = retailer’s return on investment, used as a criteria in retailer’s profit margin computation.

• $H_p$ = selling price of subsidized urea fertilizer in the level of producer (buying price that paid by the distributor to the producer when buying subsidized urea fertilizer) (Rp. / ton).

• $H_d$ = selling price of subsidized urea fertilizer in the level of distributor (buying price that paid by the retailer to the distributor when buying subsidized urea fertilizer) (Rp. / ton).

• $H_{ET}$ = selling price of subsidized urea fertilizer in the level of retailer(buying price that paid by the customers/farmers to the retailer when buying subsidized urea fertilizer) according to the government policy (Rp. / ton).

• $b_{ijk}$ = biner variable that shows the interconnections between first tier and third tier. If there is a moving subsidized urea fertilizer directly from the first tier ($i$) to the third tier ($k$), then the biner variable $b_{ijk} = 1$, otherwise $b_{ijk} = 0$.

• $b_{ijkl}$ = biner variable that shows the interconnections between first tier, second tier, and third tier. If there is a moving subsidized urea fertilizer from the first tier ($i$) to the third tier ($l$) via the second tier ($j$) and producer’s third tier ($k$), then the biner variable $b_{ijkl} = 1$, otherwise $b_{ijkl} = 0$.

### 3.3 Cost Components in Distribution System of Subsidized Urea Fertilizer

In the mathematical model development for determining amount of subsidy for subsidized urea fertilizer, the cost components in distribution system of subsidized urea fertilizer can be categorized into three parts, they are production cost, transportation cost, and holding cost. Besides those categories, the cost components in distribution system also can be divided according to each tier’s, they are all costs at the first tier, second tier, third tier, and fourth tier. Those costs are charged to every stakeholders related to the procurement and distribution activities of subsidized urea fertilizer, which are producers, distributors, and retailers. In this paper, we use the first approach in categorizing cost components.

#### Production Cost

Including all costs spent to produce subsidized urea fertilizer until it’s ready to be sold into the second tier. It consists of cost of goods sold, which included inventory cost in the first tier, general administrative expenses, and marketing expenses in the first tier.

$$\text{Total Production Cost} = \sum_{i=1}^{n} \left[ C_i + G_i + M_i \right] P_i$$  \hspace{1cm} (1)

#### Transportation Costs

Including all costs spent to distribute urea subsidized fertilizer from one tier to the next tier. Transportation costs are summarized with considering supply point and destination point, number of subsidized urea fertilizer, transportation modes used (land and sea), and the regular tariffs.

$$\text{Total Transportation Cost} = \text{Producer’s Transportation Cost} + \text{Distributor’s Transportation Cost} \ (2)$$

#### Holding Cost

Including all costs caused by storage fertilizer at warehouses, which are summarized by considering average number of hold subsidized urea fertilizer, storage goods’ value, and the percentage of holding cost.

Average number of hold subsidized urea fertilizer is considering:

- Inventory system pattern used, as shown on Figure 3.
• Subsidized urea fertilizer’s demand pattern
  The demand pattern of subsidized urea fertilizer is categorized as seasonal demand. It will be modeled with dividing a year into three periods that synchronized with the demand characteristics of subsidized urea fertilizer which are higher in harvest seasons and lower in dry seasons.
• Number of subsidized urea fertilizer’s shipment for every period.
• Value of goods which are in storage.
• Safety stock of subsidized urea fertilizer in producers’ and distributors’ warehouses which are determined in Trading Ministry Policy No. 03/M- DAG/PER/2/2006, which are 2 weeks of demand in the producer’s warehouses and 1 week of demand in the distributor’s warehouses. Safety stock values are determined by dividing demand of goods in an ordering period for every tier into one week and two weeks of demand. According to those formulas, the producers’ safety stock and the distributors’ safety stock can be defined as follows:

\[
s_{2ij} = \sum_{i=1}^{n} \sum_{j=1}^{o} \frac{fQ_{ij}}{16}
\]

(3)

\[
s_{3ijk} = \sum_{i=1}^{n} \sum_{j=1}^{o} \sum_{k=1}^{j} \frac{fQ_{ijk}}{16}
\]

(4)

\[
s_{3dijkl} = \sum_{i=1}^{n} \sum_{j=1}^{o} \sum_{k=1}^{j} \sum_{l=1}^{k} \frac{fQ_{ijkl}}{16}
\]

(5)

Total Holding Costs = Producer’s Holding Cost + Distributor’s Holding Cost

Minimize Logistics Total Cost and Minimize Subsidy

\[
Z = \text{Total Production Costs} + \text{Total Transportation Costs} + \text{Total Inventory Costs} + \text{Total Amount of Subsidy Given to Producers} + \text{Total Amount of Subsidy Given to Distributors}
\]

Constraints functions consist of three category, they are:
1. Active constraints that actively and directly give limit to subsidy amount. The constraints are related to ROI (Return on Investment) of producers, distributors, and retailers, and also constraints related to producers’ efficiency and government subsidy’s budget.
2. Constraints that give limit to the related parameters, which are cost constraints related to the focused logistics system.
3. Biner constraints that determine supply from producers at the first tier and the second tier to distributors at the third tier. These result on the regionalization-distribution system.
4. Producers’ responsibility costs are all costs at the first, second tier, and at the third tier warehouse owned by producers or before subsidized urea fertilizer are distributed to distributors.

Cost components in the first tier consist of all costs needed to produce subsidized urea fertilizer, including inventory costs at the first tier.

Cost components in the second tier consist of all transportation costs from the first tier to the second tier...
and the holding costs in the second tier warehouses, which are part of province area.

Costs components in the third tier (sub province area) that must be paid by producers include transportation costs from the second tier warehouses to the third tier warehouses and the inventory costs at the third tier warehouses owned by producers.

Buying and selling price in distributors’ level and retailers’ level in cost components of distributors and retailers indicate transfer of ownership of subsidized urea fertilizer.

Next, we will make details for every constraints on each stakeholders.

**Producers’ constraints**

These constraints must guarantee that subsidy given to producers must be coordinated with these clauses:

1. The appropriate profit margin of producers in doing their tasks in production and procurement activities of subsidized urea fertilizer. The salvage value of producers’ total cost after being subtracted with sales revenues from their distributors would be covered by government’s subsidy.

\[
\text{Producer’s Total Cost} = \sum_{i=1}^{n} \left( \sum_{j=1}^{q_i} \left[ (d_{ijk} \times O_{TDijk} + L_{ijk} \times O_{TL2ijk}) \right] + \sum_{t=1}^{f_i} \left[ \frac{Q_{ijt} \times s_{2ij}}{2x} \times C_i \times h_{2ij} \right] \right) \]

\[
O_{L3} = \sum_{j=1}^{q_i} \sum_{k=1}^{p_{ij}} Q_{ijk} \times \left[ (d_{ijk} \times O_{TD3ijk}) + (L_{ijk} \times O_{TL3ijk}) \right] + \sum_{j=1}^{q_i} \sum_{k=1}^{p_{ij}} \sum_{t=1}^{f_i} \left( \frac{Q_{ijkt} \times s_{3ijk}}{2x} \times C_i \times h_{3ijk} \right) ;
\]

\[i = 1, 2, ..., n; j = 1, 2, ..., o_i; k = 1, 2, ..., u_{ij};\]  

2. The same price in every producers’ level that paid by distributors when buying subsidized urea fertilizer from the third tier warehouse owned by producer. According to those clauses, constraint that indicates the balance between producers’ costs, profit margin, buying price, and subsidy in producers’ level can be defined in equation (9).

\[
\frac{1}{(1 + r_P) \times (O_{L1} + O_{L2} + O_{L3}) - S_{P_{ij}}} \leq H_P;
\]

\[
O_{L1} = (P_i \times C_i + G_i + M_i);
\]

\[
O_{L2} = \sum_{j=1}^{q_i} Q_{ij} \times \left[ (d_{ijk} \times O_{TD2ijk}) + (L_{ijk} \times O_{TL2ijk}) \right] + \sum_{j=1}^{q_i} \sum_{t=1}^{f_i} \left( \frac{Q_{ijt} \times s_{2ij}}{2x} \times C_i \times h_{2ij} \right);
\]

\[
O_{L3} = \sum_{j=1}^{q_i} \sum_{k=1}^{p_{ij}} Q_{ijk} \times \left[ (d_{ijk} \times O_{TD3ijk}) + (L_{ijk} \times O_{TL3ijk}) \right] + \sum_{j=1}^{q_i} \sum_{k=1}^{p_{ij}} \sum_{t=1}^{f_i} \left( \frac{Q_{ijkt} \times s_{3ijk}}{2x} \times C_i \times h_{3ijk} \right) ;
\]

\[i = 1, 2, ..., n; j = 1, 2, ..., o_i; k = 1, 2, ..., u_{ij};\]  

**Distributors’ constraints**

These constraints must guarantee that subsidy given to distributors must be coordinated with these clauses:

1. The appropriate profit margin of distributors in doing their tasks in procurement and sales activities of subsidized urea fertilizer. The salvage value of distributors’ total cost after being subtracted with sales revenues from their retailers would be covered by government’s subsidy.

\[
\text{Distributors’ Total Costs} = \sum_{i=1}^{n} \sum_{j=1}^{q_i} \sum_{k=1}^{p_{ij}} \sum_{t=1}^{f_i} \left( \frac{Q_{ijkt} \times s_{2ij}}{2x} \times C_i \times h_{2ij} \right) + \sum_{i=1}^{n} \sum_{j=1}^{q_i} \left( Q_{ijkl} \times H_P \right) + \sum_{k=1}^{p_{ij}} \left( Q_{ijkl} \times \left[ (d_{ijk} \times O_{TD3ijk}) + (L_{ijk} \times O_{TL3ijk}) \right] \right);
\]

\[
\sum_{i=1}^{n} \sum_{j=1}^{q_i} \sum_{k=1}^{p_{ij}} \sum_{t=1}^{f_i} \left( \frac{Q_{ijkt} \times s_{2ij}}{2x} \times C_i \times h_{2ij} \right) + \sum_{i=1}^{n} \sum_{j=1}^{q_i} \left( Q_{ijkl} \times H_P \right) + \sum_{k=1}^{p_{ij}} \left( Q_{ijkl} \times \left[ (d_{ijk} \times O_{TD3ijk}) + (L_{ijk} \times O_{TL3ijk}) \right] \right)
\]

(10)

2. The same price in every distributors’ level that paid by retailers when buying subsidized urea fertilizer from the distributor’s warehouse. According to those clauses, constraint that indicates the balance between distributors’ costs, profit margin, buying price, and subsidy in distributors’ level can be defined in equation (11).

\[
\frac{1}{(1 + r_D) \times (O_{jkl} \times H_P) + \text{Distributors’ Total Costs} - S_{D_{jkl}}} \leq H_D
\]

(11)

**Retailers’ Constraints**

These constraints guarantee the appropriate retailers’ profit margin in sales activities of subsidized urea fertilizer and the maximum urea fertilizer stated by government can be reached by farmers at this retailers’ level.

\[
\text{Retailers’ Total Costs} = \sum_{i=1}^{n} \sum_{j=1}^{q_i} \sum_{k=1}^{p_{ij}} \sum_{t=1}^{f_i} \left( \frac{Q_{ijkt} \times s_{2ij}}{2x} \times C_i \times h_{2ij} \right) + \sum_{i=1}^{n} \sum_{j=1}^{q_i} \left( Q_{ijkl} \times H_P \right) + \sum_{k=1}^{p_{ij}} \left( Q_{ijkl} \times \left[ (d_{ijk} \times O_{TD3ijk}) + (L_{ijk} \times O_{TL3ijk}) \right] \right)
\]

\[
\sum_{i=1}^{n} \sum_{j=1}^{q_i} \sum_{k=1}^{p_{ij}} \sum_{t=1}^{f_i} \left( \frac{Q_{ijkt} \times s_{2ij}}{2x} \times C_i \times h_{2ij} \right) + \sum_{i=1}^{n} \sum_{j=1}^{q_i} \left( Q_{ijkl} \times H_P \right) + \sum_{k=1}^{p_{ij}} \left( Q_{ijkl} \times \left[ (d_{ijk} \times O_{TD3ijk}) + (L_{ijk} \times O_{TL3ijk}) \right] \right)
\]

(11)
\[ l = 1, 2, ..., v_{ijk}; m = 1, 2, ..., r_{ijkl} \]  

### Price Constraints

These constraints guarantee that the buying price of subsidized urea fertilizer in one tier must be lower than in the next tier.

\[ H_p \leq H_d \]  
(13)

\[ H_d \leq H_{ET} \]  
(14)

### Demand Constraints

These constraints guarantee the sufficient supply in covering subsidized urea fertilizer’s demand. In other words, these constraints guarantee the availability of subsidized urea fertilizer.

\[ \sum_{i=1}^{n} P_i \geq D + \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} \sum_{l=1}^{n} D_{ijkl} \]  
(15)

\[ Q_{ijklm} \geq D_{ijklm} \]

\[ i = 1, 2, ..., n; j = 1, 2, ..., o_i; k = 1, 2, ..., u_{ij}; l = 1, 2, ..., v_{ijk}; m = 1, 2, ..., r_{ijkl} \]  
(16)

### Supply Capacity Constraints

Supply capacity constraints guarantee that the amount of subsidized urea fertilizer distributed from one tier to the next tier must not exceed the inventory level on that tier. These constraints are defined as follows:

1. Equation (17) guarantees the synchronization between number of produced subsidized urea fertilizer with the production capacity of each producer.

\[ P_i \leq K_i \]  
(17)

2. Equation (18) guarantees that the distributed subsidized urea fertilizer to second tier’s warehouses will not exceed the inventory level in its producers’ warehouses, which assume same as producers’ production capacity.

\[ \sum_{j=1}^{n} Q_{ij} \leq P_i \quad i = 1, 2, ..., n; j = 1, 2, ..., o_i \]  
(18)

3. Equation (19) guarantees that the distributed subsidized urea fertilizer to third tier’s warehouses will not exceed the inventory level in its second tier warehouses.

\[ \sum_{k=1}^{n} Q_{ijk} \leq Q_{ij} \quad i = 1, 2, ..., n; j = 1, 2, ..., o_i \]  
(19)

4. Equation (20) guarantees that the distributed subsidized urea fertilizer to third tier’s warehouses in a period will not exceed the inventory level in its second tier warehouses at that period.

\[ \sum_{k=1}^{n} Q_{ijk} \leq Q_{ij} \quad i = 1, 2, ..., n; j = 1, 2, ..., o_i; t = 1, 2, ... \]  
(20)

5. Equation (21) guarantees that the distributed subsidized urea fertilizer to distributors’ warehouses will not exceed the inventory level in its producers’ third tier warehouses.

\[ \sum_{l=1}^{n} Q_{ijkl} \leq \sum_{l=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} D_{ijkl} \]

\[ i = 1, 2, ..., n; j = 1, 2, ..., o_i; k = 1, 2, ..., u_{ij}; l = 1, 2, ..., v_{ijk} \]  
(21)

6. Equation (22) guarantees that the distributed subsidized urea fertilizer to distributors’ warehouses in a period will not exceed the inventory level in its producers’ third tier warehouses at that period.

\[ \sum_{l=1}^{n} Q_{ijkl} \leq \sum_{l=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} D_{ijkl} \]

\[ i = 1, 2, ..., n; j = 1, 2, ..., o_i; k = 1, 2, ..., u_{ij}; l = 1, 2, ..., v_{ijk}; t = 1, 2, ... \]  
(22)

7. Equation (23) guarantees that the distributed subsidized urea fertilizer to retailers’ warehouses will not exceed the inventory level in its distributors’ warehouses.

\[ \sum_{m=1}^{n} Q_{ijklm} \leq Q_{ijkl} \quad i = 1, 2, ..., n; j = 1, 2, ..., o_i; k = 1, 2, ..., u_{ij}; l = 1, 2, ..., v_{ijk} \]  
(23)

8. Equation (24) guarantees that the distributed subsidized urea fertilizer to retailers’ warehouses in a period will not exceed the inventory level in its distributors’ warehouses at that period.

\[ \sum_{m=1}^{n} Q_{ijklm} \leq Q_{ijkl} \quad i = 1, 2, ..., n; j = 1, 2, ..., o_i; k = 1, 2, ..., u_{ij}; l = 1, 2, ..., v_{ijk}; t = 1, 2, ... \]  
(24)

### Subsidy budget constraints

This constraint guarantees that the amount of subsidy given by Indonesia’s government to support the procurement and distribution processes for subsidized urea fertilizer are not higher than the affordability of the government as seen on the planned budget.

\[ \sum_{i} S_{P i} + \sum_{i} \sum_{j} \sum_{k} \sum_{l} S_{D_{ijkl}} \leq A \]  
(25)

### Producer’s efficiency constraint Pembatas Efisiensi Produsen

This constraint guarantees the feasibility of production’s efficiency in order to get a reasonable cost of goods sold and the appropriate amount of subsidy.

\[ C_{ij} \leq C_{max} \quad i = 1, 2, n \]  
(26)
**Regionalization-Distribution Constraints**

These constraints guarantee that every third tier warehouse of producer \( i \) \((k)\) and every distributor’s warehouse can only be supplied from one warehouse in the first tier \( (i)\). M indicates a very large number.

- **The moving from the first tier area, directly to the third tier area**
  These constraints indicate that if there any moving activity of variable \( Q_{	ext{isk}} \) \((Q_{	ext{isk}} \text{ is not equal with zero})\) then value of \( b_{ik} \) will be forced to become 1, otherwise the value of \( b_{ik} \) will become zero.
  \[ b_{ik} = 0 \text{ or } 1, \quad i = 1, 2, \ldots, n; k = 1, 2, \ldots, u_{ij} \tag{27} \]
  \[ Q_{	ext{isk}} \leq M (b_{ik}), \quad i = 1, 2, \ldots, n; k = 1, 2, \ldots, u_{ij}; \tag{28} \]
  \[ t = 1, 2, \ldots, f \]

- **The moving from the first tier area, to the third tier area, via the second tier area**
  These constraints indicate that if there any moving activity of variable \( Q_{	ext{ijk}} \) \((Q_{	ext{ijk}} \text{ is not equal with zero})\) then value of \( b_{ijk} \) will be forced to become 1, otherwise the value of \( b_{ijk} \) will become zero.
  \[ b_{ijk} = 0 \text{ or } 1, \quad i = 1, 2, \ldots, n; j = 1, 2, \ldots, o_{ij}; k = 1, 2, \ldots, u_{ij} \tag{29} \]
  \[ Q_{	ext{ijk}} \leq M (b_{ijk}), \quad i = 1, 2, \ldots, n; j = 1, 2, \ldots, o_{ij}; k = 1, 2, \ldots, u_{ij}; \tag{30} \]
  \[ t = 1, 2, \ldots, f \]

- **Relation between \( b_{ik} \) and \( b_{ijk} \)**
  This constraint guarantees that fertilizer at the third tier can only be supplied from one tier. The supply could be directly from the first tier to the third tier and or via the second tier.
  \[ \sum_{i=1}^{n} \sum_{k=1}^{u_{ij}} b_{ik} + \sum_{i=1}^{n} \sum_{j=1}^{o_{ij}} \sum_{k=1}^{u_{ijk}} b_{ijk} = 1, \tag{31} \]
  \[ i = 1, 2, \ldots, n; j = 1, 2, \ldots, o_{ij}; k = 1, 2, \ldots, u_{ij} \]

**Nonnegativity constraints**

These constraints guarantee that decision variables in this model are equal or more than zero.

\[ Q_{ij} \geq 0, \quad i = 1, 2, \ldots, n; j = 1, 2, \ldots, o_{ij} \tag{32} \]
\[ Q_{ijk} \geq 0, \quad i = 1, 2, \ldots, n; j = 1, 2, \ldots, o_{ij}; k = 1, 2, \ldots, u_{ij} \tag{33} \]
\[ Q_{ijkl} \geq 0, \quad i = 1, 2, \ldots, n; j = 1, 2, \ldots, o_{ij}; k = 1, 2, \ldots, u_{ij}; \tag{34} \]
\[ l = 1, 2, \ldots, v_{ijk} \]
\[ Q_{ijklm} \geq 0, \quad i = 1, 2, \ldots, n; j = 1, 2, \ldots, o_{ij}; k = 1, 2, \ldots, u_{ij}; \tag{35} \]
\[ l = 1, 2, \ldots, v_{ijk}, m = 1, 2, \ldots, r_{ijkl} \]
\[ S_{ij} \geq 0, \quad i = 1, 2, \ldots, n \tag{36} \]
Final Model

In conclusion, the final model for integrated model of regionalization-distribution and cost subsidy for subsidized urea fertilizer in Indonesia is defined as follows:

**Objective Function**

**Minimize Logistics Total Costs and Minimize Subsidy**

\[
Z = \sum_{i=1}^{n} \left[ C_i + G_i + M_i \right] P_i + 
\sum_{i=1}^{n} \sum_{j=1}^{m} Q_{ij} \left[ \left( d_{ij} \times O_{TD2ij} \right) + \left( L_{ij} \times O_{TL2ij} \right) \right] + 
\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{n} \sum_{l=1}^{m} O_{ijklm} \left[ \left( d_{ijkl} \times O_{TD3ijkl} \right) + \left( L_{ijkl} \times O_{TL3ijkl} \right) \right] + 
\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{n} \sum_{l=1}^{m} \sum_{m=1}^{m} \sum_{l=1}^{m} \left[ \left( \frac{Q_{ijkl}}{2y} + \frac{Q_{ijkl}}{2x} \right) \times G_i + b_j \right] + 
\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{n} \sum_{l=1}^{m} \sum_{m=1}^{m} \sum_{l=1}^{m} \left[ \left( \frac{Q_{ijkl}}{2y} + \frac{Q_{ijkl}}{2x} \right) \times G_i + b_j \right] + 
\sum_{i=1}^{n} S_{P_i} + \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{n} \sum_{l=1}^{m} S_{D_{ijkl}}
\]

\[
(1 + R_p) \times (O_{L1} + O_{L2} + O_{L3}) \times S_{P_i} \leq H_p,
\]

\[
O_{L1} = (P_i \times C_i + G_i + M_i)
\]

\[
O_{L2} = \sum_{j=1}^{m} \left[ \left( d_{ij} \times O_{TD2ij} \right) + \left( L_{ij} \times O_{TL2ij} \right) \right] + \frac{Q_{ijkl}}{2x} + \frac{Q_{ijkl}}{2y} \times G_i + b_j
\]

\[
O_{L3} = \sum_{j=1}^{m} \sum_{k=1}^{n} \sum_{l=1}^{m} \sum_{m=1}^{m} \sum_{l=1}^{m} \left[ \left( \frac{Q_{ijkl}}{2y} + \frac{Q_{ijkl}}{2x} \right) \times G_i + b_j \right]
\]

\[
\frac{1 + R_{pe}}{Q_{ijkl}} \times \left( \left( Q_{ijkl} \times H_p \right) + \text{Distributors' Total Costs} - S_{D_{ijkl}} \right) \leq H_d
\]

\[
H_p \leq H_d
\]

\[
H_d \leq H_{ET}
\]

\[
\sum_{i=1}^{n} P_i \geq D, \quad D = \sum_{i} \sum_{j} \sum_{k} \sum_{l} \sum_{m} D_{ijkl}
\]

\[
Q_{ijklm} \geq D_{ijklm}
\]

\[
P_i \leq K_i
\]

\[
(\sum_{i} Q_{ijkl}) \leq Q_j
\]

\[
(\sum_{k} Q_{ijkl}) \leq Q_{ij}
\]

\[
(\sum_{l} Q_{ijkl}) \leq Q_{ijkl}
\]

\[
(\sum_{m} Q_{ijkl}) \leq Q_{ijkl}
\]

\[
\sum_{i} \sum_{j} \sum_{k} \sum_{l} S_{D_{ijkl}} \leq A
\]

\[
C_i \leq C_{\text{max}}
\]

\[
b_k = 0 \text{ or } 1
\]

\[
Q_{d_k} \leq M \times b_k
\]

\[
b_k = 0 \text{ or } 1
\]

\[
Q_{d_k} \leq M \times b_k
\]

\[
\sum_{i=1}^{n} b_i + \sum_{i=1}^{n} \sum_{j=1}^{m} b_{ijk} = 1
\]

\[
Q_j \geq 0 \times Q_{ij}
\]

\[
Q_{ij} \geq 0
\]

\[
Q_{ijkl} \geq 0
\]

\[
S_{P_i} \geq 0
\]

\[
S_{D_{ijkl}} \geq 0
\]
Where:

\[
\text{Distributors' Total Cost} = \sum_{i=1}^{n} \sum_{j=1}^{o_i} \sum_{k=1}^{u_{ij}} \sum_{l=1}^{v_{ijk}} \left[ Q_{ijkl} \times H_p + \left( d_{ijkl} \times O_{TD3ijkl} \times O_{TL3ijkl} \right) \right] + \sum_{i=1}^{n} \sum_{j=1}^{o_i} \sum_{k=1}^{u_{ij}} \sum_{l=1}^{v_{ijk}} \sum_{t=1}^{m_l} \left( \frac{Q_{ijkl}}{2y} + s_{ijkl} \right) \times H_p \times b_{3ijkl} + \sum_{i=1}^{n} \sum_{j=1}^{o_i} \sum_{k=1}^{u_{ij}} \sum_{l=1}^{v_{ijk}} \sum_{m=1}^{m_l} Q_{ijklm} \times \left[ d_{ijklm} \times O_{TD4ijklm} \times O_{TL4ijklm} \right]
\]

and

\[
i = 1, 2, ..., n; j = 1, 2, ..., o_i; k = 1, 2, ..., u_{ij}; l = 1, 2, ..., v_{ijk}; m = 1, 2, ..., m_l; t = 1, 2, ..., f
\]

4. Numerical Example

Solution for numerical example is using data from three largest producers in Indonesia which supply three provinces in Indonesia. According to national data, the demand of those three provinces in 2006 reaches more than 20% of Indonesia’s demand in fertilizer. Amount of distributed urea fertilizer is as same as the allocation of urea fertilizer’s demand in an area on 2006. Producers’ production capacity on 2006 is as same as on 2005. Supply chain structures can be shown in Figure 4.

Table 1: Number of Supply Chain Components used in Numerical Examples

<table>
<thead>
<tr>
<th>3 Plants (1st Tier)</th>
<th>2nd Tier Warehouses</th>
<th>3rd Tier Warehouses</th>
<th>Distributors</th>
<th>Retailers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant A</td>
<td>-</td>
<td>11</td>
<td>100</td>
<td>341</td>
</tr>
<tr>
<td>Plant B</td>
<td>2</td>
<td>5</td>
<td>34</td>
<td>198</td>
</tr>
<tr>
<td>Plant C</td>
<td>2</td>
<td>19</td>
<td>19</td>
<td>65</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>35</td>
<td>153</td>
<td>604</td>
</tr>
</tbody>
</table>

After we have new regionalization-distribution and the optimal quantities supplied at each tier, we have the related costs of this model. Output of model solutions are created from LINGO 8.0 extended version. The optimal value is found at the 95th iteration. Solution building report can be shown in Figure 4 and the details of solution values can be shown on Table 2.
Total logistics costs have function to guarantee the smooth distribution and procurement activities of subsidized urea fertilizer, starts from producers at the first tier until their retailers at the fourth tier.

<table>
<thead>
<tr>
<th>Table 2: The Summary of Optimal Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results Recapitulation</strong></td>
</tr>
<tr>
<td><strong>Data</strong></td>
</tr>
<tr>
<td>Subsidy Budget</td>
</tr>
<tr>
<td>Minimum Production Cost Per Producer</td>
</tr>
<tr>
<td>Demand per year</td>
</tr>
<tr>
<td>Minimum Capacity of Producer A</td>
</tr>
<tr>
<td>Maximum Capacity of Producer B</td>
</tr>
<tr>
<td>Production Cost of Producer A</td>
</tr>
<tr>
<td>Production Cost of Producer B</td>
</tr>
<tr>
<td>Production Cost of Producer C</td>
</tr>
<tr>
<td><strong>Solution Review</strong></td>
</tr>
<tr>
<td><strong>Total Objective Function Optimal Value</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Details of Total Objective Function Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Logistics Costs</td>
</tr>
<tr>
<td>Subsidy Amount for Producer A</td>
</tr>
<tr>
<td>Subsidy Amount for Producer B</td>
</tr>
<tr>
<td>Subsidy Amount for Producer C</td>
</tr>
<tr>
<td><strong>Total Producers' Subsidy Amount</strong></td>
</tr>
<tr>
<td>Subsidy Amount for Distributors of Producer A</td>
</tr>
<tr>
<td>Subsidy Amount for Distributors of Producer B</td>
</tr>
<tr>
<td>Subsidy Amount for Distributors of Producer C</td>
</tr>
<tr>
<td><strong>Total Distributors’ Subsidy Amount</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Supplied Production Quantity For Each Producers</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 of Producer A</td>
</tr>
<tr>
<td>Q12 of Producer A</td>
</tr>
<tr>
<td>Q13 of Producer A</td>
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<tr>
<td>Q13 of Producer A</td>
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<td>Q13 of Producer A</td>
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<tr>
<td>Q13 of Producer A</td>
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<tr>
<td><strong>Total Supplied Quantity of Producer A</strong></td>
</tr>
<tr>
<td>Q1 of Producer B</td>
</tr>
<tr>
<td>Q1 of Producer B</td>
</tr>
<tr>
<td>Q1 of Producer B</td>
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<tr>
<td>Q1 of Producer B</td>
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<tr>
<td><strong>Total Supplied Quantity of Producer B</strong></td>
</tr>
<tr>
<td>Q1 of Producer C</td>
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<td>Q1 of Producer C</td>
</tr>
<tr>
<td>Q1 of Producer C</td>
</tr>
<tr>
<td>Q1 of Producer C</td>
</tr>
<tr>
<td><strong>Total Supplied Quantity of Producer C</strong></td>
</tr>
</tbody>
</table>
5. Conclusion

This paper presents a development of integrated model of distribution regionalization and cost subsidy which part of production-distribution system problem. This model is considering subsidy factor as national parameter that will become a new emerging issue in production-distribution system. Supply chain performances will affect amount of subsidy given to producers and distributors. The result proves that cost subsidy is better than gas subsidy given from government right now because it considering related logistics costs in production, procurement, and distribution activities of subsidized urea fertilizer. According to the results, government should increase the amount of subsidy for fertilizer’s producers and also give subsidy to their distributors. The outcomes of this proposed solution are that the producers will not be deficit in running their activities and the farmers will not become victims when buying fertilizers exceeding the maximum price stated by government and still under their affordability. For some remote areas which have long distances and high transportation costs caused by bad infrastructures, the difference between subsidies given to distributors per kg subtracted with the price in distributors’ level will become negative. The negative amount of these values indicates that the supply chain structures can be cut so the distribution process can be directly done from producers to retailers, especially for remote areas. Distributors’ functions will become a transporter company owned by producers and the ownership of subsidized urea fertilizer is still on producers’ hand. The limitation of this model is not considering the seasonal demand and another alternative of supply chain structures. We simplify it by dividing a year into three time order periods according to the demand characteristics of urea fertilizers. In future, the model can be extended by considering 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 demand from farmers without increasing price. Results of this model can be implemented in commodities industry regulated by government.

References

### Appendix 1. Research Position According to Taxonomy of Analytical Approaches for Production-Distribution System Design Problem (Verter and Dincer [12])

<table>
<thead>
<tr>
<th>Objective Function (C/P/M)</th>
<th>Number of echelons to be located</th>
<th>Number of echelons in the production &amp; distribution system</th>
<th>Number of commodities (S/M)</th>
<th>Capacity limitations on sites (+/-)</th>
<th>Demand (DS)$^2$</th>
<th>Number of time periods (S/M)$^3$</th>
<th>Side constraints (+/-)</th>
<th>Capacity acquisition (+/-)</th>
<th>National / International Features (D,E,L,O,P,Q,T,S)$^4$</th>
<th>Industrial Application (+/-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuehn and Hamburger (1963)</td>
<td>C 3 1 M</td>
<td>+</td>
<td>D</td>
<td>S</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Efroymson and Ray (1966)</td>
<td>C 2 1 S</td>
<td>-</td>
<td>D</td>
<td>S</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Warszawski (1973)</td>
<td>C 2 1 M</td>
<td>-</td>
<td>D</td>
<td>S</td>
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<td>-</td>
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</tr>
<tr>
<td>Geoffrion and Graves (1974)</td>
<td>C 3 1 M</td>
<td>+</td>
<td>D</td>
<td>S</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
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</tr>
<tr>
<td>Akin and Khumawala (1977)</td>
<td>C 2 1 S</td>
<td>+</td>
<td>D</td>
<td>S</td>
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<td>-</td>
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<td>D</td>
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<td>Karkazis and Boffey (1981)</td>
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<td>Neebe and Khumawala (1981)</td>
<td>C 2 1 M</td>
<td>-</td>
<td>D</td>
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<td>Van Roy and Erlenkotter (1982)</td>
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<tr>
<td>Techa and Lee (1984)</td>
<td>C M M S</td>
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<td>D</td>
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<tr>
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1: C: Cost, P: Profit, M: Multiple,  
2: S: Single, M: Multiple,  
3: D: Deterministic, S: Stochastic,  
4: D: Duties, E: Exchange rate uncertainty, L: Local content requirements, O: Offset trade regulations, P: Price uncertainty, Q: Quotas, T: Tariffs, S: Subsidy