Model of Integrated Production Allocation for Minimizing Distribution Costs in a Cement Company

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Abstract. This paper, in order to get a gain after the acquisition process with whose carry out by the company and the competitor. Post-acquisition, to analyse getting better efficiency, to do so a process restructuring in an existing distribution network is consolidated and integrated by the existing distribution network with the distribution network of the newly acquired company in supply chain management. The acquisition process is expected to expand the network in the domestic market and increase the efficiency of supply chain costs by planning production allocations in an effort to optimize distribution costs more efficiently. The purpose of this work is to determine the optimal configuration of production and distribution networks with operational and financial constraints. A linear programming model is proposed to describe and to optimize the problem. By considering various parameters of the model such as plant capacity, production costs, and distribution costs, this model is hoping to be able for determining where the production of cement facilities is carried out to meet the demand for cement in the market to obtain more efficient distribution costs.

1. Introduction
The current global economy is undergoing rapid change, and of course, logistics is one area that is also experiencing rapid change, including supply chain management itself [1]. The supply chain in a company can be seen as a network that has multi-process and complex activities. The current trend of supply chain management is leading to integrated systems, where manufacturing companies seek or develop strategies globally by designing their products by producing materials, components, and labor at the lowest possible cost.

At this time in the manufacturing industry, the problem of the relationship between set up and supply chain management becomes complex and important. Where companies in making a decision must coordinate between the functions of production, storage, and distribution to control the costs of these functions to be competitive in product price competition in the market. To be able to offer attractive products at competitive prices, every company must try to reduce all operating costs of the company while maintaining product quality under established standards. One effort to reduce these costs is by optimizing production from upstream to downstream by optimizing the distribution of materials from suppliers, the flow of material in the production process to the distribution of products to the hands of consumers.

The Integration of operational activities is also carried out by one of the cement industry companies in Indonesia, which centralizes the marketing, supply chain, and procurement functions in the increasingly tight competition in the cement industry in Indonesia at this time. The Company hereinafter
referred to as "the Company", believes that the implementation of an integrated strategy in all aspects of operations will provide maximum and sustainable business results for the company going forward. In early 2019, the company will also expand its business by expanding to acquire other cement industry companies in Indonesia, thereby increasing the company's competitiveness in supply capacity and distribution networks. With the addition of supply source facilities and distribution facilities, it is necessary to re-evaluate the supply chain management, especially in the downstream supply chain or product delivery activities to customers. The cement distribution network in the "Company" uses the modes of transportation of trucks, trains, and ships. Ships are used to transport bulk cement from the Cement Plant to the Packing Plant, while trucks and trains are used to transport cement from the Cement Plant to the Distribution Center or directly to the sales district. Between the factory and the sales district, there is a Distribution Center that serves as a place to temporarily collect and store cement products from various factories to be distributed to several marketing areas around the Distribution Center which are expected to minimize distribution costs. The distribution network in "Company" in general can be described as follows:

![Distribution Network Diagram](image)

**Figure 1. Illustration of distribution network in "company"**

Post-acquisition, restructuring of the existing distribution network in the company is needed by consolidating and integrating the existing distribution network with the distribution network of the newly acquired company in supply chain management to improve distribution cost efficiency. The company's distribution costs are a large contributor to the company's cost of revenue.

**Table 1. Cost of revenue period of 2016 - 2019**

| Cost of Revenue (IDR Billion) | 2016  | 2017  | 2018  | 2019  | Growth 2017:2016 | Growth 2018:2017 | Growth 2019:2018 |
|------------------------------|-------|-------|-------|-------|------------------|------------------|------------------|
| Energy                       | 5.563 | 6.992 | 7.349 | 8.996 | 25.7%            | 5.1%             | 22.4%            |
| Distribution                 | 1.813 | 2.109 | 2.376 | 3.204 | 16.3%            | 12.7%            | 34.8%            |
| Raw Material                 | 1.376 | 1.877 | 1.876 | 1.874 | 36.4%            | -0.1%            | -0.1%            |
| Depreciation                 | 1.571 | 1.853 | 1.523 | 1.956 | 18.0%            | -17.8%           | 28.4%            |
| Labor                        | 1.534 | 1.488 | 1.223 | 2.254 | -3.0%            | -17.8%           | 84.3%            |
| Fabrication Expenses         | 4.422 | 5.535 | 7.010 | 9.370 | 25.2%            | 26.6%            | 33.7%            |
| **Total**                    | **16.279** | **19.854** | **21.357** | **27.654** | **22.0%** | **7.6%** | **29.5%** |
Distribution costs have increased from year to year, with distribution costs in 2019 reaching 3.2 trillion Rupiah. The amount of distribution costs is of concern to the company because cement products are commodities that have large volumes that require high product distribution costs. The increase in distribution costs was not followed commensurately with the increase in the volume of cement sales, where the volume of cement sales in 2016 to 2019 only experienced an increase in sales volume of 1.42%.

Table 2. Distribution costs per sales volume for the period of 2016-2019

| Year | Distribution Cost (IDR Billion) | Sales Volume (Ton) | Distribution Cost per Sales (IDR/Ton) |
|------|---------------------------------|-------------------|---------------------------------------|
| 2016 | 1.813                           | 25.682.143        | 70.594                                |
| 2017 | 2.109                           | 27.091.728        | 77.847                                |
| 2018 | 2.376                           | 27.421.500        | 86.647                                |
| 2019 | 3.204                           | 36.340.833        | 88.165                                |

By rearranging the product supply source facilities and distribution facilities is expected to get the most efficient distribution costs to produce the maximum margin.

2. Methodology

Supply Chain is a network of companies that jointly work to create and deliver a product to the end-user. These companies usually include suppliers, factories, distributors, stores, or retail, as well as supporting companies such as logistics service companies [2]. Understanding of supply chain management, in general, can be explained as the integration of various activities starting from the procurement of goods and services, turning raw materials into goods in process and finished goods, and sending these goods to customers in an efficient manner.

In the current modern economic era, distribution is one of the main determinants in developing an effective supply chain management system. Effective distribution is the process that determines the best placement of products, supplies, and choosing the right mode of transportation to serve the external supply chain [3]. So in determining the decision to establish a production facility or warehousing facility, it should be done simultaneously in matters relating to production and distribution allocations [4].

Competitive distribution management has a very important role in concentration and market penetration to gain sustainable profits by giving internal and external customer satisfaction. Distribution management is the process of managing the movement of goods from suppliers or producers to the point of sale. This is a comprehensive term that refers to various activities and processes such as packaging, inventory, warehousing, supply chain, and logistics. Effective distribution management by monitoring the movement of products from suppliers or manufacturers to the point of sale. The effective distribution gives customers convenience in the form of availability (what, where, when - the right product, in the right place, at the right time), access (customer awareness of availability and authorization to buy), and support (for example advice pre-sales, sales promotion and merchandising, after-sales service improvement). Efficiency in distribution management can be defined as the movement of goods from producers to consumers with optimal costs that are consistent with the desired customer service.

Ideally, the entire supply chain process needs to be designed, managed, and coordinated as one work unit, thus the integration of the supply chain as a key element in the supply chain management strategy. The challenge in supply chain integration is how to coordinate activities throughout the supply chain so that companies can improve performance in the form of reducing costs, increasing service levels, reducing the bullwhip effect, using better resources, and responding effectively to changes in the market. As many companies have recently realized, these challenges are met not only by coordinating production, transportation, and supply decisions but more generally by integrating from the front end of the supply chain in the form of customer demand and to the back end of the supply chain, part manufacturing from the supply chain [5].
Production allocation is carried out by determining the types of goods produced, the amount of production capacity, allocation to distribution facilities, and allocation to customers in each factory that produces. Distribution allocation determines the delivery of products from production facilities to customers with the aim of the right place, the right time, the right quality specifications, and at an efficient cost.

Using the set covering model is a way to determine the lowest cost of placing several facilities where each demand node can be reached by at least one facility. The Model Covering Set is one part of the allocation location problem [6]. The purpose of the allocation location model is to determine the location of facilities that can minimize the cost of assigning facilities to customers with the limitation that each facility is used for a specified number of customers.

For this reason, it is necessary to have activities that can be carried out by the company itself or submitted to the transportation service company to design an appropriate and appropriate distribution system by considering aspects of cost, aspects of flexibility, and aspects of the speed of response to customers. In designing a distribution system to meet customer desires suggest three criteria, namely: rapid response, product choices, and services [7].

Figure 2. Number of facilities in the distribution system network [7]

3. Model Formulation

At this stage, an analysis of the optimization of integrated production and distribution allocations is carried out to obtain optimal results. There are several methods approaches in analyzing optimization problems, wherein this study using a linear programming model to solve the problems encountered. Modeling formulation in describing supply chain networks is carried out using data collected from companies consisting of 21 supply facilities and 136 marketing districts. Among the 21 supply facilities consist of 5 integrated Cement Plants, 1 Grinding Plant (GP), 4 Packing Plants (PP), and 11 Distribution Centers (D). The following formulation models will be developed to optimize distribution costs:

3.1 Notation

The notation that will be used in the development of this modeling is as follows:

Index:
P: cement product, p ∀ P for p = 1 ... 3
I: cement plant, i ∀ I for i = 1 ... 5
J: grinding plant and packing plant, j ∀ J for k = 1 ... 5
M: distribution center (DC), m ∀ M for m = 1 ... 11
N: region or sales district, n ∀ N for n = 1 ... 136
Parameter:

\[ C_{pi}^P = \text{production cost for product } p \text{ at cement plant } i \]
\[ C_{pj}^P = \text{production cost for product } p \text{ at grinding plant or packing plant } j \]
\[ C_{pm}^S = \text{saving cost for product } p \text{ at distribution center } m \]
\[ C_{pij}^D = \text{distribution cost for product } p \text{ from cement plant } i \text{ to grinding plant or packing plant } j \]
\[ C_{pjm}^D = \text{distribution cost for product } p \text{ from grinding plant or packing plant } j \text{ to distribution center } m \]
\[ C_{pim}^D = \text{distribution cost for product } p \text{ from cement plant } i \text{ to distribution center } m \]
\[ C_{pjn}^D = \text{distribution cost for product } p \text{ from grinding plant or packing plant } j \text{ to sales district } n \]
\[ U_{pi} = \text{production capacity for product } p \text{ in cement plant } i \]
\[ V_{pj} = \text{production capacity for product } p \text{ in grinding plant or packing plant } j \]
\[ W_{pm} = \text{storage capacity for product } p \text{ in distribution center } m \]
\[ D_{pn} = \text{product demand for product } p \text{ in sales district } n \]

3.2 Decision Variable

Decision variables for supply chain distribution problems are described as follows:

\[ X_{pij} = \text{number of product } p \text{ from cement plant } i \text{ to grinding plant/packing plant } j \]
\[ X_{pjm} = \text{number of product } p \text{ from grinding plant/packing plant } j \text{ to distribution center } m \]
\[ X_{pim} = \text{number of product } p \text{ from cement plant } i \text{ to distribution center } m \]
\[ X_{pjn} = \text{number of product } p \text{ from grinding plant/packing plant } j \text{ to sales district } n \]
\[ Y_i = \text{value 1 if cement plant is operated and value 0 if it does not operate} \]
\[ Y_j = \text{value 1 if grinding plant or packing plant is operated and value 0 if it does not operate} \]
\[ Y_m = \text{value 1 if distribution center is operated and value 0 if it does not operate} \]

3.3 Objective Function

The goal of this supply chain problem is to minimize the cost of product distribution from supply sources to customers. The destination function can be described as follows:

- Production cost
  These production costs multiply the cost of production with the number of products sent from the factory to the distribution center and sent directly from the factory to the sales district.

\[
\sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{j=1}^{5} X_{pij} C_{pi}^P + \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{m=1}^{11} X_{pim} C_{pi}^P + \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{n=1}^{136} X_{pin} C_{pi}^P \\
+ \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{m=1}^{11} X_{pjm} C_{pj}^P + \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{n=1}^{136} X_{pjn} C_{pj}^P
\]  
(1)
• Distribution cost
  This distribution fee multiplies the number of products shipped with the cost of distribution.
  \[
  \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{j=1}^{5} X_{pij} C_{ pij}^D + \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{m=1}^{11} X_{pjm} C_{ pj m}^D + \sum_{p=1}^{3} \sum_{m=1}^{11} \sum_{n=1}^{136} X_{pmn} C_{ pm n}^D \\
  + \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{m=1}^{11} X_{pim} C_{ pim}^D + \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{n=1}^{136} X_{pin} C_{ pin}^D \\
  + \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{n=1}^{136} X_{pjn} C_{ pj n}^D
  \]  

(2)

• Storage cost
  This storage cost multiplies the number of products stored in the distribution center with the cost of handling and storing components while in the distribution center.
  \[
  \sum_{p=1}^{3} \sum_{m=1}^{5} \sum_{n=1}^{136} X_{pmn} C_{ pm n}^S
  \]  

(3)

• Merge objective function
  Combining the production and distribution cost functions will produce the overall optimization objective function as follows:
  Minimization of total costs (production, storage, and distribution)
  \[
  \text{Min} = \\
  \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{j=1}^{5} X_{pij} C_{ pi}^P + \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{m=1}^{11} X_{pim} C_{ pim}^P + \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{n=1}^{136} X_{pin} C_{ pin}^P \\
  + \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{m=1}^{11} X_{pjm} C_{ pj m}^P + \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{n=1}^{136} X_{pjn} C_{ pj n}^P \\
  + \sum_{p=1}^{3} \sum_{m=1}^{5} \sum_{n=1}^{136} X_{pmn} C_{ pm n}^P \\
  + \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{m=1}^{11} X_{pim} C_{ pim}^D + \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{n=1}^{136} X_{pin} C_{ pin}^D \\
  + \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{m=1}^{11} X_{pjm} C_{ pj m}^D + \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{n=1}^{136} X_{pjn} C_{ pj n}^D \\
  + \sum_{p=1}^{3} \sum_{m=1}^{5} \sum_{n=1}^{136} X_{pmn} C_{ pm n}^D
  \]  

(4)
The objective function in this model is the minimization of costs consisting of production costs, storage costs, and distribution costs. The production costs and savings costs are also taken into consideration the fixed production costs of all the supply facilities.

### 3.4 Constraint Function

Constraints in this problem include the supply ability of each supply facility, the constraints of fulfilling customer demand, and non-negative constraints. The constraint function is as follows:

- **Constraints on cement plant production capacity**
  The amount of cement production sent from the cement plant to the grinding plant and packing plant, distribution center, and sales district must not exceed the production capacity of the cement plant.

  \[ \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{j=1}^{5} X_{pij} + \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{m=1}^{11} X_{pim} + \sum_{i=1}^{5} \sum_{n=1}^{136} X_{pin} \leq U_{pi}, \quad \forall i \tag{5} \]

- **Constraints on the production capacity of the grinding plant and packing plant**
  The amount of cement production sent from the grinding plant and packing plant to the distribution center and sales district must not exceed the production capacity of the grinding plant or packing plant.

  \[ \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{m=1}^{11} X_{pjm} + \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{n=1}^{136} X_{pjn} \leq V_{pj}, \quad \forall j \tag{6} \]

- **Distribution center capacity constraints**
  The number of cement products sent from the distribution center to the marketing area must not be greater than the capacity of the distribution center.

  \[ \sum_{p=1}^{3} \sum_{m=1}^{11} \sum_{n=1}^{136} X_{pmn} \leq W_{pm}, \quad \forall m \tag{7} \]

- **Distribution center synchronization constraints**
  The number of products entering the distribution center must be the same as the number of products coming out of the distribution center, which is assumed to be zero inventory.

  \[ \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{m=1}^{11} X_{pim} + \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{m=1}^{11} X_{pjm} = \sum_{p=1}^{3} \sum_{m=1}^{11} \sum_{n=1}^{136} X_{pmn}, \quad \forall m \tag{8} \]

- **Constraints on fulfilling customer requests**
  The number of requests in the marketing area must always be fulfilled.

  \[ \sum_{p=1}^{3} \sum_{i=1}^{5} \sum_{n=1}^{136} X_{pin} + \sum_{p=1}^{3} \sum_{j=1}^{5} \sum_{n=1}^{136} X_{pjn} + \sum_{m=1}^{11} \sum_{n=1}^{136} X_{pmn} \geq D_{pn}, \quad \forall n \tag{9} \]
4. Case study

This research is limited to the distribution network optimization in Java, which is greatly affected by the acquisition process carried out by "companies" of competitor companies located on the island of Java. After the acquisition process, production facilities and distribution facilities have increased so there is a need to restructure the distribution network to get maximum cost efficiency. Facilities owned after the acquisition consist of 21 supply source facilities which include 5 Cement Plant (CP) units, 4 Packing Plant (PP) units, and 1 Grinding Plant (GP) unit, and 11 Distribution Centers (DC) to serve cement needs in Java, which are divided into 136 sales districts. There are more than 10 types of cement produced, but in this study, the focus is on 3 types of cement products that are generally sold in the market and have the highest demand for cement products in the domestic and foreign markets. The three types of cement products are Ordinary Portland Cement (OPC) or Ready Flow Plus (RFP); Portland Composite Cement (PCC) or Ready Flow (RF); and Portland Composite Cement Premium (PCC Premium) or Powermax.

4.1 Data

The data parameter is taken from the company shown in Table 3 to Table 14.

### Table 3. Supply facilities in java

| Type  | Name                  | Location          | Capacity of Supply Facilities (Ton / Month) |
|-------|-----------------------|-------------------|---------------------------------------------|
|       |                       |                   | OPC/RFP | PCC/RF | PCC Prem./Powermax |
| CP    | CP Tuban 1            | Tuban, Jawa Timur | 317.676 | 731.459 | 73.146             |
|       | CP Rembang            | Rembang, Jawa Tengah | 128.274 | 74.444 | 47.282             |
|       | CP Narogong           | Bogor, Jawa Barat | 123.939 | 261.041 | 19.593             |
|       | CP Cilacap            | Cilacap, Jawa Tengah | -     | 207.050 | -                  |
|       | CP Tuban 2            | Tuban, Jawa Timur | 75.650 | 158.873 | -                  |
| GP & PP| GP Gresik             | Gresik, Jawa Timur | 23.356 | 48.072 | 5.952              |
|       | PP Banyuwangi         | Banyuwangi, Jawa Timur | 12.800 | 30.400 | 4.800              |
|       | PP Tj. Priok          | Tanjung Priok, Jakarta | 16.000 | 24.000 | 8.000              |
|       | PP Ciwandan 1         | Cilegon, Banten | 9.000 | 36.000 | 3.000              |
|       | PP Ciwandan 2         | Cilegon, Banten | 8.000 | 37.500 | 2.500              |
| DC    | DC Cibungur           | Purwakarta, Jawa Barat | 3 x 2300 | 3 x 2300 | 3 x 2300 |
|       | DC Ciwandan           | Cilegon, Banten | 3 x 2700 | 3 x 2700 | 3 x 2700 |
|       | DC Narogong           | Bogor, Jawa Barat | 3 x 3000 | 3 x 3000 | 3 x 3000 |
|       | DC Pasoso             | Jakut, DKI Jakarta | 3 x 4000 | 3 x 4000 | 3 x 4000 |
|       | DC Bogor              | Bogor, Jawa Barat | 3 x 1500 | 3 x 1500 | 3 x 1500 |
|       | DC Cimahi             | Cimahi, Jawa Barat | 3 x 2500 | 3 x 2500 | 3 x 2500 |
|       | DC Sukabumi           | Sukabumi, Jawa Barat | 3 x 700 | 3 x 700 | 3 x 700 |
|       | DC Jogja              | Yogyakarta | 3 x 3500 | 3 x 3500 | 3 x 3500 |
|       | DC Solo               | Solo, Jawa Tengah | 3 x 1500 | 3 x 1500 | 3 x 1500 |
|       | DC Cikande            | Serang, Banten | 3 x 1200 | 3 x 1200 | 3 x 1200 |
|       | DC Cirebon            | Cirebon, Jawa Barat | 3 x 3000 | 3 x 3000 | 3 x 3000 |
After the acquisition process, the location of supply source facilities is spread throughout Java Island. This gives more advantages in the process of distributing cement products to consumers.

To meet the demand for cement on the island of Java, the "company" divided marketing districts totaling 136 districts spread across 6 provinces in Java. The total sales districts that exist are merging with the marketing district of the company that was acquired by the "company" so that it is hoped that the merging of this district will provide synergy for the two companies.

| Sales District | Sales District | Sales District |
|----------------|----------------|----------------|
| Ambarawa       | Jakarta Barat  | Kota Sukabumi  | Purworejo    |
| Babat          | Jakarta Pusat  | Kudus          | Rembang      |
| Bandung        | Jakarta Selatan| Kulonprogo     | Salatiga     |
| Bangkalan      | Jakarta Timur  | Kuningan       | Sampang      |
| Banjar         | Jakarta Utara  | Lamongan       | Semarang     |
| Banjarnegara   | Jember         | Lumajang       | Serang       |
| Bantul         | Jepara         | Madiun         | Sidoarjo     |
| Banyumas       | Jombang        | Magelang       | Situbondo    |
| Banyuwangi     | Kab. Bandung   | Magelang Kota  | Sleman       |
| Batang         | Kab. Bekasi    | Magetan        | Solo         |
| Batu           | Kab. Cianjur   | Majalengka     | Sragen       |
| Bawean         | Kab. Cirebon   | Majenang       | Sukabumi     |
| Bekasi         | Kab. Garut     | Malang         | Sukoharjo    |
| Blitar         | Kab. Indramayu | Mojokerto      | Sumedang     |
| Blora          | Kab. Karawang  | Nganjuk        | Sumenep      |
| Bogor          | Kab. Kuningan  | Ngawi          | Sumenep 2    |
| Bojonegoro     | Kab. Lebak     | Pacitan        | Surabaya     |
| Bondowoso      | Kab. Majalengka| Padalarang     | Surabaya Barat|
| Boyolali       | Kab. Purwakarta| Padangan       | Surakarta    |
| Brebes         | Kab. Subang    | Pamekasan      | Tangerang    |
| Cepu           | Kab. Sukabumi  | Pandeglang     | Tangerang Selatan|
| Ciamis         | Kab. Sumedang  | Pangandaran    | Tasikmalaya  |
| Cianjur        | Kab. Tangerang | Pare           | Tegal        |
| Cikarang       | Kab. Tasikmalaya| Pasuruan      | Temanggung   |
| Cilacap        | Karanganyar    | Pati           | Trenggalek   |
| Cilegon        | Kebumen        | Pekalongan     | Tuban        |
| Cimahi         | Kediri         | Pekalongan Kota| Tulungagung  |
| Cirebon        | Kendal         | Pemalang       | Ungaran      |
| Demak          | Klaten         | Ponorogo       | Walikukun    |
| Garuk          | Kota Bandung   | Probolinggo    | Weleri       |
| Gresik         | Kota Bekasi    | Purbalingga    | Wonogiri     |
| Grobogan       | Kota Bogor     | Purwantoro     | Wonosari     |
| Gunung Kidul   | Kota Cimahi    | Purwodadi      | Wonosobo     |
| Indramayu      | Kota Depok     | Purwokerto     | Yogyakarta   |

Costs incurred at each supply source facility can be identified as follows:
While the production operational costs incurred at the supply facilities of the grinding plant and packing plant which includes the cement grinding process and the cement packing process can be seen in the table below.

### Table 6. Production costs at the grinding plant and packing plant (IDR / Ton)

| Facilities      | Packing Cost |
|-----------------|--------------|
| PP Banyuwangi   | 12.994       |
| PP Tanjung Priok| 39.200       |
| PP Ciwandan 1   | 44.678       |
| PP Ciwandan 2   | 30.255       |
| GP Gresik       | 88.858       |

Operational costs contained in the distribution center in the form of savings costs are costs incurred from the product handling process and product storage while in the distribution center.

### Table 7. Storage cost at distribution center (IDR / Ton)

| Facilities      | Storage Cost |
|-----------------|--------------|
| DC Cibungur     | 4.786        |
| DC Ciwandan     | 1.895        |
| DC Narogong     | 4.966        |
| DC Pasoso       | 5.420        |
| DC Bogor        | 9.000        |
| DC Cimahi       | 4.786        |
| DC Sukabumi     | 11.700       |
| DC Jogja        | 4.192        |
| DC Solo         | 3.966        |
| DC Cikande      | 9.825        |
| DC Cirebon      | 11.182       |

The distribution cost per ton of cement that must be incurred by the company is very large because cement products have heavy volume characteristics and large dimensions. Distribution costs between supply facilities up to the marketing district are divided into six distribution costs between supply facilities up to consumers.

The distribution costs can be seen as follows:
### Table 8. Distribution cost from cement plant to grinding plant and packing plant (IDR / Ton)

| Cement Plant | Packing Plant & Grinding Plant |
|--------------|--------------------------------|
|              | Banyuwangi | Tj. Priok | Ciwandan 1 | Ciwandan 2 | Gresik |
| Tuban-1      | 156.012    | 210.789  | 203.984    | 207.664    | 89.931 |
| Rembang      | 242.912    | 297.689  | 290.884    | 294.564    | 115.835 |
| Narogong     | 500.800    | 55.000   | 127.600    | 127.600    | 418.700 |
| Cilacap      | 411.730    | 363.100  | 435.700    | 435.700    | 198.342 |
| Tuban-2      | 162.800    | 216.800  | 210.000    | 213.715    | 87.400  |

### Table 9. Distribution cost from grinding plant and packing plant to distribution center (IDR / Ton)

| PP & GP | Distribution Center |
|---------|---------------------|
|         | Cibungur | Ciwandan | Narogong | Pasoso | Bogor | Cimahi |
| Banyuwangi | 325.122  | 358.101  | 370.320  | 330.695 | 305.012 | 344.440 |
| Tj. Priok   | 111.428  | 77.505   | 67.974   | 48.320  | 72.300  | 434.068 |
| Ciwandan 1   | 184.028  | 23.525   | 75.514   | 81.840  | 144.900 | 217.228 |
| Ciwandan 2   | 184.028  | 23.525   | 68.274   | 73.980  | 144.900 | 217.228 |
| Gresik       | 259.041  | 226.345  | 304.239  | 252.320 | 436.000 | 190.294 |

(b)

| PP & GP | Distribution Center |
|---------|---------------------|
|         | Sukabumi | Jogja   | Solo   | Cikande | Cirebon |
| Banyuwangi | 372.112  | 285.128 | 249.720 | 368.762 | 252.648 |
| Tj. Priok   | 94.100   | 297.316 | 289.768 | 103.150 | 142.436 |
| Ciwandan 1   | 166.700  | 369.916 | 362.368 | 30.375  | 215.036 |
| Ciwandan 2   | 166.700  | 369.916 | 362.368 | 30.375  | 215.036 |
| Gresik       | 306.031  | 92.468  | 58.294  | 302.681 | 186.567 |

(b)

### Table 10. Distribution cost from cement plant to distribution center (IDR / Ton)

| CP      | Distribution Center |
|---------|---------------------|
|         | Cibungur | Ciwandan | Narogong | Pasoso | Bogor | Cimahi |
| Tuban 1 | 173.896  | 203.984  | 219.274  | 180.103 | 158.000 | 193.214 |
| Rembang | 197.414  | 277.361  | 263.234  | 256.001 | 294.500 | 210.248 |
| Narogong| 61.214   | 85.605   | 24.034   | 46.880  | 26.300  | 94.414  |
| Cilacap | 102.814  | 259.205  | 168.634  | 220.480 | 129.300 | 69.614  |
| Tuban 2 | 178.614  | 207.505  | 225.334  | 186.130 | 164.000 | 250.214 |

(b)
| CP          | Distribution Center |
|-------------|---------------------|
|             | Sukabumi | Jogja  | Solo     | Cikande | Cirebon |
| Tuban 1     | 227.800  | 133.308| 97.674   | 222.575 | 107.818 |
| Rembang     | 319.000  | 138.188| 68.034   | 326.175 | 147.218 |
| Narogong    | 50.800   | 246.508| 238.734  | 57.975  | 98.618  |
| Cilacap     | 99.400   | 82.908 | 99.034   | 231.575 | 84.818  |
| Tuban 2     | 233.800  | 135.116| 99.708   | 218.750 | 102.636 |

Table 11. Distribution cost from distribution center to sales district (IDR / Ton)

| Distribution Center | Sales District |
|---------------------|----------------|
|                     | Ambarawa | Babat | Bandung | Bangkalan | …… | Wonosari | Wonosobo | Jogja |
| Cibungur            | 281.414  | 238.556| 93.120  | 389.774   | …… | 208.814  | 176.614  | 204.814 |
| Ciwandan            | 361.361  | 268.644| 226.800 | 301.684   | …… | 381.800  | 328.800  | 378.300 |
| Narogong            | 218.700  | 372.700| 99.200  | 426.420   | …… | 254.200  | 201.200  | 250.700 |
| Pasoso              | 265.580  | 244.763| 146.080 | 274.123   | …… | 301.080  | 248.080  | 297.580 |
| Bogor               | 245.000  | 222.660| 62.100  | 252.020   | …… | 242.500  | 210.300  | 238.500 |
| Cimahi              | 294.248  | 257.874| 25.000  | 287.234   | …… | 230.400  | 198.200  | 226.400 |
| Sukabumi            | 221.900  | 292.460| 67.900  | 321.820   | …… | 205.400  | 173.200  | 201.400 |
| Jogja               | 66.588   | 197.968| 187.908 | 184.960   | …… | 34.200   | 92.140   | 25.000  |
| Solo                | 42.834   | 162.334| 204.034 | 180.960   | …… | 36.500   | 86.574   | 39.200  |
| Cikande             | 276.675  | 287.235| 157.175 | 316.595   | …… | 312.175  | 259.175  | 308.675 |
| Cirebon             | 120.082  | 172.478| 49.018  | 201.838   | …… | 155.582  | 102.582  | 152.082 |

Table 12. Distribution cost from cement plant to sales district (IDR / Ton)

| CP          | Sales District |
|-------------|----------------|
|             | Ambarawa | Babat | Bandung | Bangkalan | …… | Wonosari | Wonosobo | Jogja |
| Tuban 1     | 117.260  | 64.660| 194.000 | 94.020    | …… | 135.000  | 160.000  | 137.500 |
| Rembang     | 84.000   | 125.160| 241.980 | 154.520   | …… | 108.032  | 115.120  | 142.380 |
| Narogong    | 218.700  | 372.700| 99.200  | 426.420   | …… | 254.200  | 201.200  | 250.700 |
| Cilacap     | 122.500  | 286.220| 105.000 | 286.960   | …… | 106.000  | 73.800   | 102.000 |
| Tuban 2     | 100.300  | 63.500 | 200.000 | 100.020   | …… | 141.000  | 166.000  | 143.500 |

Table 13. Distribution cost from grinding plant and packing plant to sales district (IDR / Ton)

| PP & GP    | Sales District |
|------------|----------------|
|            | Ambarawa | Babat | Bandung | Bangkalan | …… | Wonosari | Wonosobo | Jogja |
| Banyuwangi | 273.272  | 91.352| 350.012 | 108.032   | …… | 291.012  | 316.012  | 293.512 |
| Tj. Priok  | 273.700  | 275.449| 146.900 | 304.809   | …… | 309.200  | 256.200  | 305.700 |
| Ciwandan 1 | 346.300  | 268.644| 226.800 | 298.004   | …… | 381.800  | 328.800  | 378.300 |
| Ciwandan 2 | 346.300  | 272.324| 226.800 | 301.684   | …… | 381.800  | 328.800  | 378.300 |
| Gresik     | 122.980  | 38.180 | 283.931 | 57.700    | …… | 122.600  | 139.440  | 116.800 |
Table 14. Demand sales of sales district in Java (Ton)

| No | Sales District | Sales Demand |
|----|----------------|--------------|
|    |                | Semester 1   | Semester 2   |
| 1  | Ambarawa       | 23,513       | 31,118       |
| 2  | Babat          | 8,797        | 12,054       |
| 3  | Bandung        | 92,400       | 122,986      |
| 4  | Bangkalan      | 70,451       | 88,900       |
| 5  | Banjar         | 24,625       | 31,059       |
| ... | ...            | ...          | ...          |
| 133| Wonogiri       | 52,450       | 69,774       |
| 134| Wonesari       | 22,913       | 30,337       |
| 135| Wonesobo       | 20,705       | 27,568       |
| 136| Yogyakarta     | 19,740       | 27,343       |

4.2 Results and Discussions
The process of finding solutions using Lingo software to get the optimal solution. Finding a solution using Lingo11 software is done by translating the mathematical model into coding following the syntax of the Lingo11 application.

The distribution system model that has a multi-product, multi-facility (cement plant, grinding plant, packing plant, distribution center, and sales district) has been successfully modeled using the linear programming method. The pulDRose of the model function is to minimize the total cost of distribution which consists of production costs in each facility, distribution costs from each facility to the distribution center, fixed costs in the distribution center for product storage, variable costs in the distribution center for each product, and distribution costs from distribution center to consumers.

Table 15. Comparison of results between existing vs. Lingo optimization

| Description               | Period    | Existing  | Lingo Optimization | Efficiency   |
|---------------------------|-----------|-----------|--------------------|--------------|
| Production Cost           | Semester I| IDR 4,390,072,021.885 | IDR 3,994,872,505.369 | IDR 395,199,516,515 |
|                           | Semester II| IDR 5,431,750,515.281 | IDR 5,259,567,521.741 | IDR 172,182,993,539 |
|                           | Total     | IDR 9,821,822,537.166 | IDR 9,254,440,027.111 | IDR 567,382,510,055 |
| Distribution Cost         | Semester I| IDR 1,226,525,986.876 | IDR 836,890,188.783 | IDR 389,635,798.093 |
|                           | Semester II| IDR 1,598,250,879.799 | IDR 1,108,779,663.080 | IDR 489,471,216.719 |
|                           | Total     | IDR 2,824,776,866.674 | IDR 1,945,669,851.863 | IDR 879,107,014.811 |
| Prod. Cost + Distr. Cost  |           | IDR 12,646,599,403.840 | IDR 11,200,109,878.974 | IDR 1,446,489,524.866 |

From the above table, it can be seen that both production costs and distribution costs have decreased from the results of running models using Lingo software. Production costs have decreased by IDR 567,382,510,055 due to changes in production allocation at each supply source facility in meeting the demand for all three cement products. While the optimization of distribution costs can be obtained from the optimization results of IDR 879,107,014,811. So the total cost that can be saved from the optimization of the allocation of production and distribution is IDR 1,446,489,524,866 or its value is almost 1.5 trillion rupiahs.
Table 16. Production allocation and utilization of cement plants after optimization

| Cement Plant | Capacity (Ton) | Existing Volume (Ton) | Utilization | Lingo Optimization Volume (Ton) | Utilization |
|--------------|---------------|-----------------------|-------------|--------------------------------|-------------|
| Tuban 1      | 13,467,372    | 11,289,201            | 83.83%      | 13,062,640                     | 96.99%      |
| Rembang      | 3,000,000     | 2,997,925             | 99.93%      | 859,703                        | 28.66%      |
| Narogong     | 4,854,876     | 3,292,766             | 67.82%      | 4,854,876                      | 100.00%     |
| Cilacap      | 2,484,600     | 2,137,508             | 86.03%      | 1,725,790                      | 69.46%      |
| Tuban 2      | 2,814,276     | 1,687,183             | 59.95%      | 901,895                        | 32.05%      |

Table 17. Production allocation and utilization of grinding plant & packing plants after optimization

| Grinding Plant & Packing Plant | Capacity (Ton) | Existing Volume (Ton) | Utilization | Lingo Optimization Volume (Ton) | Utilization |
|--------------------------------|----------------|-----------------------|-------------|--------------------------------|-------------|
| Banyuwangi                     | 576,000        | 480,092               | 83.35%      | 56,527                         | 9.81%       |
| Tanjung Priok                  | 726,000        | 690,409               | 95.10%      | -                              | 0.00%       |
| Ciwandan 1                     | 576,000        | 507,202               | 88.06%      | -                              | 0.00%       |
| Ciwandan 2                     | 876,000        | 840,605               | 95.96%      | -                              | 0.00%       |
| Gresik                         | 928,560        | 689,692               | 74.28%      | -                              | 0.00%       |

Table 18. Utilization of distribution center after optimization

| Distribution Center | Capacity (Ton) | Existing Volume (Ton) | Utilization | Lingo Optimization Volume (Ton) | Utilization |
|---------------------|----------------|-----------------------|-------------|--------------------------------|-------------|
| Cibungur            | 248,400        | 103,334               | 41.60%      | 87,757                         | 35.33%      |
| Ciwandan            | 324,000        | 295,448               | 91.19%      | -                              | 0.00%       |
| Narogong            | 342,000        | 329,426               | 96.32%      | 216,000                        | 63.16%      |
| Pasoso              | 432,000        | 425,155               | 98.42%      | 181,002                        | 41.90%      |
| Bogor               | 270,000        | 249,312               | 92.34%      | 162,000                        | 60.00%      |
| Cimah               | 270,000        | 126,931               | 47.01%      | 144,613                        | 53.56%      |
| Sukabumi            | 84,000         | 80,544                | 95.89%      | 35,898                         | 42.74%      |
| Jogja               | 378,000        | 150,078               | 39.70%      | 63,000                         | 16.67%      |
| Solo                | 180,000        | 169,213               | 94.01%      | 135,000                        | 75.00%      |
| Cikande             | 144,000        | 130,649               | 90.73%      | 86,400                         | 60.00%      |
| Cirebon             | 324,000        | 245,091               | 75.65%      | 253,870                        | 78.35%      |

Changes in production allocations at the cement plant facilities occur because the two cement plant units that have the lowest production costs, namely CP Tuban 1 and CP Narogong, have increased utilization, while CP Rembang and CP Tuban 2 have experienced a very significant decrease in utilization because both facilities have production costs per tons of big ones. A very striking change occurred in the grinding plant and packing plant unit units where almost all units did not operate. This happens because shipping products to GP and PP facilities generally use a sea transportation mode, where the cost of using this mode is more expensive than using a land transportation mode. Distribution center utilization has decreased, only DC Cimah and DC Cirebon have increased utilization. Only DC
Ciwanダン does not operate from the optimization results because PP Ciwandan 1 and PP Ciwandan 2 also do not operate from the results of this optimization.

5. Conclusions
Production allocation and distribution networks are very important in supply chain management. With the increase in supply source facilities after the acquisition of similar companies, it is necessary to re-arrange production allocations for each integrated cement plant and reconfigure the existing distribution network in Java. By using linear programming to obtain minimal distribution costs to provide benefits to the company after the acquisition process. With several obstacles such as production capacity in the cement plant, grinding plant, and packing plant as well as storage capacity constraints at the distribution center, the optimum optimization results are obtained for production costs and distribution costs. However, from this result, some supply facilities are not optimal in their utilization, and there are even some non-operational supply source facilities. This modeling can still be developed in future research by considering whether the company will maintain or release the source of supply and distribution facilities that are not optimal in this modeling.

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