Mixed Integer Linear Programming as a Method for Evaluation of Location and Number of Buffer Warehouse in PT Petrokimia Gresik Distribution System (Case Study: West Java and Central Java)

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***Abstract*—The new policy issued by PT Pupuk Indonesia regarding the change of the responsible party for the procurement and the distribution of subsidized NPK fertilizers affected the subsidy allocation for PT Petrokimia Gresik, as the only company to conduct the procurement and distribution of the subsidized NPK fertilizer. It is now partially charged to the other holding members such as PT Kujang Cikampek, PT Pupuk Sriwidjaja, and PT Pupuk Kaltim. Also, all members of PT Pupuk Indonesia should face the reduction of subsidy allocation from Indonesia Government. PT Petrokimia Gresik also have to deal with Phonska V project plan in order to increase capacity of NPK fertilizer. Those policies are most significantlty impactful to the decrease of subsidy allocation in West Java. Besides, Central Java, a branch area of PT Petrokimia Gresik which has the biggest number of total capacity and fixed cost, should reevaluate the number and location of the buffer warehouse. This paper is aimed to explain the methodology using Mixed integer Linear Programming (MILP) in determining the optimal number and location of buffer warehouse in West Java and Central Java in response to the policies and the project plan. Firstly, the distribution system of NPK subsidized fertilizer are described. Next, previous researches about MILP and forecasting method applied in distribution system problem is explained. After that, related data and several conditions that are applied based on actual situation are shown. It can be deducted that MILP is an optimal method for the evaluation as it fits to the characteristic and condition of distribution system in PT Petrokimia Gresik.**

***Keywords*—Number of warehouse, location of warehouse, distribution of warehouse, mixed integer linear programming (MILP), forecast.**

I. INTRODUCTION

PT PETROKIMIA GRESIK is one of holding member of PT Pupuk Indonesia (Persero) which mainly produces two types of fertilizer, subsidized fertilizer and non-subsidized fertilizer. This company is one of holding member of PT Pupuk Indonesia which has 5 fertilizer-product company and 5 non-fertilizer-product company. As an owned state company, PT Pupuk Indonesia and all holding members manage the distribution of the subsidized fertilizer in accordance with regulations from Ministry of Trade and and regulations from Ministry of Agriculture. It manages the highest retail prices, allocation of subsidized fertilizer for every province annually, and procurement and distribution of subsidized fertilizer. The distribution of subsidized fertilizer involves several parties in each level: the producer (PT Petrokimia Gresik), buffer warehouse, distributor, and retailer.

PT Petrokimia Gresik has been producing the largest amount of fertilizer with total production of 6,5 million ton per year. NPK fertilizer is the biggest capacity produced by this company, approximately 2,7 million ton per year. While obtaining the optimal production, PT Petrokmia Gresik faces several global challenges. The regulation from the Ministry of Agriculture in 2018 (Permentan No. 47/Permentan/SR.310/11/2018) assigned the reduction of subsidized fertilizer quota for each province. Consequently, the global quota is lower than quota of 2017, from 9.250.000 ton to 8.874.000 ton. Furthermore, PT Pupuk Indonesia (Persero) on new regulation change the responsible party for procurement and distribution of NPK subsidized fertilizer, which were previously only PT Petrokimia Gresik, partly handed over to other holding member such as PT Pupuk Kujang Cikampek, PT Pupuk Sriwidjaja, and PT Pupuk Kaltim. As a result, the allocation of eight provinces are affected; Jambi, South Sumatra, East Java, West Kalimantan, South Kalimantan, East kalimantan, Central kalimantan, and North Kalimantan. PT Petrokimia Gresik is definitely the impacted producer which should encounter the decrease income due to the decrease allocation and distribution area. This is also aggravated by constant spend of warehouse lease cost. West Java experienced the most significant decrease on NPK fertilizer quota and Central Java has one of the biggest number of warehouse and capacity among other branch. Hence, PT Petrokimia Gresik should re-evaluate the number and the location of buffer warehouse whether it still performs an optimal result. In 2021, PT Petrokimia Gresik plans to build Phonska V Plant with total capacity of 500.000 ton per year. This will increase the global capacity of subsidized NPK thus PT Petrokimia Gresik should rearrange the distribution system. Evaluation of number and location of buffer warehouse and the cost should be undertaken in order to achieve an effective and efficient distribution system.

This paper is aimed to describe the characteristic of distribution system of PT Petrokimia Gresik and find the

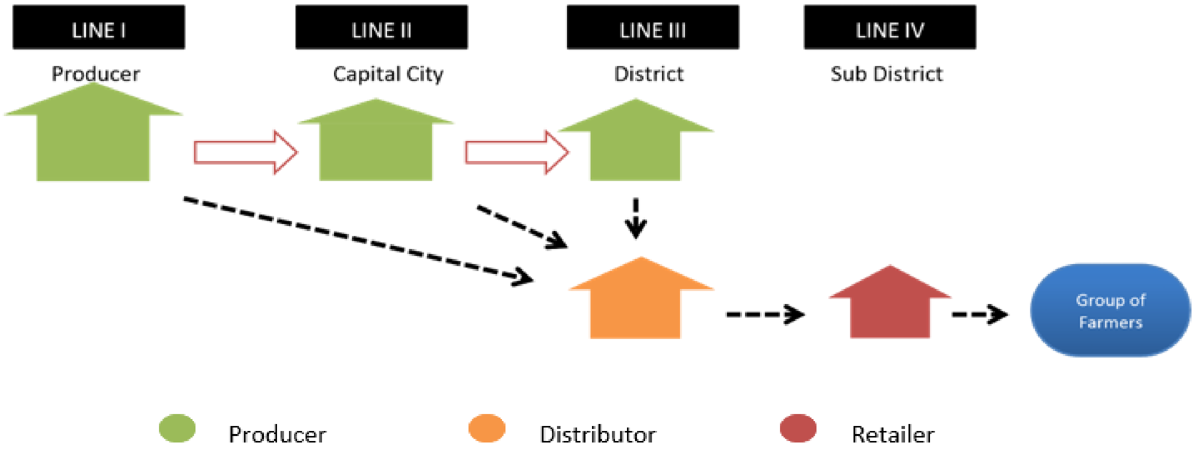

Figure 1. Distribution Flow of Subsidized Fertilizer.

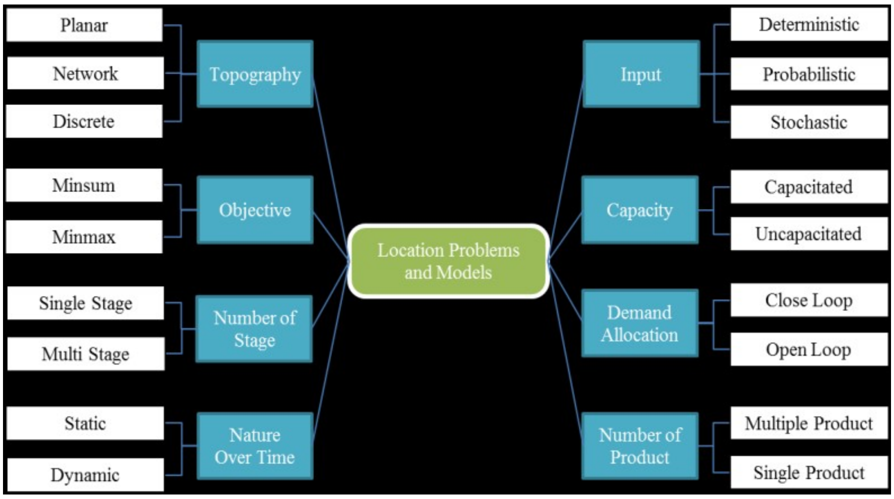

Figure 2. Classification of Facility Location.

suitable method to forecast the demand of subsidized fertilizer. Finally the method for determining the optimal number and location is identified.

II. LITERATURE STUDY

A. Government Regulation of Subsidized Fertilizer

Fertilizer is material of natural of synthetic origin which applied to soil and/or plant to supply nutrients needed by soil/or plant growth. Fertilizer gives a very important role to increase the productivity of agriculture commodity. Subsidized fertilizers are granted by Indonesia Government as a the government's program in agriculture sector to ensure food safety in Indonesia (Siregar, 2015). Particularly, it is expected that the ability of small-scaled-farmers to buy the fertilizer for agriculture is increasing due to the affordable price. The price of subsidized fertilizers are set as the highest retail price. The subsidy, sourced from Indonesia state of budget is included the price budget: the Government funds the producers so the price is lower and affordable for the farmers. The amount of cost that the government spends is the difference between highest retail price and production cost, multiplied by production capacity.

According to Agriculture Ministry Regulation (Permentan no. 130 Tahun 2014), the definition of subsidized fertilizers included the involvement of Indonesia government to supervise and control the procurement and the distribution from the producer level to the consumer level. The control also includes variety, quantity, quality, marketing area, highest retail price, and time. The producers of subsidized fertilizer assigned by the Indonesia Government are all holding member of PT Pupuk Indonesia (Persero) which produce fertilizer as the core business: PT Pupuk Iskandar Muda (PIM), PT Pupuk Sriwijaya, PT Pupuk Kujang, PT Petrokimia Gresik, dan PT Pupuk Kaltim. There are several kinds of subsidized fertilizer: Urea, SP 36, ZA, NPK, and others assigned by the government based on Trade Ministry Regulation (Permentan No. 15/MDAG/PER/4/2013).

B. Subsidized Fertilizer Distribution System

The distribution system of fertilizers produced by PT Pupuk Indonesia (Persero) in general is shown in Figure 1 and explained as follows Figure 1.

The distribution of fertilizers are started from line I (procedur's warehouse on the plant) to line II (procedur's warehouse on province-leveled branch). After that, the fertilizers are supplied to line III (producer's warehouse and distributor on province-leveled branch and district-leveled branch). Finally, they are brought to line IV (retailer). Line I to line III can be owned by either the producer or individuals. Producer which does not own the warehouse in line 3 (district and city line) to fulfill the fertilizer distribution can supply the distributor from the warehouse nearby as long as the capacity and the capability of the distribution is sufficient. For subsidized fertilizer distribution system, the distributors,

Table 1.
Researches related to mixed integer linear programming and forecasting are undergone

Title	Summary
An Algorithm for Solving Large Capacitated Warehouse Location Problems	Large capacitated warehouse problems based on Langrangian relaxation solved by mixedinteger-variable problem.
Determination of Forecasting and Raw Material Stock	Scatter plot as method of forecast that shows data fluctuation. Several alternatives are practiced: moving averages 3 months, moving averages 3 months, exponential smoothing with α=0,1; α=0,5; α=0,9 and Trend method. It is found that exponential smoothing with α=0,9 is the best method with least error. Forecasting using one or two years data is best solved by exponential smoothing.
Capacitated Facility Problem with General Setup Cost	Capacitated Facility Location Problem (CFLP) which considers general setup cost and number of warehouse location per area. The setup cost consists of fixed cost (area setup cost) and second cost (facility setup cost). Facility setup cost in a non-linear function of warehouse size per area. Those are solved by MILP solver developed by Langrangian Heuristic Algorithm.
Application of Forecasting to Determine Safety Stock Level in Electronic Industry	Method of forecasting based on history data of seasonal demand trend. It is found that the best method is combination of Holt-Winters Exponential Smoothing and Naïve with reduction of Mean Absolute Percentage Error (MAPE) to 63%
Forecaste of Sales Data using Simple Moving Average and Single Exponential Smoothing: Case Study of PT Guna Kemas Indah	Implementation of forecast for irregular sales data using simple moving average and single exponential smoothing. The result is visualized on dashboard. It is concluded that exponential smoothing give more précised prediction than simple moving average.
A New Mixed Integer Linear Programming Model for the MultiLevel Incapacitated Facility Location Problem	New MILP formulation with the validation is explained. Assumptions from literatures are also applied and simulated by CPLEX and Gurobi solver then based on proposed MILP formulation the compared to the general formulation. The results shows that CPLEX and Gurobi solves more optimally small-scaled, medium-scaled and big-scaled area
Optimization of EOQ using Forecasting Model in Textile Industry (Case Study: PT Kusuma Mulia Plasindo Infitex Klaten)	Economic Order Quantity using Forecasting of some primary data (interview of warehouse supervisor) and secondary data (purchase history data and TC 20 usage in 2016)
Analysis of Raw Material of Package Stock Control Management	Analysis of the deficiency of package raw material due to uncontrolled safety stock and reorder point and excess of package raw material due to uncategorized raw material based on priority. Processing data and Forecasting are done using SPSS software. It is continued with lot size-reorder point systems using variety of quantity, reorder point, and safety stock.

either individual or business entity, are assigned by the producer and managed by distribution level, either district, city, or sub-district based on an agreement. Some of the warehouse are leased by the producer and managed by third party in order to supply the costumer through the distributor. The customer is assigned as group of small-scaled farmers. It is listed, verified with the data of sub-district government and observed whether the farmers are based on the list then brought to central government. The farmers entitled to acquire subsidized fertilizers through authorized retailer are managed by district-level government and organization below. Authorized retailers are also listed and verified with the data of district-leveled government by checking the retailers to the distributor's list and the transaction of consumer's purchase of subsidized fertilizers to the retailer.

C. Facility Location Problem

Determining buffer warehouse location is one of facility location problem (FLP). FLP includes model, formulation, and solution to determine location in specified area. Four main components involves on the program: consumer, distribution facility, area where consumer and the facility are placed, and distance between the consumer and the facility (Faharani & Hekmatfar, 2009). According to Faharani (2009), the model to decide the location consider some aspects: the number of the facility required, the current location of the facilities, the capacity of each facility needed, and allocation of demand supplied by each facility.

The model of facility location is classified based on the topography by Klose and Drexl (2004) shown in Figure 2.

Based on the model above, this research are generally modeled to discrete category. This category is divided into several type of mixed integer programming:

1) Incapacitated single-stage capacitated models and capacitated single stage capacitated models

In this type, the relation between two points, such as warehouse and demand point is observed. Particularly, two condition are considered: limited warehouse capacity and unlimited warehouse capacity. Several models can be applied for the condition of incapacitated facilities: set covering, maximum covering, P-median and P-center models.

2) Multi-stage models (Capacitated)

This model demonstrate selection of facility location that is analyzed simultaneously. At least three groups are involved, such as delivery flow from plant, warehouse, and the kiosk.

3) Multi-product models

This models the determination of facilities for multiproduct which each has different characteristic. Modification is undergone by adding new index to identify and distinguish types of product.

4) Dynamic models

The selection of facility location is influenced by several factors which are always changing all the time, such as number of demand and price change. Thus dynamic models are constructed for selection of facility location by considering the opening period of the facility.

5) Probabilistic models

P-media is constructed with stochastic data which is usually uncertain. Assumption that the data is modeled by a certain probability distribution is applied.

Several method frequently simulated to solve this problem are location break even analysis, transportation method, factor rating method, and center of gravity method. Location break even analysis is a method to assign a location with considering the cost with function of volume, while

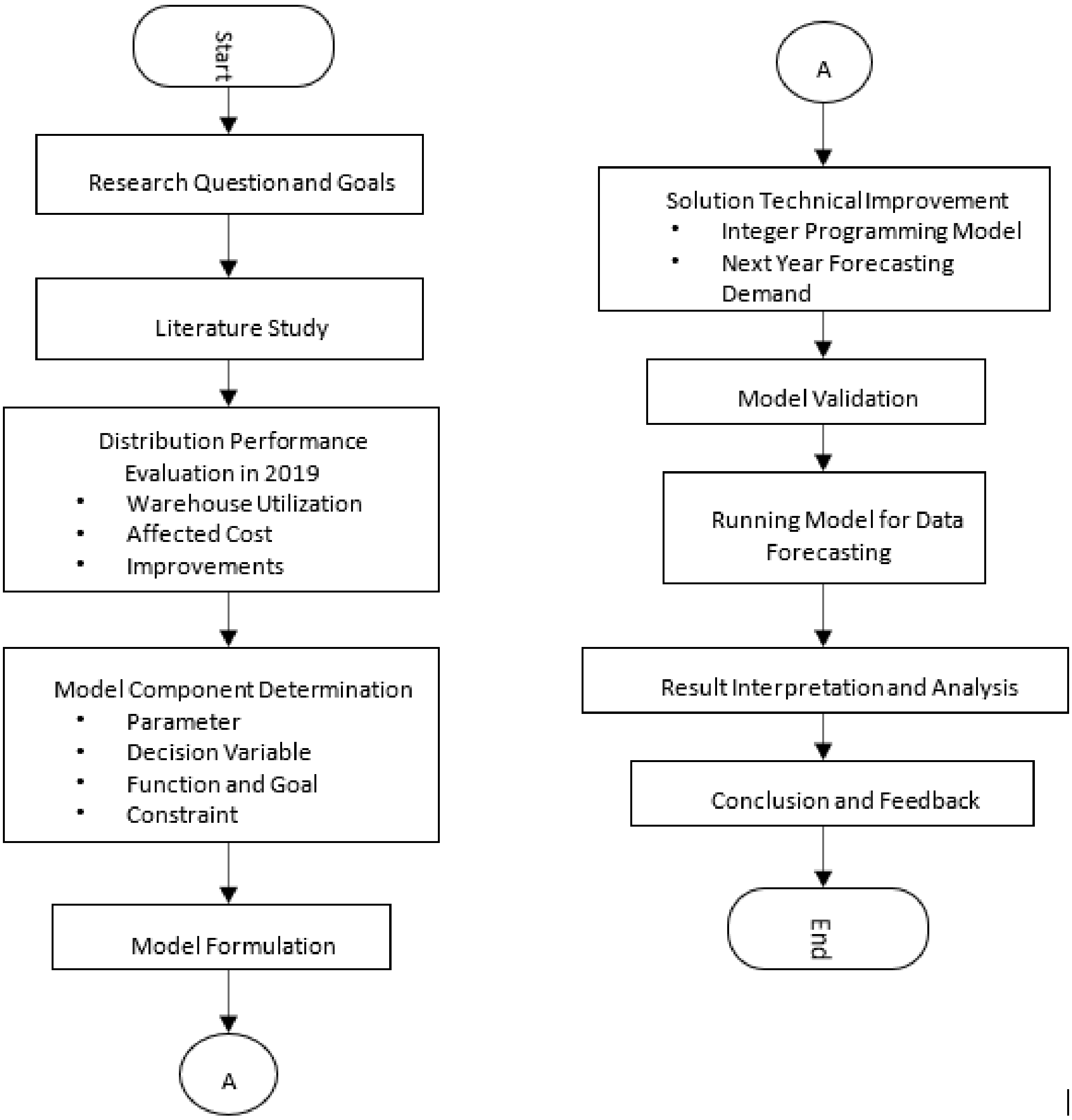

Figure 3. Diagram Flow of Research Methodology.

transportation method considers supply and demand locations which is suitable for companies who operates multiple supply and demand point. This method appraise subjective approach and compare only optional location. Another method, Center of gravity determine the location based on volume, location, and the cost of shipment. This method fits to determination only one distribution center.

D. Warehouse Location Problem

Warehouse Location Problem is one type of Facility Location Problem which determine the location of warehouse as a component of distribution facility. It is undertaken to reduce total cost of warehouse in candidate location and allocate consumer on the warehouse periodically. Warehouse Location Problem can be classified as follows:

1. Solution area: discrete and continues
2. Warehouse installation cost: Fixed and not-fixed
3. Number of Warehouse: exogenous and endogenous
4. Number of product: singular and plural
5. Duration: singular and plural
6. Warehouse capacity: limited and unlimited
7. Relation between warehouse and consumer: all-customer supply and selected-customer supply

To model the problem, some techniques can be applied: linear programming and integer programming.

E. Linear Programming

Linear programming is a tool to solve a problem related to optimization. In this tool, decision variables are set as a variable to be solved in the model. In this case, decision variables are the number of Urea and NPK fertilizer per day.

X1= number of Urea fertilizer per day

X2= number of NPK fertilizer per day

Several function affects the result of decision variables: the function that maximize (such as profit and income) an minimize (such as expense). PT Petrokimia Gresik set the fixed costs which does not affect XI and X2, thus the decision variables is relevant only to variable cost.

F. Integer Programming

Integer programming is also a tool to optimize variables by scoring all probabilities with integer number. This tool is used to find the best solution with maximum profit and minimum expense. Integer programming is applied to a more complex system than that solved by linear programming.

G. Mixed Linear Integer Programming

A more efficient technique to solve discrete variable problem is Mixed Linear Integer Programming. It consists of a set decision variable either unknown number or decision optimized (Heizer & Render, 2001). If the unknown variables are all integer numbers, the technique are called integer programming or integer linear programming. Integer programming is used generally in a practical situation. Part of it, binary integer programming is a special technique that the variables are either 0 or 1. Mixed-integer linear programming, a popular technique to decide facility location, use mixed both integer and non-integer for the variables. It is also applied to a problem related to human resources planning and facility location which are dependent to each other. Production planning, assignment problems, and time tabling as types of binary decision can also be answered by this technique.

H. Forecasting

Forecasting is a process to estimate total needs included quantity, quality, time, location to fulfill goods and service demand (Permana & Asdjudureja, 1990). Process and stock control can be solved by forecasting (Montgomery & Johnson, 1998). One of forecasting techniques are quantitative forecasting which use history data to predict future data categorized as time series data (Nafitri, 2010). Several assumptions are made: persistence, regularity, reliability and validity. Some researches related to mixed integer linear programming and forecasting are undergone in Table 1.

The analysis of number and location of buffer warehouse related to external condition such as global change of fertilizer subsidy allocation, reduction number of NPK fertilizer volume to be procured and distributed, and Phonska V project plant will be executed to solve the challenge in PT Petrokimia Gresik, especially in West Java and Central Java. It is expected that this research gives an added value and fulfill the research gap to the variety of application of MILP. Previous research considers only one transportation mode in one area while this research examine two areas and several transportation mode depending of types of fertilizer and distribution area. West Java distribution system uses ships to distribute ZA and SP-36 fertilizer and trucks to distribute Phonska fertilizer. In addition, Central Java distribution system uses only one truck to deliver all types of fertilizer (ZA, Phonska, SP-36 and Petroganik). All distribution system are begun from Gresik as the producer and the location of import port.

III. RESULT AND DISCUSSION

From the explanation above, transportation method using model of MILP is selected due to the compatibility of the condition and characteristic of PT Petrokimia Gresik distribution system, particularly West Java and Central distribution area. The effectiveness of spending fixed cost and variable cost such as transportation cost and warehouse cost respectively will be examined. This result will be applied to decide the optimal number and location of buffer warehouse.

The research begins with determination of research question. The research questions are as follows:

1. How was the performance of PT Petrokimia Gresik distribution system in area of West Java and Central Java?
2. How to find the optimal location, number, and cost of buffer warehouse of PT Petrokimia Gresik for subsidized fertilizer on each district of West Java and Central Java?
3. How to model PT Petrokimia Gresik distribution system in West Java and Central Java using Mixed Integer Linear Programming (MILP) in order to find the solution?

The data required in this research is:

1. Supply Point & Buffer Warehouse Location
2. Number of distributor and district area of distribution system
3. Sales realization during 3 years
4. Sales plan
5. Transportation route and the tariffs
6. Buffer warehouse information:
   a. Address
   b. Capacity
   c. Demand Coverage Area
   d. Lease Cost
   e. Loading Cost
7. Availability of transportation and the tariffs

The data are obtained using some program such as:

1. Documentation Study: Selection of document is done to ensure the documents are fit and compatible for the research
2. Measurement of Location using Internet based Technology with method of plotting After that, the data is processed and analyzed by several steps as follows:

a. Analyzing of characteristic and trend of fertilizer demand in West Java & Central Java in 2017-2019
b. Mapping and Developing demand fulfillment configuration based on coverage area of the supply point
c. Mapping fixed cost and variable cost due to buffer warehouse facility usage
d. Evaluation of fertilizer distribution system for each district in West Java and Central Java in 2019, considering warehouse utilization, the cost, and alternatives to obtain the optimal cost.
e. Forecasting fertilizer demand/realization in 2013 based on the data in 2017-2019 using software of minitab and simulation using Linear, Quadratic, Exponential Growth and S-Curve model. The smallest value of MAPE, MAD, and MSD before executing the forecast.
f. Planning mixed integer linear programming model to obtain the configuration of number and location of buffer warehouse with the most optimal cost. The model is shown in equation below.

$$Min \quad Z = \Sigma j \Sigma t[(\Sigma i \Sigma n.DijCijnXijtn) + \Sigma k \Sigma n(DjkCjknYjktn) + FjXjt + Vjt$$

The model requires some condition as follows

$$\Sigma jXijtn \;\; Git \qquad i, t$$

The number of products n delivered to the warehouse j from plant i on time t must not exceed the production capacity of the plant i on time t

$$\Sigma iXijtn \qquad j, t$$

The number of products n delivered to the warehouse j from plant i on time t must not exceed the capacity of warehouse j if warehouse j are built in the location.

$$\Sigma iXijtn = \Sigma kYjktn \qquad j, t$$

Equilibrium function on warehouse j in wich the number of product n delivered to warehouse j from plant i on time t is equal to the number of product delivered from warehouse j to city k on time t.

$\Sigma j Y jktn \quad hktn \qquad k, t, n$

Demand in the city k on time t must not exceed the number of product n delivered to warehouse j on time t.

$I0 + \Sigma i X ijtn \; k Y jktn + Vjtn. S(j) \qquad j, t, n$

The number of products n delivered to warehouse j from plant i on time t added to existing stock should be bigger than the number of product n yang dikir delivered to warehouse j on time t added to existing product in warehouse j on time t if warehouse j is built in the area.

$X ijtn = integer$

Available delivery = 1 and unavailable delivery = 0.

$Y jktn = integer$

Available delivery = 1 and unavailable delivery = 0.

$S j = integer$

Warehouse j open = 1

Warehouse j close = 0

g. The data is analysed to obtain the result of optimal number and location of PT Petrokimia Gresik warehouse as part of distribution system.

The methodology of this research is shown by diagram flow in Figure 3.

IV. CONCLUSION

PT Petrokimia Gresik faces some challenges as follows: The reduction of subsidy allocation by the government, changing of responsible party of preocurement and distribution of NPK subsidized fertilizer, and Phonska V project plan. Thus the changing number and location of PT Petrokimia Gresik should be undertaken. It can be determined using Mixed Integer Linear Programming. Several steps should be done in order to obtain the result: data gathering, forecasting the fertilizer demand, and modeling the distribution system considering several conditions. The result will be demonstrates on the next paper.

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