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Distribution Network Configuration of Drilling Material to Reduce Transportation Cost

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***Abstract*—Drilling; the main activity in upstream oil and gas industry; is important to increase oil and gas production to supply national energy demand. PT Pertamina EP is one of oil and gas companies involved in drilling activity. As drilling schedule and number is dynamic and changing continuously, there are uncertainties in demand, excess in one warehouse and shortage in another. Consequently, double costs arise in the activity of Inter-unit Assistance related to drilling materials, with the average cost in the last 5 years reaches IDR 46,261,256,305. This research aims to design distribution network configuration of drilling materials to reduce double costs in transportation, including its cost saving estimation. The research has seven stages, i.e. (1) defining distribution network design; (2) grouping; (30 mapping warehouse locations; (4) evaluating existing warehouses; (5) selecting location of distribution center; (6) cost saving; and (7) analysis. To select distribution center location, it uses method of center of gravity. The research concludes that defining distribution strategy through distribution center is able to reduce double costs. There are 4 (four) selected of distribution center locations in Kota Baru District, Muara Enim Regency, Indramayu Regency, and Kutai Timur Regency. The research estimates that this distribution network configuration design is able to save 27.77% or IDR 26,613.231,154 in transportation cost.**

***Keywords*—Inter-Unit Assistance, Drilling Material Transportation Cost, Center of Gravity, Distribution Network Configuration Design, Distribution Strategy.**

I. INTRODUCTION

DRILLING is a main priority in oil and gas upstream industry. To drill, the activity needs vast amounts of money, and even a small risk may affect entire company business. One of many important factors in drilling is the availability of drilling materials. Drilling schedules are dynamic and continuously changing, consequently it results in uncertainty of supply and demand of materials [1]. The dynamic change of material demands have one serious consequence, i.e., excess of materials in one warehouse and shortage in another [2][3]. It needs efforts to maintain continuity of drilling activity. When there is a shortage, the current mechanism activates inter-unit assistance, i.e., requesting supports from field/s possessing required materials. But such activation of mechanism results in double cost to transport. On the other hand, the company strategy today is direct shipment in which materials are shipped directly from factories to warehouses in fields. In average, transportation cost to ship materials between units in the last 5 (five) years is IDR 46,261,256,305. Transportation costs for inter-unit assistance activities can see Table 1.

Table 1.
Transportation Costs for Inter-Unit Assistance Activities

Year	Weight (Ton)	Transportation Costs (IDR)
2014	8.895	37,423,503,477
2015	15.119	63,609,437,781
2016	9.669	40,679,916,258
2017	9.741	40,982,838,377
2018	11.554	48,610,585,629
Average	10.169	46,261,256,305

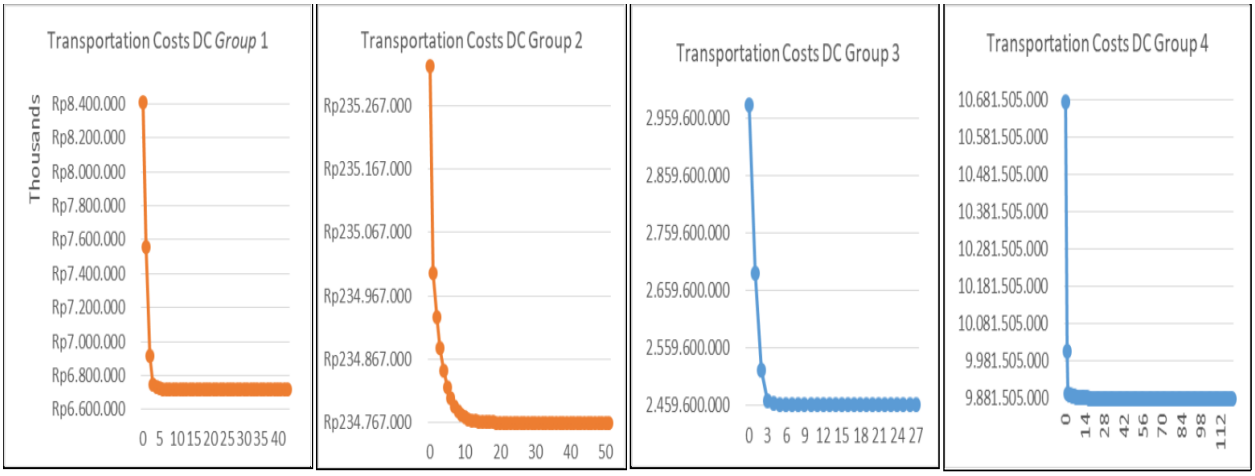
Table 2.
Results of Determination of Distribution Center Location using the Center of Gravity

Distribution Center	Latitude	Longitude
Group 1	-1.65	103.60
Group 2	-3.33	104.07
Group 3	-6.48	108.43
Group 4	0.39	117.51

Fields are separated by distance, resulting in high cost to transport inter-unit assistance. There is also no other strategy to distribute materials based on certain groups. Generally, distribution and transportation are activities to ship materials from the place they are manufactured to another place they are used [4]. There is also a distribution method through warehouse, which means materials are not shipped directly to markets or fields but transited through buffer warehouse or distribution center [5].

Materials with high uncertain levels of demand and durable products are shipped through warehouses. If supply does not meet demand, then distribution centers act to reduce uncertainty [5]. This distribution center may be selected to cut supply chain. It is expected that this distribution center to be able to supply materials to nearby fields/markets [6]. PT Pertamina EP has 20 (twenty) warehouses distributed in every field in many islands, e.g., Java, Sumatra, Sulawesi, Kalimantan, Papua, Tarakan, Bunyu, etc hence a wise decision to select distribution center locations is expected to lower transportation and total costs of Inter Unit Assistance activities.

Stages in this research are defining distribution network design, grouping, mapping warehouse locations, evaluating existing warehouses, selecting location of distribution center, cost saving, and analysis. The researcher uses method of COG (Center of Gravity). This method is one of alternatives commonly used to select locations [7][8]. The advantage is, COG method focuses on selecting a new facility between existing nodes/markets, opening probabilities to lower transportation costs.



(a) (b) (c) (d)

Figure 1. (a) Group 1 Transportation Costs; (b) Group 2 Transportation Costs; (c) Group 3 Transportation Costs; (d) Group 4 Transportation Costs.

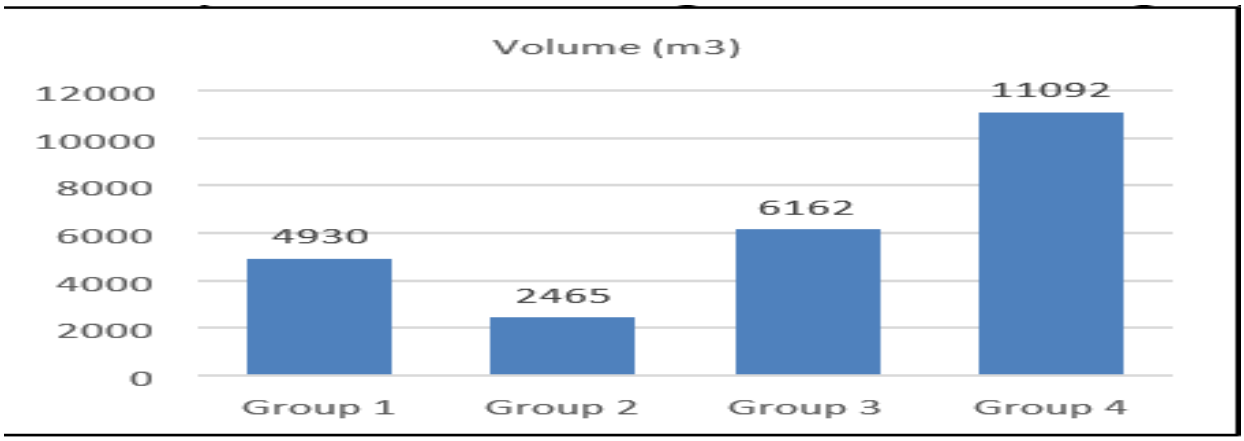


Figure 2. Drilling Material Demand for each group.

II. METHOD

This research tries to solve an existing problem, i.e.,significantly high transportation cost in inter-unit assistance activity. The research completes these following stages:

1. Gathering Data
2. Defining Distribution Strategy and Distribution Network Design
3. Grouping Operation Areas and Mapping Existing Warehouse Locations
4. Evaluating Feasibility of Existing Warehouse Becomes Distribution Center Candidate
5. Estimating and Selecting Distribution Center Location
6. Estimating Cost Saving
7. Analysis

1) Required Data

These following data are required to select distribution center locations:

1. Drilling material demand
2. Warehouse location coordinates and fields/markets
3. Transportation Cost
4. Distances between field and distribution center
5. Other literatures and supporting documents

2) Procedure and Method of Data Gathering

This research uses quantitative and qualitative data. Quantitative data are numbers taken from sources of this research. Meanwhile qualitative data comes from discussions and literature studies. Considering sources, this research uses primary and secondary data. Primary data come from Focus Group Discussions (FGDs) and secondary data come from several existing sources, such as literature study, mass media, internet, etc. In this research, secondary data are taken from documents, warehouse guides, and contracts. Procedure and method to gather data are:

1. Marking coordinates of 20 (twenty) areas and warehouses. Coordinates are marked using Google Map. Data are in the form of latitude and longitude numbers of every field.
2. Each field demand in tonnage or volume in 5 (five) years period to come, is taken from company internal data
3. Transportation costs are known from company contracts, counted in MT (metric ton) of shipped goods or materials. The cost per metric ton in IDR depends on its origin and destination of shipping. When a distribution center is selected based on the method of center of gravity, the shipping cost is estimated from contract price lists or by interpolating existing transportation cost.
4. Distance, in kilometer (km) between fields, is estimated using Haversine method. The distance is needed to select

Table 3.
Value and Percentage of Transportation Cost Savings

Keterangan	2018	2017	2016	2015	2014
Cost Savings in Bilion (Rp)	37,93	34,14	33,22	44,03	30,51
Percentage (%)	37,27	39,88	40,44	33,13	39,79

Table 4.
Rent and Operational Costs for Distribution Centers

No	Distribution Center Location	Volume (m3)	Area (m2)	Rental Fee/Year (IDR)	Operating costs /Year (IDR)
1	Jambi City	4.930	3.286	1,774,694,400	120,000,000
2	Muara Enim Regency	2.465	1.643	887,400,000	120,000,000
3	Indramayu Regency	6.162	4.108	2,218,320,000	120,000,000
4	Sangatta District	11.092	7.395	3,993,120,000	120,000,000

Table 5.
Changes in Warehouse Capacity Parameters

No	Changes in Warehouse Capacity	Optimum Costs (IDR)	Changes in Optimum Costs
1	-40%	65.659.316.703	-5,13%
2	-30%	66.546.680.703	-3,85%
3	-20%	67.434.044.703	-2,56%
4	-10%	68.321.408.703	-1,28%
5	0%	69.208.772.703	0,00%
6	10%	70.096.136.703	1,28%
7	20%	70.983.500.703	2,56%
8	30%	71.870.864.703	3,85%
9	40%	72.758.228.703	5,13%

distribution center location using method of center of gravity.

B. Defining Distribution Strategy and Distribution Network Design

In this stage, it is important to define a suitable strategy for the company first. Distribution strategy is defined based on goods or material classifications [9][10][11][12]. Afterwards, it is the activity to design material distribution network for the company with drilling material included [13].

C. Grouping Operation Areas and Mapping Existing Warehouse Locations

In this stage, the research groups operation areas or fields of the company in several clusters or groups. The grouping is important to select candidates of distribution center. Afterwards, the existing warehouse locations are mapped to estimate distance between warehouses and their coordinates.

D. Evaluating Feasibility of Existing Warehouse Becomes Distribution Center Candidate

To evaluate whether the existing warehouses are feasible to be upgraded becomes distribution centers or not, these following steps screens and scores their feasibility:

1. To screen it is important to define required criteria. Criteria are defined based on journals and finalized through focus group discussion with Logistics Experts and Analysts of the company.
2. After screening, it is important to score each cluster or regional area. Warehouses of each asset/region are to be evaluated whether they are suitable to become distribution center or not. If there are suitable warehouses, it is necessary to select one or more warehouses as candidate/s to be upgraded to function as distribution center/s.
3. After selecting distribution center candidates in each asset or region, the step is estimating total transportation cost.
4. The last step is comparing cost saving estimated using method of COG between warehouses planned to be distribution center candidates.

E. Estimating and Selecting Distribution Center Locations Using Method of Center of Gravity

This stage works to estimate and select distribution center locations. Estimation and selection use method of center of gravity, performed in each region or asset, consisting of these following steps:

1. Inputting data of coordinates of fields, demand volumes or tonnages, and transportation costs in each asset or region.
2. The second step multiplies material volume with its transportation cost in each field. The formula is $Vi\ x\ Ci$. Then, the results of all multiplications are summed up.
3. In each field, material volume is multiplied with transportation cost and subsequently also multiplied with its X-coordinate (latitude). The formula is $Vi\ x\ Ci\ x\ X$. Afterwards, all multiplication results are summed up.
4. In each field, material volume is multiplied with transportation cost and subsequently also multiplied with its Y-coordinate (longitude). The formula is $Vi\ x\ Ri\ x\ Y$. Afterwards, all multiplication results are summed up.
5. This step estimates selected X-coordinate using this following formula:

$$X = \frac{\sum_i V_i C_i X_i}{\sum_i V_i C_i} \quad (2.1)$$

6. The six th step estimates selected Y-coordinate using this following formula:

Table 6.
Changes in Operational Cost Parameters

No	Changes in Warehouse Capacity	Optimum Costs (IDR)	Changes in Optimum Costs
1	-40%	65.467.316.703	-5,41%
2	-30%	66.402.680.703	-4,05%
3	-20%	67.338.044.703	-2,70%
4	-10%	68.273.408.703	-1,35%
5	0%	69.208.772.703	0,00%
6	10%	70.144.136.703	1,35%
7	20%	71.079.500.703	2,70%
8	30%	72.014.864.703	4,05%
9	40%	72.950.228.703	5,41%

$$Y = \frac{\sum_i V_i C_i X_i}{\sum_i V_i C_i} \quad (2.2)$$

7. Converting latitude (X) and longitude (Y), i.e. X, Y from degree to radian, resulting in X_i and Y_i.
8. Estimating distance between selected candidate d_i and each field location using this following formula [14]:

$$2\left(\frac{\varphi_2-\varphi_1}{2}\right) + cos\varphi_1 . cos\varphi_2 sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)$$

$$d = 2.r.sin^{-1}(\sqrt{sin} \quad (2.3)$$

9. Estimating total transportation cost using this following formula:

$$Min\ TC = \sum_i V_i C_i d_i \quad (2.4)$$

10. The next step is to perform iterations as in steps 5 and 6 using slightly different formulas, i.e., by adding d_n, as divider to estimate X, Y; hence the formula to estimate X and $Y$are

$$X = \frac{\sum_i V_i C_i X_i / d_i}{\sum_i V_i C_i / d_i} \quad (2.5)$$

$$Y = \frac{\sum_i V_i C_i Y_i / d_i}{\sum_i V_i C_i / d_i} \quad (2.6)$$

11. Converting latitude (X) and longitude (Y), i.e., X, Y from degree to radian, resulting in X_i dan Y_i using formula (2.5) and (2.6).
12. Estimating distance between selected location candidate d_i and each field location using formula (2.3).
13. Estimating total transportation cost using formula (2.4).
14. Repeating iterations using tenth and subsequent steps until the value of X, Y does not change.

III. RESULT AND DISCUSSION

Data processing goes through 6 (six) stages. First stage is to design distribution network. Second, all fields are grouped. Third, warehouses are mapped. Fourth, existing warehouses are evaluated. Fifth, Distribution center locations are selected using method of center of gravity. And, sixth, cost saving is estimated.

A. Analysis of Center of Gravity Estimation

1) Location Selection Analysis using Center of Gravity

Estimation and selection of distribution center locations using method of center of gravity give coordinates of distribution center as shown in Table 2. Using Google Map to find coordinates of fields or markets of Pertamina EP, distribution center coordinates are located near one of company fields. In Group 1, the selected distribution center is located in coordinate (1.65, 103.60), i.e. in Jambi City. The result comes from the geographical location of Jambi City, i.e. between other fields. Other factors are high transportation rate in Ramba Field and high demands but low transportation rates in Pangkalan Susu and Rantau Fields. Thus, an ideal location to minimize the weighted distance of these four fields is Jambi City. Estimation shows that total transportation cost from factory to distribution center selected is IDR 6,717,678,438. In Group 2, the selected distribution center is located in coordinate (-3.33, 104.07) because Pendopo Field has the highest demand among other fields, i.e. 1,232 m^3. Other fields only have a part or a quarter of Pendopo Field demand. On the other hand, Pendopo Field has the lowest transportation rate. Center of gravity estimates minimum transportation cost and results in coordinate (-1.65, 102.60). Total transportation cost from factory to distribution center selected is IDR 234,767,119. In Group 3, the selected distribution center is located in the same coordinate location of Jatibarang Field. The location is selected because it has the highest demand and volume compared other fields in this group. Jatibarang Field also has the highest rate of transportation cost among other fields and geographically it is also relatively among other fields in this group. It is estimated that total transportation cost from factory to distribution center selected is IDR 2,459,603,520. In Group 4, the selected distribution center is located in the coordinate of one of the fields in this group, i.e. Field Sangatta. The reason is, the selected location minimize weighted distance between the selected location and other markets. Thus, it is expected to result in minimum transportation cost.

2) Analysis of Iteration Estimate of Center of Gravity

The distribution center is selected in each group after repeated iterations using center of gravity estimation. As stipulated in the mechanism of center of gravity estimation, iterations are repeated until the iteration process give one unchanging result. Here, the estimation must offer the lowest transportation cost. The following chart show the trend of transportation cost following completed iterations.

Figure 1 shows the trend of total transportation cost estimated in each iteration as a part of the process to select distribution center. Group 1 shows that in iteration 0, transportation cost is IDR 8,407,243,338. It decreases significantly in iteration 1 and 2. In subsequent iterations,

transportation cost is getting more stable. Iterations are repeated until iteration 43, resulting in coordinate (-1.65, 103.60), in which the coordinate is not changing anymore and showing IDR 6,717,678,438 in transportation cost. Group 2 shows that in iteration 0, the transportation cost is IDR 235,328,889. The cost is decreasing significantly in iteration 1 to 3. The subsequent iterations show that that the transportation cost is getting more stable until it reaches iteration 51, showing coordinate (-3.33, 104,07). Here, the coordinate is not changing anymore. The total transportation cost in Group 2 is IDR 234,767,119. Group 3 shows that in iteration 0, the transportation cost is IDR 2,983,193,564. The cost is decreasing significantly until iteration 3. The subsequent iterations show that that the transportation cost is getting more stable until it reaches iteration 27, showing coordinate (-6.48, 109.42). Here, the coordinate is not changing anymore. The total transportation cost in Group 3 is IDR 2,459,603.520. Group 4 shows that in iteration 0, the transportation cost is IDR 10,677,735,915. The cost is decreasing significantly until iteration 2. The subsequent iterations show that that the transportation cost is getting more stable until it reaches coordinate (0.39, 117.51). Here, the coordinate is not changing anymore. The total transportation cost in Group 4 is IDR 9,881,505.095.

3) Analysis of Selected Distribution Center

Estimation and selection of distribution centers using method of center of gravity result in coordinates for each groups, i.e. (-1.65, 103.60) for Group 1, (-3.33, 104.07) for Group 2, (-6.48, 108.43) for Group 3, and (0.39, 117.51) for Group 4. The estimated coordinate of Group 1 is located in Kenali Asam, Kota baru District, in Jambi City. The location is still in company area, i.e. in Jambi Field; hence infrastructure, heavy machinery, and good transportation are readily available. On the other hand, there is a shortage of existing warehouse capacity and personnel to handle drilling materials in Group 1 working area. The company needs more investment to rent or increase warehouse and yard capacities and other facilities also. The estimated coordinate of Group 2 is located in Suka Manis, Tanah Abang, Muara Enim Regency, South Sumatra. The location is among fields or markets of the group. It is near one of the largest fields, i.e. Prabumulih Field, hence good transportation and other facilities are adequately available. But, it still needs to prepare readiness and availability of more logistics, transportation, and other facilities. The estimated coordinate of Group 3 is located in Kedokan Agung, Kedokan Bunder, Indramayu Regency, West Java. The location is still in company area, i.e. in Jatibarang Field; hence warehouse, transportation, infrastructure, heavy machinery, and social economic factors are readily available. On the other hand, there is a shortage of existing warehouse capacity and personnel to handle drilling materials in Group 3 working area. The company needs to increase warehouse capacity and personnel number to handle drilling materials. The estimated coordinate of Group 4 is located in Sangatta District, Kutai Timur Regency, East Kalimantan. The location is still in company area, i.e. in Sangatta Field; hence it has adequate facilities and assets. But it needs to repair facilities, increase personnel number, and improve other facilities to handle drilling materials in this group.

B. Analysis of Cost Saving Using Fixed Cost Consideration

Cost saving is estimated by counting the difference between existing warehouse transportation cost and estimated transportation cost (estimated by applying distribution network configuration of drilling material using center of gravity). The cost saving is shown in Table 3. The total cost saving for 5 (five) years to come is IDR 179,834,355,769, showing an average annual IDR 35,966,871,154 in cost saving or 38.10%.

The process to select 4 (four) distribution centers for four groups needs more investment to rent/increase warehouse capacities. Such investment should return (traded off) because of decreasing transportation costs. The amount of costs is also caused by demands of drilling materials in each group as shown in Figure 2. Fixed cost is estimated using company internal data, employing rent and operational rates as shown in Table 4.

1) Estimating Fixed Cost in Group 1

The selected distribution center location of Group 1 is in Jambi City, based on center or gravity estimation. It is still in company area. After evaluation, it is concluded that warehouse capacities in Jambi Field are unable to accommodate drilling materials in Group 1; hence it needs more investment for rent and operational rates. In average, annual demands reaches 4,930 m^3. Considering that the distribution center location is still in Jambi City and near company area, the amount of investment is calculated using annual rent and operational rates. Rent and operational rates are based on company internal data. In Table 4, it is known that annual rent and operational rates are IDR 1,774,694,400 and IDR 120,000,000 respectively.

2) Estimating Fixed Cost in Group 2

The selected distribution center location of Group 2 is in Muara Enim Regency, based on center or gravity estimation. It is still near company area, i.e. Prabumulih Field, Limau Field, and Adera Field, where warehouse facilities and transportation are adequately owned. After evaluation, it is concluded that warehouse capacities are unable to accommodate drilling materials in Group 2; hence it needs more investment for rent and operational rates. In average, annual demands reaches 2,465 m^3. Considering that the distribution center location is still located in Muara Enim Regency and near company area, the amount of investment is calculated using annual rent and operational rates. Rent and operational rates are based on company internal data. In Table 4, it is known that annual rent and operational rates are IDR 887,400,000 and IDR 120,000,000 respectively.

3) Estimating Fixed Cost in Group 3

The selected distribution center location of Group 3 is in Indramayu Regency, based on center or gravity estimation. It is still near company area, i.e. Jatibarang Field, where warehouse facilities and transportation are adequately owned. After evaluation, it is concluded that warehouse capacities are unable to accommodate drilling materials in Group 3; hence it needs more investment for rent and operational rates. In

average, annual demands reaches 6,162 m^3. Considering that the distribution center location is still located in Indramayu

Regency and near company area, the amount of investment is calculated using annual rent and operational rates. Rent and operational rates are based on company internal data. In Table 4, it is known that annual rent and operational rates are IDR 2,218,320,000 and IDR 120,000,000 respectively.

4) Estimating Fixed Cost in Group 4

The selected distribution center location of Group 4 is in Sangatta District, Kutai Timur Regency, based on center or gravity estimation. It is still near company area, i.e. Sangatta Field. After evaluation, it is concluded that warehouse capacities are unable to accommodate drilling materials in Group 4; hence it needs more investment for rent and operational rates. In average, annual demands reaches 11,092 m^3. Considering that the distribution center location is located in Sangatta District and near company area, the amount of investment is calculated using annual rent and operational rates. Rent and operational rates are based on company internal data. In Table 4, it is known that annual rent and operational rates are IDR 3,993,120,000 and IDR 120,000,000 respectively.

From estimations above, the total fixed cost of four groups is IDR 9,353,640,000 annually. Cost saving using distribution network configuration design of drilling materials, with fixed costs considered, is 27.77% or IDR 26,613,231,154.

C. Sensitivity Analysis

This analysis is intended to determine the reliability of the mathematical model made against changes that occur in the delimiter. Analysis is done by changing one or more parameters in the mathematical model. In this study, the parameters used are warehouse capacities and operational costs to determine the impact or the magnitude of the effect of changes in these criteria on the system or mathematical model that has been made.

1) Changes in Warehouse Capacity Parameters

Changes in optimum costs due to changes in warehouse capacity are as table 5. From table 5 a change in warehouse capacity parameters starts from reducing the value of capacity from -40% to + 40% of the initial warehouse capacity. Changes in warehouse capacity of -40% have an impact on changes in optimum costs of -5.13%. Changes in warehouse capacity of + 20% have an impact on changes in optimum costs of 2.56%. This shows that changes in warehouse capacity parameters do not have much impact on changes in optimum costs.

2) Changes in Operational Cost Parameters

Changes in optimum costs due to changes in operating cost parameters are as table 6.

From table 6, changes in operational cost parameters are made, starting from reducing operational costs from -40% to + 40% of the initial operational costs. Changes in operating costs by -40% have an impact on changes in optimum costs of -5.41%. Changes in operating costs by + 20% have an impact on changes in optimum costs of 2.7%. This shows that changes in operational cost parameters do not have much impact on optimum cost changes.

IV. CONCLUSION

Conclusion consists of; (1) The method of center of gravity estimates coordinates of distribution centers of four groups in company working areas. Group 1 distribution center is located in Jambi City in coordinate (-1.65, 103.60) with IDR 6,717,678,438 in transportation cost. Group 2 distribution center is located in Muara Enim Regency in coordinate (-3.33, 104.07) with IDR 23,767,120 in transportation cost. Group 3 distribution center is located in Indramayu Regency in coordinate (-6.48, 1083.43) with IDR 2,459,603,520 in transportation cost. Finally, group 4 distribution center is located in Sangatta District in coordinate (0.39, 117.51) with IDR 9,881,505,095 in transportation cost; (2) In average, annual transportation cost saving as estimated in this research is 27.77% or IDR 26,613,231,154 (twenty six billion six hundred thirteen million two hundred thirty one thousand one hundred fifty four rupiah).

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