Tibuana
Journal of applied Industrial Engineering-University of PGRI AdiBuana

p-ISSN 2622-2027
DOI : https://doi.org/10.36456/tibuana.7.2.9299.144-151 *e*-ISSN 2622-2035

Implementation of the Gravity Location Models Method in Determining Regional Warehouse Locations to Minimize Goods Transport Costs at PT X

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Abstract— A supply Chain is a network of companies that work together to create and deliver a product to the end user. PT X is a company engaged in manufacturing whose products are steel pipes. not only steel pipes are produced. Supply chain management at PT X is considered inefficient because it has to supply four warehouses or depots at once. this can cost a lot of shipping costs in the PT X Supply Chain process. Therefore. supply chain management needs to be carried out using the Gravity Location Model method which aims to minimize the costs of transporting goods at PT X. this research aims to determine the variables needed to determine the location point of PT X regional warehouse using the Gravity Location Model method and to determine the regional warehouse location and optimal shipping costs using the Gravity Location Model method at PT X. From the results of research that has been carried out. the variables used to determine the location points for PT X regional warehouse construction include X and Y. Xn and Yn. dn. Cn. Dn. and TC as well as calculating cost minimization through a comparison of 20 iterations. it was found that the minimum cost was in the 11th iteration. namely IDR 386.955.50. with coordinates X = -4.13 and Y = 115.18.

Index Terms: *Supply Chain*. *Gravity Location Model*

I. INTRODUCTION

In the Industry 4.0 era. many companies are competing or vying to market their products. from small companies to relatively large companies participating in marketing their products to increase the company's productivity and income. Production activities in a company cannot be separated from the term Supply Chain or can be called the company's Supply Chain. According to (Pujawan. 2017) in (Febryanto & Prihono. 2019) Supply Chain is a network of companies that work together to create and deliver a product to the end user. Supply chain management is a concept or mechanism for increasing a company's total productivity in the supply chain by optimizing time. location. and flow of material quantities (Pongoh. 2016). A company that can control its Supply Chain means that the company can reduce costs and can still compete in the business realm. According to (Retnowo & Fira Waluyo. 2022) Supply Chain Management provides major benefits for manufacturers allowing them to improve their response to market changes. Increase visibility into aggregate demand. production. and supply across the Company. and Optimize supply to meet demand profitably.

PT X. produces steel pipes with the largest production capacity in Indonesia and is experienced in producing various kinds of steel pipes or tubes and various other products. PT X To supply several depots in areas that are quite far from the company's location. additional vehicle or expedition costs must be required to supply these depots. Broadly speaking. distribution costs can be defined as costs related to all activities. starting from when goods are purchased/produced until the goods arrive at the customer's location and are marketing or sales costs. (Muhammad et al.. 2017) Transport costs are usually calculated from the transportation distance. Therefore. there is a need for a breakthrough by building a regional warehouse located in the middle of the regional depot. This is useful for minimizing transportation distances so that you can also minimize shipping transportation costs to any regional depot and then to consumers or customers. One method for determining the location point for regional warehouse construction is to use the Gravity Location Model method. Gravity Location Model is a model used to determine the location of a facility. Part of the Supply Chain network development strategy is providing the coordinates of the closest point and the shortest distance from an object. for example. warehouses and factories which are the link between supply sources and various market sources (Prasetyo et al.. 2018) This model was developed to help multinational

p-ISSN 2622-2027
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companies in developing transportation goods because it excels in analyzing distribution cost reduction. The Gravity Location Model is based on selecting a distribution center point that provides the shortest distance to all production zone centers that require service.

II. METHODOLOGY

This research uses the Gravity Location Model method in which there are several stages to find the coordinates through several iterations. Before using the gravity location method. the data used as input parameters need to be prepared. This data includes demand data from consumers. transportation costs per unit from the facility location to the consumer. and methods for calculating the distance from the candidate facility location to each consumer (Print et al.. 2021). The population in this research is the Supply Chain Management network of PT X (Afandy et al.. 2022) Then it is calculated using the formula

$$d = \sqrt{(X - X)^2 + (Y - Y)^2}$$

Information:

dn: Distance between the facility location and the nth source of supply or barn.

Cn: Shipping costs derived from transportation costs/weight/kilometer distance. (Mawadati et al.. 2020)

Dn: number or weight of goods under one truck.

Xn and Yn: Coordinates of each depot.

Repeatedly until the coordinate points in the iteration do not experience significant changes. then that coordinate point will be used as the location for building a regional warehouse at PT X. After the coordinate points have been found. according to (Susanto. 2022) then look for the total cost or total costs for the number of iterations that have been carried out using the formula

$$T = \sum_{n-1}^{k} d$$

Information:

TC: Total Cost

dn: Distance between the facility location and the nth source of supply or barn

Dn: number or weight of goods under one truck.

Cn: Shipping costs.

To find the minimum cost value in the calculated iterations. this is done because one of the objectives of this method is to minimize the costs that have been calculated in several iterations.

III. RESULTS AND DISCUSSION

From the data that has been obtained. the calculation results are applied to the iteration tabulation with the formula $d = \sqrt{(X - X)^2 + (Y - Y)^2}$ as follows:

Table 1. Iteration 1

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	5.19	24000	0.61	-19610.1	303502.9	2821.0	75946.7358
Jakarta	-6.17	106.69	6.18	24000	0.57	-13551.3	234496.8	2197.9	83965.77128
Samarinda	-0.54	117.15	8.08	24000	0.61	-974.7	212098.0	1810.5	118314.1371
Makassar	-5.10	119.46	7.06	24000	0.85	-14802.9	346551.1	2901.0	144487.024
		Total				-48939.1	1096648.7	9730.4	422713.6681
X						-5.03			
Y						112.70			

Table 2. Iteration 2

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	5.47	24000	0.61	-18615.8	288114.9	2678.0	80002.99193
Jakarta	-6.17	106.69	6.12	24000	0.57	-13688.9	236876.8	2220.2	83122.11138
Samarinda	-0.54	117.15	6.32	24000	0.61	-1246.8	271296.7	2315.8	92497.22504
Makassar	-5.10	119.46	6.76	24000	0.85	-15462.8	362000.9	3030.3	138320.4533
		Total				-49014.4	1158289.4	10244.4	393942.7817
X						-4.78			
Y						113.07			

p-ISSN 2622-2027
DOI : https://doi.org/10.36456/tibuana.7.2.9299.144-151 *e*-ISSN 2622-2035

Table 3. Iteration 3

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	5.89	24000	0.61	-17267.5	267246.3	2484.0	86250.22947
Jakarta	-6.17	106.69	6.52	24000	0.57	-12840.2	222190.1	2082.6	88616.44443
Samarinda	-0.54	117.15	5.89	24000	0.61	-1337.6	291045.4	2484.4	86220.89566
Makassar	-5.10	119.46	6.40	24000	0.85	-16321.6	382104.2	3198.6	131043.1224
		Total				-47766.7	1162586.1	10249.6	392130.692
X						-4.66			
Y						113.43			

Table 4. Iteration 4

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	6.27	24000	0.61	-16216.7	250983.8	2332.9	91838.81028
Jakarta	-6.17	106.69	6.90	24000	0.57	-12133.9	209968.7	1968.0	93774.47351
Samarinda	-0.54	117.15	5.55	24000	0.61	-1418.8	308721.7	2635.3	81284.19444
Makassar	-5.10	119.46	6.05	24000	0.85	-17274.7	404418.4	3385.4	123812.6993
		Total				-47044.1	1174092.6	10321.6	390710.1775
X						-4.56			
Y						113.75			

Table 5. Iteration 5

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	6.61	24000	0.61	-15385.5	238119.2	2213.3	96800.48441
Jakarta	-6.17	106.69	7.24	24000	0.57	-11566.7	200153.9	1876.0	98372.816
Samarinda	-0.54	117.15	5.26	24000	0.61	-1497.1	325751.0	2780.6	77034.89104
Makassar	-5.10	119.46	5.73	24000	0.85	-18221.2	426575.8	3570.9	117381.563
		Total				-46670.4	1190599.9	10440.9	389589.7544
X						-4.47			
Y						114.03			

Table 6. Iteration 6

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	6.91	24000	0.61	-14730.1	227975.3	2119.0	101107.6554
Jakarta	-6.17	106.69	7.54	24000	0.57	-11115.4	192343.7	1802.8	102367.2635
Samarinda	-0.54	117.15	5.02	24000	0.61	-1570.6	341746.4	2917.2	73429.28607
Makassar	-5.10	119.46	5.46	24000	0.85	-19124.1	447714.7	3747.9	111839.3747
		Total				-46540.1	1209780.2	10586.9	388743.5796
X						-4.40			
Y						114.27			

p-ISSN 2622-2027
DOI : https://doi.org/10.36456/tibuana.7.2.9299.144-151 *e*-ISSN 2622-2035

Table 7. Iteration 7

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	7.16	24000	0.61	-14216.2	220022.0	2045.1	104762.5073
Jakarta	-6.17	106.69	7.78	24000	0.57	-10759.0	186176.9	1745.0	105758.0471
Samarinda	-0.54	117.15	4.81	24000	0.61	-1637.3	356259.9	3041.1	70437.88961
Makassar	-5.10	119.46	5.23	24000	0.85	-19956.7	467207.8	3911.0	107173.155
		Total				-46569.2	1229666.5	10742.2	388131.5989
X						-4.34			
Y						114.47			

Table 8. Iteration 8

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	7.36	24000	0.61	-13815.8	213825.2	1987.5	107798.5745
Jakarta	-6.17	106.69	7.99	24000	0.57	-10479.8	181345.1	1699.7	108575.8629
Samarinda	-0.54	117.15	4.65	24000	0.61	-1695.8	368988.0	3149.7	68008.15316
Makassar	-5.10	119.46	5.05	24000	0.85	-20700.1	484611.2	4056.7	103324.3345
		Total				-46691.5	1248769.6	10893.7	387706.9251
X						-4.29			
Y						114.63			

Table 9. Iteration 9

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	7.53	24000	0.61	-13505.8	209027.9	1942.9	110272.5971
Jakarta	-6.17	106.69	8.16	24000	0.57	-10262.6	177587.8	1664.5	110873.0362
Samarinda	-0.54	117.15	4.51	24000	0.61	-1745.5	379807.0	3242.1	66070.91565
Makassar	-5.10	119.46	4.89	24000	0.85	-21344.2	499688.4	4182.9	100206.7134
		Total				-46858.1	1266111.1	11032.4	387423.2623
X						-4.25			
Y						114.76			

Table 10. Iteration 10

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	7.67	24000	0.61	-13267.3	205336.8	1908.6	112254.8784
Jakarta	-6.17	106.69	8.30	24000	0.57	-10095.0	174686.5	1637.3	112714.4796
Samarinda	-0.54	117.15	4.41	24000	0.61	-1786.6	388754.5	3318.5	64550.23745
Makassar	-5.10	119.46	4.77	24000	0.85	-21887.2	512401.3	4289.4	97720.53183
		Total				-47036.1	1281179.1	11153.7	387240.1272
X						-4.22			
Y						114.87			

p-ISSN 2622-2027
DOI : https://doi.org/10.36456/tibuana.7.2.9299.144-151 *e*-ISSN 2622-2035

Table 11. Iteration 11

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	7.78	24000	0.61	-13084.8	202512.4	1882.3	113820.4334
Jakarta	-6.17	106.69	8.40	24000	0.57	-9966.3	172460.2	1616.5	114169.5045
Samarinda	-0.54	117.15	4.33	24000	0.61	-1819.8	395985.4	3380.2	63371.51457
Makassar	-5.10	119.46	4.68	24000	0.85	-22334.4	522870.8	4377.0	95763.86511
		Total				-47205.4	1293828.9	11256.0	387125.3175
X						-4.19			
Y						114.95			

Table 12. Iteration 12

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	7.86	24000	0.61	-12945.9	200361.8	1862.3	115042.1346
Jakarta	-6.17	106.69	8.49	24000	0.57	-9868.1	170761.2	1600.5	115305.4906
Samarinda	-0.54	117.15	4.27	24000	0.61	-1846.2	401720.3	3429.1	62466.82798
Makassar	-5.10	119.46	4.60	24000	0.85	-22695.4	531322.1	4447.8	94240.64205
		Total				-47355.6	1304165.4	11339.7	387055.0952
X						-4.18			
Y						115.01			

Table 13. Iteration 13

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	7.92	24000	0.61	-12840.5	198730.9	1847.2	115986.2585
Jakarta	-6.17	106.69	8.55	24000	0.57	-9793.5	169470.3	1588.4	116183.7674
Samarinda	-0.54	117.15	4.22	24000	0.61	-1866.8	406201.9	3467.4	61777.64982
Makassar	-5.10	119.46	4.55	24000	0.85	-22982.0	538032.1	4503.9	93065.32721
		Total				-47482.8	1312435.2	11406.9	387013.0029
X						-4.16			
Y						115.06			

Table 14. Iteration 14

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	7.97	24000	0.61	-12760.9	197498.1	1835.7	116710.2243
Jakarta	-6.17	106.69	8.60	24000	0.57	-9737.1	168493.2	1579.3	116857.5149
Samarinda	-0.54	117.15	4.19	24000	0.61	-1882.7	409664.1	3496.9	61255.53948
Makassar	-5.10	119.46	4.50	24000	0.85	-23206.5	543288.5	4547.9	92164.89863
		Total				-47587.2	1318944.0	11459.9	386988.1773
X						-4.15			
Y						115.09			

p-ISSN 2622-2027
DOI : https://doi.org/10.36456/tibuana.7.2.9299.144-151 *e*-ISSN 2622-2035

Table 15. Iteration 15

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	8.01	24000	0.61	-12700.8	196568.8	1827.1	117261.9953
Jakarta	-6.17	106.69	8.64	24000	0.57	-9694.4	167755.8	1572.4	117371.1952
Samarinda	-0.54	117.15	4.16	24000	0.61	-1894.9	412315.9	3519.6	60861.57456
Makassar	-5.10	119.46	4.47	24000	0.85	-23380.5	547362.3	4582.0	91478.95629
		Total				-47670.7	1324002.9	11501.0	386973.7214
X						-4.14			
Y						115.12			

Table 16. Iteration 16

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	8.04	24000	0.61	-12655.6	195869.7	1820.6	117680.5452
Jakarta	-6.17	106.69	8.67	24000	0.57	-9662.4	167200.6	1567.2	117760.9698
Samarinda	-0.54	117.15	4.14	24000	0.61	-1904.2	414333.9	3536.8	60565.14588
Makassar	-5.10	119.46	4.44	24000	0.85	-23514.3	550492.9	4608.2	90958.7262
		Total				-47736.4	1327897.1	11532.8	386965.387
X						-4.14			
Y						115.14			

Table 17. Iteration 17

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	8.06	24000	0.61	-12621.7	195344.6	1815.7	117996.8897
Jakarta	-6.17	106.69	8.69	24000	0.57	-9638.2	166783.2	1563.2	118055.64
Samarinda	-0.54	117.15	4.12	24000	0.61	-1911.2	415862.4	3549.8	60342.54977
Makassar	-5.10	119.46	4.42	24000	0.85	-23616.3	552882.8	4628.2	90565.53915
		Total				-47787.5	1330873.0	11557.0	386960.6186
X						-4.13			
Y						115.16			

Table 18. Iteration 18

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	8.08	24000	0.61	-12596.3	194950.6	1812.0	118235.3264
Jakarta	-6.17	106.69	8.71	24000	0.57	-9620.1	166470.0	1560.3	118277.786
Samarinda	-0.54	117.15	4.11	24000	0.61	-1916.5	417015.9	3559.7	60175.6286
Makassar	-5.10	119.46	4.41	24000	0.85	-23693.9	554698.1	4643.4	90269.16548
		Total				-47826.8	1333134.6	11575.5	386957.9065
X						-4.13			
Y						115.17			

p-ISSN 2622-2027
DOI : https://doi.org/10.36456/tibuana.7.2.9299.144-151 *e*-ISSN 2622-2035

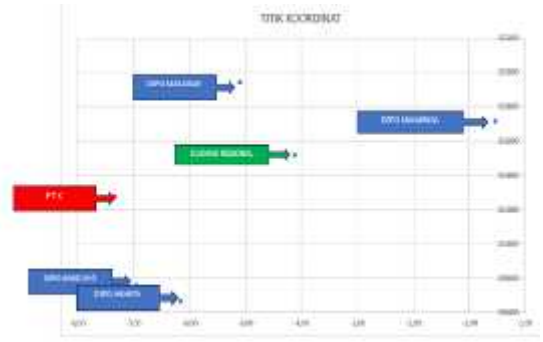
Table 19. Iteration 19

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	8.09	24000	0.61	-12577.2	194655.4	1809.3	118414.666
Jakarta	-6.17	106.69	8.72	24000	0.57	-9606.6	166235.1	1558.1	118444.9
Samarinda	-0.54	117.15	4.10	24000	0.61	-1920.5	417884.3	3567.1	60050.57819
Makassar	-5.10	119.46	4.40	24000	0.85	-23752.5	556071.4	4654.9	90046.22649
		Total				-47856.8	1334846.2	11589.4	386956.3707
X						-4.13			
Y						115.18			

Table 20. Iteration 20

Depo	Xn	Yn	dn	DN	Cn	DnCnXn/dn	DnCnYn/dn	DnCn/dn	TC
Bandung	-6.95	107.59	8.10	24000	0.61	-12562.9	194434.3	1807.2	118549.3427
Jakarta	-6.17	106.69	8.73	24000	0.57	-9596.4	166059.1	1556.5	118570.412
Samarinda	-0.54	117.15	4.10	24000	0.61	-1923.5	418536.8	3572.7	59956.95882
Makassar	-5.10	119.46	4.39	24000	0.85	-23796.8	557107.3	4663.6	89878.79042
		Total				-47879.6	1336137.5	11600.0	386955.504
X						-4.13			
Y						115.18			

From the tabulation results above. to supply the 4 shops or depots owned by PT X **X = -4.13** and **Y = 115.18** namely in the Djorong area. South Kalimantan. Development also follows the surrounding natural conditions.



Picture 1. Regional Warehouse Coordinates

Picture 2. Maps

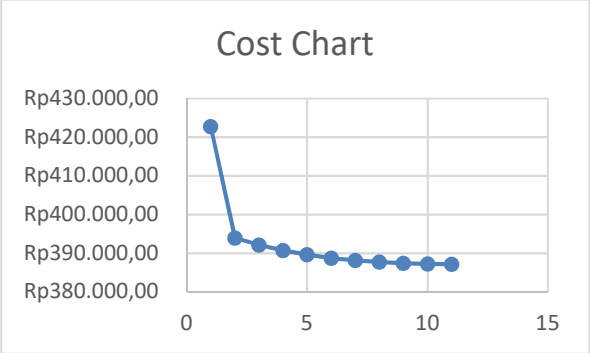
After obtaining the coordinates that are considered optimal. the next step is to calculate the total cost or TC. namely using the formula $T = \sum_{n-1}^{k} d$ as follows:

Table 21. Total Cost

	TC
Iteration 1	Rp 422.713.67
Iteration 2	Rp 393.942.78
Iteration 3	Rp 392.130.69
Iteration 4	Rp 390.710.18
Iteration 5	Rp 389.589.75
Iteration 6	Rp 388.743.58
Iteration 7	Rp 388.131.60
Iteration 8	Rp 387.706.93
Iteration 9	Rp 387.423.26
Iteration 10	Rp 387.240.13
Iteration 11	Rp 387.125.32
Iteration 12	Rp 387.055.10
Iteration 13	Rp 387.013.00
Iteration 14	Rp 386.988.18
Iteration 15	Rp 386.973.72
Iteration 16	Rp 386.965.39
Iteration 17	Rp 386.960.62
Iteration 18	Rp 386.957.91

p-ISSN 2622-2027
DOI : https://doi.org/10.36456/tibuana.7.2.9299.144-151 *e*-ISSN 2622-2035

Iteration 19	Rp 386.956.37
Iteration 20	Rp 386.955.50



Picture 3. Cost Chart

IV. CONCLUSIONS AND SUGGESTIONS

From the results of calculations using the Gravity Location Models method. it can be concluded that regional warehouse coordinate points were determined through 11 iterations. resulting in coordinate location points and minimum costs from the distribution process. The results of cost minimization calculations through comparison of 11 iterations found the minimum costs in the third iteration. 20. which is IDR. 386.955.50. with coordinates X = -4.13 and Y = 115.18. The results of these coordinates. if seen from the Google Maps map. are in the Djorong area. South Kalimantan. Warehouse construction also follows the surrounding natural conditions.

The advice obtained in this research is that it is hoped that further research using the Gravity Location Models method can expand its coverage not only between cities or provinces but also between countries so that we can see how far the Gravity Location Models method can be developed.

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