Planning of Number and Location of New Base Transceiver Station (BTS) Tower in Mobile Telecommunication System in Jombang Using Analytical Hierarchy Process Method and Geographic Information System Approach

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***Abstract*— Technology and telecommunication industry has been growing rapidly. Operators continue to race to be able to improve its services. One of them is the development of BTS to be able to serve mobile users in the area to be reached. But development without proper planning can have a bad impact in the future. This research discussed about the location arrangement and number of BTS in Jombang regency up to 5 years according to Analytical Hierarchy Process method with population density criteria, Spatial Plans (SP) and distance and will be displayed in digital map based on geographic information system. For 2014 there are 204 towers in Jombang while for 2019 it takes 231 towers to cover the needs of the people of Jombang Regency.**

Keywords— BTS, Coverage, Traffic Capacity, Geographic Information System, Analytical Hierarchy Process

I. INTRODUCTION

Service availability is pursued by a number of operators offering various systems and services that vary with the development of cellular radio network infrastructure, including in addition to the number and location of BTS Tower which is a compulsory requirement.

If viewed from the opposite viewpoint, the density of the tower location is too high to bring some problems that affect the community. On the one hand, the increasing number of tower sites will indeed support the fulfillment of the community's need for telecommunication services. On the other hand, if development is done without coordination it will disturb the beauty of a region.

To be able to solve the problem of location and number of BTS tower in Jombang need a complete and detailed Master Plan about location planning and number of BTS tower in Jombang regency. The Master Plan must continue to comply with applicable regulations.

In this research will be discussed about the location planning and the number of new BTS towers in Jombang. The result of this final project will be displayed in digital
map using Map Info and the determination of new BTS location based on Analytical Hierarchy Process method.

This study aims to find out the location of existing towers and traffic capacity in Jombang regency that will be useful to determine the number of base stations needed for the next 5 years. And can know the location and number of new BTS towers in Jombang.

This research is focused on Jombang Regency which will be displayed in Map Info and BTS location determination based on Analytical Hierarchy Process method with population density criteria, Spatial Plans and Distance.

II. RESEARCH METHODOLOGY

A. Literature Study

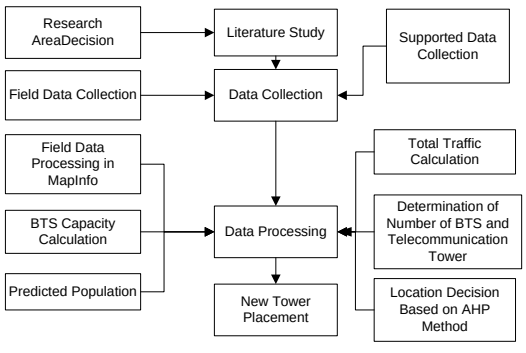

FIGURE 1 RESEARCH FLOWCHART

The area used for research is Jombang District. Jombang Regency is located at 50 20 '01 "to 50 30' 01" East Longitude and 070 24 '01 "and 070 45' 01" South Latitude, with an area of 1,159.50 Km2. Jombang Regency is divided into 21 districts

consisting of 302 villages and 4 sub-districts and includes 1,258 hamlets

B. Data Collection

The data required in this study is divided into two:

a. Field data, ie data obtained by conducting direct surveys to the field such as the tower coordinate point capture, tower height, determination of the number of base stations, and mobile operators operating in the tower.
b. Supporting data, ie data obtained from other sources such as legal basis, digital map usage, population data, Spatial Plan, existing tower zone, new tower zone, and tower free zone in Jombang regency.

C. Data Calculation

The parameters used to calculate the needs of the BTS number of Jombang Regency are:

a. The average mobile user call for the suburban area is 60 minutes and for the rural area is 45 minutes. So Offered Traffic per customer can be calculated:
   Rural : A = 45 / (24 X 60) = 31,25 mErlang
   Suburban : A = 60/ (24 X 60) = 41,67 mErlang
b. Grade of Service (GOS) is assumed 2%
c. BTS capacity used has configuration
   a) Menggunakan Using 3 sectoral antennas with 3/3/3 configuration
      1sector consists of 3 TRx
      1 TRx consists of 8 timeslots
      3 TRx = 8 x 3 = 24 timeslots
      1 sector of 3 TRx can serve 24-2 = 22 Channels.
   b) Each BTS consists of 3 sectoral antennas with each sector consisting of 3 TRx / sectoral antennas so the number of channels per BTS is 22 x 3 = 66 channels.
   c) Capacity 1 BTS consisting of 3 sectoral antennas and each sectoral antenna consisting of 3 TRx and GOS assumption of 2% = 55.33 Erlang (Referring to Table Erlang B). [5]

D. Determination of Criteria and sub criteria in Determining Location of BTS with AHP Method

In the BTS location planning can be assumed criteria and sub criteria as follows

a. Population Density

The assessment criteria of population density are as follows:

a. Good

The definition of good judgment is through the amount of population in the kecamatan including high population.

b. Enough

The definition of sufficient appraisal is that the population of the subdistrict population is not densely populated but does not include low population.

c. Less

Definition of less assessment is through the population of the population in the kecamatan include low population..

b. Spatial Plans

The assessment criteria of Spatial Plans are as follows:

a. Good

The definition of good judgment is through regional funding that is included in the main program Spatial Plans Jombang District.

b. Enough

The definition of sufficient assessment is through the regional funding included in the Jombang Spatial Plans program but not included in the main program.

c. Less

Definition of less assessment is through regional funding that is not included in the program Spatial Plans (SP) Jombang District.

c. Distance

The assessment criteria of distance are as follows:

a. Good

The definition of good judgment is through the spacing of new tower zones with areas belonging to suburban and industrial areas as the most densely populated areas in Jombang Regency fall into the suburban category.

b. Enough

The definition of appraisal is sufficient through the spacing of new tower zones with areas that are included in the residential area as it supports the activities of the people of Jombang Regency.

c. Less

The definition of scant assessment is through the spacing of new tower zones with areas with fewer residential areas and many forests or open areas.

E. Calculation of criteria with AHP Method

Criteria to be calculated with the assessment are:

a. Density: good, enough, less
b. SP: good, enough, less
c. Distance: well, enough, less

The steps that must be taken to assess the location of BTS with AHP method is:

a. Matrix of pairing criteria

This step is to compare one criterion with another. The results can be seen in table 1.

TABLE 1 MATCHED COMPARISON MATRICES

Criteria	Density	SP	Distance
Density	1	2	3
SP	0.5	1	1.5
Distance	0.33	0.67	1
Total	1.83	3.67	5.5

From Table 1, the AHP method is written to determine the value of pairwise comparison matrices, namely population density is more important 2 times than SP. Population density is more important 3 times than distance. While SP 0.5 times more important than population density. SP 1.5 times more important than distance

Then from the specified matrix values are added vertically (the same column) to produce the total value of each population density criteria, SP, and distance.

b. Criteria Value Matrix

The value of this matrix is obtained by dividing the row value of Table 1 by the number of each column Table 1. While the value in the priority column is obtained from dividing the value in the sum column by the number of criteria. Example: in the density column a value of 0.55 (Table 2) is obtained from the value of 1 column density (in Table 1) divided by total density (Table 1). In Table 2 the Priority column value of 0.55 is obtained from the total value of 1.65 divided by the number of criteria i.e. 3. And so on for all available columns. The results of the calculation can be seen in table 2.

TABLE 2 CRITERIA VALUE MATRIX

Criteria	Density	SP	Distance	Total	Priority
Density	0.55	0.54	0.54	1.65	0.55
SP	0.27	0.27	0.27	0.82	0.27
Distance	0.18	0.18	0.18	0.54	0.18

c. Sum of each line matrix

The value of this matrix is obtained by multiplying the priority value in table 2 with the value of each row of columns in table 1. Example: In Table 3, the column density value 0.55 is obtained by multiplying the density priority row 0.55 (Table 2) with the column density value 1 (Table 1). A column value of 0.28 is obtained by multiplying 0.55 by a density value of 0.5 (Table 1). The column value of 0.18 is obtained by multiplying 0.55 by the density value of 0.33 (Table 1). And so on for all available columns. While the sum of the columns in table 3 is derived from summing the values in each row in table 3. The calculation results can be seen in Table 3.

TABLE 3 SUM OF EACH LINE MATRIX

Criteria	Density	SP	Distance	Total
Density	0.55	0.54	0.54	1.63
SP	0.28	0.27	0.27	0.83
Distance	0.18	0.18	0.18	0.54

d. Consistency Ratio

Consistency ratio is calculated to prove whether CR <= 0.1. If the Consistency Ratio has reached <= 0.1 then the matrix can be used. To be able to calculate the consistency ratio can be calculated using table 4.

TABLE 4 CONSISTENCY RATIO

Criteria	Total each line	Priority	Result
Density	1.63	0.55	2.18
SP	0.83	0.27	1.10
Distance	0.54	0.18	0.27
		Total	4.00

The number of columns per row is obtained from the number field in Table 3. While the priority columns are obtained from the priority columns in Table 2. From Table 4 we can obtain the values:

a. The number of criteria is 3
b. λ max is 4/3 = 1.33
   λmax is obtained by dividing the total in Table 4 by the number of criteria (i.e. 3)
c. CI is ((1.33-3) / 3) = -0.55
   CI (Consistency Index) is the difference λ max with the number of criteria divided by the number of criteria
d. CR is (-0.55 / 0.58) = -0.94
   CR (Consistency Ratio) is the value of CI divided by RI (Random Index)

F. Calculation of subcriteria with AHP Method

Subcriteria calculations are performed for all sub-sub of all existing criteria. Subcriteria calculation is the same way with criteria calculation. Steps are as follows.

a. *Comparison matrix in pairs*

This step is the same as the step in table 1. The calculation results are shown in table 5.

TABLE 5 MATCHED COMPARISON MATRICES DENSITY CRITERIA

	Good	Enough	Less
Good	1	3	5
Enough	0.33	1	3
Less	0.20	0.33	1
Total	1.53	4.33	9

b. *Criteria Value Matrix*

This step is the same as the step in table 2 but there is addition of priority sub criteria and sub criteria. The value in the priority sub criteria column is derived from the priority value in that row divided by the highest value in the priority column. While the value of sub-criteria obtained from multiplication between the priority sub criteria with the priority criteria. The results can be seen in table 6.

TABLE 6 MATRIX OF DENSITY CRITERIA VALUES

	Good	Enough	Less	Total	Priority	Priority sub criteria	Value sub criteria
Good	0.65	0.69	0.56	1.90	0.63	1.00	0.55
Enough	0.22	0.23	0.33	0.78	0.26	0.41	0.23
Less	0.13	0.08	0.11	0.32	0.11	0.17	0.09

While the other steps are the same as the steps on the priority criteria calculation before. While the differences in paired matrix comparison for subcriteria of Spatial Plans and Distance criteria can be seen in Table 7 and Table 8.

TABLE 7 MATRIX CRITERIA PAIR CRITERIA SPATIAL PLAN

	Good	Enough	Less
Good	1	2	6
Enough	0.5	1	2
Less	0.17	0.5	1

TABLE 8 MATRIX CRITERIA PAIRE CRITERIA DISTANCE

	Good	Enough	Less
Good	1	3	4
Enough	0.33	1	3
Less	0.25	0.33	1

III. DISCUSSION

A. Mobile User Data

Teledensity of mobile users is the ratio between the number of mobile users and the population in the area in this case is Jombang. Teledensity of cellular users in Jombang can be assumed by teledensity of cellular users in East Java which is 56.5%. Teledensity of mobile users by region can be seen in figure 2. Teledensity serves as seeing the number of mobile users in a region.wilayah.

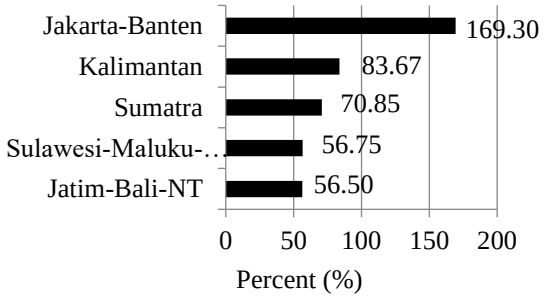

FIGURE 2 CELLULAR PHONE USER BY REGION OF 2010

According to the population data in Jombang Dalam Figures 2013, information can be obtained about the population of each sub-district and population growth data of each sub-district in Jombang Regency in 2012. Using geometric formula about population growth, it can be calculated the prediction of population for next 5 years and shown in table 9.

$$P_{2019} = P_{2014}\,(1 + X)^t \quad (1)$$

TABLE 9 POPULATION PREDICTION

District	Growth Rate	Population in 2014	Population Prediction in 2019
Bandar Kedung Mulyo	0,63%	44.300	45.714
Perak	0,59%	52.089	53.644
Gudo	0,65%	51.805	53.511
Diwek	0,58%	103.335	106.367
Ngoro	0,59%	70.508	72.613
Mojowarno	0,56%	87.560	90.040
Bareng	0,59%	50.651	52.163
Wonosalam	0,56%	31.305	32.192
Mojoagung	0,58%	74.718	76.911
Sumobito	0,59%	78.887	81.242
Jogoroto	0,50%	64.222	65.844
Peterongan	0,59%	65.306	67.256
Jombang	0,64%	140.791	145.355
Megaluh	0,71%	37.556	38.909
Tembelang	0,69%	50.479	52.245
Kesamben	0,67%	61.626	63.719
Kudu	0,74%	29.087	30.180
Ngusikan	0,71%	21.532	22.308
Ploso	0,67%	39.849	41.202
Kabuh	0,81%	40.382	42.045
Plandaan	0,79%	36.456	37.919
Total	0,64%	1.232.444	1.271.379

B. Total Costumer Traffic

The per-user traffic assumption in the suburban area is 41.67 mErlang while the rural area is 31.25 mErlang. Then the traffic per user is calculated by multiplying the number of users with the intensity of the region's traffic. While the number of users is obtained from the multiplication of population with teledensity of mobile users in East Java that is equal to 56.5%. If you can know the traffic in a region then it can be known also the optimal number of base stations in the region. Then the total result of customer traffic can be seen in table 10.

TABLE 10 TOTAL USER TRAFFIC IN JOMBANG DISTRICT IN 2019

District	Total User 2019	Morphology Area	Total Traffic 2019 (Erlang)
Bandar Kedung Mulyo	25.829	*Rural*	808
Perak	30.309	*Rural*	948
Gudo	30.234	*Rural*	945
Diwek	60.098	*Rural*	1.879
Ngoro	41.027	*Rural*	1.283
Mojowarno	50.873	*Rural*	1.590
Bareng	29.473	*Rural*	922
Wonosalam	18.189	*Rural*	569
Mojoagung	43.455	*Rural*	1.358
Sumobito	45.902	*Rural*	1.435
Jogoroto	37.202	*Rural*	1.163
Peterongan	38.000	*Rural*	1.188
Jombang	82.126	*Sub-Urban*	1970
Megaluh	21.984	*Rural*	687
Tembelang	29.519	*Rural*	923
Kesamben	36.002	*Rural*	1126
Kudu	17.052	*Rural*	533
Ngusikan	12.605	*Rural*	394
Ploso	23.280	*Rural*	728
Kabuh	23.756	*Rural*	743
Plandaan	21.425	*Rural*	670
Total	718.340		22.459

C. Determination of Number of BTS and Telecommunication Tower

The calculation of the number of base stations needed in Jombang District for 2019 was obtained by dividing the total traffic generated by mobile users (Erlang) with the capacity of 1 BTS in Jombang District. Capacity 1 BTS (E) consisting of 3 sectoral antennas with each sectoral antenna consisting of 3

TRx assuming 2% GOS is 55.33 Erlang (Referred to Erlang B Table). While the number of towers is calculated by:

M_t = ((Total BTS in2019 – Total BTSin 2014)/4)) + Total Tower in 2014

The calculation result of BTS and Telecommunication Tower for the year 2019 is shown in table 11.

TABLE 11 TOTAL NEEDS OF BTS AND CELLULAR TELECOMMUNICATION TOWER TOGETHER IN 2019

District	Total BTS 2014	Total BTS 2019	Total Tower 2014	Total Tower 2019
Bandar Kedung Mulyo	12	15	7	8
Perak	19	18	11	11
Gudo	15	18	9	10
Diwek	26	34	15	17
Ngoro	19	24	15	17
Mojowarno	19	29	10	13
Bareng	9	17	5	7
Wonosalam	13	11	10	10
Mojoagung	28	25	10	10
Sumobito	16	26	10	13
Jogoroto	13	22	7	10
Peterongan	19	22	8	9
Jombang	50	47	34	37
Megaluh	9	13	6	7
Tembelang	17	17	9	9
Kesamben	10	21	9	12
Kudu	9	10	8	9
Ngusikan	2	8	2	4
Ploso	16	14	8	8
Kabuh	12	14	7	8
Plandaan	10	13	4	5
Total	343	418	204	231

D. Determination of the Number and Location of the New Tower Zone

Determination of the number of new tower zones can be calculated using the formula:

Zone Total = (Total BTS in 2014 – Total BTS in 2019)/4

Zone Total = ((433-343)/4) = 23 Zone

The new tower zone in this final project uses a finger of 0.5 km and the area of each new tower zone can be calculated by the formula:

The area of the new tower zone = 3.14X0.5X0.5 = 0.785 Km^2

The total area of 23 new tower zones is calculated formula:

Area total zone = 23 x 0,785 = 18,055 Km^2

The location of the new tower zone can be seen in Table 12.

TABLE 12 NEW TOWER DATA

No	Location	Latitude	Longitude	Area (Km^2)
1	JBG-01	112,132556	-7,553593	0,785
2	JBG-02	112,163266	-7,473093	0,785
3	JBG-03	112,219293	-7,417982	0,785
4	JBG-04	112,247688	-7,426572	0,785
5	JBG-05	112,310092	-7,383929	0,785
6	JBG-06	112,267391	-7,450437	0,785
7	JBG-07	112,282234	-7,520841	0,785
8	JBG-08	112,367770	-7,508661	0,785
9	JBG-09	112,370295	-7,478415	0,785
10	JBG-10	112,365994	-7,589235	0,785
11	JBG-11	112,282250	-7,579282	0,785
12	JBG-12	112,258737	-7,603661	0,785
13	JBG-13	112,267559	-7,637875	0,785
14	JBG-14	112,344787	-7,672336	0,785
15	JBG-15	112,361161	-7,665761	0,785
16	JBG-16	112,250527	-7,719153	0,785
17	JBG-17	112,197652	-7,598849	0,785
18	JBG-18	112,194327	-7,542663	0,785
19	JBG-19	112,210422	-7,505237	0,785
20	JBG-20	112,276283	-7,494869	0,785
21	JBG-21	112,119391	-7,458954	0,785
22	JBG-22	112,214634	-7,584757	0,785
23	JBG-23	112,313772	-7,699618	0,785
	Total Area of the Blue Zone			18,055

E. Placement of New Tower Zone on Map Info

The placement of new zones should be according to 3 existing criteria: population density, Spatial Plans, and distance. Before determining the new tower zone, it must be known in advance about the location of the existing tower zone. In this final project the existing tower zones 2G and 3G are depicted in the red zone and will be illustrated in Figures 3 and 4. The existing tower zone consists of 1 telecommunication tower in each tower zone.

While the new tower zone serves to overcome the area that has not covered by the existing tower zone. The location of the new tower zone must also be according to the 3 criteria specified ie population density, Spatial Plans, and Distance. The new tower zone in MapInfo is depicted with blue zones. The result of the new tower zone can be seen in figure 5 and the result of combination in figure 6.

F. Decision Support System BTS Location with Analytical Hierarchy Process Method

Assessment of BTS locations that have been determined previously with 3 existing criteria of population density, Spatial Plans, and Distance. Assessment results can be seen in table 13 and the results of calculations in table 14.

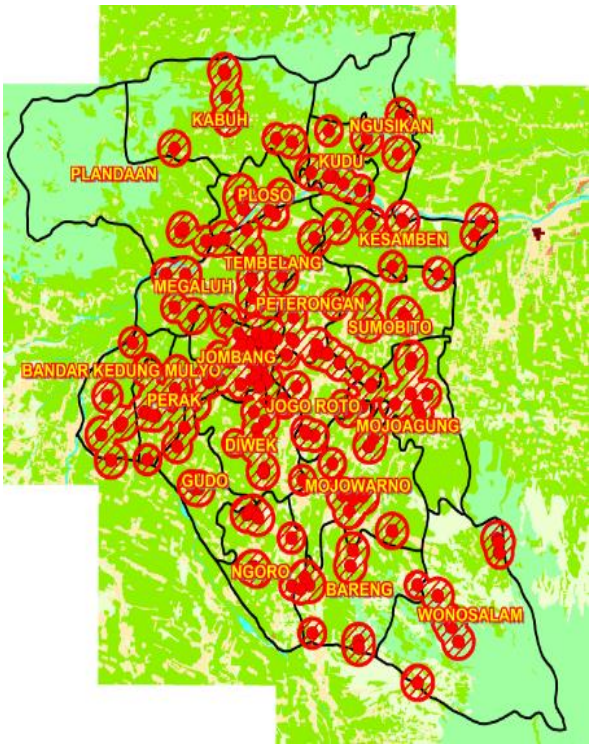

FIGURE 3 EXISTING TOWER ZONE 2G

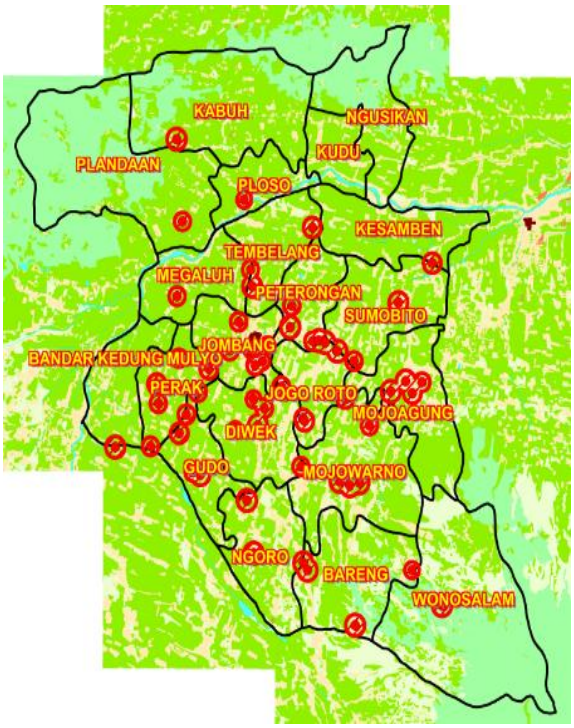

FIGURE 4 EXISTING 3G TOWER ZONE

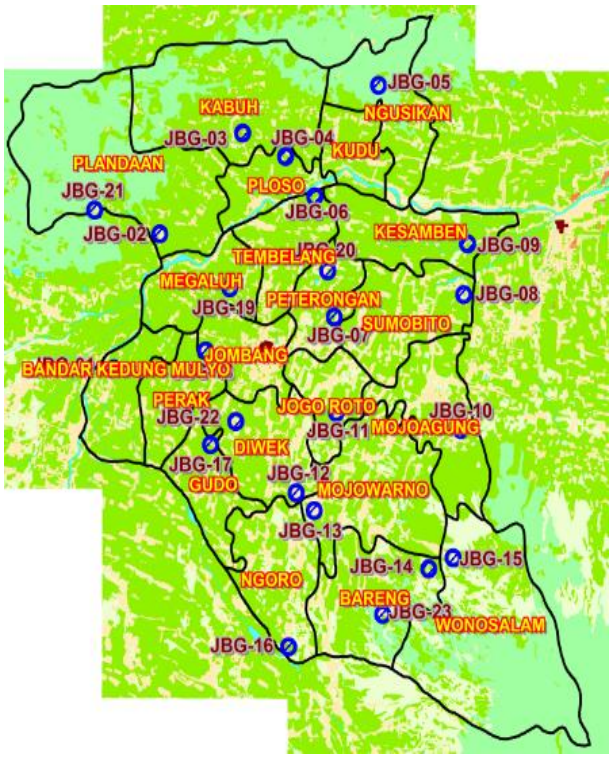

FIGURE 5 NEW TOWER ZONE

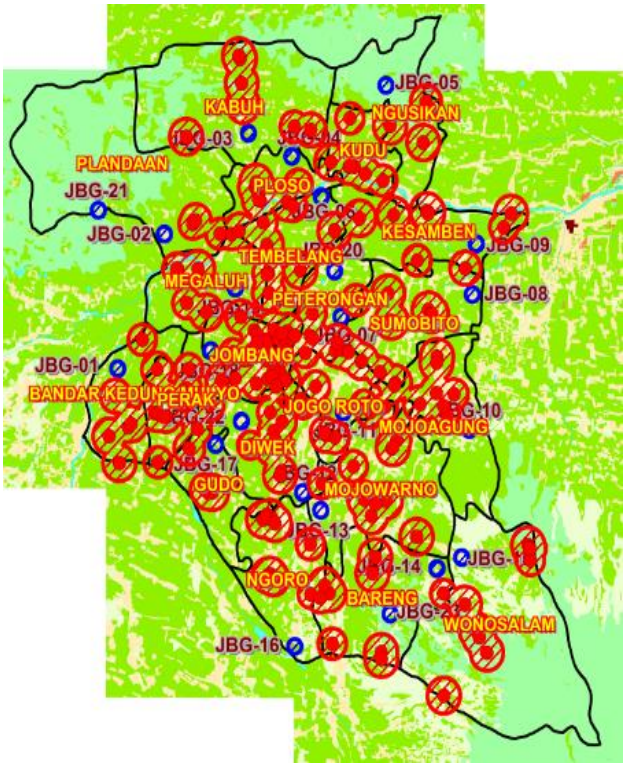

FIGURE 6 COMBINATION RESULT

TABLE 13 DETERMINATION OF SUB-CRITERIA FOR BTS LOCATION IN JOMBANG REGENCY ACCORDING TO AHP METHOD

No	Location	Density	SP	Distance
1	JBG-01	Enough	Good	Good
2	JBG-02	Less	Less	Less
3	JBG-03	Less	Enough	Good
4	JBG-04	Less	Good	Good
5	JBG-05	Less	Less	Less
6	JBG-06	Enough	Good	Less
7	JBG-07	Good	Enough	Enough
8	JBG-08	Good	Enough	Enough
9	JBG-09	Enough	Enough	Less
10	JBG-10	Good	Good	Enough
11	JBG-11	Enough	Enough	Enough
12	JBG-12	Good	Less	Good
13	JBG-13	Good	Good	Enough
14	JBG-14	Enough	Less	Enough
15	JBG-15	Less	Less	Less
16	JBG-16	Good	Less	Good
17	JBG-17	Enough	Less	Enough
18	JBG-18	Good	Good	Good
19	JBG-19	Less	Enough	Good
20	JBG-20	Good	Enough	Enough
21	JBG-21	Less	Less	Less
22	JBG-22	Good	Less	Good
23	JBG-23	Enough	Less	Enough

TABLE 14 ASSESSMENT OF SUB-CRITERIA BTS LOCATION DETERMINATION IN JOMBANG REGENCY WITH AHP METHOD

No	Location	Density	SP	Distance	AHP Method Result
1	JBG-01	0,23	0,27	0,18	0,68
2	JBG-02	0,09	0,05	0,04	0,18
3	JBG-03	0,09	0,11	0,18	0,38
4	JBG-04	0,09	0,27	0,18	0,54
5	JBG-05	0,09	0,05	0,04	0,18
6	JBG-06	0,23	0,27	0,04	0,54
7	JBG-07	0,55	0,11	0,08	0,74
8	JBG-08	0,55	0,11	0,08	0,74
9	JBG-09	0,23	0,11	0,04	0,38
10	JBG-10	0,55	0,27	0,08	0,9
11	JBG-11	0,23	0,11	0,08	0,42
12	JBG-12	0,55	0,05	0,18	0,78
13	JBG-13	0,55	0,27	0,08	0,9
14	JBG-14	0,23	0,05	0,08	0,36
15	JBG-15	0,09	0,05	0,04	0,18
16	JBG-16	0,55	0,05	0,18	0,78
17	JBG-17	0,23	0,05	0,08	0,36
18	JBG-18	0,55	0,27	0,18	1
19	JBG-19	0,09	0,11	0,18	0,38
20	JBG-20	0,55	0,11	0,08	0,74
21	JBG-21	0,09	0,05	0,04	0,18
22	JBG-22	0,55	0,05	0,18	0,78
23	JBG-23	0,23	0,05	0,08	0,36

IV. CONCLUSION

In the year 2019 in Jombang regency is predicted to have traffic of 22,459 Erlang and there are 418 BTS contained in 231 telecommunication towers. In 2019 also predicted the addition of 23 new tower zones with 0.5 km radius with total area of the zone is 18.055 Km2. According to Analytical Hierarchy Process method with population density criterion, Spatial Plans, and distance, new tower zone that has the highest priority to be built is JBG-18 located in Jombang subdistrict and has priority value 1. Then followed up to the fifth priority in a row as follows: JBG-10 in Mojoagung sub-district, JBG-13 in Mojowarno sub-district, JBG-12 in Diwek sub-district, and JBG-16 in Ngoro sub-district.

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