The Implementation of Multi Criteria Decision Making (MCDM) for the Evaluation of Sustainable Regional Development in East Java by Using the Fuzzy C-Means Method and Technique for Order Preference By Similarity To Ideal Solution (TOPSIS)

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Keywords: MCDM, *Fuzzy C-Means*, TOPSIS, Sustainable Development

Abstract: The assessment of sustainable regional development performance has several criteria, such as based on social, economic and environmental aspects. These criteria include number of sub criteria that are used as indicators. The large number of criteria and sub criteria in the assessment of sustainable regional development performance of East Java which include 29 districts and 9 cities can cause performance appraisal to be complicated, there for an approach is needed accommodate all of these criteria and sub criteria. This research was conducted using the MCDM approach and aims to determine the ranking of each district or city in the evaluation of sustainable regional development in East Java using the TOPSIS method, to provide input for decision making in the East Java local government to develop sustainable regional development based on criteria or district preference. The steps of this research consist of data analysis, data clustering using Fuzzy C-Means, and ranking using the TOPSIS method. In the clustering process, data grouped into four regional cluster: advanced, potential, developing, and Underdeveloped. The initial step of the clustering process was to cluster seven sub criteria from the economic criteria, seven sub criteria from the social criteria, and five sub criteria from the enironmental criteria, and lastly cluster all criteria. The weighting criteria was used for the ranking process. The results of this research are in the form of a ranking for each district or city in East Java, from economic, social, environmental, and overall criteria. For the ranking results, the top ten includes the Bojenogoro district, Banyuwangi district, Malang city, Mojokerto district, Kediri city, Surabaya city, Gresik and Malang district.

1 INTRODUCTION

Sustainable development is development that is oriented to the compliance of human needs through wise and efficient utilization of natural resources which also pays attention to the sustainability of its utilization for the present and future generations (Jaya, 2004).The goal of sustainable development is essentially to develop equitable development from various aspects that is equitable for the present and future generations.

There are three main factors why development must be sustainble various aspects. The first factor, in terms of economic development, is defined as development that is able to continuously produce goods and services to maintain government sustainability and avoid sectoral imbalances that can damage agricultural and industrial production.The second factor, is in terms of ecological or environmental development, where the concept of environmental sustainability must be able to maintain stable resources, avoid exploitation of natural resources and function as environmental absorption. This concept also relates to the maintenance of biodiversity, stability of air space, and other functions in the ecosystem that do not include economic sources. The third factor, in terms of social development, defines social sustainability as a system capable of achieving equality, provides social services such as supporting health, education, gender equality, and political accountability (Fauzi, 2004).

Zaenab, D., Farida, Y., Novitasari, D., Lubab, A. and Yuliati, D.
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DOI: 10.5220/0008906400002481
In *Proceedings of the Built Environment, Science and Technology International Conference (BEST ICON 2018)*, pages 281-288
ISBN: 978-989-758-414-5

These conflicting problems can be referred to as MCDM.

MCDM is a method of decision making that determines the best alternative from a number of alternatives based on certain criteria (Rani, Nessa, Faizal, & Samawi, 2014). MCDM is also used for the best selection in several cases, such as the research of the Best Supplier Selection by using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Putra, 2013). In sustainable urban development evaluation research, MCDM Uses fuzzy values to identify the coefficients of each criteria (Zhang, Xu, Yeh, Liu, & Zhou, 2016).

In the MCDM method, the crucial problem is determining the weight of each criterion and sub-criteria. This study did not carry out the collection of primary data and used secondary data. Hence the weighting approach is obtained from clustering data using the Fuzzy C-Means method. The Fuzzy C-Means method is used to cluster and weigh the criteria of sustainable regional development indicators.

The next crucial problem in MCDM is alternative decision making. Alternative decisions are taken account of from the criteria that produces the highest weight. In this research, the TOPSIS method was used for MCDM decision making because it can select the best alternative from a number of alternatives in a quick and practical manner.

Several studies that apply the combination of Fuzzy C-Means and TOPSIS methods include the Integration of Fuzzy C-Means Clustering Algorithm and TOPSIS Method for Customer Age Assessment by Amir (Azadnia, Saman, Wong, & Hemdi, 2011), Fuzzy C-Integration Means and TOPSIS for Performance Evaluation on Applications and Comparative Analysis by Chunguang (Bai, Dhavale, & Sarkis, 2014), and Decision Support Systems in Mapping National Road and Bridge Repair Priorities in Bengkulu Province Using TOPSIS and Fuzzy C-Means (Oktariani, 2017).

Thus, this research proposes a method to identify and incorporate linkage criteria in the process of evaluating sustainable regional development for district or city governments in East Java using MCDM with the Fuzzy C-Means and TOPSIS methods. This research is expected to provide input to the East Java regional governments in making decisions to develop sustainable regional development based on district or city criteria preferences.

2 LITERATURE REVIEW

2.1 Evaluation of Sustainable Regional Development

According to the Organization for Economic Operation and Development evaluation is the process of determining the value of an activity, policy, or program. Sustainable development according to Sofyan is defined as a progressive transformation of the social, economic and political structure to increase the certainty of the Indonesian people in fulfilling their current interests without sacrificing the ability of future generations to fulfil their interests (Abdurrahman, 2003).

Therefore, the evaluation of sustainable regional development is an assessment of the quality of the life development program from all aspects, including the economic, social, and environmental aspects that fulfil current interests without compromising the ability of future generations.

2.2 Criteria for Sustainable Regional Development

2.2.1 Economic Aspect

In the evaluation of sustainable development in East Java, the economic aspects were determined by the sub criteria of Gross Domestic Product (GDP), fixed investment, average per capita expenditure, GDP per capita, per capita income, GDP growth rate, and per capita expenditure rate.

2.2.2 Social Aspects

In evaluating of sustainable development in East Java, the social aspects were determined by the sub criteria of population density, population growth rate, per capita road area, per capita settlement area, unemployment ratio, gini index, and number of *puskesmas* (community health centers)

2.2.3 Environmental Aspects

To evaluation sustainable development in East Java, the environmental aspects were determined by a number of sub criteria, such as feasibility of clean water usage, areas suitable for farming per capita, investment in ecological protection, proportion of urban forest fulfilment, and number of waste disposal sites (WDS).

2.3 Multiple Criteria Decision Making (MCDM)

MCDM is considered as a term for all models and techniques related to Multiple Objective Decision Making (MODM) or Multiple Attribute Decision Making (MADM) (Tabucanon, 1988).A problem is classified as MCDM if and only if there are at least two conflicting criteria and involve two alternative solutions (Tabucanon, 1988). If a problem has at least two conflicting criteria, and each of these criteria will produce a different alternative solution, then the problem can be said to be MCDM.

2.4 Fuzzy C-Means (FCM)

Fuzzy C-Means is a data clustering technique where the presence of each data point in a cluster is determined by the value or degree of membership.

Fuzzy C-Means algorithm is as follows:

1. Data input will be in cluster *X*, in the form of a matrix measuring *n* × *m* (*n* = number of data samples, *m* = attribute of each data). *Xij* = sample data *i (i = 1, 2, ..., n)*, attribute *j (j = 1, 2, ..., m)*.
2. Determine the number of clusters, rank, maximum iteration, smallest error, initial objective function, initial iteration.
3. Generate a random number μ_{ik}, where *i* = 1, 2, ..., *n; k* = 1, 2, ..., *c*; as elements of the initial partition matrix *U*.
$$\sum_{i=1}^{c} \mu_{ik} = 1 \quad (1)$$
4. Calculate the center of the cluster *k,*$V_{kj}$with k = 1, 2, ..., c and j = 1, 2, ..., m
$$V_{kj} = \frac{\sum_{i=1}^{n}((\mu_{ik})^{w} * X_{ij}}{\sum_{i=1}^{n}(\mu_{ik})^{w}} \quad (2)$$
where:
V_{kj}= cluster center
μ_{ik} = degree of membership of point k in cluster i
w= the rank of weight
X= input data i, attribute j
5. Calculate the objective function in the t iteration
$$P_t = \sum_{i=1}^{n}\sum_{k=1}^{c}\left(\left[\sum_{j=1}^{m}(X_{ij} - V_{kj})^2\right](\mu_{ik})^{w}\right) \quad (3)$$
6. Calculate changes to the partition matrix
$$\mu_{ik} = \frac{\left[\sum_{j=1}^{m}(X_{ij} - V_{kj})^2\right]^{\frac{-1}{w-1}}}{\sum_{k=1}^{c}\left[\sum_{j=1}^{m}(X_{ij} - V_{kj})^2\right]^{\frac{-1}{w-1}}} \quad (4)$$
where:
X_{ij} = sample of data i, attribute j
V_{kj}= center cluster k for attribute j
w= the rank of weight
7. Check the stop condition
   - If *t* > Maxiteration stops
   - Otherwise, *t = t + 1*, repeat step four
8. If the condition stops, it will find clusters of cluster centers and membership levels for each criterion.

2.5 TOPSIS

The TOPSIS method is one of the MCDM models used for the assessment or selection of several alternatives in a limited number. In the TOPSIS method there is no limit on the number of attributes and alternatives used, so that it can be used to solve a case that has quantitative attributes more efficiently (Rao, 2004).

The following are the steps used to use the TOPSIS method:

1. Normalization of the decision matrix $U = (x_{ij})_{n \times m}$ using the equation 5.
$$v_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \quad (5)$$
Where, *U* = cluster membership degree matrix
x_{ij}= value of the degree matrix of alternative cluster membership *i* to attribute *j*
2. Determine the maximum and minimum values of equation (5) using the formulas in Equations 6 and 7.
$$S^{+} = \{v_1^{+}, \dots, v_m^{+}\} = \left\{\left(\max_i v_{ij} \middle| j \in I\right), \left(\min_i v_{ij} \middle| j \in J\right)\right\} \quad (6)$$
$$S^{-} = \{v_1^{-}, \dots, v_m^{-}\} = \left\{\left(\max_i v_{ij} \middle| j \in I\right), \left(\min_i v_{ij} \middle| j \in J\right)\right\} \quad (7)$$
With i is an alternative and j is a criterion.
3. Determine the distance between the values of each alternative with the positive ideal solution matrix (D_i^{+}) and the distance between the values of each alternative with the positive ideal solution matrix (D_i^{-}) with the formula in Equation 8 and 9.
$$D_i^{+} = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^{+})^2} \quad (8)$$
$$D_i^{-} = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^{-})^2} \quad (9)$$
Where $i = 1, 2, \dots, n$
4. Determine the preference value for each alternative (T_i)with the formula in Equation 10.
$$T_i = \frac{D_i^{-}}{D_i^{-} + D_i^{+}} \quad (10)$$
Where $i = 1, 2, \dots, m$
5. After the preference value is obtained, then it is sorted from the highest to the lowest preference value. High preference values will have the highest ranking, and vise versa.

3 RESEARCH METHODS

The data used in this research were 2015/2016 data from indicators of sustainable development, which include social, economic, and environmental aspects. The data was obtained from the East Java Provincial Statistics Agency, the East Java Regional Development Planning Agency, and the East Java Provincial Environmental Service. This stage of completion of the evaluation of sustainable regional development research is presented below (Fig.1):

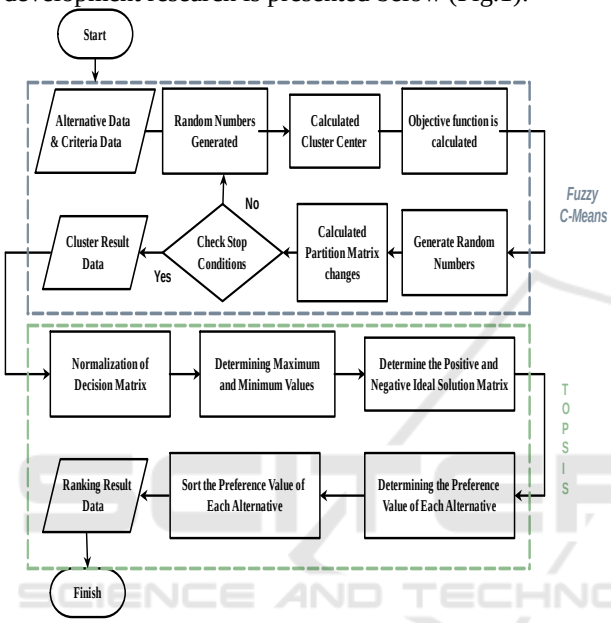

Figure 1: Research Flow Chart

The general explanation of the stages of completion of research is as follows:

a. Enter alternative data and criteria data.Alternative data consists of 38 districts/ cities in East Java, while the criteria data consists of economic criteria with seven sub-criteria, social criteria with seven sub-criteria, and environmental criteria with five sub-criteria.
b. The data is grouped or clustered into four clusters by using the Fuzzy C-Means method. This cluster process aims to weigh each criteria used for the ranking process. The weight used was obtained from the membership degree of Fuzzy C-Means. In the clustering process, the initial step was to cluster seven sub criteria from the economic criteria, seven sub criteria from the social criteria, and five sub criteria from the environmental criteria. Clustering was then performed on all criteria.
c. After obtaining the weight, the weight of the Fuzzy C-Means process is combined in the ranking process using the TOPSIS method with the aim of discovering the value of each district and city in East Java. Before obtaining the ranking results of each region, the centroid of cluster was first ranked using the TOPSIS method.
d. Ranking results were obtained for each district or city in East Java based on the criteria of sustainable regional development, which was then concluded.

4 RESULTS AND DISCUSSION

Data used from the indicators of sustainable development, which include social, economic, and environmental aspects as well as data samples shown on Table 1.

Table 1. The Original Data of All Criteria and Sub Criteria

District/City	Economic		Social		Environment	
	GDP	Per Capita Expenditure	Population Density	Gini Index	Areas Farming	WDS
Pacitan	9489,08	8048	397	0,33	64126	25
Tulungagung	23446,4	9881	972	0,36	60376	68
Lumajang	19555,2	8311	577	0,29	89769	73
Banyuwangi	46924,6	11171	277	0,34	91930	46
Pasuruan	89011,2	9198	1081	0,32	83029	39
Magetan	11398,1	10988	912	0,34	42419	38
Lamongan	23623,8	10252	667	0,3	111635	10
Kediri	76959,4	11070	4448	0,4	2456	3
Pasuruan	5076,35	12295	5560	0,39	1600	33
Surabaya	343653	16295	8166	0,42	2707,1	185

Analysis was carried out on the three criteria with 19 different sub-criteria. The economic, social and environmental criteria, were analyzed first, followed by all the criteria together. The total criteria involved nineteen sub criteria simultaneously. Using Fuzzy C-Means, the thirty eight districts/cities were grouped into four groups for each scenario of several criteria. To avoid repetition, details were given for only the economic criteria. Table 2 shows the results of applying the FCM algorithm for economic criteria which shows the value or degree of membership for each district/ city and the four groups. The maximum value of membership degree determines which cluster each district/city is For example, for the District of Pacitan, membership levels in clusters 1 to 4 are 0.9788, 0.0033, 0.0003, 0.0176. Therefore Pasuruan District was included in Cluster 1, because the value of Cluster 1 membership was the highest of the other values.

Table 2: Cluster formation by Fuzzy C-Means for Economic Criteria

District / City	Degree of Membership			
	1	2	3	4
Pacitan	0.9788	0.0033	0.0003	0.0176
Ponorogo	0.9765	0.0035	0.0003	0.0197
Trenggalek	0.9830	0.0026	0.0002	0.0142
Tulungagung	0.8793	0.0118	0.0007	0.1081
Blitar	0.9235	0.0084	0.0005	0.0676
Kediri	0.8433	0.0165	0.0011	0.1391
Lumajang	0.9612	0.0045	0.0003	0.0339
Bondowoso	0.9830	0.0025	0.0002	0.0142
Situbondo	0.9925	0.0011	0.0001	0.0063
Probolinggo	0.9447	0.0064	0.0004	0.0485
Jombang	0.8718	0.0130	0.0008	0.1143
Nganjuk	0.9798	0.0028	0.0002	0.0173
Madiun	0.9865	0.0020	0.0002	0.0113
Magetan	0.9904	0.0014	0.0001	0.0080
Ngawi	0.9807	0.0029	0.0002	0.0161
Lamongan	0.8802	0.0121	0.0008	0.1069
Bangkalan	0.9809	0.0026	0.0002	0.0163
Sampang	0.9681	0.0048	0.0004	0.0266
Pamekasan	0.9560	0.0071	0.0006	0.0364
Sumenep	0.9220	0.0084	0.0005	0.0690
Blitar City	0.9139	0.0145	0.0012	0.0705
Probolinggo City	0.9345	0.0104	0.0008	0.0544
Pasuruan City	0.9396	0.0100	0.0008	0.0496
Mojokerto City	0.8927	0.0181	0.0014	0.0878
Madiun City	0.7131	0.0476	0.0033	0.2360
Batu City	0.7095	0.0469	0.0032	0.2404
Pasuruan	0.0340	0.8473	0.0032	0.1155
Sidoarjo	0.0564	0.8077	0.0135	0.1224
Gresik	0.0255	0.8837	0.0023	0.0885
Kediri City	0.2236	0.3723	0.1308	0.2733
Surabaya City	0.0002	0.0004	0.9991	0.0003
Malang	0.1149	0.0946	0.0030	0.7876
Jember	0.1688	0.0452	0.0020	0.7840
Banyuwangi	0.0299	0.0123	0.0004	0.9574
Mojokerto	0.0183	0.0114	0.0003	0.9699
Bojonegoro	0.0427	0.0171	0.0006	0.9396
Tuban	0.0901	0.0170	0.0007	0.8922
Malang City	0.0711	0.0353	0.0011	0.8925

Before obtaining the ranking results of each region, the centroid of cluster was first ranked using the TOPSIS method (see Eq. (10)) with the aim of distinguishing regional rankings in the regions that entered the cluster and were determined with the results are in Table 3. The centroids of the clusters provide the information required for this analysis. For economic criteria, the closeness coefficients indicatethat the most desirable cluster is cluster 4, followed by clusters 1, 2, and 3.

The results of grouping the economic, social and environmental criteria using the FCM method based on membership degrees were used to identify regions based on the equation of variable characteristics, which aims to combine information on the implementation of sustainable regional development in East Java more precisely. The results of the classification are found in Table 4, where each district/city is defined as an advanced, potential, developing and underdeveloped region.

Table 3: Ranking of Centroid for ClusterEconomic Criteria using TOPSIS

Centroid of Cluster	T	Ranking
Cluster 1	0.6339	2
Cluster2	0.6151	3
Cluster3	0.3597	4
Cluster4	0.7084	1

Table 4: Interpretation of Clustering Results Using Fuzzy C-Means

District / City	Criteria		
	Economic	Social	Enviroment
Pacitan	Under developed	Under developed	Developing
Ponorogo	Under developed	Under developed	Developing
Trenggalek	Under developed	Developing	Developing
Tulungagung	Under developed	Developing	Developing
Blitar	Under developed	Advanced	Potential
Kediri	Under developed	Advanced	Developing
Malang	Developing	Under developed	Advanced
Lumajang	Under developed	Developing	Potential
Jember	Developing	Underdeveloped	Advanced
Banyuwangi	Developing	Potential	Potential
Bondowoso	Underdeveloped	Under developed	Developing
Situbondo	Underdeveloped	Underdeveloped	Developing
Probolinggo	Under developed	Under developed	Potential
Pasuruan	Potential	Developing	Potential
Sidoarjo	Potential	Developing	Under developed
Mojokerto	Developing	Developing	Developing
Jombang	Under developed	Developing	Developing
Nganjuk	Under developed	Developing	Developing
Madiun	Under developed	Developing	Developing
Magetan	Under developed	Developing	Developing
Ngawi	Under developed	Under developed	Developing
Bojonegoro	Developing	Under developed	Potential

Tuban	Developing	Developing	Advanced
Lamongan	Under developed	Developing	Advanced
Gresik	Potential	Advanced	Developing
Bangkalan	Under developed	Under developed	Potential
Sampang	Under developed	Developing	Potential
Pamekasan	Under developed	Developing	Developing
Sumenep	Under developed	Developing	Advanced
Kediri City	Potential	Under developed	Under developed
Blitar City	Under developed	Under developed	Under developed
Malang City	Developing	Under developed	Under developed
Probolinggo City	Under developed	Under developed	Under developed
Pasuruan City	Under developed	Under developed	Under developed
Mojokerto City	Under developed	Under developed	Under developed
Madiun City	Under developed	Under developed	Under developed
Surabaya City	Advanced	Developing	Under developed
Batu City	Under developed	Under developed	Under developed

The next step determined the ranking of each region using TOPSIS from the results of the FCM membership degree and centroid of cluster ranking in Table 3. This was determined by the calculation of the proximity coefficients by using the TOPSIS algorithm and shown on Table 5 for the ranking of economic criteria. The same method was used to obtain the overall ranking of districts/cities based on economic, social, environmental criteria, and all criteria obtained, as seen on Table 6.

Table 5: Ranking of Economic Criteria using TOPSIS

District / City	T	Economic
Pacitan	0.3677	25
Ponorogo	0.3679	24
Trenggalek	0.3673	30
Tulungagung	0.3781	12
Blitar	0.3729	17
Kediri	0.3831	10
Malang	0.3907	2
Lumajang	0.3692	22
Jember	0.3925	1
Banyuwangi	0.3695	6
Bondowoso	0.3673	29
Situbondo	0.3666	33
Probolinggo	0.3707	20
Pasuruan	0.3814	36
Sidoarjo	0.3835	35
Mojokerto	0.3684	7
Jombang	0.3684	11
Nganjuk	0.3676	26
Madiun	0.3671	31
Magetan	0.3668	32
Ngawi	0.3675	27
Bojonegoro	0.3711	5
Tuban	0.3764	3
Lamongan	0.3780	13
Gresik	0.3768	37
Bangkalan	0.3675	28
Sampang	0.3686	23
Pamekasan	0.3696	21
Sumenep	0.3731	16
Kediri City	0.4958	34
Blitar City	0.3737	15
Malang City	0.3760	4
Probolinggo City	0.3717	18
Pasuruan City	0.3711	19
Mojokerto City	0.3761	14
Madiun City	0.4085	9
Surabaya City	0.3660	38
Batu City	0.4095	8

The results of the ranking of overall criteria shows that the district/cities in the top ten were the Bojonegoro district, Banyuwangi district, Malang city, Mojokerto district, Kediri city, Surabaya city, Sidoarjo district, Pasuruan district, Gresik district, and Malang district.

Table 6: Ranking of different perspectives using TOPSIS

District / City	Economic	Social	Enviroment	All Criteria
Pacitan	25	12	28	32
Ponorogo	24	7	19	31
Trenggalek	30	22	21	25
Tulungagung	12	24	31	16
Blitar	17	35	12	13
Kediri	10	37	20	14
Malang	2	11	37	10
Lumajang	22	31	17	30
Jember	1	16	35	11
Banyuwangi	6	38	16	2
Bondowoso	29	3	25	36
Situbondo	33	13	27	35
Probolinggo	20	10	18	29
Pasuruan	36	34	15	8
Sidoarjo	35	23	1	7
Mojokerto	7	26	24	4
Jombang	11	20	33	15
Nganjuk	26	33	32	38
Madiun	31	32	26	27
Magetan	32	28	22	26

Ngawi	27	1	23	37
Bojonegoro	5	4	11	1
Tuban	3	21	36	12
Lamongan	13	25	34	24
Gresik	37	36	30	9
Bangkalan	28	2	14	34
Sampang	23	29	13	28
Pamekasan	21	27	29	33
Sumenep	16	30	38	23
Kediri City	34	14	8	5
Blitar City	15	15	3	21
Malang City	4	6	10	3
Probolinggo City	18	17	7	20
Pasuruan City	19	8	6	22
Mojokerto City	14	5	2	19
Madiun City	9	9	4	17
Surabaya City	38	19	9	6
Batu City	8	18	5	18

The success of district/city performance in sustainable regional development in East Java shows that the areas in the top ten positions tend to be high industrial areas and have rich agricultural resources. Malang District and Malang City are included in the top ten regions because they have extensive natural resources in the form of agriculture compared to the other district/cities.

Mojokerto, Sidoarjo, Pasuruan, Gresik, and Surabaya regencies were in the top ten positions in the evaluation of sustainable development because these districts/cities have the characteristics of industrial cities where regional economic development is fairly rapid, as well as having high investment and balanced public services in the regions. Although the Bojonegoro and Banyuwangi Ditricts are large areas, they are further away from the center of the industrial areas; however, their public service facilities are proportionate according to their regions.

From the results of this analysis, the implementation of MCDM using the FCM and TOPSIS methods can be used as an alternative for the evaluation of sustainable regional development in East Java Province because there are groupings and rankings. This is also supported by research on the typology of competitiveness of the districts/cities in East Java (Suliswanto, 2017). This research explained the economic conditions and the strength of competitiveness of each district/city in East Java. However, some district/city rankings also had non-conformities. This was possible due to the preferences of economic, social and environmental criteria. Therefore, other approaches that utilize other methods are needed to accommodate differences in these criteria preferences.

5 CONCLUSION

The results of clustering based on the indicators of sustainable regional development in East Java from the economic, social, environmental aspects by using the method of Fuzzy C-Means was successfully built and is deemed usable. Fuzzy C-Means was able to group as four clusters, namely as advanced, potential, developing, and under developed regional clusters. This was based on empirical data from the clustering results according to the existing district/city conditions.

The results of the ranking of each district or city in the evaluation of sustainable regional development in East Java based on cluster results using the TOPSIS method show several conformities with the research of typology of competitiveness of districts/cities in East Java in 2017 by Suliswanto. The ranking results of the top ten were: Bojonegoro district, Banyuwangi district, Malang city, Mojokerto district, Kediri city, Surabaya city, Sidoarjo district, Pasuruan district, Gresik district, and Malang district.

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