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Performance evaluation of 198 village governments using fuzzy TOPSIS and intuitionistic fuzzy TOPSIS

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Abstract
Currently, volatility, uncertainty, complexity, and ambiguity (VUCA) have become unavoidable problems. In addition, knowledge or information that is not managed properly can result in inappropriate decision-making processes within an organization. Business Intelligence conception is then becoming an essential view for converting unstructured data and information into a more actionable strategic plan that allows organizations to make competitive decisions. Village Government (VG) is the smallest organization in the Indonesian government system because VG implemented regulation and development programs in all areas of a national government. VG executes a series of tasks every year starting from planning, budgeting, administrating, executing, and reporting. However, the important role of VG in the development of a country brings also some drawbacks such as corruption and other domino effects. Several factors have been identified that cause those problems such as lack of capabilities in managing village organization and human resources quality. Monitoring and evaluation regarding those VG performances normally have been done each year. However, measurable evaluation standard for VG performance until recently has not been determined nationally. This study is intended to make a comprehensive standard of village government performance assessment through a Good Governance Framework approach. This study involved 198 villages from Madiun Regency as a case study. Seventy-four measured parameters were proposed to evaluate VG performance mapping. Fuzzy TOPSIS is implemented to rank those 198 villages into 4 groups of VG performance levels. The fuzzy TOPSIS classification result has been validated by using manual scoring and the accuracy reached 86,4%.

1. Introduction

With the global environment becoming more dynamic, organizations face rapid changes caused by technological development, intense global competition, alterations in governmental regulations, and shifts in organizational structures. Those conditions make a confusing challenge for leaders to make a good decision. In a world where volatility, uncertainty, complexity, and ambiguity (VUCA) has become the new normal, the faith to determine a definite strategic plan is fading away, and adapting to changes become a major and constant challenge faced by organizations [1].

Huge unorganized knowledge and information could contribute to an imperfect view of the facts and a partial decision-making process for an organization. Data analytics enables leaders to decide according to statistical facts. These facts could be used to guide decisions on future organizations by assessing the condition and competition in the long term. The organization needs a concept to increase the intelligent organizational effectiveness and decision-making analysis in organizations. The Business Intelligence concept may play a significant role in optimizing organizational effectiveness. Business Intelligence helps gather essential information from a wide variety of unstructured data and convert them into actionable insights that allow organizations to make information-based policy decisions and improve business efficiency and productivity [2].

In the new normal condition, this concept is needed by various sectors, for example, engineering, government, education, medicine, psychology, automotive, economy, design, creativity, and many more. The subject of this study is decision-making in the village government (VG) because villages are the lowest structure in the government for implementing regulation and development programs in Indonesia. The number of VG in Indonesia reaches 74.953 [3]. It becomes the concern of the government to manage the success of the national development programs. Therefore, VG has routine tasks which are regulated centrally starting from planning, budgeting, administration, reporting, and accountability [4][5][6].

In Indonesia, the central government's concrete steps to support villages is to disburse funds with a total nominal budget of IDR 400 trillion for the last 7 years. On the other hand, villages also receive a disbursement of funds from the provincial and local governments as their income [6]. The amount of budget and heavy responsibility that must be managed by VG has not been comparable to the readiness of human resources. Various background factors are education level, lack of understanding of regulations, low willingness to learn, and weak in escort and supervision from central and local government. Those matters have impacted many problems from VG administration such as misuse of village budgets and corruption. Based on data from Indonesia Corruption Watch (ICW) from 2015 to 2020, there were 439 cases in the VG and reached a state loss of IDR 188 billion [7].

The factors that lead to increased cases of corruption in the VG start from the implementation of village governance that is not based on business processes following applicable regulations. The next factors are monitoring and evaluation from the central and local governments that are not carried out intensively and measurably. To increase the success of a project or activity in an organization, it must be supported by a monitoring and evaluation process by the team. The supporting factors in this process include communication, commitment, leadership patterns, political management, management of community demand, and motivation [8].

Previous research is still limited to factor analysis in each phase of the VG task. Thus, it has not been able to analyze the factors that affect the performance of the VG comprehensively. Therefore, this study intends to construct a comprehensive standard of VG performance assessment through a Good Governance Framework (GGF) approach based on 9 principles. In the GGF, the area of concern consists of planning, participation, transparency, accountability, effectivity, service, economy, bureaucracy relations, and community safety [9].

The performance appraisal standard will be used as a measuring tool to analyze and make the decision making of the best performing villages using one of the Multi-Criteria Decision Making (MCDM) methods, namely Fuzzy TOPSIS and Intuitionistic Fuzzy TOPSIS. TOPSIS method is often used as a method for decision-making based on multi-criteria. This method is based on the concept that the best alternative has the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution [10]. The result of the TOPSIS method in this research is in the form of village rankings from the best to the worst. These results are expected to be taken into consideration in formulating policies related to reward and punishment to VG, assisting in the preparation of local government programs in solving the problems that arise in the VG and optimizing escorting and evaluating of VG.

2. Research Method

2.1 Literature Review

The Previous research on the application of Fuzzy TOPSIS as the reference was listed in Table 1.

Table 1. Literature Review

No.	Title and Author	Result
1.	"Evaluation and Selection of Mobile Health (mHealth) applications"[23].	This research aimed to select the best Mobile Health Application among 10 options based on 9 criteria and 32 sub-criteria using the AHP and Fuzzy TOPSIS methods.
2.	"Factors Influencing Medical Tourism Adoption in Malaysia: A DEMATEL Fuzzy TOPSIS Approach" [24].	This research aimed to find out the most influential factors in the medical tourism sector in Malaysia using DEMATEL and Fuzzy TOPSIS based on 16 criteria. DEMATEL is used to find the relationship between factors and Fuzzy TOPSIS is used to find the most influential factor.
3.	"Fuzzy Multi-Attribute Decision Making for Classification of Entrepreneurial Potential Based on Theory of Planned Behavior" [27].	This research aimed to propose the Multi-Attribute Decision Making (MADM) method to determine entrepreneurial potential based on the Theory of Planned Behavior (TPB) consisting of 14 criteria. The result indicated that the fuzzy SAW-TOPSIS method had the most optimal performance.
4.	"TOPSIS Fuzzy Method on Employee Recruitment Decision Making in PT. Global Solutions Enterprise" [26].	This research aimed to provide decision-making techniques in employee recruitment in PT. Global Solutions Enterprise. As a result, the Fuzzy TOPSIS method can be implemented for making employee recruitment decisions.
5.	"A Decision Making and Clustering Method Integration based on the Theory of Planned Behavior for Student Entrepreneurial Potential Mapping in Indonesia" [27].	Experiments in this research indicated that the fuzzy SAW-TOPSIS method and the clustering method can be used for decision-making in evaluating the entrepreneurial potential of students.

Fuzzy TOPSIS was used in this study because the concept is simple and easy to understand, computationally efficient, and can measure the performance of decision alternatives in a simple mathematical form. This method can be combined into one with other methods to solve decision-making problems [11][12][13].

2.2 Research Flow and Data Structure

According to the research flow in Figure 1, the research began with a discussion of the GGF with 7 experts consisting of 4 internal experts and 3 external experts. Furthermore, based on the agreed GGF, the criteria that became the basis for preparing the questionnaire were obtained.

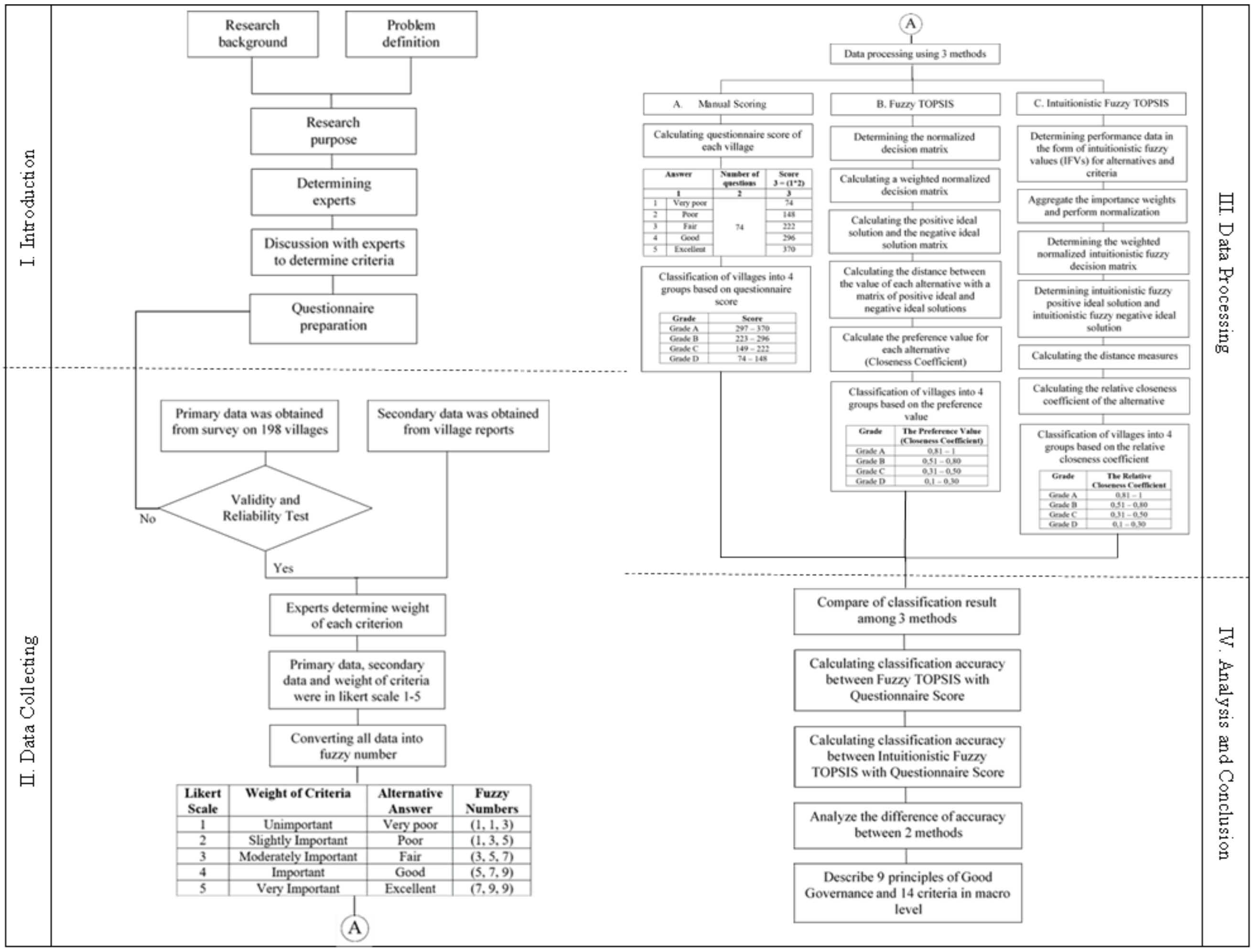

Figure 1. Research Flow

The data we used in this study was obtained from a case study on 198 villages in Madiun Regency. Sixty measured parameters, combined with 23 other secondary parameters have been proposed to evaluate VG performance mapping. The survey was conducted on 198 villages and secondary data was obtained from village reports during 2020.

The data structure in this research consisted of 3 levels: level 1 was the goal, level 2 was the principle, level 3 was the criteria and level 4 was the alternative. The data structure was detailed in Figure 2. After data was collected, the next step was data processing using manual scoring, Fuzzy TOPSIS (FT), and Intuitionistic Fuzzy TOPSIS (IFT). The final step was analysis comparing the three methods for measuring VG performance and concluding the result.

2.3 Good Governance

The World Bank defines good governance as the implementation of solid development and responsible management. It is related to a clean and dignified government, free from corruption, collusion, and nepotism, applying the principles of transparency, accountability, law enforcement, participation, and disclosure of information to the public [14]. In their research "A Good Governance Framework for Urban Management" found a Good Governance framework as a performance reference that can be applied in local governments [9]. It obtained a framework consisting of 13 criteria; Accountability, Transparency, Participation, Effectivity, Equality, Vision and Planning, Sustainability, Legitimacy and Bureaucracy, Civic Capacity, Service Delivery, Efficient Economy, Relationship, and Security [9]. This framework is used as a reference in evaluating the VG performance. In this study, we used 9 principles of Good Governance based on that reference to derive 14 criteria. The principles and the criteria in this study were detailed in Figure 2.

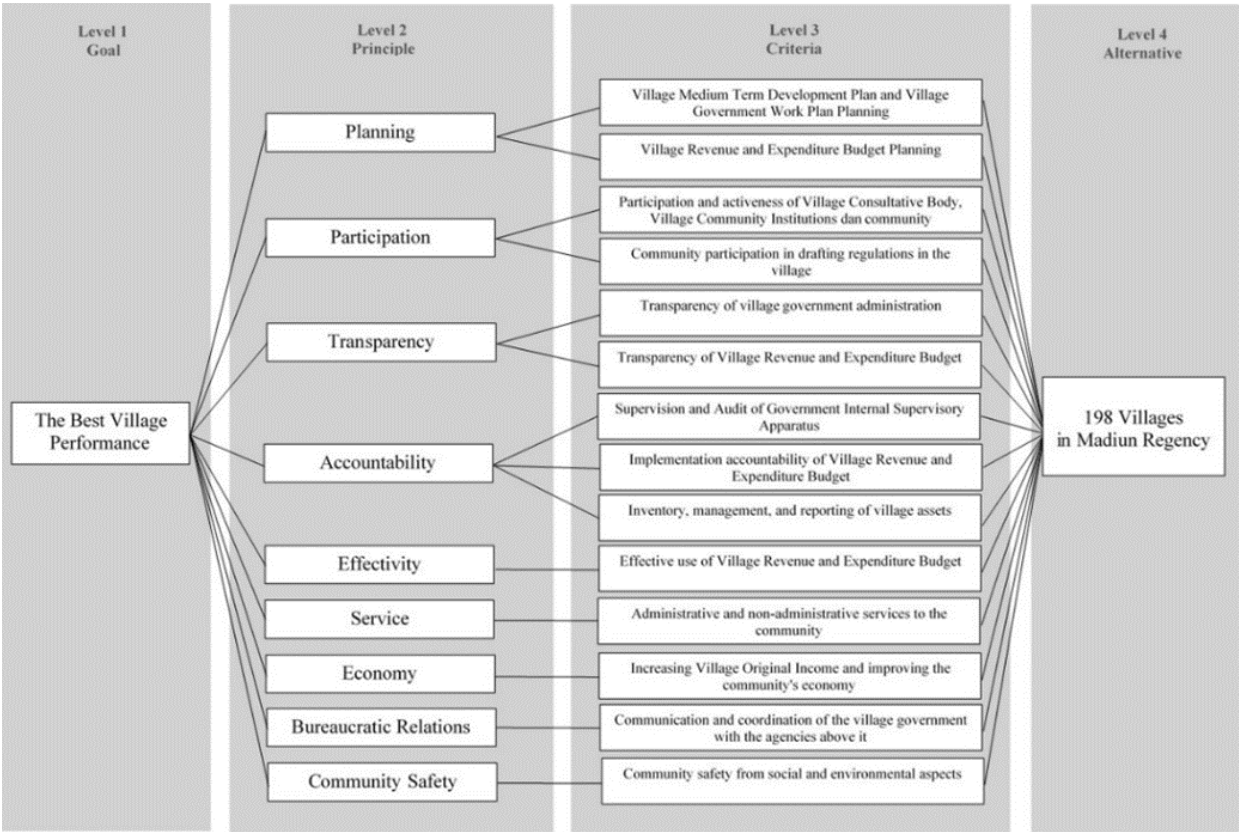

Figure 2. Data Structure

2.4 Fuzzy TOPSIS (FT)

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was developed by Yo on and Hwang in 1980 as an alternative decision-making method that has many criteria or attributes. TOPSIS is based on the concept that the best alternative has the shortest distance from the positive ideal solution and has the longest distance from the negative ideal solution [11][12][13]. In making decisions, experts can use crisp numbers or linguistic numbers. Under certain conditions, experts find it easier to use linguistic numbers in solving problems to make decisions. Therefore, it takes a TOPSIS method combined with a fuzzy method for the solution called Fuzzy TOPSIS (FT). The set of fuzzy numbers for the weight of the criteria and alternative answers in this research had been determined by the researcher as shown in Table 2 below.

Table 2. Fuzzy Numbers for Criteria and Alternatives

Criteria Weight	Alternative Answer	Fuzzy Numbers
Unimportant	Very poor	(1, 1, 3)
Slightly Important	Poor	(1, 3, 5)
Moderately Important	Fair	(3, 5, 7)
Important	Good	(5, 7, 9)
Very Important	Excellent	(7, 9, 9)

The steps of the Fuzzy TOPSIS method are as follows [15]:

1. Determining the normalized decision matrix as presented in Equation 1.

$$\text{Benefit Criteria} \quad \tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right);\ c_j^* = \max_i\{c_{ij}\}$$
$$\text{Cost Criteria} \quad \tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right);\ a_j^- = \min_i\{a_{ij}\} \qquad (1)$$

2. Calculating a weighted normalized decision matrix as presented in Equation 2.

$$\widetilde{w}_{ij} = \tilde{r}_{ij} \, x \, w_j \tag{2}$$

3. Calculating the positive ideal solution and the negative ideal solution matrix as presented in Equation 3 and Equation 4.

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*);\ \tilde{v}_j^* = \max_i\{v_{ij3}\} \tag{3}$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-);\ \tilde{v}_j^- = \min_i\{v_{ij}\} \tag{4}$$

4. Calculating the distance between the value of each alternative with a matrix of positive ideal and negative ideal solutions as presented in Equation 5, Equation 6, and Equation 7.

$$d(\tilde{x}, \tilde{y}) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]} \tag{5}$$

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*) \tag{6}$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \tag{7}$$

5. Calculate the preference value for each alternative (Closeness Coefficient) as presented in Equation 8.

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*} \tag{8}$$

The largest preference value is the best alternative and the smallest preference value is the worst alternative.

2.5 Intuitionistic Fuzzy TOPSIS (IFT)

Intuitionistic Fuzzy Set (IFS) was introduced by Atanassov. IFS theory is a generalization of the classical Fuzzy Set Theory (FST) proposed by Zadeh in handling vagueness and uncertainty in computing information. While the FST only introduces a membership function, the IFS theory is characterized by a membership function, a non-membership function, and a hesitancy degree that respectively express support, opposition, lack of knowledge, and neutrality in eliciting information. Step of The Intuitionistic Fuzzy TOPSIS method for evaluating survey data [16][17]:

1. Determining performance data in the form of intuitionistic fuzzy values (IFVs) form alternatives and n criteria. Let X be a universe of discourse of objects. An intuitionistic fuzzy set A in X is given by Equation 9.

$$A = \{< x, \mu A(x), \nu A(x) > | x \in X\} \tag{9}$$

where $\mu A, \nu A : X \rightarrow [0, 1]$ are functions with the condition for every $x \in X$ is given by Equation 10.

$$0 \leq \mu A(x) + \nu A(x) \leq 1 \tag{10}$$

$\mu A(x)$ represent degrees of membership, $\nu A(x)$ represent degrees non-membership, and $\pi A(x) = 1 - \mu A(x) - \nu A(x)$ represent the intuitionistic fuzzy index (hesitation margin) of the element x in the set A.

2. Aggregate the importance weights and perform normalization.
3. Determining the weighted normalized intuitionistic fuzzy decision matrix as presented in Equation 11.

$$v_{ij} = r_{ij} \, x \, w_j \tag{11}$$

4. Determining intuitionistic fuzzy positive ideal solution and intuitionistic fuzzy negative ideal solution as presented in Equation 12, Equation 13, Equation 14, Equation 15, Equation 16, and Equation 17.

$$A^{+} = \left(\mu_j^{+}, v_j^{+}\right) \tag{12}$$

$$A^{-} = \left(\mu_j^{-}, v_j^{-}\right) \tag{13}$$

$$\mu_j^{+} = (\left(\max_i \mu_{\tilde{v}_{ij}} | j \in C_b\right), \left(\min_i \mu_{\tilde{v}_{ij}} | j \in C_c\right) \tag{14}$$

$$v_j^{+} = (\left(\min_i v_{\tilde{v}_{ij}} | j \in C_b\right), \left(\max_i v_{\tilde{v}_{ij}} | j \in C_c\right) \tag{15}$$

$$\mu_j^{-} = (\left(\min_i \mu_{\tilde{v}_{ij}} | j \in C_b\right), \left(\max_i \mu_{\tilde{v}_{ij}} | j \in C_c\right) \tag{16}$$

$$v_j^{-} = (\left(\max_i v_{\tilde{v}_{ij}} | j \in C_b\right), \left(\min_i v_{\tilde{v}_{ij}} | j \in C_c\right) \tag{17}$$

5. Calculating the distance measures as presented in Equation 18 and Equation 19.

$$S_{IF}^{+} = \sqrt{\frac{1}{2n}\sum_{j=1}^{n}\left[(\mu_{\tilde{v}_{ij}} - \mu_j^{+})^2 + (v_{\tilde{v}_{ij}} - v_j^{+})^2 + (\pi_{\tilde{v}_{ij}} - \pi_j^{+})^2\right]} \tag{18}$$

$$S_{IF}^{-} = \sqrt{\frac{1}{2n}\sum_{j=1}^{n}\left[(\mu_{\tilde{v}_{ij}} - \mu_j^{-})^2 + (v_{\tilde{v}_{ij}} - v_j^{-})^2 + (\pi_{\tilde{v}_{ij}} - \pi_j^{-})^2\right]} \tag{19}$$

6. Calculating the relative closeness coefficient of the alternative I as presented in Equation 20.

$$RC_{iIF} = \frac{S_{IF}^{-}}{S_{IF}^{+} + S_{IF}^{-}} \tag{20}$$

Rank the alternatives by maximizing the relative closeness coefficient.

3. Results and Discussion

The results of the validity test and reliability test on 60 questions found 51 questions were valid and were added 23 secondary data. Thus, the total parameter used in this study was 74 parameters.

3.1 Ranking Results using Fuzzy TOPSIS (FT)

In this research, alternatives and criteria had been defined. They would be processed using FT. The criterion value was obtained from the average value of all answers and converted into fuzzy numbers as shown in Table 2. Data structure for all alternatives and criteria is detailed in Table 3.

Table 3. Criteria Value in Fuzzy Numbers

No	Village Name	C1	C2		C14
1	BAL1	(5,7,9)	(7,9,9)	…	(5,7,9)
2	BAL2	(7,9,9)	(7,9,9)	…	(5,7,9)
⋮	⋮	⋮	⋮	⋮	⋮
198	WUN1	(7,9,9)	(7,9,9)	…	(5,7,9)

The next step was to calculate the weight of each criterion in Table 3. The weight was obtained from the 7expert's opinion as shown in Table 4.

Table 4. Criteria Weights in Fuzzy Numbers

Criteria	Weight		
Criteria 1	3,00	8,43	9,00
Criteria 2	5,00	8,71	9,00
⋮	⋮	⋮	⋮
Criteria 14	3,00	7,29	9,00

Based on processing using FT, a preference value was obtained for each alternative as shown in Table 5.

Table 5. Preference Value of 198 Villages using FT

Ranking	Village Name	Preference Value
1	WUN10	0,9673
2	DOL3	0,9582
⋮	⋮	⋮
198	WUN7	0,4336

The highest preference value was the best alternative namely WUN10 with a preference value of 0.9673 and the worst alternative was WUN7 with a preference value of 0.4336.

3.2 Ranking Results using Intuitionistic Fuzzy TOPSIS (IFT)

The second method to rank the best villages performance in this study was the IFT. The results of IFT as shown in Table 6.

Table 6. Preference Value of 198 Villages using IFT

Ranking	Village Name	Preference Value
1	DOL3	0,7563
2	DOL6	0,7414
⋮	⋮	⋮
198	WUN7	0,3708

The best alternative was DOL3 with a preference value of 0.7563 and the worst alternative was WUN7 with a preference value of 0.3708. There were differences in the first ranked village by FT method. Meanwhile, for the lowest village, the results were the same.

3.3 Assessment Results using Manual Scoring

The ranking results using FT and IFT methods required supporting data as a validator. The validator of this research was obtained from manual scoring. Comparison of the results of the FT and IFT ranking with manual scoring would result in an accuracy of village group mapping. The calculation of the manual scoring was obtained by multiplying the answer scores for each category with a total number of 74 questions as described in the data processing step in Figure 1. The scores for each village are described in the following Table 7.

Table 7. Manual Score of 198 Villages

No.	Village Name	Manual Scoring
1	BAL1	276
2	BAL2	291
⋮	⋮	⋮
198	WUN12	293

3.4 Comparison of Classification Using FT, IFT, and Manual Scoring

Based on the preference value of the results of the FT and IFT method, rankings of 1 to 198 had been obtained for all villages in Madiun Regency. Furthermore, the villages were classified based on their preference values into 4 groups. The results of the classification based on the FT method as shown in Figure 3 indicated that the villages included in Grade A with a preference value of 0.81 – 1 were 56 villages, Grade B with a preference value of 0.51 – 0.80 were 138 villages and the remaining 4 villages were in Grade C with a preference value of 0.31 – 0.50. The result of the classification based on the IFT method indicated that the villages were only classified into 2 groups, namely Grade B was 173 villages and Grade C was 25 villages. Furthermore, the results of village mapping based on the manual scoring can be seen that 59 villages fell into Grade A with a score of 297 – 370 and the rest fell into Grade B of 139 villages with a score of 223 – 296. According to the classification results which were validated using manual scoring, an accuracy rate was obtained for FT reached 86,4% and 57,6% for IFT.

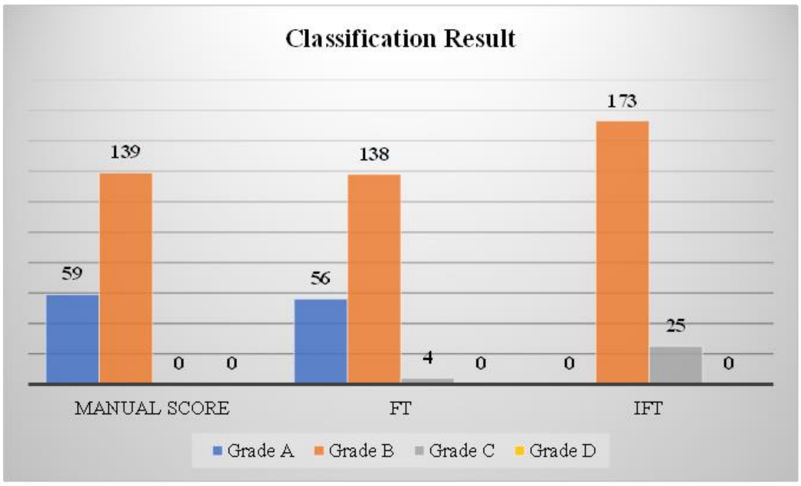

Figure 3. Classification Result

3.5 Village Performance Characteristics Based On 14 Criteria

The results of the FT classification showed that villages in Madiun Regency could be categorized into 3 levels based on their performance in governance. Figure 4 shows that on a macro basis, it is explained that all villages were in a condition that was close to very good on criterion 13, namely communication and coordination of the village government with the agencies above it. This showed that the compliance of the village government to carry out its main tasks and functions is always in line with the direction of the agency above it. However, the worst condition for villages where the average score is mostly below 3.00 which means poor is on criterion 12. Criterion 12 was related to the economy in rural communities. Based on this condition, it can be seen that most villages in Madiun Regency were still unable to independently empower the economy and generate village original income to improve the welfare of their community. This character showed that villages in Madiun Regency still rely on transfer funds from the central, provincial, and local governments to drive their economy.

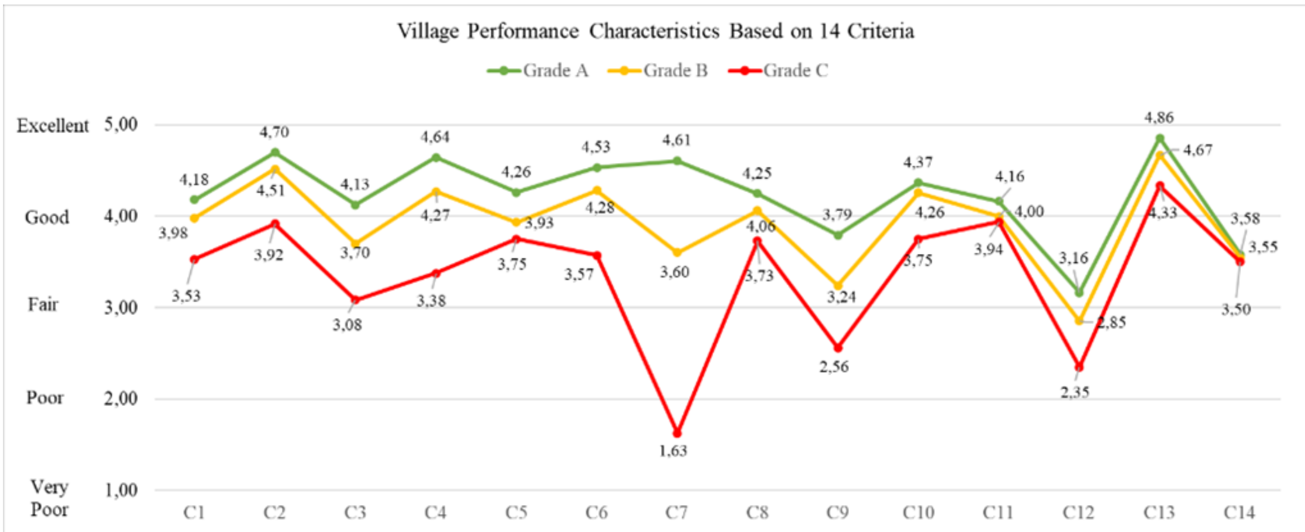

Figure 4. Village Performance Characteristics Based on 14 Criteria

4. Conclusion

This study showed that decision-making analysis in order to choose the best performing village from 198 villages in Madiun Regency based on the GGF with 14 criteria could use the FT and IFT method. Seventy-four parameters have been proposed to evaluate VG performance. The best village results from FT were obtained with a preference value of 0.9673, namely WUN10. The result of FT classification accuracy was better than IFT. FT obtained 86,4%, while IFT achieved 57,6%.

Based on the GGF, four principles still need to be improved in VG, namely participation, accountability, economy, and community safety due to their low value. Based on GGF criteria, the worst condition that must be improved is the economy in the village that related to increasing the village's original income and improving the community's economy.

From this study, we found that GGF can expose the challenges and problems in the VG which can be grouped into 7 aspects, namely, quality and capacity of village employees, understanding of regulations and technical implementation in the field, work management in organizations, quality and roles of the village society, facilities and infrastructure at the office, knowledge management within the organization, and the quality and capacity of village heads.

We opinioned that the accuracy obtained from this study was influenced by several factors, such as synchronizing questions and answers in the questionnaire requiring proof or validation of the survey. Sometimes, secondary data is required as evidence during the survey so that the process of scoring can be made more objective.

For future study, Dimensional Reduction methods such as Principal Component Analysis (PCA), Singular Value Decomposition (SVD), Linear Discriminant Analysis (LDA), and others can be used to preprocess the data before conveying them into Multi-Criteria Decision Making (MCDM) method so that a better accuracy can be obtained.

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