Multi-Objective Preference Analysis: A Novel Multi-Criteria Decision Analysis Approach for Smart Sharia Tourism Planning

Fristi Riandari *, Sarjon Defit, and Yuhandri

Department of Information Technology, Faculty of Computer Science,
Universitas Putra Indonesia "YPTK", Padang, Indonesia
Email: fristy.rianda@ymail.com (F.R.); sarjon_defit@upiyptk.ac.id (S.D.); yuyu@upiyptk.ac.id (Y.)
*Corresponding author

***Abstract*—This research aimed to introduce the Multi-Objective Preference Analysis (MOPA) method within Multi-Criteria Decision Analysis (MCDA) to address complex decision problems. This method was applied to improve accuracy by using modified criterion weights through pairwise comparisons. It also combined modified criterion weights with normalized alternative performance ratings using linear max techniques. Moreover, the efficacy of the MOPA method was determined in the context of Islamic tourism development. The results showed that the method consistently produced high confidence weight values compared to the other MCDA methods. This was characterized by the closeness of its values to 1 on the [0–1] scale as showed by the 0.917 recorded for the MOPA, 0.078 for Analytic Hierarchy Process (AHP), 0.066 for SAW, 0.697 for Simple Additive Weighting (SAW), and 0.700 for Multi-Objective Optimization by Ratio Analysis (MOORA). The precision associated with this method assisted Islamic tourism development by improving the decision-making quality. Furthermore, sensitivity analysis was used to confirm the robustness of the method in line with the variations in criteria weights in order to ensure its suitability for dynamic decision environments. The variance test showed that the statistical significance ($p < 0.05$) of the proposed MOPA method was appropriate, showing it was an effective decision-making tool compared to other methods. Therefore, the MOPA method was introduced as a powerful and reliable tool to improve decision-making, specifically in the context of Islamic tourism development. This research contributed to the body of knowledge by offering a more objective and robust method to have better informed and optimized outcomes.**

***Keywords*—decision-making analysis, multi-criteria, Multi-Objective Preference Analysis (MOPA), normalization technique, weight modification**

I. INTRODUCTION

The development of a Decision Support System (DSS) is a complex multi-stage process that requires considerable effort from a methodical and technical perspective [1]. DSS refers to computerized multidimensional data management systems that support stakeholders in using modern data-driven methods to identify and solve problems as well as to improve decision-making capabilities [2]. For example, the benchmark analysis of several alternative configurations can be facilitated by creating a DSS to directly compare different criteria [3] and this is known as Multi-Criteria Decision Analysis (MCDA).

MCDA is a globally recognized highly productive tool normally used to handle complex decision problems. It is the most appropriate tool for solving problems where the solution is based on several characteristics. This is based on its ability to divide the decision problem into smaller parts that are easier to understand. Then analyze each part separately, and finally integrate all the parts to build a meaningful solution [4]. MCDA method provides a framework for collecting, storing, and processing all relevant information characterized by social, political, environmental, and economic value assessments. It also has the capacity to alleviate the problems caused by limited human computing power. This is achieved by replacing the intuitive or adaptive choices with justified and mutually accepted models but there are usually DMs with conflicting preferences in MCDA [5]. The research conducted by Baltaza *et al.* [6] explained the method as a decision-making tool intended to support decision-makers faced with several conflicting evaluations. Moreover, the utilization of MCDA can assist in overcoming the limitations of more singular methodologies.

The method was introduced in the 1960s to determine existing conflicts and find ways to compromise through a transparent process. This has led to the development of several forms of MCDA to improve the quality of decisions with multiple criteria by making choices more explicit, rational, and efficient. This shows that MCDA is a branch of the general class of Operations Research models designed to deal with the decision-making process in the presence of multiple objectives [7]. It is a group of techniques that explicitly evaluate multiple conflicting criteria while deciding to find the most optimal solution. MCDA is also explained as a set of

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methods that combine alternative decisions with quantitative and qualitative outcomes in a compact solution. This is in line with the ability of the Operations Research field to provide optimal solutions where the decision-making process is associated with multiple criteria [8]. Meanwhile, one of the problems normally encountered during the application of MCDA is the selection of an aggregation procedure to solve the decision problem [9].

MCDA method has been applied in different fields such as urban regeneration, urban and housing market sustainability, sustainable housing affordability, real estate valuation, wind energy, waste and water resource management, building site planning, inventory classification, and the mining industry. Furthermore, several relevant studies have been conducted over the past few decades to solve problems in the field of tourism such as project identification [10], ecotourism location [11–13], tourism strategy prioritization policy [14], health tourism [15], smart tourism [16] and tourism competitiveness [17, 18].

Some of the most popular MCDA methods introduced and found in international literature include VIšekriterijumsko KOmpromisno Rangiranje (VIKOR) as well as other “classics” such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Preference Rangking Organization Method for Enrichment Evaluation (PROMETHEE), Analytic Hierarchy Process (AHP) Elimination Et Choix Traduisant la Realité (ELECTRE), etc. [19]. Several others have also been developed in recent decades but none of these methods can be considered the universally “best” or “most suitable” for all types of problems and applications [20]. This is because each MCDA method has a unique method, principles, and techniques, as well as its advantages and disadvantages. Therefore, the selection of an appropriate method requires careful consideration of the specific characteristics of the problem at hand, the preferences of the decision-makers, and the available data.

The most prevalent methods have been identified to include the Analytic Hierarchy Process (AHP), Technique for Orders Preference by Similarity to Ideal Solution (TOPSIS), and Simple Additive Weighting (SAW) [21, 22]. AHP allows quantitative as well as qualitative evaluation of criteria and alternatives using the same scale of preference [23]. However, this method has a glaring weakness in the form of the several alternatives needed to be compared before a decision is made [24]. The process of multiple comparisons is not only time-consuming but also has the potential to produce significant inconsistencies. This was confirmed by the results of a previous research [25] that AHP produced unreliable results when solving problems related to high-order matrices [26]. This method is considered a powerful tool for determining weights in MCDA but it does not always match human cognitive tendencies [27].

In contrast to AHP which is time-consuming in its analysis, a research in 2022 compared SAW and TOPSIS, and the results showed that TOPSIS produced a slightly higher range of MCDA final scores in individual scenarios compared to SAW [28]. The significant differences in the final results were associated with the different normalization techniques applied by the two methods as showed by the application of max-min in TOPSIS and linear max in SAW. The fundamental weakness was found in the potential for ranking alternatives due to the choice of different normalization techniques. This shows that the selection of the most appropriate normalization technique for each MCDA decision problem is also crucial to achieving optimal alternative ranking accuracy [29]. The glaring weakness of the AHP method is showed in the risk of losing important information due to the use of additive aggregation. Meanwhile, TOPSIS is faced with significant challenges in weighing and maintaining the consistency of judgment [30].

The weaknesses identified in some classical MCDA methods are observed to be related to the problems of analysis efficiency, consistency, precision, accuracy, and human cognitive tendencies. Therefore, there is a need to develop new methods as a significant contribution to the improvement of multi-criteria decision-making process as well as to minimize the potential weaknesses faced by traditional methods such as AHP, TOPSIS, and SAW.

The development of this new method is expected to ensure a more effective and reliable multi-criteria decision-making process. This is considered important to enable decision-makers to select the optimal solution with greater confidence, as well as minimize the risk of potential weaknesses often faced by traditional methods. The positive contribution of this attempt is to improve the quality and efficiency of applying multi-criteria decision-making processes in different fields.

The next section of this article focuses on the literature review and the third discusses the methodology. The fourth gives an example case to be solved by the new MCDA method and explores the significance of this research with a detailed discussion and comparative analysis of the results obtained. Meanwhile, the fifth section provides an overview of the implications and some important conclusions on the proposed model with necessary suggestions for further research directions.

II. Literature Review

The Information and Communication Technology (ICT) sector is important to the improvement of innovation and productivity due to its ability to leverage artificial intelligence, big data, and computerized information [31]. ICT has been recognized as an innovative stimulus that can enhance economic and social development at various levels, both in developing and less developed countries [32]. The term “smart” is usually associated with being fast and delivering quick results [33]. Therefore, the reason the computerized artificial intelligence aspect of ICT is introduced is to provide information for decision-makers through the concept of DSS. The process focuses on conducting analysis using MCDA methods to compare different criteria. This MCDA analysis is currently being used widely in several fields, including tourism.

Tourism is an important and rapidly growing sector of the world economy and also serves as a major source of foreign currency earnings for several developing countries [34]. It was also reported as one of the leading sectors contributing significantly to the national income of Indonesia [35]. This further enabled the development of sustainable tourism such as agritourism, ecotourism, and sharia tourism [36–38]. Sharia tourism was observed to be supported by different facilities and services provided by the community, entrepreneurs, and government to fulfill Sharia provisions in accordance with Islamic teachings [39]. Currently, the concept of sharia has become a trend in the global economy, ranging from food and beverage products, finance, to lifestyle, thereby leading to the introduction of several tourism products with halal and Islamic concepts in different countries [40].

Tourism-related research has been intensively conducted over the past few decades. For example, Bhattacharya [41] estimated that 800 million people or approximately 12% of the world population, go abroad every year and this makes tourism one of the largest global enterprises with a significant contribution to the global economy. The research applied a hybrid technique developed by combining SERVQUAL and AHP to assess the level of service provided by the tourism industry based on 5 dimensions including tangible, reliability, responsiveness, assurance, and empathy. It was concluded that the methodology could be used to evaluate the quality of several services offered at any spatial scale.

He *et al.* [18] discovered more significant demand uncertainties and complex dynamics in the tourism industry due to intense competition among sustainable Community-Based Tourisms (CBTs). This led to the development of MCDA model through the integration of several methods such as the Interval-Valued Pythagorean Fuzzy Method, Stepwise Weight Assessment Ratio Analysis (SWARA), and Multi-Objective-based Ratio Analysis (MOORA) to conceptualize sustainable Community-Based Tourism (CBT). A comprehensive framework was later produced for evaluating sustainable CBT in the context of the Indian-Himalayan region in the form of ranking alternatives. It was concluded that the model developed had the ability to treat the multi-fact dimensions of the criteria considered.

Sahani [42] analyzed the evaluation of existing or planned tourism itineraries by applying the integrated methods of AHP and ELECTRE. It was reported that the results could be used to assist environmental planners and other related organizations in planning sustainable ecotourism. Another research by Gu *et al.* [43] explained that the concept of destination attractiveness generated widespread interest from practitioners but most measurement methods developed produced little consensus. Therefore, the Analytic Hierarchy Process (AHP) was combined with the Fuzzy Comprehensive Evaluation Method (FCEM) to create a new Fuzzy-Analytic Hierarchy Process (F-AHP) method for measuring nature-based tourism attractiveness, and the method proved useful.

AHP was also combined with Multi Attributive Border Approximation Area Comparison (MABAC) to select a health tourism strategy through analytical analysis of the Strengths, Weaknesses, Opportunities, and Threats (SWOT). The selection of the AHP was due to its simple structure, ability to handle complex decision problems, and focus on determining the criterion distance of each observed alternative from the approximate boundary area. Meanwhile, the MABAC was used to rank the alternatives. A systematic quantitative framework was subsequently provided to select the best health tourism strategy. The proposed AHP-MABAC method was also observed to be versatile and considered applicable to the same industry using different factors and/or alternatives [15].

Arbolino *et al.* [10] focused on identifying tourism projects in order to maximize the overall utility of the stakeholders. This was achieved using weighting criteria such as the general selection as well as the environmental, social, and economic weights assigned by the stakeholders. MCDA method was used to simultaneously address many issues related to tourism policymaking using the weighted sum method and AHP. The application of these decision support techniques led to the conclusion that multi-criteria methods were not always sufficient.

AHP was also implemented to solve the problem of ecotourism location suitability. The method was combined with a fuzzy method and a Geographic Information System (GIS). The results showed that the proposed methodology could be applied to tourism management strategies at all levels of government and the private sector in the decision-making process due to its flexible nature [11]. Another research also used AHP to analyze coastal tourism locations and this led to the selection of six suitable locations considered appropriate to aid the development of future city plans. The results were expected to be reviewed by local authorities to make better decisions in planning tourism and future land use [44].

An intensive tourism development analysis was conducted to evaluate the land suitability of Torghabeh Shandiz in Khorasan Razavi Province, Iran using MCDA hybrid methods with the SAW, F-AHP, and Weighted Linear Combination (WLC). A total of 60 evaluation criteria were filtered by the SAW method to produce 25 which were further divided into 4 categories including environmental, economic, socio-cultural, and managerial. The F-AHP procedure presented by Mikhailov [45] was later used to weigh the set of filtered criteria while WLC was applied separately to evaluate land suitability in terms of economic, sociocultural, and managerial criteria. The results showed the capacity of MCDA hybrid technique in evaluating tourism development [46].

MCDA was also applied for factor assessment in medical tourism using two techniques including DEMATEL and Fuzzy TOPSIS. It was discovered that humans and technology were the most important factors in the adoption of medical tourism in Malaysia. These results were expected to be useful the industry stakeholders to potentially allocate investments in developing countries [47]. Another research also integrated Geographic Information Systems (GIS) into the F-AHP to evaluate the relative importance of physical, natural, environmental, and socioeconomic factors in the determination of suitable ecotourism sites. The F-AHP was applied to weigh these factors to index and map the suitability of the area for ecotourism. It was discovered that the strategies to develop land for ecotourism required careful planning and F-AHP was found to be used for the decision-making process. This was due to its ability to show the methods to be used in locating ecotourism areas needed to design tourism strategy and policy. The method was also recommended to be used in future research to analyze and weigh important factors in different areas of tourism management, as well as in other regions and cultures [11].

The WSM technique was found to be the simplest and most widely used MCDA technique to evaluate several alternatives in terms of a set of decision criteria. This was associated with its replicability in tourism development areas. However, the method could be scaled up for other types of tourism or on a case-by-case basis to predict potential tourism activity nodes in non-tourism zones [48]. Moreover, the importance of stakeholders in religious tourism was assessed using a F-AHP. The results showed that this method outperformed other quantitative methods in evaluating the relative importance of criteria in complex decision problems. The inference was based on its reliance on the decision-making activities of a group of experts but the sample size was not enough to obtain comprehensive results. Therefore, future research should review the size of the panel as well as the expertise and experience of the experts to ensure that the evaluation conducted using F-AHP or other MCDA methods is valid [49].

MCDA evaluation was used to analyze the potential of nature-based tourism in protected and sensitive areas using CRITIC and PROMETHEE-GAIA methods. A total of 26 criteria were obtained from the literature, weighted using the CRITIC technique, and compared with 3 available ones. The next stage was alternative evaluation which was conducted based on weighted criteria using the PROMETHEE-GAIA technique. The results provided different practical implications for local stakeholders regarding the potential of nature-based tourism in the region [50].

Tourism is an important industry to drives national economic development due to its good economic and ecological functions and its indispensability in achieving sustainable urban development [50]. The term "Islamic tourism" is currently popular in the world of tourism and has also been identified with similar related concepts such as Islamic Tourism, Halal Friendly Tourism Destination, Halal Travel, Muslim-Friendly Travel Destinations, or halal lifestyle. This means the concept is broader than religious tourism which is focused on the framework of worship or religious interests such as hajj and umrah to the haram land, or pilgrimages to the tombs of saints, glories, or religious figures by some Muslims [38].

Shariah tourism was introduced in 2000 based on the resolution from the meeting held by the Organization of the Islamic Conference (OIC) [51]. It was designed to provide a religious lifestyle for Muslim tourists during their vacations. Islamic tourism was also identified to be flexible, rational, simple, balanced, and developed to motivate travelers to gain happiness and blessings from Allah [52]. However, it was discovered that some of the classic MCDA methods such as TOPSIS, SAW, and AHP have weaknesses in providing analysis results. There is also a very rare application of these methods in the context of tourism research.

III. Materials and Methods

The last few decades have seen dramatic improvements in all major areas of MCDA including the algorithms, procedures, and selection paradigms of formal models. This was further observed in the evaluation theory comprising the assumptions and structured representations of values or preferences, as well as evaluation methodologies associated with elicitation, estimation, and scaling of individual preferences, utilities, and subjective probabilities in MCDA situations. It is important to state that there is no unique, well-defined methodology to be followed step-by-step from the beginning to the end of the decision-making process. Therefore, aggregation is very important in dealing with objects that can only be described and compared using a few characteristics. This is normally used to operate a synthesis of contradicting object features in order to achieve certain goals such as the selection and sorting of objects into different categories [9].

The aim of this research was to compare structured processes from different perspectives, identify objectives, and create alternatives. Each MCDA method was defined by a decision matrix consisting of the set of alternatives A_i (i=1, …, m), set of criteria C_j (j=1,…, n), the relative importance of criteria or weights W_j and r_{ij}, according to the ranking of alternatives i in relation to the criteria j [29].

MCDA is an important component of sustainability assessment tools as it allows the evaluation of the uncertainties associated with the data used and identifies the relevance and/or importance of each criterion used in the sustainability assessment [31]. MCDA is also defined as an analytical quantitative instrument that focuses on the process of supporting decision-making between alternatives based on multiple criteria, to facilitate decisions [53].

Decision-making is considered an important issue for companies to determine the best from feasible alternatives. Therefore, the practical process of decision-making associated with multiple evaluation criteria was termed MCDA [54]. The model applied in this research is presented in the following matrix format:

$$
\begin{array}{c} \quad\quad C_1 \quad C_2 \quad \ldots \quad C_n \\ G = \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{bmatrix} G_{11} & G_{21} & \cdots & G_{1n} \\ G_{21} & G_{22} & \cdots & G_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ G_{m1} & G_{m2} & \cdots & G_{m} \end{bmatrix} \\ W = [W_1, W_2, \ldots, W_n] \end{array} \tag{1}
$$

Decision-making is also considered a multi-dimensional process that requires consideration of certain influential factors to identify the best alternative. In MCDA problem, the decision maker is usually required to select the most appropriate alternative that meets the evaluation criteria among a set of candidate solutions. This means it is necessary to form a data set that analyzes the factors or criteria influencing the alternatives and this first requires collecting the data (see Fig. 1).

Fig. 1. Dataset formation.

The processes applied to conduct this research from start to finish are showed in the flow chart presented in Fig. 2. The novelty of MCDA was modeled based on related literature studies as showed by the analysis of their structure, working system, and existing classic methods. The shortcomings identified in the AHP, TOPSIS, and SAW methods were used to develop a new model to serve as the solution to produce optimal results as presented in Phase 4.

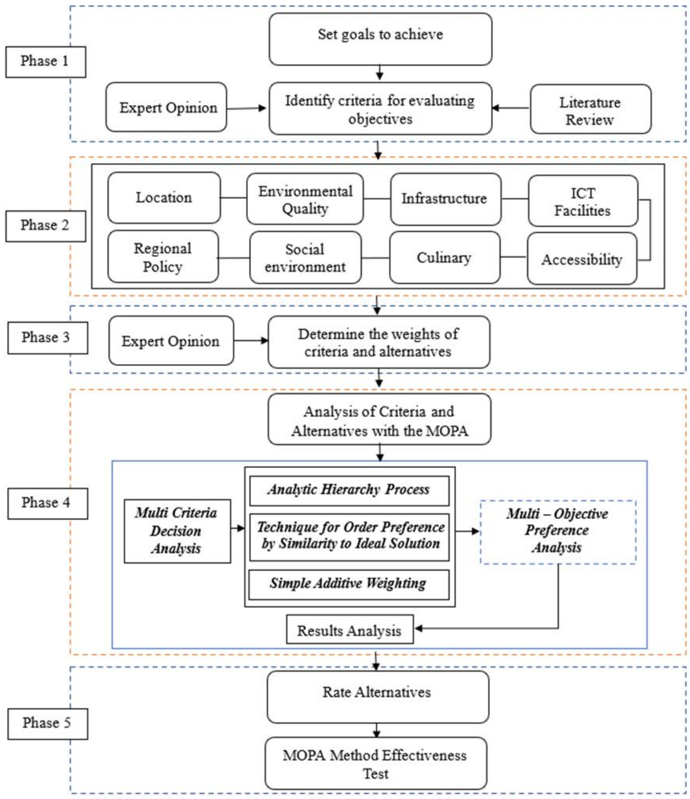


Fig. 2. Research flow chart.

Fig. 2 briefly shows that the goal of the research is to test the performance of the method using Sharia tourism development as a case study. This was achieved based on the weights provided for the criteria and alternatives through an expert opinion. The results obtained from the methods used were sorted based on the closeness to 1 followed by the assessment of their effectiveness using a confidence index in the range [0–1] represented as θ. A greater θ showed stronger confidence [55] as observed from the sensitivity Analysis and Variance (ANOVA) test.

A. Proposed MOPA Decision-Making Algorithm

The proposed MOPA method was in four steps which were presented in a mathematical model. The main stage was the formation of a normalization matrix, the second was to determine the final importance weight of the criteria based on pairwise comparison analysis, the fourth was used to normalize the criteria, and the last was used for the ranking of the criteria. The detailed process associated with each step is explained as follows:

1) Step 1: Normalization matrix

The criteria normalization matrix was formed using the following Eq. (2):

$$
R = \begin{bmatrix} r_{11} & r_{12} & r_n \\ \vdots & r_{22} & \vdots \\ r_n & r_{32} & r_n \end{bmatrix} \tag{2}
$$

where, R is the normalization matrix of pairwise comparisons of alternatives against criteria. The alternative weights were compared against each criterion in the form of a matrix in this step.

2) Step 2: Formation of weighted criteria final score (W_j)

The proposed MOPA method was calculated by result the difference between criteria using the pairwise comparison scale table developed by Saaty [56]. The difference value was determined using the following Eq. (3):

$$\lambda\_(n=1)=\frac{\Delta_{ij}}{\sum_{n=1}^{n}\Delta_{ij}} \tag{3}$$

One of the rules in the MOPA was that the total weight of all criteria should be 1 and this was designed to ensure more consistency and standard in the measurement process as well as to avoid over-emphasis and facilitate the interpretation of the final results.

All the criteria already had weights with a total accumulation of 1 during this step and the weight of each criterion was compared. Those with a greater weight were further converted based on the Saaty comparison scale table. Moreover, the difference value of each criterion compared to the total difference was stated in the comparison column and added up based on row (i). The total sum was later divided by the number of criteria used in the case based on the following Eq. (4):

$$\begin{gathered} W_j=\lambda_1+\lambda_2+\lambda_3+\cdots+\lambda_n / \forall\in j \\ W_j=r_{11}+r_{12}+r_{13}+\cdots+r_{nn} / \forall\in j \\ W_j=\frac{\sum_{\lambda\_(n=i)}^{n}\lambda\_(n=i)}{\forall\in j} \end{gathered} \tag{4}$$

where, $\lambda\_(n=i)$ is the characteristic of the criteria row (i), W_j is the final importance weight of the criteria, is the difference between the criteria row (i) and the criteria column (j), and represents all the members of the criteria row (i). The result obtained was used to determine the characteristic or original value of the final weight of the criteria (W_j). The difference reported was later normalized and the mean was calculated as the characteristic weight of each criterion to improve the accuracy of the analysis.

3) Step 3: Criteria normalization

The proposed method is optimized with the linear max normalization technique based on the evaluation results from previous studies that the linear max technique is the best in most cases compared to the other four techniques [29]. Therefore, the proposed optimization technique is as follows:

$$\forall AC_j=\begin{cases} C_j^+=\dfrac{C_j}{\max\in C_j},\vee \\ C_j^-=\dfrac{\min\in C_j}{C_j} \end{cases} \tag{5}$$

where, $\forall C_j$ represents all criteria, C_j^+ is the benefit criteria, C_j^- is the cost criteria, $\max\in C_j$ is the largest value of a criterion member, and $\min\in C_j$ is the smallest value of the criteria member.

The alternatives were normalized in this step based on the weights of each criterion. Moreover, the criteria had two characteristics which were cost and benefit. For the cost aspect, a lower alternative weight had better performance but the opposite was observed for the benefit criteria. The normalization process within the MOPA method was achieved using a linear max technique. In this method, the lowest weight among alternatives on the cost criteria served as the divisor for each weight associated with similar criteria. On the other hand, for the benefit criteria, the largest alternative weight acted as the divisor for each weight related to similar criteria. This normalization process eliminated the difference and allowed a fair comparison between the alternatives.

4) Step 4: Ranking

The ranking was conducted in the proposed method using Eq. (6):

$$AC_i=\sum_{n=1}^{n}C_{ij}\times W_1,W_2,W_3\dots W_j \tag{6}$$

The normalization results of each alternative were multiplied by the final weight of the criteria and then summed up. The alternative with the largest weight was subsequently selected as the best.

B. Dataset

The performance of the MOPA method was analyzed using the decision-making process of Sharia tourism development. This was achieved through the determination of 8 criteria to measure and assess the performance or characteristics of each alternative as showed in the following Table I.

TABLE I. CRITERIA FOR ISLAMIC TOURISM DEVELOPMENT

Criteria	Weight
Location (C1)	0.05
Environmental Quality (C2)	0.05
Infrastructure (C3)	0.1
ICT Facilities (C4)	0.1
Accessibility (C5)	0.15
Culinary (C6)	0.15
Social Environment (C7)	0.2
Regional Policy (C8)	0.2

C. Experience Example

There were 18 alternative locations available in North Sumatra to be used as sharia tourism development areas. These locations were marked with A1 to A4 based on a weight assessment index of Very Good (4), Quite Good (3), Little Good (2), and Not Good (1) as showed in the normalization matrix presented in Step 1.

1) Step 1

A total of 8 criteria were developed for Sharia tourism development as previously stated. These include C1 for location, C2 for Environmental Quality to C8 for

Regional Policy. There were also 4 alternatives and this led to the presentation of the matrix with 4 rows and 8 criteria, showing the weight of alternatives on each criterion as follows.

$$AC = \begin{matrix} & C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 \\ A_1 & 4 & 3 & 3 & 2 & 3 & 4 & 3 & 4 \\ A_2 & 3 & 4 & 4 & 2 & 3 & 3 & 2 & 4 \\ A_3 & 4 & 2 & 3 & 4 & 3 & 4 & 3 & 3 \end{matrix}$$

2) Step 2

The second step after the determination of the alternative performance ranking was to form a paired criterion matrix. This was necessary to determine the original value or characteristic to be used as the final importance value (weight) of the criterion W_j. Moreover, all the comparison results for each criterion were added based on each column using the formula $\sum_{n=1}^{n} r_{ij}$.

$$C_1 = \frac{\frac{1}{32}+\frac{1}{32}+\frac{0.33}{19}+\frac{0.33}{19}+\frac{0.20}{9}+\frac{0.20}{9}+\frac{0.14}{3}+\frac{0.14}{3}}{8} = 0.33$$

The results showed that the final weight of C1 was 0.03 and the same method was applied to all other criteria to determine their final weights.

3) Step 3

The criteria for each alternative were normalized in the third step using the matrix formed in Step 1. This was achieved through the utilization of the max linear normalization technique. Alternative 1 was normalized using the following process and the same trend was also applied to the others.

$$AC_{11} = 3/4 = 0.75, AC_{12} = 3/4 = 0.75, AC_{13} = 3/4 = 0.75,$$
$$AC_{14} = 2/4 = 0.50, AC_{15} = 3/3 = 1, AC_{16} = 4/4 = 1,$$
$$AC_{17} = 3/3 = 1, AC_{18} = 4/4 = 1$$

The linear max method was used and this was achieved by taking the lowest value among alternatives in the cost category and using it as the divisor for the weights of other alternatives on the same criteria. Conversely, for the benefit criteria, the highest alternative weight served as the divisor for the weight of each alternative on those criteria. Basically, on the cost criteria, the lowest alternative weight was used as the divisor for each criterion weight, and conversely, on the benefit criteria, the highest alternative weight became the value for each alternative weight. The results are presented in the following matrix form:

$$AC = \begin{matrix} & C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 \\ A_1 & 0.75 & 0.75 & 0.75 & 0.50 & 1 & 1 & 1 & 1 \\ A_2 & 1 & 1 & 1 & 0.50 & 1 & 0.75 & 0.67 & 1 \\ A_3 & 0.75 & 0.50 & 0.75 & 1 & 1 & 0.75 & 1 & 0.75 \end{matrix}$$

4) Step 4

The last step after the normalization stage was the calculation of ranking for each alternative according to the proposed mathematical model. This was achieved by multiplying the normalization results on each alternative row in Step 3 with the final weight of the criteria Wj determined in the initial step as follows:

$$AC_1 = \begin{matrix} & A_1 & A_2 & A_3 \\ C_1 & 0.75 & 1 & 0.75 \\ C_2 & 0.75 & 1 & 0.50 \\ C_3 & 0.75 & 1 & 0.75 \\ C_4 & 0.75 & 0.50 & 1 \\ C_5 & 1 & 1 & 1 \\ C_6 & 1 & 0.75 & 0.75 \\ C_7 & 1 & 0.67 & 1 \\ C_8 & 1 & 1 & 0.75 \end{matrix} \; x \; \begin{matrix} W_j \\ 0.03 \\ 0.03 \\ 0.06 \\ 0.06 \\ 0.13 \\ 0.13 \\ 0.28 \\ 0.28 \end{matrix}$$

The results obtained are presented in Table I and the values for each alternative were summed up followed by the selection of the alternative with the highest final result as the best solution. The ranking process showed that A1 had a value of 0.94, A2 had 0.84 and A3 was 0.86.

IV. Results and Discussion

A review was conducted to evaluate the importance of the proposed methodology in terms of feasibility, usability, reliability, and accuracy. This was achieved using 18 alternatives locations in North Sumatra as sharia tourism development areas marked A1 to A18 and 8 criteria presented in Table I. The weighting index of the alternatives was determined through the opinion of experts in the field of Islamic tourism. The alternatives are presented in the normalization matrix developed based on the MOPA method proposed in the following Step 1.

A. Step 1

The normalization matrix is presented as follows:

$$AC = \begin{matrix} & C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 \\ A_1 & 3 & 2 & 3 & 3 & 3 & 4 & 3 & 4 \\ A_2 & 4 & 4 & 2 & 3 & 4 & 2 & 3 & 3 \\ A_3 & 3 & 3 & 4 & 2 & 2 & 4 & 2 & 2 \\ A_4 & 4 & 2 & 4 & 3 & 4 & 2 & 3 & 4 \\ A_5 & 4 & 3 & 4 & 2 & 2 & 4 & 4 & 2 \\ A_6 & 2 & 3 & 2 & 3 & 2 & 3 & 2 & 4 \\ A_7 & 4 & 4 & 4 & 4 & 3 & 2 & 2 & 4 \\ A_8 & 3 & 3 & 4 & 4 & 2 & 4 & 4 & 4 \\ A_9 & 4 & 2 & 4 & 2 & 4 & 3 & 4 & 3 \\ A_{10} & 3 & 2 & 3 & 4 & 2 & 2 & 4 & 3 \\ A_{11} & 3 & 2 & 2 & 3 & 4 & 4 & 3 & 4 \\ A_{12} & 4 & 3 & 3 & 4 & 3 & 3 & 3 & 2 \\ A_{13} & 4 & 3 & 3 & 2 & 4 & 3 & 4 & 3 \\ A_{14} & 3 & 4 & 4 & 4 & 2 & 4 & 2 & 2 \\ A_{15} & 3 & 2 & 2 & 4 & 4 & 2 & 2 & 3 \\ A_{16} & 3 & 3 & 4 & 2 & 3 & 3 & 2 & 3 \\ A_{17} & 3 & 4 & 3 & 3 & 3 & 4 & 3 & 3 \\ A_{18} & 2 & 2 & 3 & 3 & 4 & 4 & 3 & 2 \end{matrix}$$

B. Step 2

The comparison values were calculated to determine the characteristics of the criteria as showed in the following Table II:

TABLE II. CRITERIA IMPORTANCE WEIGHT W_j

Alt	Characteristic Value								Total	Mean W_j
C1	0.03	0.03	0.02	0.02	0.02	0.02	0.04	0.04	0.23	0.03
C2	0.03	0.03	0.02	0.02	0.02	0.02	0.04	0.04	0.23	0.03
C3	0.09	0.09	0.05	0.05	0.04	0.04	0.06	0.06	0.49	0.06
C4	0.09	0.09	0.05	0.05	0.04	0.04	0.06	0.06	0.49	0.06
C5	0.16	0.16	0.16	0.16	0.11	0.11	0.10	0.10	1.05	0.13
C6	0.16	0.16	0.16	0.16	0.11	0.11	0.10	0.10	1.05	0.13
C7	0.22	0.22	0.27	0.27	0.33	0.33	0.30	0.30	2.23	0.28
C8	0.22	0.22	0.27	0.27	0.33	0.33	0.30	0.30	2.23	0.28

C. Step 3

The criteria for each alternative were normalized and the results were presented in the following matrix form:

$$
\begin{array}{c} \\ AC = \end{array}
\begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \\ A_7 \\ A_8 \\ A_9 \\ A_{10} \\ A_{11} \\ A_{12} \\ A_{13} \\ A_{14} \\ A_{15} \\ A_{16} \\ A_{17} \\ A_{18} \end{array}
\begin{array}{cccccccc}
C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 \\
0.67 & 0.50 & 0.75 & 0.75 & 0.75 & 1.00 & 0.75 & 1.00 \\
0.50 & 1.00 & 0.50 & 0.75 & 1.00 & 0.50 & 0.75 & 0.75 \\
0.67 & 0.75 & 1.00 & 0.50 & 0.50 & 1.00 & 0.50 & 0.50 \\
0.50 & 0.50 & 1.00 & 0.75 & 1.00 & 0.50 & 0.75 & 1.00 \\
0.50 & 0.75 & 1.00 & 0.50 & 0.50 & 1.00 & 1.00 & 0.50 \\
1.00 & 0.75 & 0.50 & 0.75 & 0.50 & 0.75 & 0.50 & 1.00 \\
0.50 & 1.00 & 1.00 & 1.00 & 0.75 & 0.50 & 0.50 & 1.00 \\
0.67 & 0.75 & 1.00 & 1.00 & 0.75 & 1.00 & 1.00 & 1.00 \\
0.50 & 0.50 & 1.00 & 0.50 & 1.00 & 0.75 & 1.00 & 0.75 \\
0.67 & 0.50 & 0.75 & 1.00 & 0.50 & 0.50 & 1.00 & 0.75 \\
0.67 & 0.50 & 0.50 & 0.75 & 1.00 & 1.00 & 0.75 & 1.00 \\
0.50 & 0.75 & 0.75 & 1.00 & 0.75 & 0.75 & 0.75 & 0.50 \\
0.50 & 0.75 & 0.75 & 0.50 & 1.00 & 0.75 & 1.00 & 0.75 \\
0.67 & 1.00 & 1.00 & 1.00 & 0.50 & 1.00 & 0.50 & 0.50 \\
0.67 & 0.50 & 0.50 & 1.00 & 1.00 & 0.50 & 0.50 & 0.75 \\
0.67 & 0.75 & 1.00 & 0.50 & 0.75 & 0.75 & 0.50 & 0.75 \\
0.67 & 1.00 & 0.75 & 0.75 & 0.75 & 1.00 & 0.75 & 0.75 \\
1.00 & 0.50 & 0.75 & 0.75 & 1.00 & 1.00 & 0.75 & 0.50
\end{array}
$$

$$
AC_j = \begin{array}{c} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \end{array}
\begin{bmatrix}
0.67 & 0.50 & 0.67 & 0.50 & 0.50 & 1.00 & 0.50 & 0.67 & 0.50 & 0.67 & 0.67 & 0.50 & 0.50 & 0.67 & 0.67 & 0.67 & 0.67 & 1.00 \\
0.50 & 1.00 & 0.75 & 0.50 & 0.75 & 0.75 & 1.00 & 0.75 & 0.50 & 0.50 & 0.50 & 0.75 & 0.75 & 1.00 & 0.50 & 0.75 & 1.00 & 0.50 \\
0.75 & 0.50 & 1.00 & 1.00 & 1.00 & 0.50 & 1.00 & 1.00 & 1.00 & 0.75 & 0.50 & 0.75 & 0.75 & 1.00 & 0.50 & 1.00 & 0.75 & 0.75 \\
0.75 & 0.75 & 0.50 & 0.75 & 0.50 & 0.75 & 1.00 & 0.50 & 1.00 & 1.00 & 0.75 & 1.00 & 0.50 & 1.00 & 1.00 & 0.50 & 0.75 & 0.75 \\
0.75 & 1.00 & 0.50 & 1.00 & 0.50 & 0.50 & 0.75 & 0.50 & 1.00 & 0.50 & 1.00 & 0.75 & 1.00 & 0.50 & 1.00 & 0.75 & 0.75 & 1.00 \\
1.00 & 0.50 & 1.00 & 0.50 & 1.00 & 0.75 & 0.50 & 1.00 & 0.75 & 0.50 & 1.00 & 0.75 & 0.75 & 1.00 & 0.50 & 0.75 & 1.00 & 1.00 \\
0.75 & 0.75 & 0.50 & 0.75 & 1.00 & 0.50 & 0.50 & 1.00 & 1.00 & 1.00 & 0.75 & 0.75 & 1.00 & 0.50 & 0.50 & 0.50 & 0.75 & 0.75 \\
1.00 & 0.75 & 0.50 & 1.00 & 0.50 & 1.00 & 1.00 & 1.00 & 0.75 & 0.75 & 1.00 & 0.50 & 0.75 & 0.50 & 0.75 & 0.75 & 0.75 & 0.50
\end{bmatrix}
x
\begin{bmatrix} 0.03 \\ 0.03 \\ 0.06 \\ 0.06 \\ 0.13 \\ 0.13 \\ 0.28 \\ 0.28 \end{bmatrix}
$$

D. Step 4

The final value of MCDA was calculated in the form of ranking in Step 4 of the MOPA method. This was achieved by multiplying the normalization results with the final weight of the Wj criteria as presented in the above matrix.

The multiplication results of each alternative were summed up and alternative with the highest final value was considered the best solution. Moreover, the final scores obtained from the MOPA were compared to those of other existing classic MCDA methods such as the AHP, SAW, TOPSIS, and MOORA in Table III. Confidence index and significance were also assessed to determine the performance of the MOPA compared to these existing methods.

Similar test cases were also conducted using the SuperDecision tool. This was achieved by first inputting the intended goals, criteria, and alternatives to form clusters. Each cluster was connected by a matrix, for example, the goals cluster was connected by a matrix to the criteria cluster which was also further associated with the alternative cluster by another. The completion of the cluster formation process was followed by the pairwise comparisons of criteria based on the importance weights of each criterion and alternative as showed in the following Fig. 3.

The comparison of the 8 criteria and 18 alternatives with SuperDecision showed that Alternative 8 was the solution due to its final value of 0.078 as presented in Fig. 4. This was observed to be similar to the results of the model developed.

A system implementation was conducted to facilitate the utilization of the MOPA by users. This was achieved by ensuring the method could be used automatically, thereby leading to significant operational efficiency and reduction in human errors during data processing. It also provided a structured platform for storing and managing information, assisted management in making better and informed decisions, and was flexibly designed to be adapted to changing needs. This system implementation is presented in the following Fig. 5.

TABLE III. COMPARISON OF TEST CASE RESULTS BETWEEN THE MOPA AND OTHER MCDA METHODS

Alt	MOPA	AHP	SAW	TOPSIS	MOORA
A1	0.842	0.063	0.06	0.647	0.224
A2	0.735	0.052	0.053	0.483	0.196
A3	0.608	0.038	0.047	0.341	0.171
A4	0.821	0.064	0.059	0.595	0.217
A5	0.743	0.058	0.054	0.497	0.199
A6	0.709	0.048	0.052	0.439	0.187
A7	0.748	0.057	0.056	0.493	0.206
A8	0.917	0.078	0.066	0.697	0.247
A9	0.838	0.066	0.059	0.632	0.221
A10	0.760	0.056	0.054	0.514	0.199
A11	0.861	0.067	0.061	0.66	0.228
A12	0.688	0.045	0.052	0.418	0.191
A13	0.830	0.065	0.059	0.623	0.218
A14	0.646	0.043	0.052	0.39	0.190
A15	0.671	0.044	0.05	0.413	0.184
A16	0.678	0.042	0.051	0.392	0.186
A17	0.788	0.054	0.058	0.57	0.217
A18	0.746	0.050	0.057	0.505	0.209

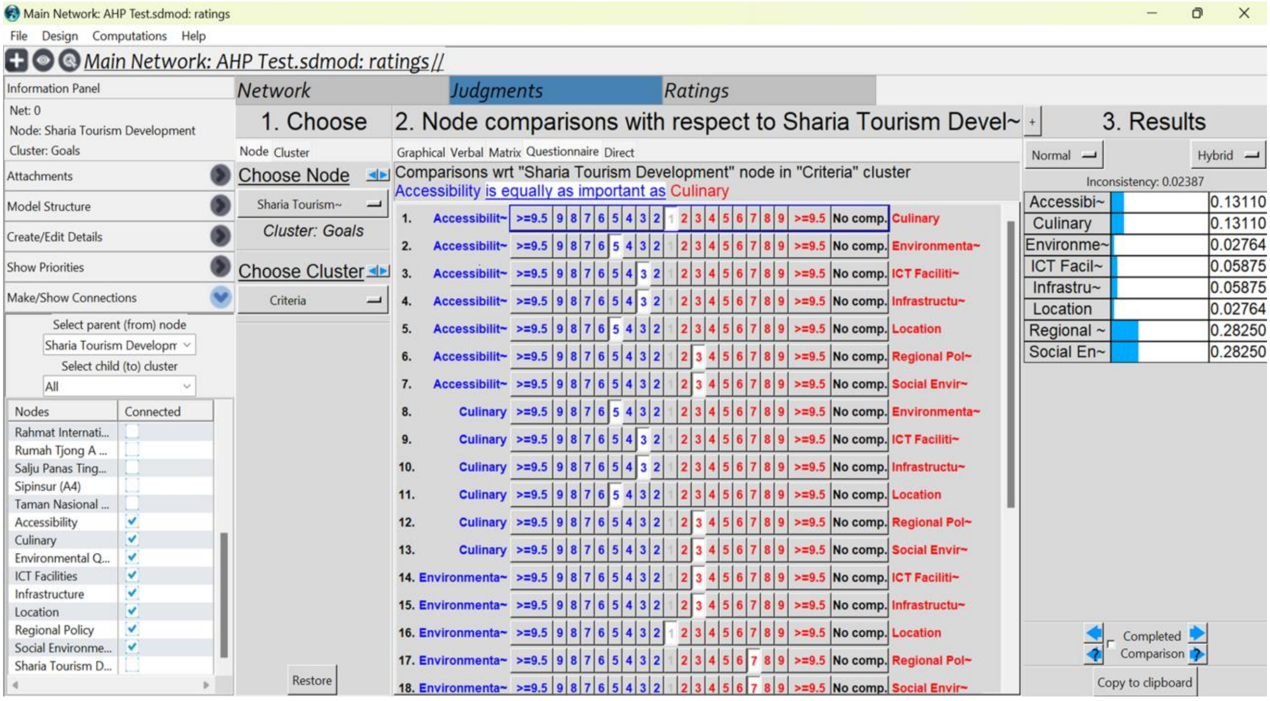


Fig. 3. Pairwise comparison of criteria and alternatives in SuperDecision.

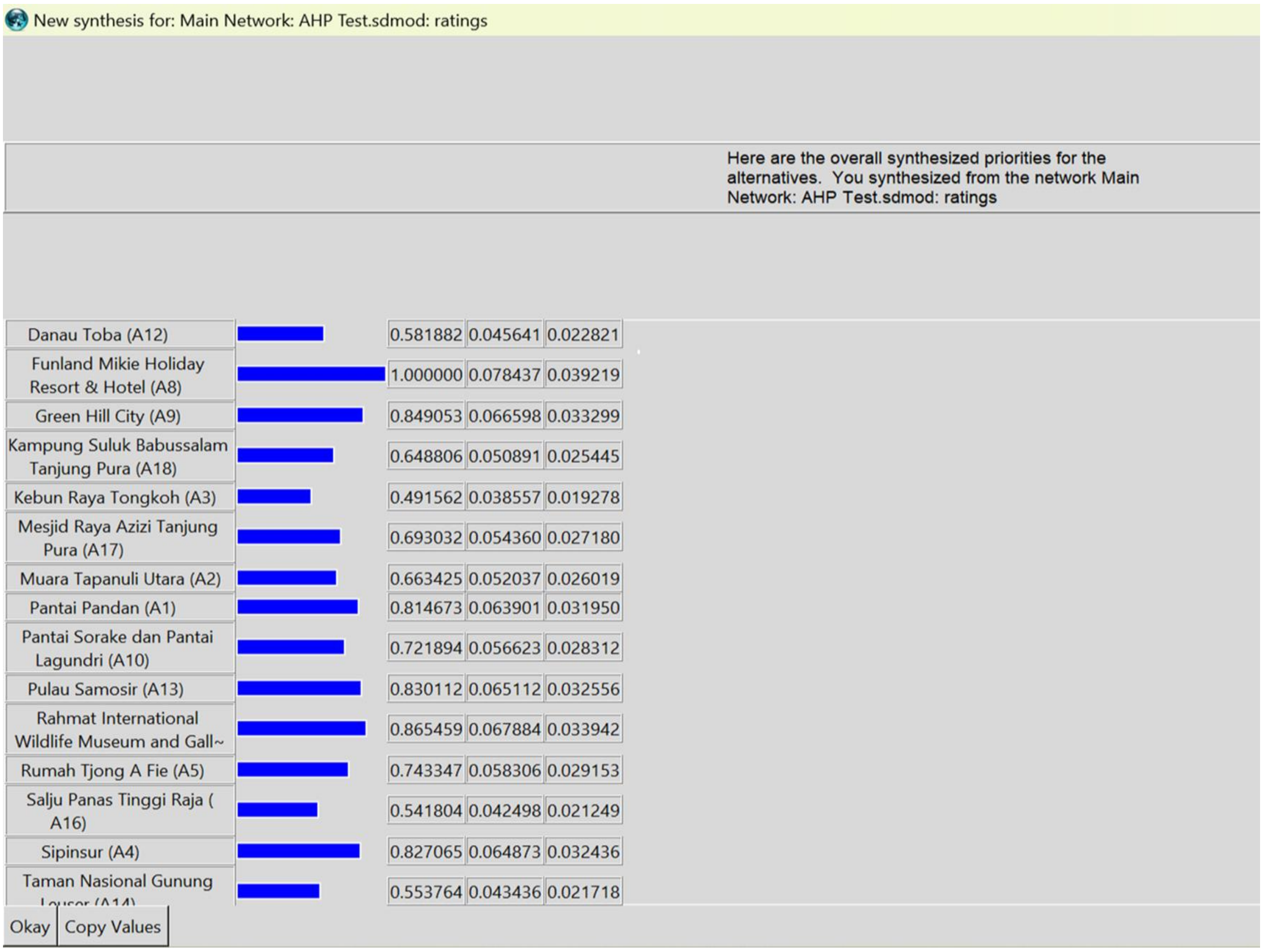
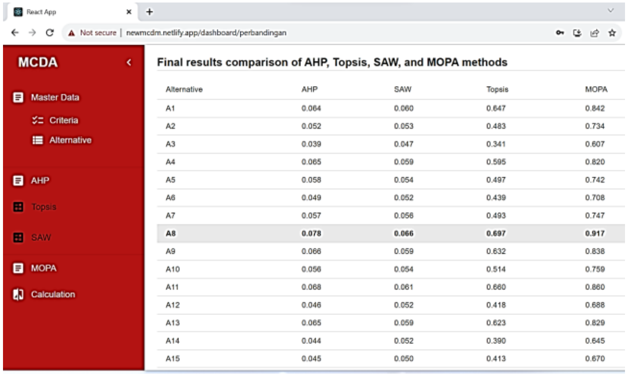


Fig. 4. Case analysis results with SuperDecision.



Alternative	AHP	SAW	Topsis	MOPA
A1	0.064	0.060	0.647	0.842
A2	0.052	0.053	0.483	0.734
A3	0.039	0.047	0.341	0.607
A4	0.065	0.059	0.595	0.820
A5	0.058	0.054	0.497	0.742
A6	0.049	0.052	0.439	0.708
A7	0.057	0.056	0.493	0.747
A8	**0.078**	**0.066**	**0.697**	**0.917**
A9	0.066	0.059	0.632	0.838
A10	0.056	0.054	0.514	0.759
A11	0.068	0.061	0.660	0.860
A12	0.046	0.052	0.418	0.688
A13	0.065	0.059	0.623	0.829
A14	0.044	0.052	0.390	0.645
A15	0.045	0.050	0.413	0.670

Fig. 5. System implementation.

The steps developed in the proposed MOPA method to analyze 18 tourist sites referred to as alternatives for the Sharia tourism development based on 8 criteria were used to identify the 3 alternatives with the largest values in Table II. It was discovered that the 8th alternative had the first largest value of 0.917 for the MOPA, 0.078 for AHP, 0.066 for SAW, 0.697 for TOPSIS, and 0.700 for MOORA as presented in Fig. 6. This led to its selection as the main area to be developed as a Sharia tourism location. The MOPA and other classic MCDA methods showed the same alternative as the best location but the MOPA method provided had the value that was closest to 1 and a confidence index (θ) with a greater value showing stronger confidence [55]. This was reinforced by Vafaei *et al.* [29] which applied the normalization technique scales to transform all criteria into 0–1 intervals during the discussion of the importance of normalization in MCDA. Another research by Gigović *et al.* [57] also determined the suitability index value for ecotourism development using a 0–1 interval.

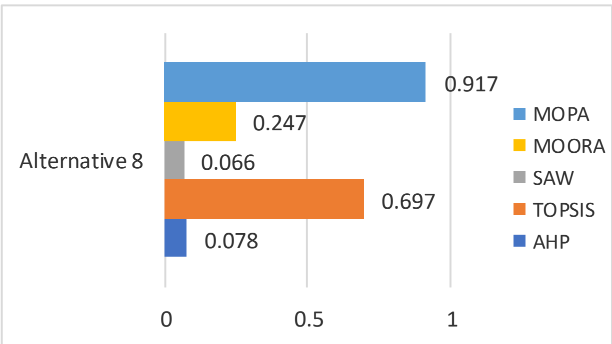


Fig. 6. System implementation.

The results obtained from the AHP, TOPSIS, MOORA, SAW, and the proposed MOPA methods were subjected to a variance test known as ANOVA based on the recommendation of previous research. This was possible because MCDA could be evaluated using different techniques including outlier detection such as line charts, histograms, scatter plots, and box plots, location and size measures such as max, min, and scale, and statistical measures such as ANOVA, Euclidean distance, Standard Deviation (STD), KS mean derived from Pearson correlation, Rank Consistency Index (RCI), and Mean Square Error (MSE) [29].

The ANOVA results with a *P*-value exceeding the predetermined significance level, usually 0.05, show insufficient statistical evidence to reject the null hypothesis. This simply means there is not enough evidence to conclude a significant difference between the tested groups. In MCDA, a *P*-value below the 0.05 significance level is generally preferred and this value serves as the standard threshold in statistics for determining whether an outcome is significantly different from the null hypothesis. The existence of a lesser value shows there is sufficient statistical evidence to support the rejection of the null hypothesis. The ANOVA test was conducted in this research using phyton software and the results are presented in the following Table IV.

TABLE IV. ANOVA TEST

MCDA Method	Significance (*P*–Value)
MOPA	0.040
MOORA	0.076
AHP	0.019
TOPSIS	0.053
SAW	0.093

The MOPA method had 0.040 which was $p < 0.05$, showing the rejection of the null hypothesis and this showed it had strong evidence to be used as a basis for decision making. The value was followed by the AHP method with 0.019 which showed the variables or factors tested in MCDA had a significant influence on the differences in alternative assessments or rankings. Meanwhile, the other methods such as MOORA, TOPSIS, and SAW had values $p > 0.05$ which was not strong enough to reject the null hypothesis. This showed that these methods did not have enough strong evidence to serve as the basis for decision-making.

The ANOVA variance test results showed that the new MOPA method developed was significantly more effective as a decision-making tool than MOORA, TOPSIS, and SAW methods. This further confirmed the observation from its confidence index which was the closest to 1. Moreover, it was found to require less computation time compared to the AHP due to its simple mathematical model. It was discovered that the number of processes performed required a lot of time and increased exponentially with the addition of other elements. This could be a problem when the time and resources were limited or there was the need to compare too many elements, leading to fatigue for the decision maker or proneness to inconsistent and unreliable decisions. Moreover, the results showed that the SAW, TOPSIS, and MOORA methods produced a lower range of final MCDA values compared to AHP due to the differences in normalization techniques. It was further discovered that the MOPA method was able to provide an optimal level of accuracy compared to other classical MCDA methods used even though it was simple and required less computational time.

V. Conclusion

This research develops a data-driven decision-making method to help multi-criteria optimization. This research is a literature study using a multi-criteria decision analysis approach as the basis for decision making. The MOPA method is developed by using a simple mathematical model, modifying the weights, and choosing the max linear normalization technique as a normalization technique that can minimize the risk of losing information on the data. Based on the test results, even with a simple model and little computation time, it is known that the MOPA method has a confidence index closest to 1 on the [0–1] index scale and sensitivity analysis results ($p > 0.05$) so it can be concluded that the proposed MOPA method is a decision-making tool that has a high level of accuracy based on the confidence index scale and is significantly effective. By proving its effectiveness, the MOPA method can be a more robust and scalable alternative to conventional methods such as AHP, SAW, TOPSIS, and MOORA. This paves the way for advancement in decision-making analysis in the field of Islamic tourism. Being able to optimize decisions regarding tourism projects and initiatives, the Islamic tourism industry has the potential to become more competitive and sustainable in the long time.

The MOPA method has the limitation that it can only evaluate criteria that are independent or not interrelated among other criteria because in many actual working conditions, some criteria have a dependency relationship with other criteria so in future research can be done to develop MOPA methods that can evaluate interrelated criteria.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Fristi Riandari proposed the problem, conducted the research, designed the methodology, tested the results, and conducted the implementation with guidance from Sarjon Defit and Yuhandri. Fristi Riandari, Sarjon Defit, and Yuhandri drafted the paper and the results. All authors approved the final version of this paper.

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