Article

Fuzzy Multi Criteria Decision Making Model for Agritourism Location Selection: A Case Study in Vietnam

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Abstract: Agritourism is an increasing new trend in the global tourism industry. Vietnam has a long tradition of agricultural production combined with diverse natural resources stretching from the north to the south, bringing advantages in the development of agritourism. The study aims to choose the most appropriate agritourism location in Vietnam for long-term investment. A hybrid fuzzy multi-criteria decision model (FMCDM) is proposed to find the optimal location based on eco-nomic, social, and environmental factors. In the first stage, the fuzzy analytic hierarchy process (FAHP) is used to estimate the relative criteria rating through the evaluation process. In the second stage, the fuzzy technique for order preference using similarities to ideal solution (FTOPSIS) is applied to rank the potential alternative locations. Finally, the best alternative to tourist site investment is Can Tho (A8), which maximizes resources and enhances the local benefits. Future research can also be used to support similar site-selection processes in other regions or could be applied to other types of tourism.

Keywords: fuzzy multi-criteria decision making; fuzzy AHP and TOPSIS; location selection; agritourism; local tourism

1. Introduction

In recent decades, agritourism has become more and more popular, and is being developed as a promising, multi-beneficial field for many countries worldwide. Many sustainable strategies, suitable for each region, have been studied and applied to develop and improve the economy and society, with a strong connection to local communities. The formation and development of tourist destinations is rich and diverse, based on the inherent potential in each country, such as development policies, cultural imprints, infrastructure, environment, and unique agricultural products with high quality, which meet tourists' needs when visiting and experiencing the area [1,2]. In France, visitors can experience cultural traditions, vast vineyards, and winemaking processes [2,3]. In the US, agritourism with planned farms, comprising family farms, animal-lover farms, and nature-lover farms, has proven efficient and created many business opportunities for American farmers, helping them to get rich on their own land [4,5]. In Korea, agritourism has also been implemented since 2006 and is considered as one of the main agricultural development strategies to bring more benefits to farmers, offsetting the decrease in income from traditional agriculture, and enhancing the link between rural and urban areas [6,7]. Several agritourism areas in Taiwan have been also planned, with clear development strategies, improving service quality, attracting tourists, and maintaining their long-standing traditional agriculture [8,9].

Vietnam is in a tropical climate area, and 80% of the total areas is agricultural land (General Statistics Office, Hanoi, Vietnam, 2020). Agriculture has a long tradition, which is developed based on the diversity of ecosystems and natural resources. Agricultural products are abundant, with a typical agricultural culture in each region stretching, from the

North to the South. In addition, Vietnam is a multi-ethnic country, with 54 different ethnic groups who live together and participate in agricultural production activities. Therefore, the agritourism industry has formed its own cultural identity, applying the characteristics of each region. Specifically, agritourism in the Mekong Delta has been formed and developed, with typical destinations such as orchards (coconuts, oranges, durians, etc.), flower villages with typical features of riverine agriculture, and high-tech aquaculture models. Visitors can participate in experiential activities with farmers, such as tending, harvesting, and processing agricultural products. In addition, visitors also learn about the distinctive features of Riverland, participate in festivals, and enjoy the unique local cuisine. Agritourism in the South-Central Coast region is a combination of coastal resorts and cultivation and livestock farms. This is a potential agritourism model, with meaningful activities such as picking grapes, learning about the winemaking process, and visiting the vast goat- and sheep-farming fields. In the Central Highlands, tourists have the opportunity to directly attend to the production activities that generate typical regional products such as coffee, pepper, cocoa, rubber, and medicinal plants. In addition, tourists can experience, feel, and enjoy the beauty of the local scenery in the working and leisure process. The northern region, with the advantage of its mountainous terrain, many scenic spots, and cool climate, has formed tourism models, with sightseeing in terraced fields and large tea hills, and combines agro-ecotourism with homestays, and traveling flower gardens. Overall, these models have great development potential, with beautiful natural and artificial landscapes, and fresh-natural agricultural products to attracti many domestic and foreign tourists.

According to the report of the Ministry of Agriculture and Rural Development in 2019, there are 34,348 agricultural farms in the entire country, but tourist activities only occur in 3–5% of the total farms in each region. Most of the tourism models are small-scale and spontaneous, and the agricultural products are simple and unfocused on trademark. The agritourism products in many localities are currently at a simple level, and the quality has not yet met the tourists' needs. In addition, the level of tourism labor does not meet practical needs, and agricultural production is not associated with the development of tourism. Cooperation between tour operators and tourism destinations is still limited. In addition to, infrastructure and supporting facilities at agritourism sites have not been fully invested with low quality and capital investment, and the local development policies have not been implemented effectively.

It can be seen that agritourism is still emerging in Vietnam, with a series of challenges, as well as a potential industry that could attract investors. Therefore, conducting extensive research and applying the methods of agritourism exploitation and development are essential to Vietnam's agritourism. In particular, evaluating a suitable agritourism destination based on several criteria, such as topography, natural resources, infrastructures, policies, economic growth, and agricultural products, is a significant step in the investment decision because it affects the operation efficiency, business revenue, and local benefits of sustainable development. Selecting the most appropriate location, with advantages in terms of nature, environment, public facilities, economy, culture, and advanced agricultural production, will decrease investment costs and enhance profits for businesses. The location could also become a typical professional agritourism site, satisfying customers' requirements, increasing income for local people, promoting featured images, and preserving traditional cultural values.

Selection of the most suitable site is important in various fields, and is studied and conducted by many methods with high applicability and reliability. It was reported that a model of fuzzy linear programming was applied to find the optimal locations for biomass power plants [10]. The mixed-integer linear programming model was applied to select the location of the urban distribution center, reducing costs for the environment, economy and society [11]. The appropriate wave energy-converter site was studied using a multi-criteria approach (MCA) based on the impact of factors such as available potential and wave characteristics [12], and solar PV power plant location was also selected by data envelopment analysis (DEA) and the grey-based multiple criteria decision making

(G-MCDM) [13]. Another method, the multi-criteria decision-making (MCDM) technique, was also used for the optimal location selection problem in many fields. The best location of the transshipment port was presented based on quantitative and qualitative concerns [14], and evaluation frameworks were also proposed to determine the optimal site of wind plants [15,16]. Sagnak et al. evaluated potential sites to choose the optimal one for an e-waste collection center in sustainable supply chains based on the Fuzzy Best–Worst method [17]. Pamucar et al. [18] utilized a new hybrid DEMATEL-MAIRCA model to determine the sustainable selection of a multimodal logistics center, where the DEMATEL tool is used to evaluate the influence coefficients of the criteria, and MAIRCA analysis is used to determine the best-ranked location. Several other techniques have been also developed and applied to effectively deal with decision-making problems, such as the SWARA method [19], game theory [20], extensions of the EDAS technique [21], and the ARAS method [22]. The hybrid models have been used to solve similar issues over the last two decades. Ruzgys et al. [23] reported that the combination of two SWARA-TODIM methods is the powerful means of selecting modernized apartment buildings. Yazdani et al. [24] proposed the hybrid technique to select an appropriate supplier to enhance the company's operating efficiency, two DEMATEL and BWM techniques are integrated to identify the weight criteria, and the most appropriate supplier is determined using the CoCoSo-G method. Karabasevic et al. [25] presented a recruitment procedure framework to help companies choose between prospective employees by applying the SWARA and ARAS approaches. With this method, a potential candidate can be selected despite the uncertainties of the employer. Turskis et al. [26] showed that the optimal waste incineration site can be chosen using complex AHP and ARAS-F techniques. As a result, the requirement for relevant actors can be solved by reducing operating costs and creating a safe environment, which should be far from the residential area. Although there are various evaluation methods, the MCDM model is a popular technique, and used effectively for optimum site decision-making under multiple conflicting criteria in many fields. This method also plays an important role in management science, which can enhance service quality and help to rank hospitals [27]. In the MCDM-based methods, two techniques are usually used to build a more accurate decision-making structure to evaluate and select the optimum site, since they can solve complex problems, which simultaneously denote qualitative and quantitative evaluations of the criteria [28,29]. One of them is the analytic hierarchy process (AHP) and another is the technique for order of preference by similarity to the ideal solution (TOPSIS) [30]. The general structure of studies based on the MCDM method is itemized as follows. Firstly, the alternative options and the criteria to evaluate these options are proposed. Then, the criteria weights against options are calculated based on the influent coefficients of each criterion in comparison to others, using the AHP technique. Finally, the ranking of alternative options can be determined by these criteria weights using TOPSIS [31]. In addition, the combination of fuzzy AHP and fuzzy TOPSIS has become a strong tool to combine multiple alternatives into the most optimal option under the influence of the criteria [32]. In comparison to the traditional methods, the score of the criteria weights in the fuzzy approach can more easily and accurately be determined. Experts or managers only need to conduct qualitative assessments. While the criteria are evaluated in pairwise comparisons, the relative influence between one criterion and another is digitized by fuzzy sets. Therefore, this method can help experts and investors to avoid the uncertainty and vagueness during decision-making [33]. Many studies have been conducted based on the integration of two AHP and TOPSIS techniques in the fuzzy environment to solve complex problems. In the tourism industry, Baki et al. suggested a fuzzy AHP-TOPSIS model to improve the operating efficiency of hotel websites by intensifying of competitiveness, brand value, and customers number [34]. This can help to identify the most suitable third-party logistics (3PL) for cold chain management, especially given the priority solutions for reverse logistics barriers that were also applied by the same tools [35,36]. Additionally, the other aspects were investigated by this fuzzy AHP-TOPSIS model, such as assessing sustainable urban development in an emerging econ-

omy [37], evaluating the maintenance factors that affected sustainable manufacturing [38], and finding the optimal sitting for electric vehicle charging stations [39].

According to a review of the above studies, it can be seen that the hybrid MCDM method was effectively applied in decision-making regarding the optimum site selection in varied sectors. However, the related literature on choosing the most potential site of agritourism in Vietnam is unavailable, and this has not been fully researched and exploited to date. For this reason, the Fuzzy AHP and Fuzzy TOPSIS method are integrated to address our concerns regarding this problem. The study aims to efficiently assist investors or decision-makers in the evaluation and selection of suitable agritourism locations in Vietnam. The literature procedure is organized as follows. Firstly, an evaluation of the criteria weightings is conducted using the fuzzy AHP method based on experts' opinions combined with a literature review. Next, the alternatives to the tourist site are ranked by applying fuzzy TOPSIS. The model's result assists investors in further development, based on the priority ranking of the agritourism sites.

The remaining structure of the paper is as follows: Section 2 shows the literature review, Section 3 introduces the research methodology, Section 4 presents the empirical study of the reality context, and Section 5 presents the discussion. Finally, conclusions regarding the proposed model are given in Section 6.

2. Literature Review

Tourism is both a multi-industry, due to its interaction with others, and contains special characteristics and features [40]. The selection of a suitable model for investment in and the development of tourism destinations is recommended [41]. Therefore, many authors have been interested in and explored this topic in many aspects. Friedmann [42] argued that the trend of tourism investment in undeveloped areas, such as rural areas, is increasingly popular and the success of new tourism forms in many countries has attracted investment and regional expansion strategies. Lee [43] reported that hotel location choice requires consideration of the expected hotel scale, which directly affects the target and its operations in the short- and long-term business strategy. Serafeim Polyzos [44] explained the difference in tourism investment decisions in Greece using a regression model. The author realized that the local tourism resources have not been effectively managed and exploited, so the tourism industry needs to define specific goals to come up with appropriate strategies and policies for the development of tourist destinations. Another research framework regarding the location selection problems for international resort parks, based on Porter's Diamond model (1990), has been proposed by [41]. Through expert survey and model analysis, the key components for optimal selection, such as incentives policies, company plans, demand, and supporting sectors, were shown to assist in the decision of local authorities and the tourism industry. Zarei Morteza [45] introduces an evaluation model to support investors in suitable tourist destination decisions based on ANP and TOPSIS approaches. Khalid [46] argued that the process of determining a tourist destination is a complicated issue, because it widely involves local activities. Thus, he developed an integrated system of tools, including an expert system (ES), geographic information system (GIS), and multi-criteria assessment (ANP OWA), to assist decision-makers in finding the optimal solution for ease of accessibility. Safak Aksoy [47] pointed out that hotel location decisions are a matter of concern for investors and hotel managers due to the operational diversities and competitive advantages in business. Furthermore, the author also analyzed the influence of selecting tourist sites based on the behavior and decisions of tourists, using a combination of multi-criteria decision techniques and tourists' post-purchase evaluations (PPE). Similarly, a good location choice for international tourist hotels can be determined by enhancing competition and profit, shorting the payoff time, and providing convenient lodgings for customers [48]. In summary, on the basis of related studies on tourism development aspects, extensive studies on investing agritourism location selection have been formed and implemented.

3. Materials and Methods

In this study, an integrated FAHP and FTOPSIS model is used to deal with location selection problems. To identify the optimal location, the research process shows these steps in Figure 1.
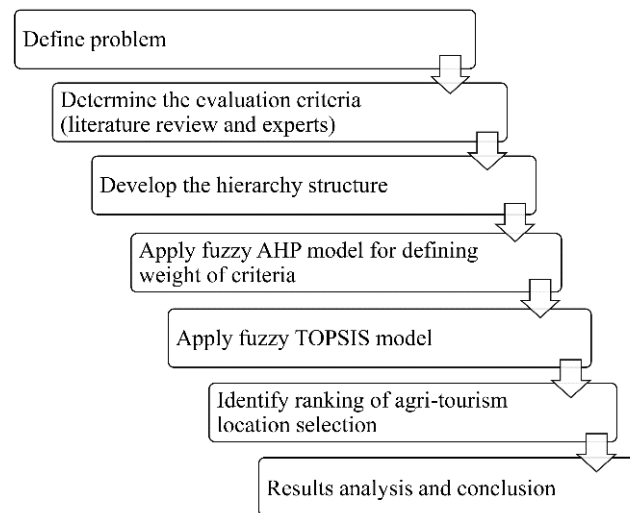

Figure 1. Research framework.

3.1. Fuzzy Set Theory

3.1.1. Triangular Fuzzy Number

The fuzzy set theory is defined according to Zadeh [49] to deal with uncertain problems. It describes a fuzzy number allowing the decision-makers to connect the unquantifiable, insufficient, or unclear information into the decision model. The fuzzy extent analysis is used to identify the criteria for an important and alternative performance [50]. Assuming that a triplet (a, b, c) is defined as triangular fuzzy number (TFN), which denotes lower, middle, and upper values, respectively, as shown in Formula (1) and Figure 2

$$f_D(x) = \begin{cases} (x-a)/(b-a) & a \le x \le b \\ (x-c)/(b-c) & b \le x \le c \\ 0 & otherwise \end{cases} \tag{1}$$

where membership function f_D: R → [0, 1]

3.1.2. Linguistic Values

The intervals of the linguistic variable are proposed by Gumus [51], ranging from 1 to 9, and used to rate the criteria and the alternatives, in which fuzzy numbers are transformed. In more detail, the membership function of the linguistic scale of criteria and alternatives is shown in Tables 1 and 2.

The triplets, $\widetilde{m} = (m_1, m_2, m_3)$ and $\widetilde{n} = (n_1, n_2, n_3)$, are two triangular fuzzy numbers and the distance between these numbers is calculated by as Formula (2) as follows:

$$d(\widetilde{m}, \widetilde{n}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]} \tag{2}$$
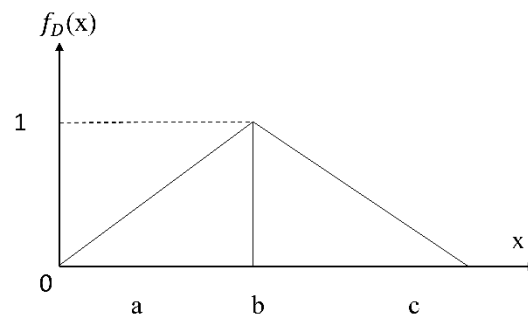
Figure 2. The membership function of triangular fuzzy number.

3.2. Fuzzy Analytic Hierarchy Process (FAHP)

The analytic hierarchy process (AHP) is a useful tool of the MCDM technique, which is proposed to deal with complex decision problems [52]. This method describes the structure at different element levels, including criteria, subcriteria, and alternatives, and provides a comparison between them [53]. However, the AHP method is unable to solve a very unbalanced scale of judgment with certainty, and the results are affected by the decision-makers' perspective on the numbers in practical cases [54]. To further improve this technique, the fuzzy AHP extends the AHP [55]. This evaluation is more convenient and appropriate than traditional methods due to its the ease of expressing ideas [48]. Hence, the fuzzy AHP technique is widely used in reality. The most suitable supplier is chosen to satisfy the specific needs of the airline retailing industry as a highly complex concept, and an efficient system in terms of both quantitative and qualitative decision factors is built to select the global vendor using the fuzzy AHP technique [56,57]. Similarly, this method is applied to find the optimal location for a warehouse, looking at the effectiveness of the supply chain [58]. Moreover, the fuzzy AHP tool solves the sustainability issues when making decisions regarding strategic planning and management in both business and society [59]. In particular, the proposed model of a fuzzy AHP procedure is shown to measure the criteria weightings, following these steps.

Step 1   Pairwise comparison matrices of criteria

Assume that a decision group has K experts, who are decision-makers, to invest in this project. By asking which of the two dimensions is more important, pair-wise comparison matrices are constructed among all the criteria of the hierarchical structure, following the Formula (3) matrix ($\widetilde{U^k}$):

$$\widetilde{U}^k = \begin{bmatrix} 1 & \widetilde{u}^k_{12} & \cdots & \widetilde{u}^k_{1n} \\ \widetilde{u}^k_{21} & 1 & \cdots & \widetilde{u}^k_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{u}^k_{n1} & \cdots & \cdots & 1 \end{bmatrix} \tag{3}$$

where $\widetilde{u^k_{ij}}$ is the fuzzy comparison value by kth decision-makers from the ith to jth criterion.

Step 2   Fuzzy geometric mean and fuzzy criteria weightage

Determine the fuzzy geometric mean and fuzzy weights of each criterion based on the geometric technique introduced by [60], using Formulas (4) and (5), respectively.

$$\widetilde{r}_i = (\widetilde{u}_{i1} \otimes \cdots \otimes \widetilde{u}_{ij} \otimes \cdots \otimes \widetilde{u}_{in})^{1/n} \tag{4}$$

$$\widetilde{w}_i = \widetilde{r}_i \otimes [\widetilde{r}_1 \oplus \cdots \oplus \widetilde{r}_i \oplus \cdots \oplus \widetilde{r}_n]^{-1} \tag{5}$$

where $\widetilde{u}_{ij} = \frac{\sum_{k=1}^{K} \widetilde{u^k_{ij}}}{K}$ is the integrated fuzzy comparison value by the kth decision-maker from the ith to jth criterion, $\widetilde{r}_i$ is fuzzy geometric mean of the ith criterion, $\widetilde{w}_i$ is fuzzy weight of the ith criterion.

Table 1. Linguistic scales of criteria ratings for FAHP.

Linguistic Variable	Fuzzy Number	Triangular Fuzzy Scale			Reverse Triangular Fuzzy Number		
Equal	$\widetilde{1}$	1	1	1	1	1	1
Weak advantage	$\widetilde{2}$	1	2	3	1/3	1/2	1
Not bad	$\widetilde{3}$	2	3	4	1/4	1/3	1/2
Preferable	$\widetilde{4}$	3	4	5	1/5	1/4	1/3
Good	$\widetilde{5}$	4	5	6	1/6	1/5	1/4
Fairly good	$\widetilde{6}$	5	6	7	1/7	1/6	1/5
Very good	$\widetilde{7}$	6	7	8	1/8	1/7	1/6
Absolute	$\widetilde{8}$	7	8	9	1/9	1/8	1/7
Perfect	$\widetilde{9}$	8	9	10	0	1/9	1/8

Table 2. Linguistic scales of alternative ratings for FTOPSIS model.

Linguistic Variable	Triangular Fuzzy Scale		
Very poor (VP)	1	1	3
Poor (P)	1	3	5
Fair (F)	3	5	7
Medium good (MG)	5	7	9
Good (G)	7	9	10
Very good (VG)	9	10	10

Step 3   BNP value for rating weight

Calculate the best non-fuzzy performance (BNP) value to analyze the rating weights of criteria, following Formula (6):

$$BNP_{wi} = \frac{[(U_{wi} - L_{wi}) + (W_{wi} - L_{wi})]}{3} + L_{wi} \tag{6}$$

where BNP_{wi} is the best non-fuzzy performance value, and (U_{wi}, W_{wi}, L_{wi}) are the upper, midle and lower values of criteria weight.

3.3. Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS)

The technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a technique that can be used to the solve MCDM problem by finding the best option from all the feasible alternatives [61,62]. The optimal results have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS). However, the concept needs to be transformed into a linguistic assessment instead of numerical values to deal with problems in real-life situations [63]. Fuzzy TOPSIS extends the classical TOPSIS approach in a fuzzy environment, which is used in a broad variety of real-world applications in different fields [64]. The optimal warehouse location, with strategic importance for many companies, is developed based on this technique [65]. In addition, the group decision-making of Fuzzy TOPSIS is proposed to identify the best alternatives in cases of accidents with oil spills in the sea [66]. Additionally, this method can also be combined with other methods to solve problems in evaluating hazardous waste transportation firms and improving the sustainable performance of the agri-food value chain [67].

The proposed fuzzy TOPSIS model is shown to define the optimal alternative, following these steps:

Step 1   The results of weight ratings by decision-makers

After applying the FAHP method, the relative fuzzy weight of the criteria is obtained and used for the next step.

Step 2   Aggregated fuzzy comparison value by decision makers

The aggregate fuzzy value $\widetilde{z}_{ij}$ of alternative A_i in respect to criterion C_j is built based on a decision group with K persons [51], following Formula (7):

$$\widetilde{z}_{ij} = \frac{1}{K}\left(\widetilde{z}_{ij}^1 \oplus \cdots \oplus \widetilde{z}_{ij}^k \oplus \cdots \widetilde{z}_{ij}^K\right) \tag{7}$$

where $\widetilde{z}_{ij}^k$: is fuzzy rating value alternative A_i in respect to criterion C_j by kth expert and $\widetilde{z}_{ij}^k = (a_{ij}^k, b_{ij}^k, c_{ij}^k)$.

Step 3　Fuzzy comparison decision matrix of alternatives and criteria

According to the linguistic rating value of relative alternatives in Table 2, the fuzzy decision matrix of alternatives and criteria is constructed following Formula (8):

$$\widetilde{Z} = \begin{bmatrix} 1 & \widetilde{z}_{12} & \cdots & \widetilde{z}_{1n} \\ \widetilde{z}_{21} & 1 & \cdots & \widetilde{z}_{2n} \\ \vdots & \cdots & \ddots & \vdots \\ \widetilde{z}_{m1} & \cdots & \cdots & 1 \end{bmatrix} \text{ such that } i = 1, 2, \ldots, m; \ j = 1, 2, \ldots, n \tag{8}$$

where $\widetilde{z}_{ij}$ is fuzzy comparison value, denoted as triangular fuzzy number $\widetilde{z}_{ij} = (a_{ij}, b_{ij}, c_{ij})$.

Step 4　Normalized fuzzy-decision matrix

Formula (9) for the normalized fuzzy-decision matrix is introduced as follows:

$$\widetilde{R} = \left[\widetilde{r}_{ij}\right]_{m \times n} \quad i = 1, 2, \ldots, m; \ j = 1, 2, \ldots, n \tag{9}$$

The details of the normalized process for the benefit and cost criteria are shown in Formulas (10) and (11), respectively:

$$\widetilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \ \frac{b_{ij}}{c_j^+}, \ \frac{c_{ij}}{c_j^+}\right), \tag{10}$$

$c_j^+ = max_i \left\{c_{ij} \backslash i = 1, 2, \ldots, m\right\}$ for benefit criteria.

$$\widetilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \ \frac{a_j^-}{b_{ij}}, \ \frac{a_j^-}{a_{ij}}\right) \tag{11}$$

$a_j^- = min_i \left\{a_{ij} \backslash i = 1, 2, \ldots, m\right\}$ for cos t criteria.

Step 5　Weighted normalized fuzzy-decision matrix

Formula (12) for the weighted normalized fuzzy-decision matrix is as follows:

$$\widetilde{V} = \left[\widetilde{v}_{ij}\right]_{m \times n} \quad i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{12}$$

where: $\widetilde{v}_{ij} = \widetilde{r}_{ij}(\times)\widetilde{w}_i$.

Step 6　FPIS and FNIS

The fuzzy positive-ideal solution (FPIS) A^+ and fuzzy negative-ideal solution (FNIS) A^- are calculated following Formulas (13) and (14), respectively:

$$A^+ = (\widetilde{v}_1^+, \cdots, \widetilde{v}_j^+, \cdots, \widetilde{v}_n^+) \tag{13}$$

$$A^- = (\widetilde{v}_1^-, \cdots, \widetilde{v}_j^-, \cdots, \widetilde{v}_n^-) \tag{14}$$

Step 7　The distance of each weighted alternative

Compute the distance of each alternative, following the Formulas (15) and (16):

$$\widetilde{d}_i^+ = \sum_{j=1}^{n} d(\widetilde{v}_{ij}, \widetilde{v}_j^+) \quad i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{15}$$

$$\widetilde{d}_i^- = \sum_{j=1}^{n} d(\widetilde{v}_{ij}, \widetilde{v}_j^-) \quad i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{16}$$

Step 8   Closeness coefficient of each alternative

Determine the closeness coefficients (relative gaps-degree) of each alternative to find the best alternatives, which are closer to the FPIS and farther from the FNIS, as $\widetilde{CC}_i$ approaches 1. The results are decided by decision-makers aiming achieve the aspiration levels, following Formula (17):

$$\widetilde{CC}i = \frac{\widetilde{d}_i^-}{\widetilde{d}_i^- + \widetilde{d}_i^+} \quad i = 1, 2, \ldots, m \tag{17}$$

where $\frac{\widetilde{d}_i^-}{\widetilde{d}_i^- + \widetilde{d}_i^+}$ is fuzzy satisfaction degree.

4. Empirical Study

This section describes the practicality of the proposed integrated MCDM approach through a case study of Vietnam. The research framework is presented by the hierarchy structure for location a selection model with three levels, comprising an objective level, criteria level, and alternative level, as shown in Figure 3. The model's result shows the most optimal location for agritourism investment based on three basic steps: (1) identifying the relative criteria for the evaluation process, (2) analyzing the weightage of criteria, (3) determining the ranking of potential alternatives.

4.1. Identyfing the Relative Criteria for Evaluation Process

Agritourism is not only a driving force for local economic growth but also the integration of appropriate land-use policies [68]. Therefore, a new agritourism destination is based on an analysis of the economic, socio-cultural, environmental, and professional aspects, as well as its geographical site and landscape qualities. The geographic conditions is one of the factors with a significant impact on the potential development of an agritourism location. Tourism developers can evaluate its characteristics, level of exploitation and land quality, to ensure its suitability for the development of tourism associated with agriculture production. The availability of agricultural production models will determine their size and ability to invest in recreational and entertainment activities. Moreover, the suppliers of raw materials and water sources near the tourist destination, who will support its production activities, also need to be considered [41,48,69,70].

From the economic perspective, local development greatly affects the sustainability of agritourism, helping to maintain the revenue of tourist attractions and people, as well as attracting many potential customers. Moreover, the expanded consumption market can increase competitiveness and ensure a stable output for agricultural products. The investment of science and technology in the production process, combined with various types of tourism, also contributes to enhancing the value and quality of products [68–71]. In terms of social issues, this factor, including government regulation, regional development strategy and social stability, expresses the importance of tourist activities. Flexible and appropriate policies in the region, combined with the active participation of local residents, businesses and investors, helps to create a strong association, which can greatly contribute to the sustainable development of agritourism. In addition, the abundant and qualified human resources can increase professionalism, improve service quality, and provide a hospitable and attractive tourism environment [69,70,72,73].
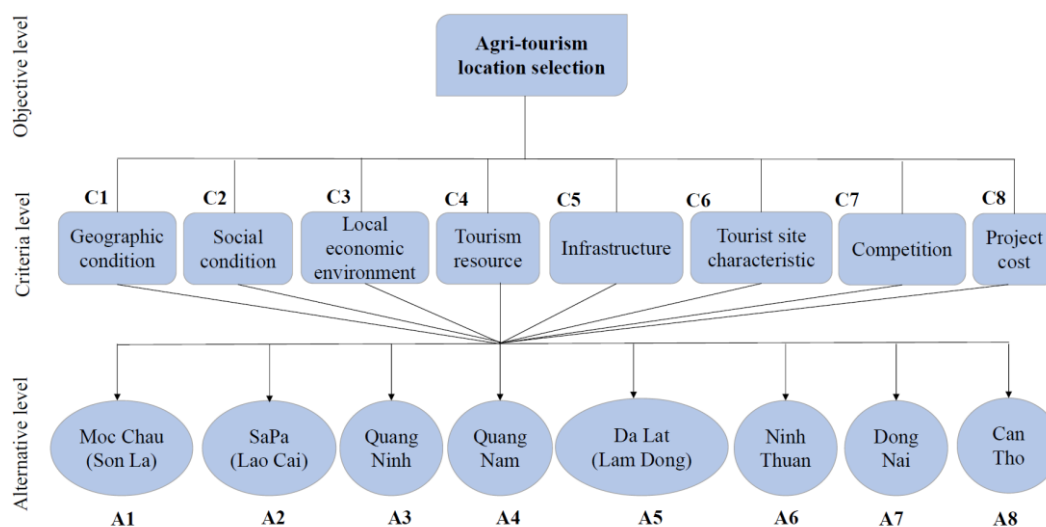
Figure 3. Research framework.

Tourism resource is an important resource to create tourism products. Their scale and development depend on the quantity, quality, and combination of the available resources. The tourism market can be developed and expanded if the resources are at a large scale and of high quality. The effective use and exploitation of rich natural beauty, traditional cultural values, and typical agricultural products are also highlights that can attract visitors [1,68,69,74]. Furthermore, the infrastructure represents the level of development of a locality, since it directly affects economic activities. For the tourism industry, a good infrastructure is a necessary condition for communication and travel needs such as the availability of transport systems, chain stores, communication facilities and other services. In addition, the variety and convenience of transportation also relate to the safety, cost and duration of the trip, ensuring that tourists have easy access to the tourist destination [75–78]. Tourist site characteristics are expressed through a combination of its internal uniqueness and external richness. Special interior designs should be suitable for the local culture, and the supporting services of accommodation and restaurants should be convenient for tourists, which will highlight and enhance the value of the destination. In addition, entertainment activities and outside experiences will also be interested in investing in new locations, creating diversity to meet the needs of visitors [48,70]. Moreover, competition is an indispensable factor in the development of the tourism industry. The availability of related tourism activities is the main force promoting competitiveness in creating high-quality tourism products and services that satisfy visitor requirements. Therefore, investors can provide an appropriate business strategy to effectively exploit the new agricultural tourism destination [48,75,79]. Lastly, project cost is a significant factor when deciding whether to invest in a new location. This is carefully considered by investors with the goal of optimizing costs, utilizing resources and maximizing profit. Although the physical characteristics of each region are different, the basic expenditure budget includes land costs, labor costs, transportation costs and operating costs [14,65,80].

A description of each factor used to evaluate the alternative location decisions is given in the following list:

- Geographic conditions (C1): land characteristics and quality, water supply, level of land availability and expansion possibilities, existing agricultural production model, variety of agricultural activities, proximity to material suppliers.
- Social conditions (C2): government laws, land regulations, level of social stability, tourism sector structure policies, tourism development programs, agriculture expansion strategy, labor resources, local communities' perception of tourism.

- Local economic environment (C3): level of economic growth in the region, investment opportunities in tourism activities, consumption capacity in the agricultural products' market, capital investment in agricultural science and technology.
- Tourism resources (C4): landscape, availability of agricultural products, typical local products and cuisine, regional cultures, traditional customs, cultural heritage.
- Traffic conditions (C5): the variety of transportation alternatives, the distance to airports, freeways and bus stations, the convenience of communication between traffic facilities, the ease of traffic routes, parking areas.
- Tourist site characteristics (C6): internal services: architecture and landscape appearances, inside decoration, supporting services (accommodation, restaurant), external services: entertainment activities, relaxation, sports and outside experiences.
- Competition (C7): availability of other forms of agritourism, availability of other tourism services, availability of public facilities (park, museum, theaters).
- Project costs (C8): land costs, labor costs, operation costs, transportation costs.

After identifying these criteria, potential alternatives are proposed in the selection process. These places are usually famous scenic spots stretching from North to South Vietnam, described in more detail in Table A1 (Appendix A) [81–88].

4.2. Analyzing Weightage of Criteria

The initial pair-wise comparison matrices are established based on the evaluation of decision-makers, with three representatives. Then, according to Table 1, the linguistic scales is converted to a fuzzy number in Table A2 (Appendix A).

The synthetic pair-wise comparison matrix of criteria is presented following Formula (3) shown in Table 3.

Table 3. Fuzzy pairwise comparison matrices of criteria.

Criteria	C1	C2	C3	C4
C1	1	(1, 1.26, 1.44)	(1, 1.26, 1.44)	(0.3, 0.44, 0.79)
C2	(0.69, 0.79, 1)	1	(0.3, 0.44, 0.79)	(0.26, 0.35, 0.55)
C3	(0.69, 0.79, 1)	(1.26, 2.29, 3.3)	1	(0.26, 0.35, 0.55)
C4	(1.26, 2.29, 3.3)	(1.82, 2.88, 3.91)	(1.82, 2.88, 3.91)	1
C5	(0.28, 0.38, 0.63)	(1, 1.26, 1.44)	(0.28, 0.38, 0.63)	(0.44, 0.55, 0.79)
C6	(0.69, 0.79, 1)	(1.26, 1.82, 2.29)	(0.48, 0.63, 1)	(0.26, 0.35, 0.55)
C7	(0.48, 0.63, 1)	(0.69, 1, 1.44)	(1, 1.59, 2.08)	(0.44, 0.55, 0.79
C8	(0.18, 0.22, 0.28)	(0.2, 0.26, 0.35)	(0.26, 0.35, 0.55)	(0.18, 0.22, 0.28)
	C5	**C6**	**C7**	**C8**
C1	(1.59, 2.62, 3.63)	(1, 1.26, 1.44)	(1, 1.59, 2.08)	(3.63, 4.64, 5.65)
C2	(0.69, 0.79, 1)	(0.44, 0.55, 0.79)	(0.69, 1, 1.44)	(2.88, 3.91, 4.93)
C3	(1.59, 2.62, 3.63)	(1, 1.59, 2.08)	(0.48, 0.63, 1)	(1.82, 2.88, 3.91)
C4	(1.26, 1.82, 2.29)	(1.82, 2.88, 3.91)	(1.26, 1.82, 2.29)	(3.63, 4.64, 5.65)
C5	1	(0.69, 0.79, 1)	(0.69, 1, 1.44)	(1, 1.26, 1.44)
C6	(1, 1.26, 1.44)	1	(0.69, 0.79, 1)	(1.82, 2.88, 3.91)
C7	(0.69, 1, 1.44)	(1, 1.26, 1.44)	1	(0.69, 1, 1.44)
C8	(0.69, 0.79, 1)	(0.26, 0.35, 0.55)	(0.69, 1, 1.44)	1

The fuzzy geometric mean, fuzzy criteria weightage BNP values are demonstrated by applying Formulas (4)–(6), as in Table 4.

4.3. Determining the Ranking of Potential Alternatives

The fuzzy comparison decision matrix of alternative and criteria is constructed following Formulas (7) and (8), as in Table A3 (Appendix A).

The normalized and weighted normalized fuzzy-decision matrix of alternative and criteria ais built, and FPIS and FNIS values are shown using Formulas (9)–(14), as in Tables A4 and A5 (Appendix A).

Table 4. The weight of criteria rating.

Criteria	Fuzzy Geometric Mean			Fuzzy Weight			BNP	Rank
	a	b	c	a	b	c		
C1	1.0722	1.4236	1.7819	0.0922	0.1599	0.2689	0.174	2
C2	0.6516	0.8206	1.1194	0.0560	0.0922	0.1689	0.106	6
C3	0.8636	1.2154	1.6456	0.0743	0.1365	0.2483	0.153	3
C4	1.6031	2.3210	2.9581	0.1379	0.2607	0.4464	0.282	1
C5	0.5959	0.7508	0.9929	0.0513	0.0843	0.1498	0.095	7
C6	0.7787	0.9881	1.2779	0.0670	0.1110	0.1928	0.124	4
C7	0.7172	0.9553	1.2786	0.0617	0.1073	0.1929	0.121	5
C8	0.3447	0.4282	0.5720	0.0297	0.0481	0.0863	0.055	8

The distance between the weight and closeness coefficients of each alternative are computed based on Formulas (15)–(17), as in Table 5. Then, the final ranking of the proposed FTOPSIS model shows the top three potential agritourism locations, which are Can Tho, Da lat city, Quang Nam, based on ranking scores of 0.7539, 0.7269, and 0.7066, respectively.

Table 5. The closeness coefficient of each alternative.

Alternatives		d^+	d^-	CC_i	Rank
Moc Chau	A1	0.3026	0.4547	0.6552	4
Sa Pa	A2	0.3514	0.4065	0.5483	6
Quang Ninh	A3	0.3343	0.4411	0.5799	5
Quang Nam	A4	0.2323	0.5377	0.7066	3
Da lat city	A5	0.2069	0.5486	0.7269	2
Ninh Thuan	A6	0.2882	0.4798	0.5060	7
Đong Nai	A7	0.3880	0.3759	0.5052	8
Can Tho	A8	0.1945	0.5734	0.7539	1

5. Discussion

Agritourism is becoming more popular, a prospective and highly efficient economic possibility in both the agriculture and tourism industries. In Vietnam, agritourism has gradually brought social and economic benefits to many localities and businesses. In the orientation of Vietnam's tourism expansion strategy, ecotourism associated with agriculture is identified as one of the five main product lines. Agritourism has been developed in the country by varied tourism products, along with regional cultural characteristics, as shown in the eight potential alternatives in this research. Each alternative has scenic beauty and diverse capabilities, with a high level of ability to develop tourism in the future. However, the strengths of these existing destinations have not been promoted to meet demands and attract many domestic and foreign tourists. Therefore, selecting a suitable location for agritourism investment is an essential action to utilize resources, and improve quality and sustainability.

This paper contributed a research framework for tourist site-selection by applying the hybrid MCDM approach. Fuzzy AHP determines the importance of the criteria and fuzzy TOPSIS presents the priorities of the alternatives. In the decision-making process, following the weights obtained from fuzzy AHP, the optimal solution is determined from fuzzy TOPSIS calculation. The highlight of the proposed model is that finding the weight of the criteria and evaluating the criteria process are performed simultaneously, and combined with fuzzy TOPSIS to provide a solution in a short period of time. The model's effectiveness is illustrated through an empirical study in Vietnam and the model's result is feasible. It can be combined with other models to diversify options or conduct extensive research on different topics in the future.

During the model-building process, eight evaluation criteria are proposed, including geographical conditions, social conditions, local economic environment, tourism resources, infrastructure, tourist site characteristics, competition, and project costs. The model's

results indicate that the most important factors are tourism resources (C4) and geographical conditions (C1), respectively. Consequently, investors should focus on the exploitation of local resources and topography to determine goals, select typical tourism products, and offer appropriate solutions for tourism development. In addition, other factors that need to be considered in location assessment are the local economic environment (C3) and tourist site characteristics (C6). Local development conditions such as abundant capital, the availability of economic activities, and a large market have a significant impact on investment in new tourist destinations. Moreover, the unique beauty and varied services of the tourist destination are also highlights for the customer's choice. In the next stage, eight potential alternatives are suggested. Through the evaluation process, the best location for agritourism investment was found to be Can Tho. The advantages of diverse agricultural resources, such as immense rice fields, four seasons of fruit trees, and aquaculture, provide an opportunity to develop agritourism in the area. Moreover, Can Tho is also the center of the Mekong Delta region, with high economic growth, and can provide the opportunity to experience village life, including farming, planting, casting nets, slapping ditches to catch fish, enjoying local food, and cycling around the countryside. These have created outstanding strengths for the creation of tourism products. Da Lat and Quang Nam are other priority destinations found in the decision-making process.

6. Conclusions

We proposed a decision-making model based on the combination of two fuzzy AHP and fuzzy TOPSIS methods, which are capable of determining the most optimal agritourism location for investors in Vietnam. In the beginning, relevant criteria were determined in the assessment process based on expert opinions and related articles, and potential alternative sites in Vietnam were proposed. Then, the ordered weighting of criteria was obtained based on the fuzzy AHP calculation and the priority ranking of the alternative locations was found using the fuzzy TOPSIS. The result of the model shows that tourism resources (C4) is the most important evaluating criterion, and Can Tho (A8) is the best location for investment in a new agritourism destination. This model will assist investors or decision-makers in determining optimal solutions based on economic, social, and environmental issues. Following the above presentation, the advantages of the proposed method and this research can be described as follows:

- The proposed model is a case study for evaluating and selecting the agritourism destination in Vietnam, based on the analysis of actual conditions in each region, expert interviews, and literature reviews.
- In Vietnam, although there are many potential agricultural areas for the development of agritourism, with the advantages of natural resources, topography, and unique culture, this is the first study to assess and select the most appropriate site using the fuzzy AHP and fuzzy TOPSIS methods. With this technique, an optimal destination, along with alternative solutions, was selected to be built and developed into a typical location for the agritourism industry, enhancing people's incomes and investors' profits, attracting tourists and meeting their demands.

The results of this research can provide a valuable orientation when choosing the optimal destination for other tourism industries in Vietnam, including heritage tourism, cultural tourism, craft tourism, eco-tourism, and ethnic tourism. It can be also applied to the selection of an optimal location for related agricultural projects, such as the location of farms, hi-tech agricultural areas, and factories processing agricultural products.

Appendix A

Table A1. The list of potential alternatives.

Famous Celebrations	Tourism Activities		Agricultural Products	Tourism Resources		Local Program	Transportation
	Tourism Products	**Local Cuisine**		**Natural Resource**	**Culture**		
Alternative 1: Moc Chau (Son La Province) Located in southeast Son La province (1.050 m from sea level)							
Moc Chau tea festival, Moc Chau fruit picking festival	Moc Chau tea hill and farm, golden rice fields, plum valley, Luong village, strawberry farm	Dried bamboo shoots, plum jam, honey, plum wine, wine, meat guarding the kitchen	Milk, teas (Shan Tuyet, Oloong), safe vegetables (Cabbage), fruit (avocado, peach, plum), forest flowers	Diverse ecosystem: 1600 ha of grassland, 7500 ha of fruit production, 37,000 tons of productivity	Cultural diversity, with 12 ethnic groups (Thai, Mong, Dao, etc.)	Investing in a synchronous technical and infrastructure system, high-quality and diversified tourism products bearing the cultural identity of Son La ethnic groups; crop-restructuring strategy	shuttle services, motorbike
Alternative 2: Sapa (Lao Cai Province) Located in northwest Lao Cai province (1500 m from sea level)							
Sapa Autumn Festival, Dancing Tet festival, Love market	Ta Phin Community tourism, Tai Nung pear garden, Sa Pa hand-picking vegetables, fruits, shiitake mushrooms and strawberries, orchid garden, Sa Pa ancient roses	Salmon, fresh sturgeon, cold vegetables, Thang Co soup, pig armpits, mushrooms	Vegetables (cabbage, cauliflower, "Sa Pa Su su", "Sapa safe vegetables"), rice (300 ha), medical plants (70 ha)	The "kingdom" of fruits (flower peaches, big yellow peaches, purple plums, tam Hoa plums), flowers (lily, plum, pear)	Ethnic groups living in Black H'Mong, Red Dzao, Tay, Dzay	Creating a brand and attractive destination, responsible improvements in tourism services' quality by people, local authorities and enterprises, building safe and friendly tour routes, ecological environment protection; expanding tourism to villages	train, shuttle services, motorbikes

Table A1. *Cont.*

Famous Celebrations	Tourism Activities		Agricultural Products	Tourism Resources		Local Program	Transportation
	Tourism Products	Local Cuisine		Natural Resource	Culture		
Alternative 3: Quang Ninh Located in northeast Vietnam, likened to "miniature Vietnam": seas, islands, hills, plains, midlands and borders							
Tuan Chau water music festival, Ha Long Carnaval, Yen Tu Buddhist festival	Yen Duc village, Van Yen orange garden, Dong Trieu ceramics village, Quang La flower paradise, Yen Tu flower valley, Le Loi high-quality flower and vegetable fields, Tung Sau pearl farming area	Ha Long squid cake, Quang Yen spring rolls, Tien Yen hill chicken, Sa Sung, nodding cake, Yen Tu apricot wine	Ba Che tea, hydroponic vegetables, fruit trees, sea products	4 tourist centers, 33 routes, 91 tourist spots, 5 provincial tourist sites, Ha Long Bay (7 Natural Wonders of the World), Tuan Chau Peninsula	Convergence and interference in the diversity of the Red River civilization	Setting criteria for safe tourist facilities, creating sustainable and high-quality tourism products, develop a series of cultural, sports and tourism events to stimulate tourism demand, promoting agricultural restructure for large-scale and hi-tech production, promoting aquaculture with tourism model	Van Don airport, train, boats (Tuan Chau–Coto island route), shuttle services
Alternative 4: Quang Nam A province in the central region, mountains and seas (125 km coastline); river system (900 km)							
Hoi An Lantern Festival, Hoi An Carneval	Tra Que vegetable village, Thanh Ha pottery village, fishing village, Dai Binh fruit village, Loc Yen ancient village, Co-tu community tourism village, Tay Giang native orange garden, Dien Phuong mat-weaving village	Quang noodles, Toi cake, Nui Thanh Flying Fish, Quang Nam Green Eel Porridge, Filtered Powder Cake	Variety of fruits (orange, mango), medicinal plants (Ngoc Linh Gingseng, Tra Que)	World cultural heritages (My Son relic site and Hoi An ancient town), Cu Lao Cham, a world biosphere reserve, 06 national monuments	Varied traditional cultural and historical features, 70 festivals	Developing agricultural combined tourism program, "One Commune-One Product" (OCOP), cooperating and investing in green tourism and local community participation, developing traditional craft villages, organizing annual cultural-tourism events	Chu Lai airport, train, shuttle services, motorbikes

Table A1. *Cont.*

Famous Celebrations	Tourism Activities		Agricultural Products	Tourism Resources		Local Program	Transportation
	Tourism Products	**Local Cuisine**		**Natural Resource**	**Culture**		
Alternative 5: Da Lat Located on Lam Vien plateau, Lam Dong province, Central highlands of Vietnam (1500 m from sea level)							
Dalat flower festival, Central Highlands Gong Festival	Dalat wine, Cau Dat Tea Hill, strawberry garden, hydroponic vegetable garden, Ho Xuan Huong tourism "One day as a farmer", Trai Mat high-tech agricultural tourism "One day with high-tech agriculture", organic garden, Van Thanh flower village	Beef hotpot, chicken heart cakes, butter cream, pancakes, yogurt cheese, soy milk, artichoke	Leading in "Green agriculture", typical local products: vegetables and flowers, other products (strawberries, tea coffee)	Well-known as a "tourist paradise", "kingdom of flowers" (200 species), forest flowers (cherry blossom, orchid) wildflowers, the East West flower	Gentle people, both traditional and modern young city, diversity of ethnicities in the Central Highlands' heritage	Development as a multi-sectoral approach with the No. 1 Da Lat brand name of Vietnam, the No. 1 vegetable production center of Southeast Asia, Vietnam's No. 1 agricultural tourism destination, the No. 1 Center for HR training, research and development in agricultural industry in the Central Highlands	Lien Khuong airport, shuttle services
Alternative 6: Ninh Thuan Located in a coastal province in the south–central coast region, terrain (mountains, semi-mountainous hills, coastal plains)							
Ninh Thuan Grape and Wine Festival, Apsara dance shows	Vineyards, apple orchards, goat farms, Lam Son ecological fruit garden, Phuoc Binh orchard, Bau Truc Village, Ninh Phuoc lotus lake eco-cultural tourist area combined with the culture of the Cham people	Phan Rang chicken rice, Can cake (pancakes), sour meatball, rice paper with fish sauce, fish cake soup	"capital of fish sauce", green vineyards, white salt fields with sunlight, wild grasslands with sheep and goats, making baskets of bottles	Natural and humanistic tourism resources, famous beautiful beaches: Ninh Chu, Ngoan Muc pass, Vinh Hy bay, adventure sports (motorcycle)	Champa ancient cultural and architectural (music and dance) culture, Champa traditional villages and festivals	Investments in marine, eco, combined cultural–historical tourism, supporting green agriculture and cooperative production, exploiting potential entertainment services, developing the "Farm trip to survey community tourism products in Ninh Thuan 2020" Program	Cam Ranh airport, shuttle services, train

Table A1. *Cont.*

Famous Celebrations	Tourism Activities			Agricultural Products	Tourism Resources		Local Program	Transportation
	Tourism Products	Local Cuisine			Natural Resource	Culture		
Alternative 7: Dong Nai Located in the southeast region, with an important position in the key economic development in the south of the country								
Long Khanh fruit festival	Long Khanh Fruit Garden, ecotourism (Mango Garden, Tre Viet Tourism Village), Hoang Hac Gia Trang tourist area	Grapefruit wine, Bien Hoa fish salad, bitter leaf forest hotpot		5 key crop areas (perennial industrial crops and fruit trees); 15 key national agricultural products: rubber, coffee, pepper, Xuan Loc mango	30 tourist sites (tourist attractions entertainment resorts, etc.)	30 ethnic groups living, land of ancient civilizations with many valuable cultural and historical relics	Inviting tourist destination investment, participating in programs (VITM, Food Festival South area, etc.), advertising tourist on TV programs ("Dong Nai tourist rendezvous" and exhibiting in tourism Dong Nai Culinary Tourism Culture Week), creating tourism product chains.	Tan Son Nhat airport-Ho Chi Minh city, shuttle services, train
Alternative 8: Can Tho The capital of the southwest region, one of the key economic regions of the Mekong Delta and the fourth key economic region of Vietnam								
Cai Rang Floating Market Cultural Tourism Festival, Mekong River Garden fruit festival	Con Son community tourism, agritourism in Cai Rang, Binh Thuy and Phong Dien districts, My Khanh hi-tech ornamental flower villages, Cai Khe ecotourism, fruit garden (coconut, plums longans, etc.)	Phu Sa cork hotpot and 10 styles Ba Khia, fish sauce hotpot, pancakes, grilled snails with pepper, Phong Dien cake, Cong cake		High-quality "big rice field", safe vegetable garden, fruit garden (Phong Dien orange, Ha Chau strawberry), red-fleshed, or dried fish, canned fish sauce	Canal system in The Mekong Delta (28,000 km), diverse ecosystem ranging from freshwater to saltwater, rich cultural treasures, varied tourism types, ecology, resort and island, community	Hospitable people, peaceful scenery	Building project "Development of agricultural tourism in Can Tho city in 2021–2025, vision to 2030", developing community tourism models and forming a food belt, applying hi-tech agriculture in ornamental flower villages; defining a riverine urban area in tourism development	Can Tho airport, shuttle services

Table A2. Linguistic scale of experts.

	C1	C2	C3	C4	C5	C6	C7	C8		C1	C2	C3	C4	C5	C6	C7	C8		C1	C2	C3	C4	C5	C6	C7	C8
C1	**1**	$\tilde{2}$	$\tilde{1}$	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{2}$	$\tilde{1}$	$\tilde{5}$	**C1**	**1**	$\tilde{1}$	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{2}$	$\tilde{4}$	**C1**	**1**	$\tilde{1}$	$\tilde{2}$	$\tilde{2}^{-1}$	$\tilde{2}$	$\tilde{1}$	$\tilde{2}$	$\tilde{5}$
C2	$\tilde{2}^{-1}$	**1**	$\tilde{2}^{-1}$	$\tilde{4}^{-1}$	$\tilde{1}$	$\tilde{3}^{-1}$	$\tilde{2}$	$\tilde{5}$	**C2**	$\tilde{1}$	**1**	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{3}$	**C2**	$\tilde{1}$	**1**	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{4}$
C3	$\tilde{1}$	$\tilde{2}$	**1**	$\tilde{3}^{-1}$	$\tilde{2}$	$\tilde{2}$	$\tilde{2}^{-1}$	$\tilde{3}$	**C3**	$\tilde{1}$	$\tilde{2}$	**1**		$\tilde{3}$	$\tilde{1}.$	$\tilde{2}^{-1}$	$\tilde{4}$	**C3**	$\tilde{2}^{-1}$	$\tilde{3}$	**1**	$\tilde{2}^{-1}$	$\tilde{3}$	$\tilde{2}$	$\tilde{1}$	$\tilde{2}$
C4	$\tilde{3}$	$\tilde{4}$	$\tilde{3}$	**1**	$\tilde{2}$	$\tilde{4}$	$\tilde{1}$	$\tilde{4}$	**C4**	$\tilde{2}$	$\tilde{2}$	$\tilde{4}$	**1**	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$	$\tilde{5}$	**C4**	$\tilde{2}$	$\tilde{3}$	$\tilde{2}$	**1**	$\tilde{3}$	$\tilde{3}$	$\tilde{2}$	$\tilde{5}$
C5	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	**1**	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$	**C5**	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{3}^{-1}$	$\tilde{1}$	**1**	$\tilde{1}$	$\tilde{2}$	$\tilde{1}$	**C5**	$\tilde{2}^{-1}$	$\tilde{2}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	**1**	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{1}$
C6	$\tilde{2}^{-1}$	$\tilde{3}$	$\tilde{2}^{-1}$	$\tilde{4}^{-1}$	$\tilde{2}$	**1**	$\tilde{2}^{-1}$	$\tilde{3}$	**C6**	$\tilde{1}$	$\tilde{2}$	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{1}$	**1**	$\tilde{1}$	$\tilde{2}$	**C6**	$\tilde{1}$	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}$	**1**	$\tilde{1}$	$\tilde{4}$
C7	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{2}$	$\tilde{1}$	$\tilde{1}$	$\tilde{2}$	**1**	$\tilde{2}$	**C7**	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	**1**	$\tilde{1}$	**C7**	$\tilde{2}^{-1}$	$\tilde{2}$	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{2}$	$\tilde{1}$	**1**	$\tilde{2}^{-1}$
C8	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{4}^{-1}$	$\tilde{2}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	**1**	**C8**	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{4}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{1}$	**1**	**C8**	$\tilde{5}^{-1}$	$\tilde{4}^{-1}$	$\tilde{2}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{4}^{-1}$	$\tilde{2}$	**1**

Table A3. Fuzzy comparison decision matrix of alternatives and criteria.

	C1			C2			C3			C4			C5			C6			C7			C8		
	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
A1	F	MG	MG	VG	VG	VG	F	MG	F	VG	G	G	VP	VP	P	G	VG	VG	G	G	MG	VP	P	P
A2	MG	F	MG	G	VG	VG	F	MG	MG	G	VG	G	VP	VP	VP	G	VG	G	F	F	MG	P	VP	P
A3	VG	G	G	P	F	F	G	VG	G	MG	F	F	G	G	VG	G	G	VG	VG	G	G	MG	MG	G
A4	G	VG	G	MG	F	F	G	G	VG	MG	MG	G	MG	G	G	MG	G	MG	G	VG	G	P	F	F
A5	MG	F	MG	G	MG	G	VG	VG	VG	VG	G	VG	MG	F	MG	G	G	VG	G	VG	VG	MG	G	G
A6	G	MG	G	MG	MG	F	G	MG	MG	MG	MG	MG	G	MG	G	G	MG	MG	MG	G	G	F	P	P
A7	G	MG	MG	MG	G	MG	G	G	G	MG	F	MG	F	MG	MG	MG	MG	G	MG	MG	F	MG	MG	G
A8	G	VG	VG	F	F	F	G	G	VG	VG	VG	G	VG	G	G	G	MG	MG	G	G	MG	MG	MG	F

Table A4. Normalized fuzzy-decision matrix of alternatives and criteria.

	C1			C2			C3			C4			C5			C6			C7			C8		
A1	0.433	0.633	0.833	0.900	1.000	1.000	0.367	0.567	0.767	0.767	0.933	1.000	0.100	0.167	0.367	0.833	0.967	1.000	0.633	0.833	0.967	0.231	0.429	1.000
A2	0.433	0.633	0.833	0.833	0.967	1.000	0.433	0.633	0.833	0.767	0.933	1.000	0.100	0.100	0.300	0.767	0.933	1.000	0.367	0.567	0.767	0.231	0.429	1.000
A3	0.767	0.933	1.000	0.233	0.433	0.633	0.767	0.933	1.000	0.367	0.567	0.767	0.767	0.933	1.000	0.767	0.933	1.000	0.767	0.933	1.000	0.107	0.130	0.176
A4	0.767	0.933	1.000	0.367	0.567	0.767	0.767	0.933	1.000	0.567	0.767	0.933	0.633	0.833	0.967	0.567	0.767	0.933	0.767	0.933	1.000	0.158	0.231	0.429
A5	0.433	0.633	0.833	0.633	0.833	0.967	0.900	1.000	1.000	0.833	0.967	1.000	0.433	0.633	0.833	0.767	0.933	1.000	0.833	0.967	1.000	0.103	0.120	0.158
A6	0.633	0.833	0.967	0.433	0.633	0.833	0.567	0.767	0.933	0.500	0.700	0.900	0.633	0.833	0.967	0.567	0.767	0.933	0.633	0.833	0.967	0.176	0.273	0.600
A7	0.567	0.767	0.933	0.567	0.767	0.933	0.700	0.900	1.000	0.433	0.633	0.833	0.433	0.633	0.833	0.567	0.767	0.933	0.433	0.633	0.833	0.107	0.130	0.176
A8	0.833	0.967	1.000	0.300	0.500	0.700	0.767	0.933	1.000	0.833	0.967	1.000	0.767	0.933	1.000	0.567	0.767	0.933	0.633	0.833	0.967	0.120	0.158	0.231

Table A5. Weighted normalized fuzzy-decision matrix of alternatives and criteria.

	C1			C2			C3			C4			C5			C6			C7			C8		
A1	0.040	0.101	0.224	0.050	0.092	0.169	0.027	0.077	0.190	0.106	0.243	0.446	0.005	0.014	0.055	0.056	0.107	0.193	0.039	0.089	0.187	0.007	0.021	0.086
A2	0.040	0.101	0.224	0.047	0.089	0.169	0.032	0.086	0.207	0.106	0.243	0.446	0.005	0.008	0.045	0.051	0.104	0.193	0.023	0.061	0.148	0.007	0.021	0.086
A3	0.071	0.149	0.269	0.013	0.040	0.107	0.057	0.127	0.248	0.051	0.148	0.342	0.039	0.079	0.150	0.051	0.104	0.193	0.047	0.100	0.193	0.003	0.006	0.015
A4	0.071	0.149	0.269	0.021	0.052	0.130	0.057	0.127	0.248	0.078	0.200	0.417	0.032	0.070	0.145	0.038	0.085	0.180	0.047	0.100	0.193	0.005	0.011	0.037
A5	0.040	0.101	0.224	0.035	0.077	0.163	0.067	0.137	0.248	0.115	0.252	0.446	0.022	0.053	0.125	0.051	0.104	0.193	0.051	0.104	0.193	0.003	0.006	0.014
A6	0.058	0.133	0.260	0.024	0.058	0.141	0.042	0.105	0.232	0.069	0.182	0.402	0.032	0.070	0.145	0.038	0.085	0.180	0.039	0.089	0.187	0.005	0.013	0.052
A7	0.052	0.123	0.251	0.032	0.071	0.158	0.052	0.123	0.248	0.060	0.165	0.372	0.022	0.053	0.125	0.038	0.085	0.180	0.027	0.068	0.161	0.003	0.006	0.015
A8	0.077	0.155	0.269	0.017	0.046	0.118	0.057	0.127	0.248	0.115	0.252	0.446	0.039	0.079	0.150	0.038	0.085	0.180	0.039	0.089	0.187	0.004	0.008	0.020
A+	0.077	0.155	0.269	0.050	0.092	0.169	0.067	0.137	0.248	0.115	0.252	0.446	0.039	0.079	0.150	0.056	0.107	0.193	0.051	0.104	0.193	0.007	0.021	0.086
A−	0.040	0.101	0.224	0.013	0.040	0.107	0.027	0.077	0.190	0.051	0.148	0.342	0.005	0.008	0.045	0.038	0.085	0.180	0.023	0.061	0.148	0.003	0.006	0.014

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