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A fuzzy multi-criteria approach to sustainable island-based tourism development

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Abstract. This paper aims to propose a framework by which decision-makers can evaluate and compare alternatives for sustainable island-based tourism development. The uncertainties and risks involved in information and judgment within the evaluation process were taken into account by using a hybrid approach, which combined the Delphi method, fuzzy set theory, and a discrete multi-criteria method based on prospect theory called TODIM (an acronym in Portuguese of interactive and multiple-criteria decision making). The decision making model examined 3 different techniques for aggregating the viewpoints of different decision-makers and explored how the aggregation technique would affect the ranking of the alternatives. To demonstrate the potential application of the proposed approach, it was examined for the development of Hendourabi Island (Iran) for tourism. Results showed that among the 3 alternative development plans, decision-makers preferred the medium-size development alternative, since it offered a balance between benefits of tourism market and costs of project development under an uncertain future. It also allowed for adaptive management. Results also showed that the proposed approach, which reduced loss regret in decision-making under uncertain future, could be used effectively for planning the island development under an uncertain dynamic future considering the risk and uncertainty associated with human judgment.

1. Introduction

The role of sustainable development in the society has been extensively emphasized as echoed by the Earth Summit in 1992 and 2002 held in Rio de Janeiro and Johannesburg, respectively. Sustainability principles in tourism development refer to the environmental, economic, and sociocultural aspects. Various types of tourism such as sustainable tourism, ecotourism, and responsible tourism have many aspects in common, but they are not really all the same. According to the World Tourism Organization (WTO), sustainable tourism is tourism development with a balance between environmental, economic, and socio-cultural aspects to guarantee its long-term sustainability. Applying these concepts to sustainable tourism, the WTO defines sustainable tourism development as meeting the needs of present tourists and host regions while protecting and enhancing opportunities for the future [1]. Ecotourism is defined by The International Ecotourism Society (TIES) as: "Responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and

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education". The principles of ecotourism are: a) to minimize negative environmental impact and b) to spread environmental as well as cultural awareness and respect. Ecotourism is a strategy for supporting conservation and providing communities in and around protected areas with income. It embraces the principles of sustainable tourism in view of the economic, social, and environmental impacts of tourism. It is important to realize that any form of tourism could become more sustainable, but not all forms can be ecotourism. Island-based tourism is a type of tourism in small and very small island destinations that embraces the principles of ecotourism.

Island-based tourism provides various recreation activities and attractions, such as beautiful scenery, natural resources, and water- and land-based activities. It creates an excellent environment for tourism-based experiences, but may result in negative environmental impacts. Small islands as tourism destinations are unique and fragile ecosystems with inherent environmental challenges. Observing sustainability principles in planning and management can maximize the tourism profit while minimizing the negative environmental impacts.

Sustainable tourism development including tourism on small islands is one of the fastest growing areas of tourism research. Hashemkhani Zolfani et al. [2] carried out a comprehensive literature review of sustainable tourism definitions and applications. They showed that sustainable development was intrinsically dynamic. Therefore, it should be considered in different aspects of and perspectives to the dynamic framework of sustainability. They also stressed that decision- and policy-making in the tourism industry should be multi-dimensional and consider causal relations of issues. Moreover, planning as the key to sustainable tourism needs to be coordinated and comprehensive in a long-term vision. Some attempts have been made to identify appropriate tourism sustainability criteria and indicators during the past few decades. For example, Chen [3] evaluated the ecological conditions of Kinmen National Park in Taiwan during 2002–2011 using the tourism ecological footprint and tourism ecological capacity indicators.

Literature review shows that numerous tourism research studies and findings exist on the social and ecological aspects of ecotourism. For instance, it has been emphasized that understanding attitudes and desires of the local communities towards tourism development as well as their involvement and hospitality are the key issues to the success of sustainable tourism development in islands [4]. Regarding tourism market, some researchers have found out that luxury and sustainability are interrelated, and that sustainable tourism encourages a higher spending market in small islands (e.g. [5]). Marion et al. [6] examined the recreation ecology literature and the visitor impacts on vegetation, soil, wildlife, and water resources in wilderness and other protected natural areas. It was emphasized that understanding these impacts and their relationships with influential factors was necessary for land managers in order to select management actions that would effectively avoid or minimize adverse impacts on resources.

Evaluating of the above literature review determines that more research is needed to offer a comprehensive decision-making framework that unites various dimensions of sustainability and incorporates them into models of tourism planning in order to achieve sustainable development. Multi-Criteria Decision-Making (MCDM) is an appropriate tool for planning multidimensional sustainable development. It is a process of evaluating real-world cases in order to find a suitable option among several available options. MCDM is divided into Multi-Objective Decision-Making (MODM) and Multi-Attribute Decision-Making (MADM). MODM is related to decision problems with continuous decision space, whereas MADM concentrates on problems with discrete decision spaces. A typical example of MODM is mathematical programming problems with multiple objective functions. Unlike MODM, in MADM problems, the set of decision alternatives are predetermined. In addition, MCDM can be classified based on the type of the data used in deterministic, stochastic, or Fuzzy MCDM (FMCDM) methods.

Since in various real decision-making cases, decisions are often made based on the subjective preferences of decision-makers and the evaluation, judgment, and decision are based on natural language for different criteria, it is recommended to address this type of information through an FMCDM approach [7,8]. Bellman and Zadeh [8] introduced and applied the theory of fuzzy sets to problems of MCDM as an effective approach to treating vagueness, lack of knowledge, and ambiguity inherent in the human decision-making process.

With this background, this paper proposes an FMCDM approach integrated with prospect theory alongside Delphi technique for sustainable island-based tourism development. The main objective of this study is to provide a framework by which decision-makers can evaluate and compare alternatives for sustainable island-based tourism development under uncertain dynamic future considering the risk and uncertainty associated with human judgment. A qualitative Delphi technique is used to identify a set of qualitative sustainability criteria and to rate the alternatives accordingly. This approach takes into account the uncertainty of the decision matrices, risk behavior, and the preference of the decision-makers to find the best alternative in an MCDM problem while reducing loss regret in decision-making under uncertain future. It examines 3 different techniques of aggregating the viewpoints of different decision-makers and explores how the aggregation technique affects the results. The approach is then applied to the case of Hendourabi Island development in Persian Gulf, Iran. This study offers a novel development and application of the combined FMCDM and Delphi approach to Hendourabi Island sustainable development. It brings some important social, economic, and environmental elements into light, which constitute the identity of the Hendourabi Island directly related to the value given to the Island.

2. Methodology

One of the MCDM methods that takes into account the risk of attitude/preferences of the decision-makers is TODIM (an acronym in Portuguese for iterative MCDM), proposed by Gomes and Lima [9]. TODIM is a particular multi-criteria approach based on the prospect theory. It uses a pairwise comparison between different criteria in order to remove the odds led by comparisons. Fuzzy TODIM (FTODIM) is an extension of TODIM that makes it possible to deal with the inherent uncertainty and imprecision of the process of decision-making by performing the value judgments on a linguistic scale using the hierarchy of norms and fuzzy value judgments.

2.1. Data collection

The main data and information sources for this study include existing research documents and governmental and non-governmental data, interview, and questionnaire. Additional information about data collection including Delphi survey and its reliability and validity are presented below.

2.1.1. Delphi survey

Powell [10] described the Delphi technique as a series of sequential questionnaires or "rounds" interspersed by controlled feedback, which seek to gain the most reliable consensus among opinions of an "expert panel." The Delphi has been shown to be a widely used and flexible method that is particularly useful in achieving consensus in large, complex problems with uncertainty. It is also beneficial when other methods are not adequate or appropriate for data collection. Linguistic scales or fuzzy scales, in contrast to the traditionally used Likert scale, can deal with uncertainty of expert opinions and handle vague situations when an expert lacks sufficient knowledge or certainty about their response. An extended fuzzy Delphi method by Kaufmann and Gupta [11] uses a fuzzy scale by means of triangle membership functions to achieve consensus among the expert assessments. The classical Delphi method has also been extended based on cloud model in order to deal with the fuzziness and uncertainty of the subjective judgments of experts [12].

The sustainability criteria in this study are identified based on the sustainability principles and suggested criteria worldwide as well as the envisioned role, function, and goals of Hendourabi Island in a fuzzy Delphi process. Seven experts in economics, environment management, and systems analysis were selected to participate in the Delphi process and to answer the questionnaires about the criteria for sustainable development of Hendourabi Island. The data collection process included some consecutive rounds. Before the first round, the panelists were interviewed with a set of flexible questions asking them to generate ideas about the issue. To reduce the subjectivity in the evaluation process, participants were initially provided with 22 sustainability criteria identified in relation to sustainable development of Hendourabi Island. Before proceeding to the consecutive rounds, the panelists were asked for their comments on the format, language use, and content validity of the initial list. Experts then identified the most valuable criteria based on the indicators of being relevant, precisely defined, unambiguously related to the assessment goal, sensitive to stress on the ecotourism management and ecological or social systems, and appealing to users. Their experiences were collected and used for designing the first-round questionnaire. Experts were then asked by email to evaluate 3 plans against the selected criteria during 3 survey rounds. Each criterion was related to a key factor of sustainability evaluated against 5 Likert-type scales (from 1 = very low to 5 = very high). Providing feedback to the participants gave the experts the opportunity to revise their answers if necessary. In the second round, the completed questionnaires of the panelists in the previous round were sent to the panel along with the average responses of the first round to provide feedback on the other responses while asking them to revise their own if necessary. In each consecutive round, experts were asked to review the outcome of the previous round and answer whether they agree with that outcome or recommend changes by giving their rationale for making those changes. The iterations were repeated with the goal of reducing the range of responses until "consensus" was achieved. It should be noted that consensus does not mean 100% agreement. Delphi consensus with 70as the standard [13].

2.1.2. Reliability and validity

Before using the data in the MCDM process, the information presented in questionnaires should be evaluated for validity and reliability. Validity, which means accuracy of question design, shows whether or not the questionnaire is able to measure a specific characteristic consistently using a set of questions [14]. Construct validity, which relies on a clear explanation of the construct, is the most valuable and difficult form of validity. Delphi method itself can contribute to construct validity since it uses successive rounds of the questionnaire so that researchers would make sure that the respondents understand the items correctly. Also, the descriptions of parameters in the questionnaire helps the respondents to understand the construct. Construct validity could also be checked by asking the experts to validate the final results.

Reliability refers to consistency of the results and it is related to if the questionnaire produces the same output under the same conditions [14]. For the purpose of estimating the reliability of the questionnaires given to the experts, Cronbach's alpha method is used. Cronbach's alpha index coefficient ranges from 0 to 1, with 0 meaning no consistency and 1 meaning perfect consistency in the measurements.

The standardized Cronbach's alpha (α) is usually calculated using the following expression:

$$\alpha = \frac{k\bar{r}}{(1 + (k-1)\bar{r})}, \tag{1}$$

where k is the number of indicators and $\bar{r}$ is the mean inter-indicator correlation. The Cronbach's value of 0.7 or higher is usually regarded as an indication of acceptable reliability of data.

2.2. Combining prospect theory and fuzzy numbers with MCDM

The original formulation of MCDM methods based on prospect theory was proposed by Gomes and Lima [9], known as TODIM. TODIM's multi-criteria value function is composed of parts whose mathematical descriptions reproduce the gain and loss functions. The global multi-criteria value function of TODIM then aggregates all the measures of the gains and losses by considering all of the considered criteria.

Despite the fact that the TODIM method has been successfully used and empirically validated in different applications, it has some shortcomings because of its inability to deal with inherent uncertainty and imprecision of the process of decision-making, which is present in many MCDM problems. To overcome this problem, the strong aspects of prospect theory and fuzzy numbers have been combined to handle both risk and uncertain MCDM problems by extending TODIM, resulting in FTODIM [15].

FTODIM as a discrete multi-criteria method, is based on an empirically verified model of how people make effective decisions when faced with risk. In *FTODIM* formulation, the global multi-criteria value function aggregates all of the measures of the gains and losses by considering all of the criteria. The *FTODIM* method has been successfully used and empirically validated for different fields of application [9,16].

The MCDM, prospect theory, ranking of alternatives based on dominance, TODIM, fuzzy numbers, and *FTODIM* algorithms are described in the following subsections.

2.2.1. Multi-Criteria Decision-Making (MCDM)

MCDM has experienced signiǐb01cant development in the last few decades mainly due to the wide variety of problems that can be addressed using this methodology. MCDM has been regarded as a suitable set of methods to perform sustainability evaluations as a result of its flexibility and the possibility of facilitating the dialogue between stakeholders, analysts, and scientists. Cinelli et al. [17] highlighted the wide potentials of MCDA in supporting an emerging and heterogeneous area as sustainability assessment. Nevertheless, the classic MCDM methods have shortcomings in dealing with real-world problems, mainly due to the inherent uncertainties and risks involved in human decision-making process.

The extensive number of possible MCDM methods and their extensions results in a problem with proper selection and application of them in specific decision situations. The MCDM methods significantly differ in many dimensions such as complexity, the way in which preferences and evaluation criteria are represented, the type of data aggregation, the possibility of including uncertain data, and the availability of implementations in decision support systems or criteria compensation. Decision-makers are often unable to fully justify their choice of the method applied to solving a specific decision situation. The selection of a multi-criteria method is usually carried out arbitrarily and motivated by the decision-makers' knowledge of a given method or availability of software supporting the method. It is difficult to answer the question of which method is most suitable to solve a given type of problem. The selection of a proper MCDM method for a given decision situation is salient, since various methods can yield different results for the same problem. Wątróbski et al. [18] provided a hierarchical set of characteristics for the methods containing 9 descriptive properties in 56 studied MCDM methods for selecting MCDM methods for decision-making situations.

2.2.2. Prospect theory

Prospect theory, which was first developed by Kahneman and Tversky [19], belongs to the field of cognitive psychology and describes how people make decisions based on judgments under conditions of risk. Prospect theory has successfully been used as the behavioral model of decision-making under risk in many fields. Kahneman and Tversky [19] define the subjective value v of an outcome x as a two-part power function of the form:

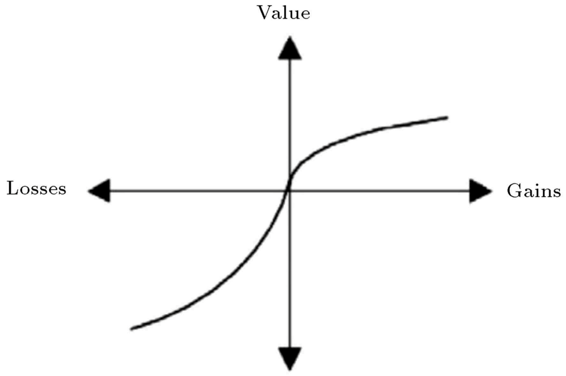

Figure 1. Value function of the prospect theory [19].

$$v(x) = \begin{cases} x^{\alpha} & x \geq 0 \\ -\theta(-x)^{\beta} & x < 0 \end{cases} \quad (2)$$

where α and β are the gain and loss parameters, respectively. The value function, in contrast to the utility function, does not directly take into account the risk (probability). Figure 1 shows a S-shape value function that is concave above the reference or neutral point representing gains, and convex below the reference point representing losses. The concavity for gains describes a risk aversion attitude and the convexity describes a risk seeking attitude. The value function has asymmetric shape and is steeper in the domain of losses than in that of gains implying relative loss aversion.

The parameter θ characterizes loss aversion, such that larger values of θ represent larger loss aversion. Different choices of θ lead to different shapes of the prospect theoretical value function in the negative quadrant. Each shape characteristic of the value function models psychological processes. Kahneman and Tversky [19] observed that in situations involving gains, people tended to be more conservative regarding risk, while in situations involving losses, they were more prone to risk. Therefore, when people have a chance of winning, they prefer a lower but certain gain to the risk for higher although uncertain gains. When a situation involves losses, people prefer to risk losing more but with the possibility of losing nothing than to suffer a smaller but certain loss. Different types of decision-makers can be understood in terms of their risk and loss attitudes. If $\theta > 1$, then an individual is loss averse and weighs losses θ-times more than gains of the same magnitude, which is reflected in a steeper curvature of the value function in the loss domain. In other words, the situations involving losses are usually more relevant and striking than situations involving gains. Hence, greater focus on real or feared losses than on prospective or forgone gains is expected. Strack and Viefers [13] have explained these characteristics as the essential assumptions of prospect theory that we:

- Dislike losses more than we appreciate gains of equal size;
- Dislike losses so much that it makes us willing to take greater risk to avoid them.

In case of risk aversion, $\theta > 1$. Kahneman and Tversky [19] experimentally determined the median values of $\alpha = \beta = 0.88$ and $\theta = 2.25$. Further, they suggested the value of θ between 2.0 and 2.5.

2.2.3. Ranking of alternatives by dominance matrix

Alley et al. [20] suggested a relatively simple method to identify the most preferred alternative by comparing alternatives mutually based on decision-maker's decision matrix. A decision matrix is defined as:

$$A = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}, \quad (3)$$

where x_{ij} is the rating of alternative A_i, $i = 1, \cdots, m$, according to criterion C_j, $j = 1, \cdots, n$. In other words, each row of the matrix gives the rating of one alternative under different criteria. The dominance matrix $\zeta = [\zeta_{ij}]_{m \times m}$ is calculated based on A, where ζ_{ij} is the number of criteria under which alternative j has larger ratings than alternative i, i.e., the number of times that alternative j dominates alternative i. The sum of the jth column of ζ is the number of times that the jth alternative dominates all others. Hence, the most desirable alternative is the one that has the largest column total. Once the best alternative is identified, it is removed from the analysis and a new dominance matrix is calculated for the remaining alternatives to find the second best one. This procedure is repeated until all alternatives are ranked based on their dominance.

2.2.4. TODIM method

TODIM method is a discrete multi-criteria method based on prospect theory. The prospect theory is able to describe decisions between alternatives that involve risk and attempts to model real-life choices rather than optimal decisions. The TODIM method relies on a value function that provides the dominance degree of each alternative over the others with respect to different criteria. As in the prospect theory of Kahneman and Tversky [19], the aim of this value function is to model the gain and loss attitudes of the DM on each criterion. The TODIM method has been applied to different multi-criteria problems including environmental studies. In tourism, the prospect theory and analysis of loss aversion incorporated in TODIM is especially relevant because of the high-risk nature of the tourism industry [21]. In addition, tourism is characterized by high consumer involvement with important psychological connotations.

2.2.5. Fuzzy numbers

In general, people express thoughts and perceptions using natural language, which is often vague or difficult to state mathematically. In various decision-making cases, evaluation, judgment, and decision are based on natural language, which might be vague. To overcome this problem, fuzzy numbers in fuzzy theory are introduced in a way to express linguistic variables appropriately. A fuzzy number can be seen as an extension of an interval with varied grades of membership. In the classical definition of a set, an element is either included or not included in the set. Hence, if we define a membership function for the elements, it takes binary values. However, for a Triangular Fuzzy Number (TFN) $\tilde{A}$ on $\mathcal{R}$, the membership function $\mu_{\tilde{A}}(x) : \mathcal{R} \rightarrow [0, 1]$ is defined as:

$$\mu_{\tilde{A}}(x) = \begin{cases} (x - a_1)/(a_2 - a_1) & a_1 \leq x \leq a_2 \\ (x - a_3)/(a_2 - a_3) & a_2 \leq x \leq a_3 \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

where a_1 and a_3 are the lower and upper bounds of the fuzzy number, respectively, and a_2 is the modal of the fuzzy number (Figure 2).

Adapting the fuzzy numbers approach, answers of an expert to the questionnaire in terms of linguistic scales should be first converted to fuzzy numbers. For a 5-point linguistic scale, several methods of conversion to TFNs have been described by Chen et al. [22]. The first method devised by Chang and Chen [23] for TFNs is generally used as the primary method due to its simplicity, whereas other definitions are addressed in sensitivity analysis. Fuzzy models using TFNs have proven quite effective for solving decision-making problems in which the available information is imprecise. Table 1 gives the definitions used to convert linguistic scales in the questionnaire to fuzzy numbers.

2.2.6. Fuzzy TODIM (FTODIM)

Using the theory of fuzzy sets in problems of MCDMis an effective approach to treating vagueness, lack of knowledge, and ambiguity inherent in the human decision-making process, which is known as FMCDM. Among many FMCDM methods, FTODIM method has its favorable characteristics compared with the conventional approaches. One of its merits is the capacity to treat risk as an important aspect in decision-making process. Moreover, the FTODIM method is able to test specific forms of the loss and gain functions (risks) under uncertainty. Qin et al. [24] proposed an extended TODIM method to handle multi-criteria group decision-making under triangular intuitionistic fuzzy environment. In parallel to FTODIM development, Luo et al. [25] studied the application of probabilistic linguistic relations through a group decision-making problem of evaluating the sustainability of constructed wetlands. Zhang et al. [26] proposed a probabilistic linguistic TODIM method considering the decision-makers' psychological factors.

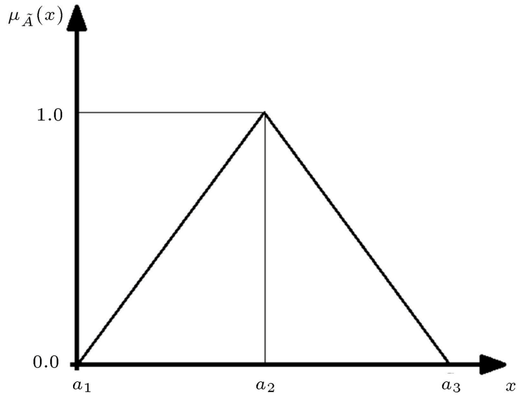

Figure 2. Membership functions of the Triangular Fuzzy Number (TFN).

Table 1. Different methods to convert 5-point linguistic scale to Triangular Fuzzy Numbers (TFNs) [22].

Method	Linguistic scale	Fuzzy number
1	Very low	(0, 0, 0.25)
	Low	(0, 0.25, 0.5)
	Medium	(0.25, 0.5, 0.75)
	High	(0.5, 0.75, 1)
	Very high	(0.75, 1, 1)
2	Very low	(0, 0, 0.3)
	Low	(0, 0.3, 0.5)
	Medium	(0.2, 0.5, 0.8)
	High	(0.5, 0.7, 1)
	Very high	(0.7, 1, 1)
3	Very unimportant	(0, 0, 1/7)
	Unimportant	(0, 1/7, 3/7)
	Fair	(1/7, 3/7, 5/7)
	Important	(3/7, 5/7, 1)
	Very important	(5/7, 1, 1)
4	Very poor	(0, 0, 0.2)
	Poor	(0, 0.2, 0.4)
	Medium	(0.3, 0.5, 0.7)
	Good	(0.6, 0.8, 1)
	Very good	(0.8, 1, 1)

2.2.6.1 FTODIM algorithm

In algorithmic form, implementation of FTODIM is described in the following steps [23]:

Step 1: A fuzzy decision matrix is defined as:

$$\tilde{A} = \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mn} \end{bmatrix}, \tag{5}$$

where $\tilde{x}_{ij}$ is a fuzzy number, which indicates the rating of alternative $\tilde{A}_i$, $i = 1, \cdots, m$, according to criterion C_j, $j = 1, \cdots, n$. A weight vector $W = (w_1, \cdots, w_n)$ is defined corresponding to criteria $C_1, \cdots, C_j$ such that $\sum_{j=1}^{n} w_j = 1$. This weight vector allows for giving more weight to more important criteria. As the data of fuzzy decision matrix originate from different sources, the matrix must be normalized to be dimensionless, which allows a valid comparison of various criteria with each other. Therefore, the fuzzy-decision matrix $\tilde{A} = [\tilde{x}_{ij}]_{m\times n}$ with $i = 1, \cdots, m$ and $j = 1, \cdots, n$ is normalized, which results in the corresponding fuzzy decision matrix $\tilde{R} = [\tilde{r}_{ij}]_{m\times n}$. Jahan and Edwards [27] classified the various normalization techniques and compared their effectiveness with each other. In any normalization process, it is crucial to make a distinction between benefit criteria (whose values are always better when larger) and cost criteria (whose values are always better when smaller). Hence, the criteria are classified into two types: benefit and cost. According to the linear max-min normalization method, the fuzzy normalized value $\tilde{r}_{ij}$ for TFNs is calculated as:

with $k = 1, \cdots, 3$ for cost criteria:

$$\tilde{r}_{ij}^{k} = \frac{\max(a_{ij}^{3}) - a_{ij}^{k}}{\max(a_{ij}^{3}) - \min(a_{ij}^{1})}, \tag{6}$$

with $k = 1, \cdots, 3$ for benefit criteria:

$$\tilde{r}_{ij}^{k} = \frac{a_{ij}^{k} - \min(a_{ij}^{1})}{\max(a_{ij}^{3}) - \min(a_{ij}^{1})}, \tag{7}$$

Step 2: The dominance of each alternative $\tilde{A}_i$, $i = 1, \cdots, m$ over alternative $\tilde{A}_k$, $k = 1, \cdots, m$ concerning criterion C_j, $j = 1, \cdots, n$ is calculated using:

$$\phi_j\left(\tilde{A}_i, \tilde{A}_k\right) = \begin{cases} \sqrt{\frac{w_{jr}}{\sum_{j=1}^{n} w_{jr}} \cdot d\left(\tilde{r}_{ij}, \tilde{r}_{kj}\right)} & \left[m\left(\tilde{r}_{ij}\right) - m\left(\tilde{r}_{kj}\right)\right] > 0 \\ 0 & \left[m\left(\tilde{r}_{ij}\right) - m\left(\tilde{r}_{kj}\right)\right] = 0 \\ \frac{-1}{\theta}\sqrt{\frac{\sum_{j=1}^{n} w_{jr}}{w_{jr}} \cdot d\left(\tilde{r}_{kj}, \tilde{r}_{ij}\right)} & \left[m\left(\tilde{r}_{ij}\right) - m\left(\tilde{r}_{kj}\right)\right] < 0 \end{cases} \tag{8}$$

where w_{jr} is the relative weight of the criterion j with respect to a reference criterion r. The reference criterion is usually defined as the criterion with the highest importance weight. This normalization method is called linear normalization [27]. The parameter θ addresses loss aversion, i.e., it determines the effect of the losses (when $\tilde{r}_{ij} < \tilde{r}_{kj}$). If $\theta > 1$, the losses are attenuated. If $\theta < 1$, the losses are amplified. Thus, parameter θ allows for ranking the alternatives according to the gains and the losses. For large values of θ, the best alternatives are those that provide more gains while for small values of θ, the best alternatives are those that provide small losses. $m(\tilde{r}_{ij})$ and $m(\tilde{r}_{kj})$ stand for the defuzzified values of the fuzzy numbers $\tilde{r}_{ij}$ and $\tilde{r}_{kj}$, respectively. For a fuzzy number such as $\tilde{a} = (a_1, a_2, a_3)$, the defuzzified value is calculated by:

$$m\left(\tilde{a}\right) = \frac{(a_1 + a_2 + a_3)}{3}. \tag{9}$$

The term $d(\tilde{r}_{ij}, \tilde{r}_{kj})$ designates the distance between the two TFNs $\tilde{r}_{ij}$ and $\tilde{r}_{kj}$. In general, the distance between two arbitrary fuzzy numbers $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ is defined by:

$$d\left(\tilde{a}, \tilde{b}\right) = \sqrt{\frac{1}{3}\sum_{i=1}^{3}(a_i - b_i)^2}. \tag{10}$$

Three cases can occur in Eq. (8):

(i) The value of $m(\tilde{r}_{ij}) - m(\tilde{r}_{kj})$ is positive, representing a gain;

(ii) The value of $mm(\tilde{r}_{ij}) - m(\tilde{r}_{kj})$ is nil;

(iii) The value of $m(\tilde{r}_{ij}) - m(\tilde{r}_{kj})$ is negative, representing a loss.

Step 3: The dominance of $\tilde{A}_i$, $i = 1, \cdots, m$, over alternative $\tilde{A}_k$, $k = 1, \cdots, m$, is obtained by:

$$\delta\left(\tilde{A}_i, \tilde{A}_k\right) = \sum_{j=1}^{n} \phi_j\left(\tilde{A}_i, \tilde{A}_k\right). \tag{11}$$

Step 4: The overall dominance of each alternative $\tilde{A}_i$, $i = 1, \cdots, m$ is calculated by normalizing the final matrix of dominance according to:

$$\xi\left(\tilde{A}_i\right) = \frac{\sum_{k=1}^{m} \delta\left(\tilde{A}_i, \tilde{A}_k\right) - \min_i\left\{\sum_{k=1}^{m} \delta\left(\tilde{A}_i, \tilde{A}_k\right)\right\}}{\max_i\left\{\sum_{k=1}^{m} \delta\left(\tilde{A}_i, \tilde{A}_k\right)\right\} - \min_i\left\{\sum_{k=1}^{m} \delta\left(\tilde{A}_i, \tilde{A}_k\right)\right\}}, \tag{12}$$

where $\xi(\tilde{A}_i)$ is the overall dominance of alternative i. Ordering the ξ values provides the final ranks of alternatives. The best alternative is the one with the highest value of ξ.

2.2.6.2. Aggregation of decision matrices of multiple decision-makers

The algorithm described in Section 2.2.6.1 is applied to a single decision matrix coming from one decision-maker. In the case of several decision-makers, to facilitate comparisons among the proposed alternatives, various viewpoints represented by different decision-makers should be aggregated. In this paper, 3 distinct methods of aggregation are defined. For the sake of simplicity, they are referred to as Aggregation 1, Aggregation 2, and Aggregation 3.

Aggregation 1. The first aggregation method aggregates data from different decision-makers by aggregating decision matrices through a weighted average [28]. In this approach, a weight vector $V = \{v_1, \cdots, v_L\}$ is defined corresponding to $DM_1, \cdots, DM_L$ decision-makers. Then, the aggregated decision matrix is calculated using this weight vector. If there is no prior knowledge about vector V, then an equal weight is assigned to all decision-makers. This method is used by Krohling and de Souza [15].

Aggregation 2. The second method of aggregation, proposed by de Souza and Krohling [29], is a different approach from FTODIM1. First, it applies the FTODIM algorithm (Section 2.2.6.1) to each decision-maker's decision matrix separately. As a result, it obtains a distinct vector of overall dominance (ξ) for each decision-maker. Since the decision matrices from different decision-makers are not the same, the vectors of overall dominance (i.e., the ranks of alternatives) are different. In other words, the final rankings of alternatives vary from one decision-maker to another. As a result, the method seeks a global ranking of alternatives. To this aim, the method constructs a matrix of overall dominance (D) as follows:

$$D = \begin{bmatrix} \xi_{11} & \cdots & \xi_{1L} \\ \vdots & \ddots & \vdots \\ \xi_{1m} & \cdots & \xi_{mL} \end{bmatrix}, \tag{13}$$

where ξ_{il} is the overall dominance of alternative i according to decision-maker l. Then, it treats this matrix as a new decision matrix and applies the TODIM algorithm to it. The dominance of each alternative $\tilde{A}_i$, $i = 1, \cdots, m$, over alternative $\tilde{A}_k$, $k = 1, \cdots, m$, concerning decision-maker DM_l, $l = 1, \cdots, L$, is calculated using:

$$\phi_l\left(\tilde{A}_i, \tilde{A}_k\right) = \begin{cases} \sqrt{\frac{v_l}{\sum_{l=1}^{L} v_l} \cdot (\xi_{il} - \xi_{kl})} & (\xi_{il} - \xi_{kl}) > 0 \\ 0 & (\xi_{il} - \xi_{kl}) = 0 \\ \frac{-1}{\theta} \sqrt{\frac{\sum_{l=1}^{L} v_l}{v_l} \cdot (\xi_{kl} - \xi_{il})} & (\xi_{il} - \xi_{kl}) < 0 \end{cases} \tag{14}$$

where all terms have been defined previously. The dominance of $\tilde{A}_i$, $i = 1, \cdots, m$, over alternative $\tilde{A}_k$, $k = 1, \cdots, m$, is obtained by:

$$\delta(\tilde{A}_i, \tilde{A}_k) = \sum_{l=1}^{L} \phi_l\left(\tilde{A}_i, \tilde{A}_k\right). \tag{15}$$

Finally, the global dominance of each alternative $\tilde{A}_i$, $i = 1, \cdots, m$, is calculated by:

$$\xi\left(\tilde{A}_i\right) = \frac{\sum_{k=1}^{m} \delta\left(\tilde{A}_i, \tilde{A}_k\right) - \min_i \left\{ \sum_{k=1}^{m} \delta\left(\tilde{A}_i, \tilde{A}_k\right) \right\}}{\max_i \left\{ \sum_{k=1}^{m} \delta\left(\tilde{A}_i, \tilde{A}_k\right) \right\} - \min_i \left\{ \sum_{k=1}^{m} \delta\left(\tilde{A}_i, \tilde{A}_k\right) \right\}}. \tag{16}$$

Aggregation 3. The third method of aggregation is called pessimistic aggregation [28], since it takes the "worst" case viewpoint into account in order to minimize risk. In this approach, decision matrices from all decision-makers are compared with each other to construct a new decision matrix such that the worst rating for each criterion is chosen for each alternative. Then, the FTODIM method (Section 2.2.6.1) is applied to this new decision matrix. Pessimistic aggregation attempts to minimize risk by considering the "worst" case viewpoint. In contrast, an optimistic aggregation, as the name implies, provides the "best" case viewpoint. In realistic situations, it is doubtful that this type of aggregation would have many useful applications.

3. Case study

Iran's famous historical sites have been attracting visitors from within and outside the region for centuries. One such tourist attraction location is the Kish Island located in the Persian Gulf. Kish Island attracts people from Iran, neighboring countries, and all over the world as it is being operated by the country's Kish Free Zone Organization (KFZO) with no visa requirement. There are other smaller islands located near Kish Island that could be further developed for additional tourist attraction. The case study for tourism development in one small island, named Hendourabi, is discussed below.

Hendourabi (Figure 3) is an Iranian Island in the Persian Gulf with an area of 22 square kilometers. The island is located 28 kilometers away from the popular Kish Island and its distance to the coastline is only 8 kilometers at 26°40′N53°38′E. While Kish, the main island, has already been established as an international tourism destination since more than 40 years ago and further developed and extended in recent decades, the neighboring Hendourabi Island has not

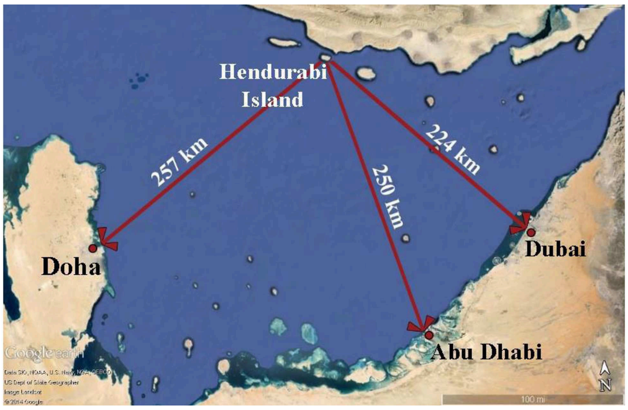

Figure 3. Location of the island in relation to the southern Persian Gulf shorelines [31].

yet been discovered for tourism. Although being entirely undeveloped yet, Hendourabi Island features a strong basis for developing tourism, mainly due to its natural beauty and location. One of its attractions is the wild and original nature of the island. Major tourism activities in Hendourabi Island focus on water activities as core theme, including corral riffs journeys, snorkeling/diving, swimming/beachside, surfing, and fishing.

Hendourabi Island has a unique and fragile ecosystem due to the environmentally susceptible intertidal zone and coral reef ecosystems. Persian Gulf, in general, is one of the areas showing serious declination in coral reefs. This rich ecosystem, defined as the rainforest of the sea, has ecological, economic, medical, recreational, and cultural values for communities. Human activity is one of the main factors that threaten the health of corals [30]. Increase in sea temperature, sea level, and sea pH are broader threats associated with climate change. High salinity of water, oil pollution, water and air pollution, poor land practices, coastal development, recreation, ship grounding sedimentation, urban runoff toward the sea, coral mining, overfishing, and diving are reported as threats to the coral reefs in the region. Vulnerability assessments to understand impacts of climate change on ocean and coastal socio-ecological systems as well as to recognize the feasibility or suitability considerations relevant to implementing coastal adaptation strategies are important for the economies and livelihoods. It is also essential to devise methodologies for bridging the gap between climate science, law, and policy to advance coastal adaptation planning. Regarding the coastal and marine nature of Hendourabi Island and its relatively small area, the socio-economic and environmental integrity of the island is crucial.

KFZO has adopted the vision to develop Hendourabi Island as a place for high-quality tourism targeting both domestic and international tourists. An assessment of potential target groups of Hendourabi Island leads to the selection of domestic upper-middle income groups and the upper-middle and upper-class groups from neighboring countries as the most promising tourism groups of the future. In addition, Hendourabi faces significant competition by some international destinations such as the UAE and Southeast Asia with similar attractive seasons. Instead of forming competitions with larger neighboring tourist destinations, Hendourabi can be developed as a complementary element, especially to the Kish Island. This proximity even allows to draw synergies by combining the value propositions of both islands. Therefore, tourists staying at Kish Island could come to Hendourabi Island for single- or multiple-day tours.

Considering the cultural and comfort characters of Hendourabi Island as well as its location with minimal distance to Kish Island as Iran's number-one island for tourism destination, the vision of the Hendourabi Island is "calm island" with the following roles and functions [31]:

- Sea-based development in the synergistic link with Kish Island and other surrounding islands;
- Locating deployment and provision of services with high quality and environmentally friendly standards;
- Representing the unique features of the southern zone of Iran and its peaceful and beautiful marine nature;
- Attracting tourists and special users from national to transnational levels.

The strategic goal of the plan is "Sustainable Development of Hendourabi Island" with the main goals as:

- Balanced loading of activities with fragile and vulnerable natural environment capacities;
- Making income, sustainable employment, and self-sufficiency with an emphasis on private sector investment;
- Completing the Kish tourism network as well as the diversity of activities;
- Maximum safety and service capabilities against natural and human hazards.

As the result, sustainable development of the island with an emphasis on the mutual synergy of economic efficiency and environmental protection to meet the growing desire for natural-coastal tourism facilities at the national and transnational level is one of the main principles of intervention.

Based on the sustainability pillars, 3 development alternative plans have been identified. The significance of each of them varies depending on its importance for sustainable development of Hendourabi Island. Accordingly, the consultants have proposed 3 alternative

Table 2. Comparison of alternative plans [31].

Characteristic	Plan 1 Small-scale tourism development	Plan 2 Moderate tourism development	Plan 3 Large-scale tourism development
Persons per km^2	311	398	485
Theoretical max. number of people on island (high-season peak day, 100% occupancy)	6901 p	8828 p	10762 p
Total daily max. number of tourists (high-season/peak day)	3080	4080	5080
Total number of annual visitors	343090	457453	518211
Total required building land, ha	1147	1357	1576
Total number of employees	2077	2580	3088
Hendourabi village permanent residence	3821	4675	5600
Required developed (building) land per tourist, m^2/p	372	333	310

plans as described in Table 2 [31]. The first alternative, called "environmental-oriented development plan," emphasizes the environmental aspects and deals more with the activities which take place in the nature, whereas the third alternative, called "economic-tourism development plan," is based on economic self-sufficiency. The second alternative is between the first and third alternatives in terms of environmental and economic dimensions of sustainability. In this study, these 3 alternative development plans are evaluated and ranked using the chosen sustainability criteria and the FTODIM algorithms.

4. Results and discussion

4.1. Delphi data collection results

4.1.1. Sustainability criteria and ratings

The present study uses the Delphi method to facilitate identifying the potential sustainability criteria and rating the alternatives using a 5-point Likert scale. In the first run of the Delphi process, a questionnaire of 17 questions (17 criteria) as the result of the interviews was emailed to 7 different experts to be filled out. In each consecutive round, experts were asked to review the outcome of the previous round and either agree with that outcome or recommend. In this study, the third round was the final round, because there were small differences between the first two rounds and no difference in the final scores in round three. Therefore, in the third round, it was concluded that the experts had reached acceptable consensus. Since consensus was achieved effectively among the expert assessments, we did not use a fuzzy scale in the Delphi process. Rather, we used a fuzzy scale for the experts' evaluations in the FMCDM process. The final questionnaires (Table 3) were analyzed and checked for reliability and validity of the results.

4.1.2. Evaluation of the reliability of collected data

The calculated values of Cronbach's alpha (Table 4) show that the questionnaire is reliable to evaluate development plans based on sustainability criteria. Cronback's alpha is also calculated in the case of omission of each individual question from the questionnaire (Table 5). If alpha increases after omission of each item, omitting that question can improve the internal consistency of the questionnaire. Based on this table, omission of any question, except for question 17, will result in a lower Cronbach's alpha. Therefore, only this question is removed from the questionnaires.

4.2. Ranking of plans based on dominance matrix

To rank plans using the methodology described in Section 2.2.2, decision matrices from all decision makers are aggregated by Aggregation 1 (Table 6) followed by calculating the dominance matrix (Table 7). To further investigate the potential effects of aggregation on final results, the decision matrices are also combined by Aggregation 3 method (Table 8). Then the dominance of the plans is calculated based on the aggregated decision matrix (Table 9). The ratings of alternatives in the decision matrix of Aggregation 1 method are real numbers since they are the averages of ratings from

Table 3. Classification of the important sustainability criteria used as the output in Delphi process for assessing Hendourabi Island ecotourism.

Sustainability principle	Sustainability factor	Criteria
Environmental	Vulnerability (human, ecosystem, environment)	1. Endangering the island's biological resources as the main source of natural tourism 2. Loading the island's ecological carrying capability 3. Human vulnerability-severity of natural risks such as earthquake 4. Human vulnerability-military risks due to maritime status
Economic	Effectiveness of the development plan	5. Expanding the range of tourists and increasing revenue 6. Effectiveness of the development plan (land required per visitor) 7. The speed of realization
Economic	Self-sufficiency	8. Sustainable employment, investment attractiveness, and increased revenue
Economic	Volume of investment	9. Cost of investing and the need for huge investments with increasing loading on the island
Economic	Flexibility of development	10. Flexibility for phase-to-phase development and operations
Economic	Economic risks	11. Concerns about the failure to attract enough tourists due to the presence of powerful and competing tourist centers around the island 12. Concerns about the failure to attract enough tourists due to political reasons 13. Concerns about the failure to attract enough tourists due to climate change 14. Concerns about not attracting foreign tourists to increase the tourism industry's revenue 15. Concerns about limitation of land allocation to the investor
Social	Compliance with calm island characters	16. Island's completeness in the Kish tourism network, diversity of activities, and supplement to Kish Island tourism 17. Concerns about attracting less investors due to restrictions on land allocation to the investors

Table 4. The values of Cronback's alpha for different plans under initial and final questionnaires.

Questionnaire	α		
	Plan 1	**Plan 2**	**Plan 3**
Initial	0.63	0.65	0.65
Final	0.72	0.70	0.66

all decision makers. The ratings of alternatives in the decision matrix of Aggregation 3 method, on the other hand, are integer numbers as the original ratings are given on a 5-point linguistic scale. This aggregation method chooses the worst viewpoint of decision makers for each plan under each criterion. According to the dominance matrix of Aggregation 1 method (Table 6), Plan 2 is favored by the average viewpoints of all decision makers. However, Aggregation 3 method, whose strategy is to assign the most pessimistic ratings among all decision-makers to each plan for minimizing risks, suggests that Plan 1 is the most desired development plan, since its costs of failure under uncertain future are less than those of the other two plans.

4.3. FTODIM results

Using the methods described in Section 2.2.3, the data obtained from each questionnaire are converted to TFN by the first method described in Table 1. Identical weights are assigned to all criteria. In addition, the loss aversion parameter is assumed to be θ=2. The FTODIM algorithm is applied to each decision-maker's decision matrix separately (Section 2.2.6.1). Then, the information from different decision-makers are combined using 3 aggregation methods described in Section 2.2.6.2. The global dominance of each alternative, according to each decision-maker and 3 aggregation methods, is presented in Table 10 and Figure 4. Figure 4 shows the overall values obtained for the FTODIM for each of the 7 DMs. This figure is a convenient form of eliciting the preference structure of the DMs. The higher values of dominance (ξ) show

Table 7. The dominance matrix calculated for aggregated decision matrix (Table 6) using Aggregation 1.

	Plan 1	**Plan 2**	**Plan 3**
Plan 1	—	8	6
Plan 2	7	—	3
Plan 3	9	13	—
Sum	16	21	9

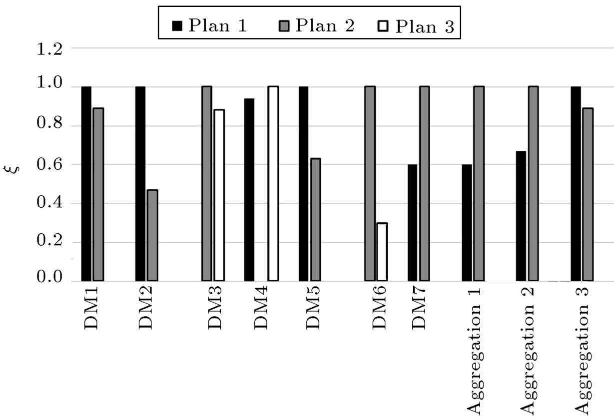

Figure 4. Dominances of Plans based on each decision-maker's (DM's) rating, separately, and the overall dominances in Aggregation 1, Aggregation 2, and Aggregation 3 methods.

better ranks. Results show that decision-makers prefer Plan 2 according to Aggregation 1 and Aggregation 2 methods, since it is a medium-size tourism development plan that offers a balance between benefits of tourism market and costs of project development under an uncertain future. Aggregation 3 method, on the other hand, shows that Plan 1 is the preferred plan since, it involves a risk aversion approach which prefers lower benefits with lower risks rather than higher benefits under higher risks. Hence, it chooses Plan 1 since this plan requires less investment than Plans 2 and

Table 5. The values of Cronback's alpha if each question is omitted.

Plan	Values of Cronback's alpha for each omitted question																
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	0.62	0.62	0.57	0.57	0.69	0.71	0.56	0.63	0.64	0.58	0.62	0.57	0.59	0.62	0.71	0.62	0.72
2	0.63	0.57	0.63	0.66	0.64	0.66	0.63	0.68	0.62	0.62	0.60	0.60	0.58	0.63	0.68	0.65	0.70
3	0.59	0.55	0.64	0.65	0.69	0.67	0.57	0.64	0.72	0.64	0.55	0.57	0.63	0.62	0.65	0.71	0.66

Table 6. Aggregated decision matrix using Aggregation 1 method.

Plan	Criterion															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	4.13	3.00	3.25	3.13	2.25	2.00	3.38	3.13	2.00	3.63	3.63	3.00	3.00	2.50	2.50	2.87
2	3.25	3.25	3.25	3.25	2.38	2.38	2.50	2.25	2.75	2.13	3.25	2.00	2.25	3.38	3.13	3.38
3	2.25	3.13	2.88	2.88	2.25	2.63	2.25	1.88	2.63	1.75	2.88	1.63	1.88	4.00	3.50	3.25

Table 8. Aggregated decision matrix using Aggregation 3 method.

Plan	Criterion															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	5	4	4	4	4	2	3	3	2	5	5	5	4	4	3	4
2	4	5	4	5	3	3	4	3	2	3	5	3	4	5	4	5
3	3	4	3	4	3	4	4	2	3	3	4	3	3	5	4	3

Table 9. The dominance matrix calculated for aggregated decision matrix (Table 8) using Aggregation 3.

	Plan 1	**Plan 2**	**Plan 3**
Plan 1	—	7	5
Plan 2	4	—	2
Plan 3	9	8	—
Sum	13	15	7

3, and if the tourism project development encounters unforeseen obstacles due to uncertainties, Plan 1 would entail lower costs/losses than Plans 2 and 3. A notable strategy used in this research is that some of the criteria under which the plans are evaluated specifically address uncertainties involved in tourism development (Table 3). These criteria along with the Aggregation 3 method provide valuable information for tourism managers who put higher emphasis on risk aversion methods.

4.4. Sensitivity analysis of parameters of FTODIM

In order to investigate the effects of uncertain parameters on the ranking of the plans, a sensitivity analysis is carried out based on Aggregation 1 and Aggregation 2 methods that present Plan 2 as the best alternative. The aim of this analysis is to investigate if uncertainty in the parameters of the FTODIM algorithm would change the final conclusion.

4.4.1. Sensitivity analysis of the weights of criteria

Considering equal weights for all decision-makers, assuming $\theta = 2$, and using the first method described in Table 1 to define TFNs, the weights of criteria are systematically altered to assess the sensitivity of final results to the weights of criteria. All criteria are classified into 3 sustainability principles and 7 sustainability factors (Table 3). The weight of each sustainability principle is increased by 10, 20, and 30% with respect to other sustainability principles, and the dominances of plans are calculated using FTODIM algorithm along with Aggregation 1 and Aggregation 2 methods (Table 11). Figure 5 presents the values of the dominance of Plan 1 under different weighting schemes. It suggests that by assigning a larger weight to environmental principle, the dominance of Plan 1 increases, while by giving a larger weight to economic principle, the dominance of this plan decreases. The reason is that Plan 1 is associated with the lowest tourism development among the plans and hence, it is in favor of environment, but opposed to economic gain. A similar analysis is done based on sustainability factors (Table 12). Results show that changes in the weights of criteria up to 30% do not alter the final ranking of plans. In all cases, Plan 2 is the most desirable alternative with Plan 1 closely behind it. In addition, in all cases, Plan 3 is the least desirable alternative. Among the sustainability factors, volume of investment, flexibility of development, and economic risks seem to be the most influential factors that could potentially change the final outcome of the decision-making algorithm. These findings are valid for both Aggregation 1 and Aggregation 2 methods. The sensitivity of the dominance of Plan 1 to changes in the weights of sustainability factors is demonstrated in Figure 6.

4.4.2. Sensitivity analysis of fuzzy numbers

Considering equal weights for decision-makers, equal weights for criteria, and setting $\theta = 2$, the dominances of plans are calculated based on 4 different definitions of fuzzy numbers (Table 1). The constancy of the values of the dominance of Plans 2 and 3 and little variation in the value of the dominance of Plan 1 show insensitivity of the analysis to the definition of fuzzy numbers (Table 13) and reinforcing confidence in the findings. Hence, the final ranking of the plans is not affected by changing the definition of TFNs such that Plan 2 and Plan 3 are the most and least

Table 10. Dominance of each plan (ξ) obtained by applying Fuzzy TODIM (FTODIM) to each Decision-Maker (DM), separately, and aggregating the results from decision-makers using 3 aggregation methods.

Plan	**DM1**	**DM2**	**DM3**	**DM4**	**DM5**	**DM6**	**DM7**	**Aggregation 1**	**Aggregation 2**	**Aggregation 3**
1	1.00	1.00	0.00	0.94	1.00	0.00	0.60	0.60	0.67	1.00
2	0.89	0.47	1.00	0.00	0.63	1.00	1.00	1.00	1.00	0.89
3	0.00	0.00	0.88	1.00	0.00	0.30	0.00	0.00	0.00	0.00

Table 11. Results of the sensitivity analysis of the weights of criteria in which the dominances of Plan 1 (ξ_1), Plan 2 (ξ_2), and Plan 3 (ξ_3) are calculated by increasing the weights of one sustainability principle with respect to other sustainability principles. Each row of the table presents the dominance of plans if the weights of the corresponding sustainability principle is increased.

Sustainability principle	ξ_1	ξ_2	ξ_3	ξ_1	ξ_2	ξ_3	ξ_1	ξ_2	ξ_3
	10% increase in weight			20% increase in weight			30% increase in weight		
Aggregation 1									
Environmental	0.56	1.00	0.00	0.57	1.00	0.00	0.59	1.00	0.00
Economic	0.64	1.00	0.00	0.62	1.00	0.00	0.61	1.00	0.00
Social	0.60	1.00	0.00	0.60	1.00	0.00	0.60	1.00	0.00
Aggregation 2									
Environmental	0.64	1.00	0.00	0.65	1.00	0.00	0.66	1.00	0.00
Economic	0.66	1.00	0.00	0.64	1.00	0.00	0.63	1.00	0.00
Social	0.66	1.00	0.00	0.67	1.00	0.00	0.67	1.00	0.00

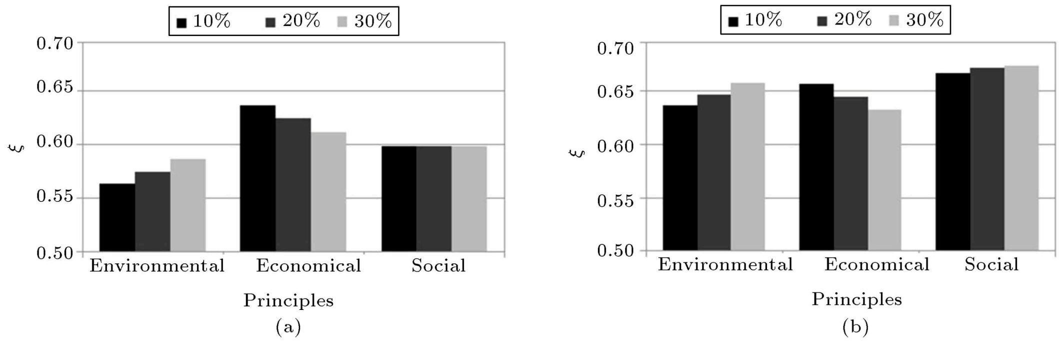

Figure 5. Sensitivity analysis of the effects of sustainability principles on the dominance of Plan 1 based on FTODIM algorithm using (a) Aggregation 1 and (b) Aggregation 2 methods.

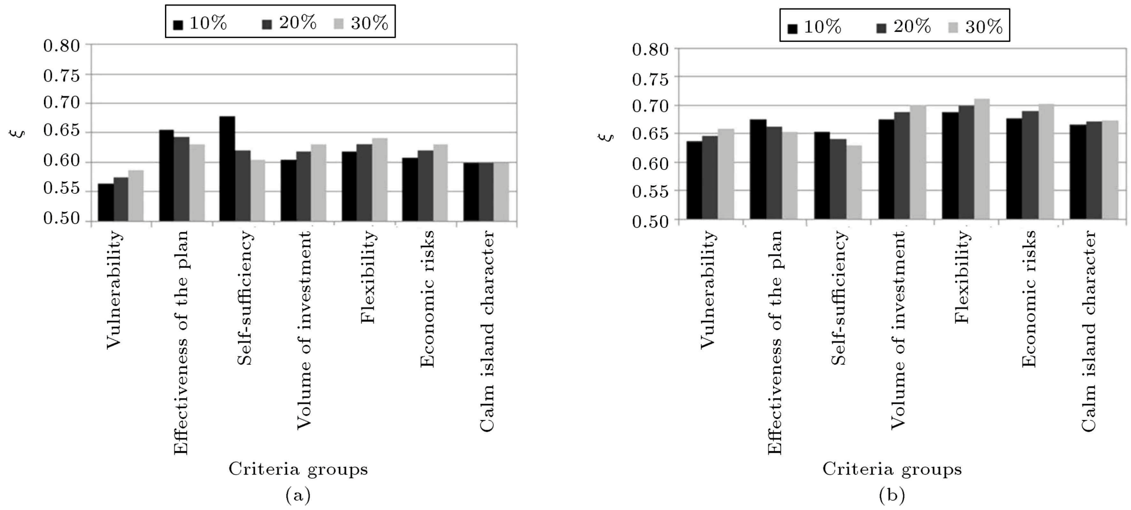

Figure 6. Sensitivity analysis of the effects of sustainability factors on the dominance of Plan 1 based on FTODIM algorithm using (a) Aggregation 1 and (b) Aggregation 2 methods.

desired alternatives, respectively, based on all fuzzy number definitions. Figure 7 also supports the fact that the dominances of plans are almost insensitive to the definition of fuzzy numbers in the proposed methodology.

4.4.3. Sensitivity analysis of loss aversion parameter (θ)

The value function of the prospect theory is determined by the value of loss aversion parameter (θ). Table 14 and Figure 8 show that the final ranking of plans is

Table 12. Results of the sensitivity analysis of the weights of criteria in which the dominances of Plan 1 (ξ_1), Plan 2 (ξ_2), and Plan 3 (ξ_3) are calculated by increasing the weights of one sustainability factor with respect to other sustainability factors. Each row of the table presents the dominance of plans if the weight of the corresponding sustainability factor is increased.

Sustainability factor	ξ_1	ξ_2	ξ_3	ξ_1	ξ_2	ξ_3	ξ_1	ξ_2	ξ_3
	10% increase in weight			20% increase in weight			30% increase in weight		
Aggregation 1									
Vulnerability (human, ecosystem, environment)	0.56	1.00	0.00	0.57	1.00	0.00	0.59	1.00	0.00
Effectiveness of the development plan	0.65	1.00	0.00	0.64	1.00	0.00	0.63	1.00	0.00
Self-sufficiency	0.68	1.00	0.00	0.62	1.00	0.00	0.60	1.00	0.00
Volume of investment	0.60	1.00	0.00	0.62	1.00	0.00	0.63	1.00	0.00
Flexibility of development	0.62	1.00	0.00	0.63	1.00	0.00	0.64	1.00	0.00
Economic risks	0.61	1.00	0.00	0.62	1.00	0.00	0.63	1.00	0.00
Compliance with calm island characters	0.60	1.00	0.00	0.598	1.00	0.00	0.60	1.00	0.00
Aggregation 2									
Vulnerability (human, ecosystem, environment)	0.64	1.00	0.00	0.64	1.00	0.00	0.66	1.00	0.00
Effectiveness of the development plan	0.67	1.00	0.00	0.66	1.00	0.00	0.65	1.00	0.00
Self-sufficiency	0.65	1.00	0.00	0.64	1.00	0.00	0.63	1.00	0.00
Volume of investment	0.67	1.00	0.00	0.69	1.00	0.00	0.67	1.00	0.00
Flexibility of development	0.689	1.00	0.00	0.70	1.00	0.00	0.71	1.00	0.00
Economic risks	0.67	1.00	0.00	0.69	1.00	0.00	0.70	1.00	0.00
Compliance with calm island characters	0.67	1.00	0.00	0.67	1.00	0.00	0.67	1.00	0.00

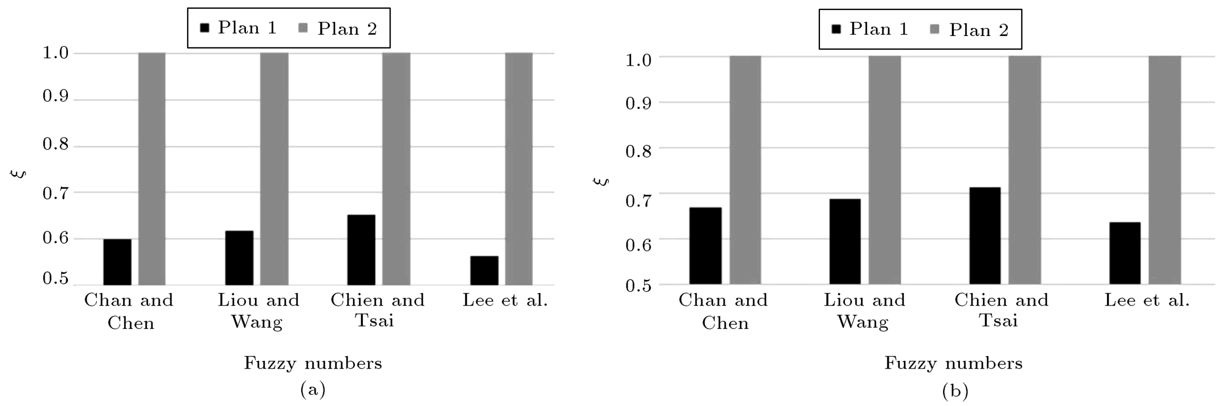

Figure 7. Sensitivity analysis of the effects of the definition of fuzzy numbers on the dominances of plans based on FTODIM algorithm using (a) Aggregation 1 and (b) Aggregation 2 methods. The dominance of Plan 3 is zero in all cases.

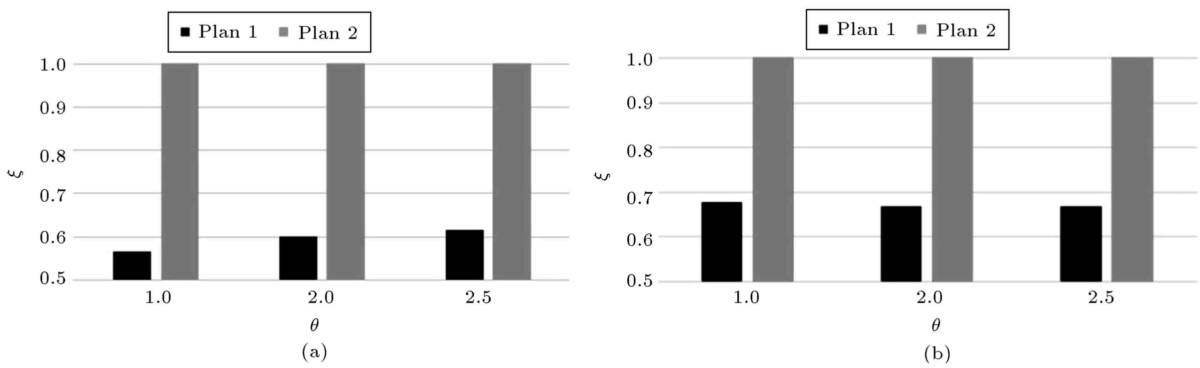

Figure 8. Sensitivity analysis of the effect of loss aversion parameter θ on the dominances of plans based on FTODIM algorithm using (a) Aggregation 1 and (b) Aggregation 2 methods. The dominance of Plan 3 is zero in all cases.

Table 13. Results of sensitivity analysis of the definition of fuzzy numbers in which the dominances of Plan 1 (ξ_1), Plan 2 (ξ_2), and Plan 3 (ξ_3) are calculated based on different definitions of Triangular Fuzzy Numbers (TFNs).

Fuzzy number method	Aggregation 1			Aggregation 2		
	ξ_1	ξ_2	ξ_3	ξ_1	ξ_2	ξ_3
1	0.60	1.00	0.00	0.67	1.00	0.00
2	0.62	1.00	0.00	0.68	1.00	0.00
3	0.65	1.00	0.00	0.71	1.00	0.00
4	0.56	1.00	0.00	0.63	1.00	0.00

Table 14. Results of sensitivity analysis of the dominances of Plan 1 (ξ_1), Plan 2 (ξ_2), and Plan 3 (ξ_3) for loss aversion parameter (θ).

θ	Aggregation 1			Aggregation 2		
	ξ_1	ξ_2	ξ_3	ξ_1	ξ_2	ξ_3
1	0.56	1.00	0.00	0.68	1.00	0.00
2	0.60	1.00	0.00	0.67	1.00	0.00
2.5	0.61	1.00	0.00	0.67	1.00	0.00

robust against the loss aversion parameter. Although higher values of θ show lower tolerance for "cost criteria," as explained by the behavior of the value function, even the maximum value of 2.5 is not high enough to change the overall ranking of the plans in favor of Plan 1.

5. Conclusion

In the context of sustainable development planning discussed in this paper, the combined application of FTODIM framework and Delphi process was found to be an effective tool for evaluating sustainable tourism development in small islands. The above techniques were specifically used for sustainable development decision making regarding Hendourabi Island in Kish Island and the results obtained from this study showed that:

- Small island sustainable development problem could have only been described on the basis of a system comprising alternatives with qualitative criteria and objectives faced with the uncertain future conditions, judgment uncertainties, and risks;
- Loss regret in small island development decision-making under uncertain future could be reduced using the loss aversion prospect theory;
- With regard to the small number of studies for this area, on the one hand, and more coastal development plans in the country and worldwide, on the other hand, the proposed approach and methodology could help the planners to make better informed and effective decisions.

While good progress has been made with the current study, there are some issues that could be addressed to improve the outcome of the modeling tool in future studies:

- Investigating the feasibility of other fuzzy Delphi methods such as Cloud Delphi Model (CDM) for capturing uncertainties of subjective cognition and judgmental inputs as well as complex, large, and multidisciplinary real-life decision problems;
- Exploring how a future scenario analysis offers a framework that includes future in present decision-making for developing a sustainable plan, considering the uncertainties and dynamics of the natural and human drivers of the future and how the consideration of multiple possible futures contributes to robustness of planning;
- Adding the capability of automatic sensitivity analysis to the FTODIM model to calculate the changes in the final scores of alternatives in light of changing in the weight of particular criteria and ranks of alternatives, immediately.

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