Article

Developing a Risk-Based Consensus-Based Decision-Support System Model for Selection of the Desirable Urban Water Strategy: Kashafroud Watershed Study

Reza Javidi Sabbaghian [1] and A. Pouyan Nejadhashemi [2],*

[1] Department of Civil Engineering, Hakim Sabzevari University (HSU), Sabzevar 96179-76487, Iran; r.javidi.s@hsu.ac.ir
[2] Department of Biosystems and Agricultural Engineering, Michigan State University (MSU), East Lansing, MI 48824, USA
* Correspondence: pouyan@msu.edu; Tel.: +1-517-432-7653

Abstract: In recent years, complexities related to a variety of sustainable development criteria and several preferences of stakeholders have caused a serious challenge for selecting the more desirable urban water strategy within watershed. In addition, stakeholders might have several risk attitudes depending on the number of criteria satisfied by water strategies. Accordingly, a risk-based consensus-based group decision-support system model is proposed for choosing the more desirable water strategy, using the external modified ordered weighted averaging (EMOWA) and internal modified ordered weighted averaging (IMOWA) operators. The operators calculate the scores of strategies in several risk-taking attitudes of group decision-making, considering the sustainable development criteria. Additionally, the consensus-seeking phase is considered using a risk-based weighted Minkowski's method. This model is successfully implemented for the Kashafroud urban watershed in Iran, for selecting the more desirable urban water strategy in 2040. Accordingly, in the completely risk-averse viewpoint, the stakeholders select the combined supply-demand management strategy satisfying all of the criteria. In contrast, in the completely risk-prone standpoint, the stakeholders choose the demand management strategy satisfying at least one criterion. Developing the risk-based consensus-based group decision-support system model is suggested for integrated urban watershed management for selecting the more desirable strategy, satisfying the sustainable development criteria.

Keywords: integrated urban watershed management; group decision-support system; risk analysis; group consensus; Kashafroud watershed

1. Introduction

According to the recent reports published by United Nations, the population of the world has been estimated at 7.7 billion people in 2019 and projected to continue its increasing trend to around 8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion in 2100 [1]. Furthermore, it is predicted that most of the world population will live in urban regions rather than rural areas. The growth of the urban population faces some challenges, including unsuitable urban planning and management, insufficient public services, social and cultural anomalies, economic problems associated with urban poverty, environmental contamination, and supplying secure and sustainable water [1,2].

Amongst the aforementioned urban challenges, the water supply is one of the most serious. Concerning water supply, water withdrawal from renewable resources, water transfer, treatment of

wastewater, water allocation for several demands, satisfying security and sustainability, and consensus-seeking among urban stakeholders with different preferences are the main issues [2,3]. Therefore, the water supply issues should be met by implementing desirable water strategies, which consider multiple sustainable development criteria [4]. Additionally, the several preferences of multiple stakeholders regarding the relevant water demands should be satisfied and group consensus could be achieved [5]. Accordingly, Parkinson et al. have presented the integrated urban watershed management (IUWM) approach, which has been developed for better management of water and wastewater strategies in an urban setting [6].

One of the most complicated challenges for implementing IUWM is increasing the variety of sustainable development objectives, including water resources sustainability, environmental sustainability, socio-economic sustainability, and the related criteria [4,7]. This has led to a serious problem for selecting the more desirable urban water strategy, by which the sustainable development objectives and the important relevant criteria should be satisfied, in addition to achieving the group consensus among the stakeholders. Accordingly, implementing IUWM requires evaluation of the water strategies for supplying the urban demands, while considering the sustainable development criteria and the final group agreement [8,9].

The other significant challenge for implementing IUWM is related to the variety of risk-taking attitudes of stakeholders' groups [10]. The risk-taking attitudes represent the number of criteria that should be satisfied by the urban water strategies [11,12]. The risk-taking cases, which are identified by the risk-taking degrees, are expressed by some linguistic phrases such as "selecting the more desirable strategy for satisfying all criteria" in the completely risk-averse viewpoint, "selecting the more desirable strategy for satisfying at least one criterion" in the completely risk-prone standpoint, and the other cases between these two limits [13,14].

In order to take on the aforementioned challenges, an appropriate model for IUWM should be developed to consider the sustainable development objectives, risk-taking attitudes of stakeholders, and a final group consensus in evaluation of urban water strategies. Simonovic and Bender analyzed the collaborative planning-support system (CPSS) model, as the subset of the decision-support system (DSS) model, which considers all relevant aspects of sustainable water resources planning and management, especially in the process of criteria selection [15]. In the group decision support system (GDSS) approach, the main three issues, such as selection of criteria, generation of alternatives, and evaluation of alternatives based on the criteria are considered based on the balancing and reinforcing aspects for better decision analysis [16–18]. Accordingly, developing a group decision-support system (GDSS) model within an urban watershed needs to analyze a multiple criteria decision-making (MCDM) process, in which the final criteria and water strategies are selected, the strategies are evaluated with respect to the criteria, and the water strategies are ranked for several risk-taking cases.

For analyzing the MCDM process in a GDSS model, a large variety of methodologies have been utilized, of which the most frequently used methods have been well demonstrated in the literature [19]. The most important methods are classified into four categories, including: scoring methods [20], distance-based methods [20–23], outranking methods [20,24–26], and pair-wise comparisons methods [27,28]. The differences between these methods are related to their strategies for solving MCDM problems.

For risk analysis in the MCDM process, some of the risk-based methodologies have been utilized. The most commonly used method is using the family of the ordered weighted averaging (OWA) operator, which considers the risk analysis in the decision-making process [4,8,9]. The OWA family includes a group of operators with several properties. In this family, the most frequently used operators are the OWA, induced ordered weighted averaging (IOWA), and hybrid weighted averaging (HWA). The OWA operator considers only the risk-taking attitudes and disregards the criteria weights. The IOWA operator considers the risk-taking attitudes and the importance orders of criteria, whereas it ignores the criteria weights. The HWA operator considers the risk-taking attitudes and criteria weights, while disregards the stakeholders' power weights [11,12].

In recent years, related to the context of urban water management, several studies have been done based on MCDM methodologies [29–37]. However, in this paper, a risk-based consensus-based GDSS model is developed for IUWM within the study area of an urban watershed. Accordingly, the following improvements are performed in this study that are distinctive comparing to similar works in IUWM:

- Developing a comprehensive GDSS model for IUWM based on group risk considerations and group consensus measuring.
- Improving the OWA operator properties, considering the risk-taking attitudes of decision-making, importance degrees of criteria, and the stakeholders' power weights simultaneously.
- Considering the two types of aggregation, including the external modified ordered weighted averaging (EMOWA) and the internal modified ordered weighted averaging (IMOWA), for selecting the more desirable urban water strategy in several risk-taking attitudes of stakeholders.
- Selecting final criteria for the MCDM process by use of a risk-based group consensus method.
- Seeking group consensus among stakeholders during the GDSS process by use of a risk-based weighted Minkowski's method.

Accordingly, in order for sustainable water resources management, this research makes the connection between the outputs of watershed modeling and the inputs of a GDSS model for analyzing the risk-based MCDM process. This paper can be used to select the most effective sustainable development criteria of watershed by the stakeholders of the watershed. Additionally, it can assist water scientists and analysts of water resources management to analyze the several impacts of implementing water strategies on the selected sustainable development criteria. Furthermore, it can help all stakeholders to identify the conditions of watershed including several demands, probable water supply resources, and the related impacts on the criteria, which result in better decision making for a sustainable watershed. Ultimately, this study leads to a collaborative group consensus among stakeholders and, consequently, facilitates integrated watershed management.

This paper is organized as follows: Section 2 proposes the flow diagram and explains the complete analysis of the risk-based consensus-based GDSS model for the urban watershed. In addition, this section introduces the study area of the urban watershed, the criteria, the urban water strategies, and the participating stakeholders in the decision-making process. The methodology is also applied for IUWM of the study area. In Section 3, the results, including the scores of urban water strategies, the group consensus measurements, and the final ranking of strategies, are obtained in several risk-taking cases. Section 4 discusses the results and effects of several risk-taking cases on the scores and ranking of the strategies. Finally, Section 5 concludes this paper and proposes future research.

2. Materials and Methods

2.1. Overview of the Methodology

In watershed planning and management, especially for IUWM, the stakeholders have several opinions about the importance degrees of sustainable development criteria. Accordingly, the final most effective criteria should be selected based on stakeholders' group consensus. Additionally, the several water strategies, which are classified in three categories of supply management, demand management, and combined supply-demand management, should be evaluated with respect to the selected criteria. The impacts of watershed modeling outputs related to each water strategy on each criterion is considered as the evaluation value of that corresponding strategy with regard to that corresponding criteria. Therefore, the evaluation values of water strategies should enter to the MCDM process of the GDSS model as its inputs for analyzing the model.

In order to analyze the GDSS model based on the risk-taking considerations of the group of stakeholders and group consensus, the risk-based consensus-based GDSS model is developed for urban watershed management in this study. In the risk analysis, a type of OWA operator is proposed to improve the properties of the OWA, IOWA, and HWA operators. Therefore, the stakeholders

can evaluate the water strategies with respect to the selected criteria and rank the strategies in each risk-taking attitude of the group. Indeed, each stakeholder and the group of stakeholders can determine that, in each risk-taking case, which water strategy is more desirable and how many criteria are satisfied by that strategy. By using a risk-based weighted Minkowski's method, the stakeholders' group consensus is controlled, and the level of group consensus is determined in each risk-taking case. If the final group agreement is reached, the GDSS process is terminated; otherwise, the threshold level of agreement is reconsidered, or the iterated GDSS process continues based on evaluating other water strategies until the final agreement is achieved.

2.1.1. The Proposed Risk-Based Consensus-Based GDSS Process

The proposed flow diagram of the risk-based consensus-based GDSS process for the IUWM is represented in Figure 1, which includes the six phases of identification and selection, weighting, evaluation, aggregation and risk analysis, consensus-seeking, and ranking:
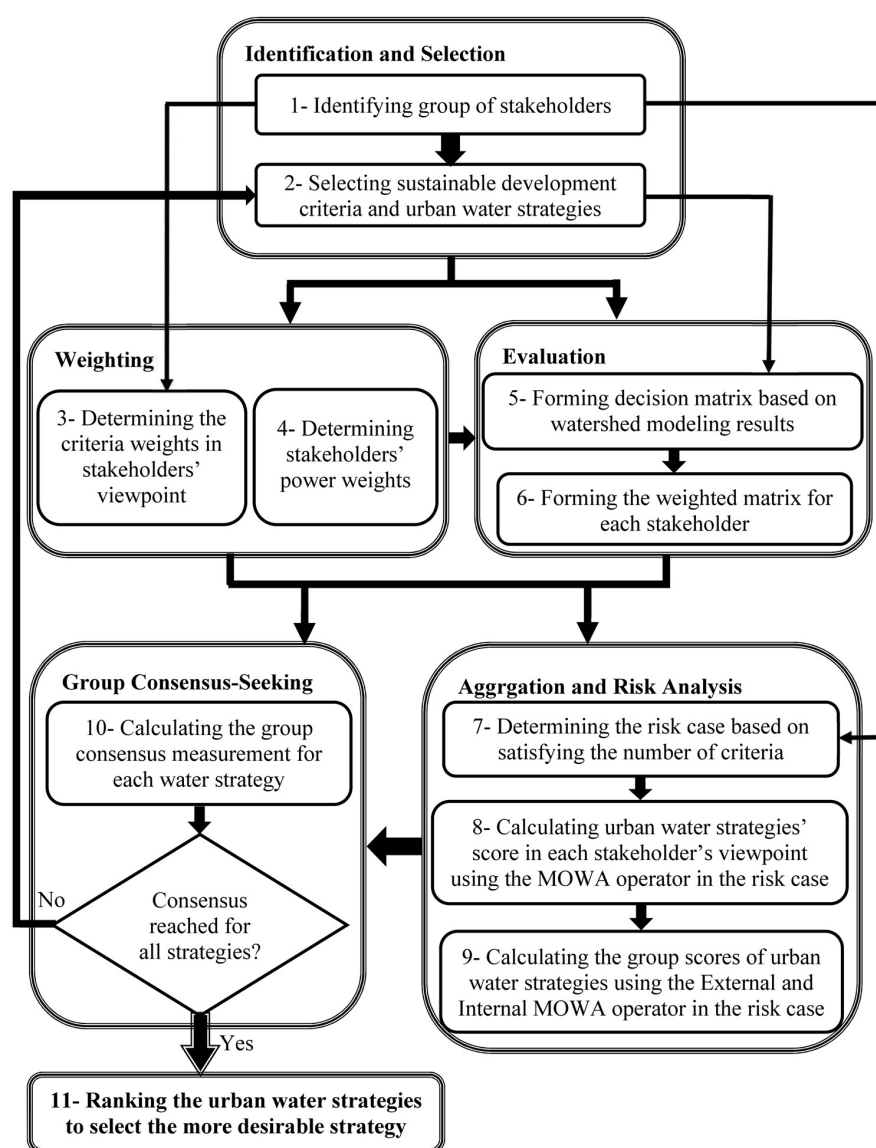
Figure 1. Proposed risk-based consensus-based group decision support system (GDSS) process for the integrated urban water management (IUWM). MOWA: modified ordered weighted averaging.

In the process, first, m' initial water strategies are scored by each of the p stakeholders. Additionally, n' initial criteria are weighted by each of the p stakeholders. Accordingly, $C' = \left\{ C'_1, \ldots, C'_{i'}, \ldots, C'_{n'} \right\}$ is assumed as the set of initial criteria; $S' = \left\{ S'_1, \ldots, S'_{j'}, \ldots, S'_{m'} \right\}$ is considered as the set of initial feasible strategies; and $Sth. = \left\{ Sth._1, \ldots, Sth._k, \ldots, Sth._p \right\}$ is the set of stakeholders. After selection of final strategies and criteria, m final strategies are evaluated with regard to n final criteria by each of the p stakeholders. For convenience, $C = \{ C_1, \ldots, C_i, \ldots, C_n \}$ is assumed as the set of final criteria, and $S = \left\{ S_1, \ldots, S_j, \ldots, S_m \right\}$ is considered as the set of final feasible strategies. Additionally, $\lambda = \left(\lambda_1, \lambda_2, \ldots, \lambda_p \right)^T$ is the vector of the stakeholders' power weights, where $\lambda_k \geq 0$. In addition, $w^{(k)} = \left(w_1^{(k)}, w_2^{(k)}, \ldots, w_n^{(k)} \right)^T$ is the vector of criteria weights in the kth stakeholder's viewpoint $(w_i^{(k)} \geq 0$, $\sum_{i=1}^n w_i^{(k)} = 1$, $k = 1, 2, \ldots, p)$.

2.1.2. Identification and Selection Phase

In Steps 1 and 2 of the proposed process (Figure 1), the stakeholders are identified to select final sustainable development criteria and choose final water strategies based on the stakeholders' group consensus.

In order to select the final appropriate criteria from a large number of criteria, first the Delphi methodology is used to extract the initial criteria from the large number of sustainable development criteria by obtaining the opinions of stakeholders through a survey process [15,38,39]. After that, considering the watershed facts comprises meteorological, hydrological, and hydrogeological characteristics of the watershed, priorities of the watershed, and concepts of sustainable development criteria, all stakeholders are asked about the relevant preferences of the initial criteria. The final sustainable development criteria are selected from the set of initial criteria based on the primitive consensus-based weighted Minkowski's method using Equation (1):

$$Consensus^{(G)}\left(C'_{i'} \right) = 1 - \left\{ \sum_{k=1}^{p} \left\{ \lambda_k \times \left| w'^{(G)}_{i'} - w'^{(k)}_{i'} \right|^2 \right\} \right\}^{\frac{1}{2}}, i' = 1, 2, \ldots, n' \tag{1}$$

where λ_k is each stakeholder's final power weight. The power weight is determined primarily by the linguistic variable followed by defuzzifying the equivalent fuzzy number and obtaining each stakeholder's final power weight. $w'^{(k)}_{i'}$ and $w'^{(G)}_{i'}$ denote the preference values of the i'th initial sustainable criteria based on the kth stakeholder's viewpoint and group viewpoint, respectively, where $w'^{(k)}_{i'}$ is determined like the stakeholders' final power weights, and $w'^{(G)}_{i'} = \sum_{k=1}^{p} \lambda_k \times w'^{(k)}_{i'}$. In addition, $Consensus^{(G)}\left(C'_{i'} \right)$ is the consensus measurement for the i'th initial criteria. According to the group consensus-seeking literature, a threshold level of agreement (TLA) is determined by group of stakeholders to control the final agreement level between the individual stakeholders' viewpoints and the overall group opinion related to the initial criteria. The criteria that satisfy the condition of $Consensus^{(G)}\left(C'_{i'} \right) \geq TLA$ are selected as the final sustainable water criteria and considered as the inputs of the risk-based GDSS model.

Regarding the generate water strategies in the group decision-making process, the design theory has been widely accepted, as it is one of the most frequently used methodologies [16,40]. Accordingly, the C-K theory (concepts–knowledge) has been considered as a generative process that allows stakeholders to describe and analyze innovative design processes for generating strategies [41,42]. For operationalizing the C-K theory, the method of K-C-P (knowledge-concepts-proposals) has been proposed to manage the GDSS design process, in which multiple stakeholders could be included [43].

In this study, all details about watershed conditions, including meteorological, hydrological, and hydrogeological characteristics of watershed, water resources, water demands, and properties of sustainable development criteria, are provided for stakeholders within the questionnaire during

the survey process [16]. Post-survey, all stakeholders are asked to comment about the initial water strategies. The final water strategies are chosen from the set of initial strategies according to the primitive consensus-based weighted Minkowski's method using Equation (2):

$$Consensus^{(G)}\left(S'_{j'}\right) = 1 - \left\{\sum_{k=1}^{p}\left\{\lambda_k \times \left|a^{(G)}_{j'} - a^{(k)}_{j'}\right|^2\right\}\right\}^{\frac{1}{2}}, j' = 1, 2, \ldots, m' \tag{2}$$

where $a^{(k)}_{j'}$ and $a^{(G)}_{j'}$ represent the preference values of the j'th initial water strategy based on the kth stakeholder's viewpoint and the group viewpoint, respectively, where $a^{(k)}_{j'}$ is determined like the stakeholders' final power weights, and $a^{(G)}_{j'} = \sum_{k=1}^{p}\lambda_k \times a^{(k)}_{j'}$. In addition, $Consensus^{(G)}\left(S'_{j'}\right)$ is the consensus measurement for the j'th initial water strategy. According to the group consensus-seeking literature, the strategies that satisfy the condition of $Consensus^{(G)}\left(S'_{j'}\right) \geq TLA$ are chosen as the final water strategies and considered as the inputs of the risk-based GDSS model. The other strategies are not chosen but have the chance to be reconsidered in the iterative process of the GDSS model. Additionally, these strategies could be analyzed in the K-C-P methodology for generating new strategies.

2.1.3. Weighting Phase

Regarding Step 3, the criteria weights are determined. In the MCDM problems, several methods have been applied for calculating criteria weights [38,44]. One of the most commonly used methodologies is the entropy method, which represents the dispersion of a criterion in evaluations of strategy [39,45]. In this study, the entropy method is utilized to calculate the entropy weight of each criterion by using Equation (3):

$$u^{(k)}_i = \frac{1 + K\sum_{j=1}^{m}\left\{\overline{a}^{(k)}_{ij} \times \log\left(\overline{a}^{(k)}_{ij}\right)\right\}}{\sum_{i=1}^{n}\left\{1 + K\sum_{j=1}^{m}\left\{\overline{a}^{(k)}_{ij} \times \log\left(\overline{a}^{(k)}_{ij}\right)\right\}\right\}} \tag{3}$$

where $K = 1/\log(n)$ is a constant value, n and m are the numbers of final criteria and final strategies, respectively, and $\overline{a}^{(k)}_{ij}$ is the normalized value of $a^{(k)}_{ij}$. $a^{(k)}_{ij}$ represents the evaluation value of the jth strategy with respect to the ith criterion based on the kth stakeholder's viewpoint. $u^{(k)}_i$ is the entropy weight of the ith criterion in the kth stakeholder's viewpoint.

In this paper, in addition to the entropy weight of each criterion as an objective weight, the linguistic importance degree of each criterion is also considered as a subjective weight, which represents the stakeholders' preferences related to that corresponding criterion.

In order to express the stakeholders' viewpoints, some of the methodologies have been proposed based on the fuzzy set theory and fuzzy logic [46]. In water resources management problems, the three types of response, such as crisp response, linguistic fuzzy response, and conditional fuzzy response, could be utilized for analyzing input values [47].

In this study, the linguistic fuzzy response is used for determining the importance degrees of criteria, which utilizes fuzzy membership functions and concludes accurate outputs [48]. Accordingly, each stakeholder determines the importance degree of each criterion by using one of the linguistic members from the set of S = (No importance, Very low importance, Low importance, Slightly low importance, Moderate importance, Slightly high importance, High importance, Very high importance, Perfect importance) [49,50]. The linguistic importance degrees of criteria are fuzzified by the trapezoidal-triangular fuzzy membership functions [51,52]. The trapezoidal-triangular fuzzy membership functions, which are used for importance degrees of criteria and the stakeholders' power weights, are represented in Figure 2:
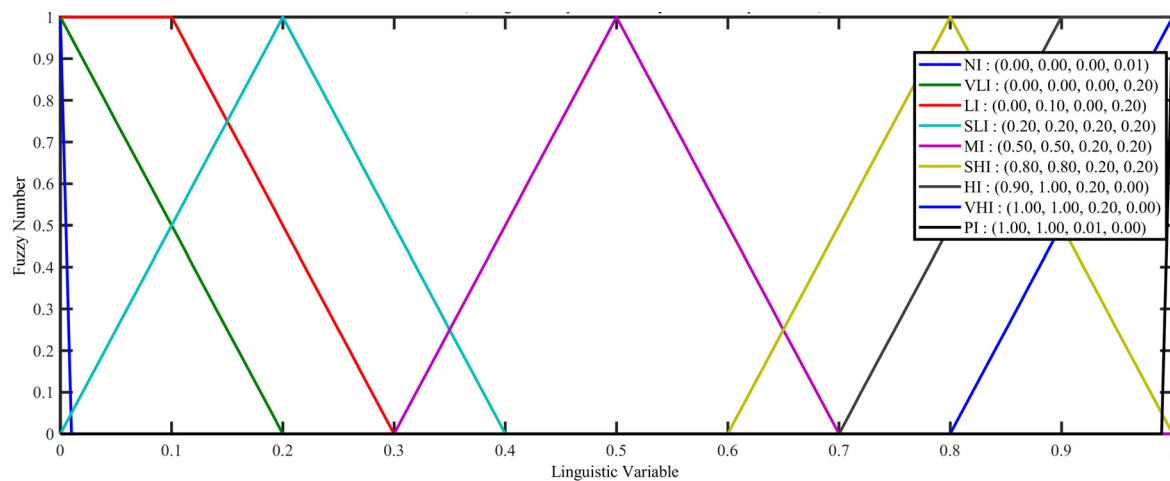
Figure 2. Trapezoidal-triangular fuzzy membership functions of linguistic variables. No importance (NI), very low importance (VLI), low importance (LI), slightly low importance (SLI), moderate importance (MI), slightly high importance (SHI), high importance (HI), very high importance (VHI), and perfect importance (PI).

The fuzzified variables are defuzzified by using the centroid method [51,53,54]. Accordingly, the defuzzified importance degree of each criterion (subjective weight) is determined using Equation (4):

$$\hat{w}_i^{(k)} = \frac{\int \mu\left(\hat{w}_i^{(k)}\right) \times \hat{w}_i^{(k)} \times d\left(\hat{w}_i^{(k)}\right)}{\int \mu\left(\hat{w}_i^{(k)}\right) \times d\left(\hat{w}_i^{(k)}\right)} , \ i = 1, \ldots, n \ ; k = 1, \ldots, p \tag{4}$$

where $\hat{w}_i^{(k)}$ is the defuzzified importance degree of the ith criterion in the kth stakeholder's viewpoint. $\mu\left(\hat{w}_i^{(k)}\right)$ is the trapezoidal-triangular fuzzy membership function of $\hat{w}_i^{(k)}$.

The linguistic variables and the defuzzified values are presented in Table 1.

Table 1. Linguistic variables and the equivalent fuzzy interval and defuzzified values [51].

Linguistic Variable	Fuzzy Numbers	Defuzzified Value
No importance (NI)	(0.00, 0.00, 0.00, 0.01)	0.001
Very low importance (VLI)	(0.00, 0.00, 0.00, 0.20)	0.063
Low importance (LI)	(0.00, 0.10, 0.00, 0.20)	0.106
Slightly low importance (SLI)	(0.20, 0.20, 0.20, 0.20)	0.200
Moderately importance (MI)	(0.50, 0.50, 0.20, 0.20)	0.500
Slightly high importance (SHI)	(0.80, 0.80, 0.20, 0.20)	0.800
High importance (HI)	(0.90, 1.00, 0.20, 0.00)	0.894
Very high importance (VHI)	(1.00, 1.00, 0.20, 0.00)	0.937
Perfect importance (PI)	(1.00, 1.00, 0.01, 0.00)	1.000

The final weight of the ith criterion in the kth stakeholder's viewpoint is determined by using Equation (5):

$$w_i^{(k)} = \frac{\hat{w}_i^{(k)} \times u_i^{(k)}}{\sum_{i=1}^{n} \hat{w}_i^{(k)} \times u_i^{(k)}} \tag{5}$$

Like the process illustrated for determination of the subjective weight for each criterion, the final power weight for each stakeholder (λ_k) is also determined using Equation (6):

$$\lambda_k = \frac{\int \mu(\lambda_k) \times \lambda_k \times d(\lambda_k)}{\int \mu(\lambda_k) \times d(\lambda_k)} \ , \ i = 1, \ldots, n \ ; k = 1, \ldots, p \tag{6}$$

2.1.4. Evaluation Phase

Regarding Step 5, a decision matrix is formed for each stakeholder, in which m strategies are evaluated with regard to n criteria. Each element of decision matrix $(a_{ij}^{(k)})$ represents the evaluation value of the jth strategy with regard to the ith criterion based on the kth stakeholder's viewpoint.

The stakeholders' decision matrices are then normalized by using the first type of linear normalization method, which is applicable for both the positive and negative criteria based on Equations (7) and (8), respectively [55]. $\bar{a}_{ij}^{(k)}$ is the normalized evaluation value of $a_{ij}^{(k)}$:

$$\bar{a}_{ij}^{(k)} = \frac{a_{ij}^{(k)}}{a_i^{(k)*}} \ \text{where} \ a_i^{(k)*} = max_j\left\{a_{ij}^{(k)}\right\} \tag{7}$$

$$\bar{a}_{ij}^{(k)} = \frac{a_i^{(k)\sim}}{a_{ij}^{(k)}} \ \text{where} \ a_i^{(k)\sim} = min_j\left\{a_{ij}^{(k)}\right\} \tag{8}$$

2.1.5. Aggregation and Risk Analysis Phase

In GDSS for watershed management, a group of stakeholders have several risk-taking attitudes towards decision-making, which are expressed by linguistic phrases such as "selecting the more desirable water strategy based on satisfying all of criteria" in the completely risk-averse (completely conservative or completely pessimistic) viewpoint and "selecting the more desirable water strategy based on satisfying at least one criterion" in the completely risk-prone (completely nonconservative or completely optimistic) standpoint. In addition, the other risk-taking attitudes such as "most of, many of, half of, some of, and a few of" are applied between these two cases [13,56]. Accordingly, the risk-taking degree of θ has been assigned for each of the risk-taking cases [57,58]. Several risk-taking cases, equivalent linguistic phrases, and the relevant risk-taking degrees are presented in Table 2.

Table 2. Risk-taking cases, equivalent linguistic phrases, and relevant risk-taking degrees [58].

Risk-Taking Case	Equivalent Linguistic Phrase	Risk-Taking Degree (θ)
Completely risk-averse	Satisfies all of the criteria	0.001
Risk-averse	Satisfies most of the criteria	0.091
Fairly risk-averse	Satisfies many of the criteria	0.333
Neutral risk	Satisfies half of the criteria	0.500
Fairly risk-prone	Satisfies some of the criteria	0.667
Risk-prone	Satisfies few of the criteria	0.909
Completely risk-prone	Satisfies at least one criterion	0.999

Regarding Step 7, for each risk-taking case, a corresponding risk-based order weights vector of $v = (v_1, v_2, \ldots, v_n)^T$, $v_i \geq 0$, $\sum_{i=1}^{n} v_i = 1$ is determined. The order weights are determined for several risk cases and the relevant risk-taking degrees of θ based on the regular increasing monotone (RIM) fuzzy linguistic quantifier and using Equation (9) [13,56,58,59]:

$$v_i = \left(\frac{i}{n}\right)^{\left(\frac{1}{\theta}\right)-1} - \left(\frac{i-1}{n}\right)^{\left(\frac{1}{\theta}\right)-1} \ , \ i = 1, 2, \ldots, n \tag{9}$$

2.1.6. External Aggregation

In the external aggregation, the order weights vector for each risk-taking case is utilized to calculate the scores of water strategies in each stakeholder's opinion. In order to complete Step 8, an n-dimensional function of $F : I^n \rightarrow J$ is used for a weighted normalized matrix related to each stakeholder for aggregating its evaluation values within the first aggregation. In this function, I denotes the set of evaluation values of each strategy, and J represents the corresponding score.

Therefore, according to the external risk analysis through the EMOWA operator, the evaluation values of each strategy associated with each stakeholder are aggregated to calculate the score of that corresponding strategy in several risk-taking cases using Equation (10):

$$F^{(k)}_{EMOWA}\left(w_1^{(k)}\bar{a}_{1j}^{(k)},\ldots,w_n^{(k)}\bar{a}_{nj}^{(k)}\right)\left(S_j\right) = \sum_{i=1}^{n}\left\{\left\{\left(\frac{i}{n}\right)^{(\frac{1}{\theta})-1} - \left(\frac{i-1}{n}\right)^{(\frac{1}{\theta})-1}\right\} \times b_i^{(k)}\right\} \tag{10}$$

where $v = (v_1, v_2, \ldots, v_n)^T$ is the risk-based order weights vector associated with n criteria, for which $v_i \geq 0$, $\sum_{i=1}^{n} v_i = 1$. Additionally, $b_i^{(k)}$ is the ith largest value of the $\left(w_1^{(k)}\bar{a}_{1j}^{(k)}, w_2^{(k)}\bar{a}_{2j}^{(k)}, \ldots, w_n^{(k)}\bar{a}_{nj}^{(k)}\right)$ vector related to each stakeholder's weighted normalized evaluation matrix. Finally, $F^{(k)}_{EMOWA}\left(S_j\right)$ is the score of the jth strategy from the kth stakeholder's viewpoint. In Equation (10), the scores of strategies from each stakeholder's viewpoint is calculated for several risk-taking cases.

Regarding Step 9, in the second aggregation, a p-dimensional function of $F^G : I^p \rightarrow J$ is applied to a group of stakeholders for aggregating their scorings related to each strategy. In this function, I denotes the set of stakeholders' scorings related to each strategy, and J represents the corresponding group score.

Therefore, the second aggregation step is accomplished, in which the stakeholders' scorings related to each strategy are aggregated to calculate the group score of that corresponding strategy in several risk-taking cases by using Equation (11):

$$F^G_{EMOWA}\left(S_j\right) = \sum_{k=1}^{p}\left\{\lambda_k \sum_{i=1}^{n}\left\{\left\{\left(\frac{i}{n}\right)^{(\frac{1}{\theta})-1} - \left(\frac{i-1}{n}\right)^{(\frac{1}{\theta})-1}\right\} \times b_i^{(k)}\right\}\right\} \tag{11}$$

where λ_k is the kth stakeholder's power weight, and $F^G_{EMOWA}\left(S_j\right)$ is the score of the jth strategy from the viewpoint of the group. In Equation (11), the scores of strategies from the group of stakeholders' viewpoints is calculated for several risk-taking cases.

2.1.7. Internal Aggregation

In the internal aggregation, the order weights vector for each risk-taking case is directly used to calculate the scores of water strategies in the group of stakeholders' viewpoints. Accordingly, in the one-step aggregation, an n-dimensional function of $F^G : I^p \rightarrow J$ is used for the group weighted normalized matrix related to the group of stakeholders for aggregating its evaluation values. In this function, I denotes the set of group evaluation values of each strategy, and J represents the corresponding group score.

Therefore, with respect to the internal risk analysis performed by the IMOWA operator, the evaluation values of each strategy associated with the group of stakeholders are aggregated to calculate the score of that corresponding strategy in several risk-taking cases using Equation (12):

$$F^{(G)}_{IMOWA}\left(w_1^{(G)}\bar{a}_{1j}^{(G)},\ldots,w_n^{(G)}\bar{a}_{nj}^{(G)}\right)\left(S_j\right) = \sum_{i=1}^{n}\left\{\left\{\left(\frac{i}{n}\right)^{(\frac{1}{\theta})-1} - \left(\frac{i-1}{n}\right)^{(\frac{1}{\theta})-1}\right\} \times b_i^{(G)}\right\} \tag{12}$$

where $v = (v_1, v_2, \ldots, v_n)^T$ is the risk-based order weights vector related to n criteria, for which $v_i \geq 0$, $\sum_{i=1}^{n} v_i = 1$. Additionally, $b_i^{(G)}$ is the ith largest value of the $\left(w_1^{(G)} \bar{a}_{1j}^{(G)}, w_2^{(G)} \bar{a}_{2j}^{(G)}, \ldots, w_n^{(G)} \bar{a}_{nj}^{(G)} \right)$ vector related to the group weighted normalized evaluation matrix. Finally, $F_{IMOWA}^{(G)}(S_j)$ is calculated as the score of the jth strategy from the group of stakeholders' viewpoints for several risk-taking cases.

2.1.8. Group Consensus-Seeking Phase

Regarding Step 10 (Figure 1), group consensus should be controlled to confirm that a final agreement is reached among stakeholders about water strategies. Accordingly, the consensus measurement for each strategy is calculated in order to control the final agreement amongst stakeholders associated with all water strategies.

In recent years, various methodologies have been utilized for calculating consensus measurements. Most of the frequently used methodologies have been classified in the two general approaches [60–65]. The first approach has been developed based on the hard consensus, in which the consensus measurements are calculated concerning the similarity of individual preferences compared with the group opinion [5]. Next, this is compared with the threshold level of agreement (TLA) index. The second approach has been developed according to the soft consensus, in which the individuals change their opinions collaboratively, until a consensus is reached [66,67].

In this paper, a hard consensus approach is utilized for seeking consensus among stakeholders for the first implementation of the risk-based GDSS process. After the first implementation, a soft consensus approach is used in the iterative implementation of the risk-based GDSS process if a final agreement is not reached. First, the risk-based weighted Minkowski's method is applied to calculate the consensus measurements for water strategies. In this study, the Euclidean Minkowski's distance is used for calculating the consensus measurement of each strategy, which implies a simple squared weighting and the related parameter of q equals 2 ($q = 2$). Regarding the relationship between the Minkowski's parameter of q and the risk-taking degree of decision-making [68], the Euclidean Minkowski's method minimizes the distance between the individual viewpoints and the group opinion regarding water strategies leading to a consensus amongst the majority of stakeholders [69]. By using the Euclidean distance, the score of each water strategy ($F_{EMOWA}^{(k)}(S_j)$, $j = 1, 2, \ldots, m$), determined by individual stakeholders, is compared with the score of that corresponding strategy, determined by the group of stakeholders ($F_{EMOWA}^{(G)}(S_j)$ or $F_{IMOWA}^{(G)}(S_j)$, $j = 1, 2, \ldots, m$). The consensus measurement for each water strategy is calculated based on the EMOWA and IMOWA results, using Equations (13) and (14):

$$Consensus_{EMOWA}^{(G)}(S_j) = 1 - \left\{ \sum_{k=1}^{p} \lambda_k \times \left| F_{EMOWA}^{(G)}(S_j) - F_{EMOWA}^{(k)}(S_j) \right|^2 \right\}^{\frac{1}{2}}, \quad j = 1, 2, \ldots, m \quad (13)$$

$$Consensus_{IMOWA}^{(G)}(S_j) = 1 - \left\{ \sum_{k=1}^{p} \lambda_k \times \left| F_{IMOWA}^{(G)}(S_j) - F_{EMOWA}^{(k)}(S_j) \right|^2 \right\}^{\frac{1}{2}}, \quad j = 1, 2, \ldots, m \quad (14)$$

where $Consensus_{EMOWA}^{(G)}(S_j)$ and $Consensus_{IMOWA}^{(G)}(S_j)$ are the consensus measurements for the jth water strategy, where its score is calculated based on using EMOWA or IMOWA in several risk-taking cases, respectively.

According to Equations (13) and (14), it is considered that the lower distances between the individual stakeholders' viewpoints and the overall group opinion associated with each water strategy leads to higher consensus measurement for that strategy.

To control the hard consensus in this study, the TLA index is determined as the linguistic variable of "slightly high" and defuzzified to the corresponding crisp value of 0.800. The consensus measurements for strategies are compared with the selected TLA. Accordingly, the final agreement amongst stakeholders is achieved when $\forall j, Consensus_{EMOWA}^{(G)}(S_j) \geq TLA$ for external aggregation or

$\forall\,j, Consensus_{IMOWA}^{(G)}\left(S_j\right) \geq TLA$ for internal aggregation. Otherwise, the risk-based GDSS process is iterated, and the soft consensus approach is implemented. According to this issue, all stakeholders are asked about their preferences related to the generation of new strategies, considering the combination of rejected strategies. The generation of strategies' process could be modeled by the K-C-P methodology. The iterative risk-based GDSS process is then implemented based on the evaluation of newly generated strategies, the combined rejected strategies, and the previously agreed strategies with respect to the final selected criteria. This process is iterated until a sufficient level of agreement is achieved amongst all stakeholders.

Ultimately, after a final agreement among all stakeholders, the water strategies are ranked based on the group scores in the several risk-taking cases.

2.2. Study Area

The study of the risk-based GDSS model is performed on the Kashafroud urban watershed area, which is located in North-Eastern Iran with a longitude of 58°20′ up to 60°08′ and latitude of 35°40′ up to 36°03′ (Figure 3). The Kashafroud watershed is one of the largest and the most populated watersheds in Iran. The mean, minimum, and maximum watershed elevations above sea level are 1846 m, 390 m, and 3302 m, respectively. The watershed has a total area of 1,565,000 ha and a growing population that is estimated to reach 5,100,000 by 2040 [70]. The total urban water demand is predicted to reach 490 million cubic meters (MCM) by 2040. This watershed has a cold and arid climatic, and the mean annual precipitation is less than 250 mm [71].
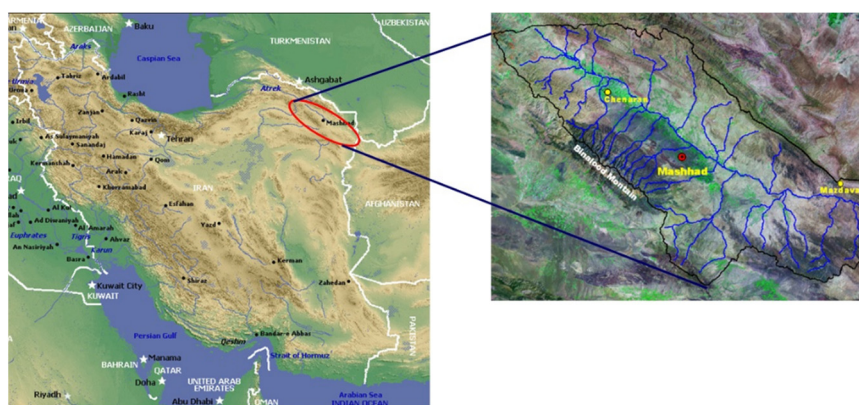

Figure 3. Location of the Kashafroud watershed in North-Eastern Iran.

In recent years, the Kashafroud urban watershed has encountered challenges, including an increase in the variety of water demands, quantitative and qualitative degradation of water resources, and relevant conflicts among stakeholders [72,73]. In efforts to resolve the challenges, the integrated water resources management (IWRM) approach for the Kashafroud watershed was proposed by the Iran Ministry of Energy in 2010. Since 2015, the IWRM project for this watershed has been analyzed based on the MODSIM modeling by common collaboration between the ToossAb Water Engineering Consultant Company and Iran Water Resources Management Company. The summary of the average 40-year long-term hydrological and hydrogeological budget entail results from comprehensive studies performed for this project, including the meteorological and climatic, hydrologic, hydrogeologic, and socio-economic issues [74–77] (see Appendix A, Table A1). Additionally, for several urban, agricultural, industrial, and environmental water demands of the Kashafroud watershed, the current water consumptions have been specified, and the water demands of 2040 have been predicted [71,78–80] (see Appendix A, Table A2).

According to the detailed data obtained from reports and several analysis on the watershed data, the most competitive water strategies have been modeled by the collaboration of the Iran

Water Resources Management Company and ToossAb consultant company based on the iterative calibration-validation process within the MODSIM modeling project [81].

However, a GDSS model should be developed for the Kashafroud watershed based on the IWRM project data and MODSIM modeling outputs considering the stakeholders' participation in a group MCDM process. This study proposes the risk-based GDSS model for evaluating the predefined water strategies with respect to the criteria while improving the properties of the risk-based operator for modeling GDSS, analyzing the effects of several risk-taking attitudes of stakeholders based on strategies ranking, and investigating the stakeholders' consensus.

2.2.1. Stakeholders

A thorough and extensive study was performed in efforts to analyze the risk-based consensus-based GDSS process for the Kashafroud watershed. The six most influential stakeholders in the urban watershed decision-making process, including governmental stakeholders and non-governmental organizations (NGOs), were selected based on the study. The governmental stakeholders' members include experts, deputies, and chief executive officers (CEOs). Details on the six identified stakeholders and the relevant members for Kashafroud urban watershed are presented in Table 3.

Table 3. List of stakeholders and the relevant members collaborated in the Kashafroud GDSS model. NGOs: non-governmental organizations.

Stakeholder's ID	Stakeholder's Name	Stakeholder's Role	Number of Members	Members' Roles
$Sth._1$	The state regional water company	Regional water management authority	9	1 CEO, 2 deputies, 6 experts
$Sth._2$	The state agricultural organization	Agricultural water user	2	1 deputy, 1 expert
$Sth._3$	The urban water and wastewater company	Potable urban water and wastewater user	4	1 CEO, 1 deputy, 2 experts
$Sth._4$	The state industrial township company	Industrial water user	1	1 CEO
$Sth._5$	The state environmental protection agency	Environmental water user	2	2 experts
$Sth._6$	The NGOs as the representative of people	Water and environmental resources defenders	3	2 faculty members, 1 farmers' representative

2.2.2. Initial Criteria

In order to qualify the four sustainable development objectives for the Kashafroud watershed, including water resources sustainability, environmental sustainability, economic sustainability, and social sustainability, a detailed survey was distributed in the urban watershed to collect viewpoints from the relevant stakeholder members. The survey was conducted through one-on-one interviews, collaborative workshop meetings in the presence of all members, and responses from the provided questionnaires. Fifty-three multiple criteria in the four categories of sustainable development objectives were reviewed by the stakeholders in the primitive screening process. Considering the watershed conditions and related priorities, 21 criteria were voted as the initial criteria and are represented in Table 4. These criteria are defined according to reports provided by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), International Association of Hydrogeologists, and the national reports provided by Iran Water Resources Management Company in the IWRM project [82–86].

Table 4. The initial sustainable development criteria for the Kashafroud watershed [82–85].

Objective	Initial Criterion	Criterion ID
Water resources sustainability	Water stress	C'_1
	Groundwater dependency	C'_2
	Adjustable protentional of Surface Water Resources	C'_3
	Development of groundwater	C'_4
	Percentage of water supply for agricultural demand	C'_5
	Percentage of water supply for potable urban demand	C'_6
	Percentage of water supply for industrial demand	C'_7
	Percentage of water supply for environmental demand	C'_8
	Renewable water resources per capita	C'_9
	Potable water consumption per capita	C'_{10}
	Industrial water consumption per capita	C'_{11}
	Reliability for water supply	C'_{12}
	Balancing between using surface water and groundwater	C'_{13}
	Groundwater unsustainability	C'_{14}
	Surface water dependency on other watersheds	C'_{15}
Environmental sustainability	Purified sewerage ratio	C'_{16}
Economic sustainability	Potable water losses	C'_{17}
	Benefit per cost ratio	C'_{18}
Social sustainability	Conflict resolution amongst water stakeholders	C'_{19}
	Creating job opportunities	C'_{20}
	Social equity	C'_{21}

The initial criteria were weighted in the final screening process to select the final criteria based on a group consensus.

2.2.3. Water Strategies

After the investigation of several water strategies by the Ministry of Energy and the watershed stakeholders, the most competitive urban water strategies were selected by the stakeholders for the IWRM project to make a decision about choosing the more desirable strategy within the Kashafroud watershed [81]. Table 5 presents the five final water strategies for the Kashafroud urban watershed classified by supply management, demand management, and combined supply-demand management.

The main reasons for the selection of these five competitive strategies by the stakeholders include:

- Classification of the strategies within supply management, demand management, and combined supply-demand management.
- Investigating the effects of Doosti Dam on supplying the several demands, as well as the influences of substituting other water strategies instead of this project.
- Comparing the supply management and demand management approaches in regard to the several sustainable development criteria.
- Comparing the role of the two under-studied supply management projects, including the Idelik inter-basin water transfer and the utilization of purified wastewater on agricultural lands.

Table 5. The urban water strategies for the Kashafroud watershed by the 2040 vision.

Type of Strategy	Strategy ID	The Existing water Resources	The Under-Studying Supply Management Strategies		The Under-Studying Demand Management Strategies	Dependency on Water Transfer from Doosti Dam
		Withdrawal from Existing Dams and Groundwater Reservoir	Utilization of Purified Wastewater on Agricultural lands	Idelik Inter-Basin Water Transfer	Improving Water Network Efficiency and Modifying Cropping Pattern	
Supply management	S_1	Yes	No	No	No	Yes
	S_2	Yes	No	Yes	No	Yes
	S_3	Yes	Yes	No	No	Yes
Demand management	S_4	Yes	No	No	Yes	Yes
Combined supply-demand management	S_5	Yes	Yes	Yes	Yes	No

The existing water resources include the Ardak, Kardeh, Torogh, Dolatabad, Chalidarreh, and Esjil dams, as well as the groundwater reservoir. The under-studying supply management strategies include the utilization of purified wastewater on agricultural lands and the Idelik inter-basin water transfer. However, the Idelik project might cause conflicts between the stakeholders of the northern watershed and the Kashafroud watershed. The multi-criteria effects of this project and utilization of purified wastewater on agricultural lands are compared for the strategies S_2 and S_3.

The Doosti Dam is considered as a structural supply management that plays an active role in supplying water for the Kashafroud watershed. However, this project has high operation and maintenance costs, and its implementation could lead to dependence on the transboundary river basin. Therefore, the stakeholders' approach is to substitute more reliable water strategies instead of the dam for providing urban water.

The under-studying demand management strategies include improving water network efficiency and modifying cropping patterns, which are typical for strategies S_4 and S_5. The difference between these two strategies is that the strategy S_4 is considered as just a demand management approach with dependency on the Doosti Dam, while the strategy S_5 is considered as both a supply and demand management approach with no dependency on water transfer from the Doosti Dam.

The existing and under-studying strategies of the Kashafroud watershed are shown in Figure 4.

2.2.4. Data Collection

In order to analyze the risk-based GDSS model for selecting the more desirable water strategy, two types of data were collected. The first type of data is related to the criteria, including the selection of final criteria and weighting of the final criteria. The second type of data is associated with the strategies, including the evaluation of strategies with respect to the final criteria.

Accordingly, for collecting the first type of data, a survey questionnaire was prepared, and the 21 members of the six stakeholders were interviewed to capture their viewpoints about the importance degrees of the initial criteria and the final criteria, using the linguistic answers (no importance, very low importance, low importance, slightly low importance, moderately importance, slightly high importance, high importance, very high importance, and perfect importance) (see Appendix B, Table A3)

For collecting the second type of data, the results of the MODSIM modeling project and the data from the meteorology and climatology, hydrology, hydrogeology, and socio-economic reports [74–77,79], as well as information from the reports of urban, agricultural, industrial, and environmental water demands for the Kashafroud watershed, were utilized for evaluation of the water strategies with respect to the sustainable development criteria (see Appendix A, Tables A1 and A2; see Appendix C, Table A6).
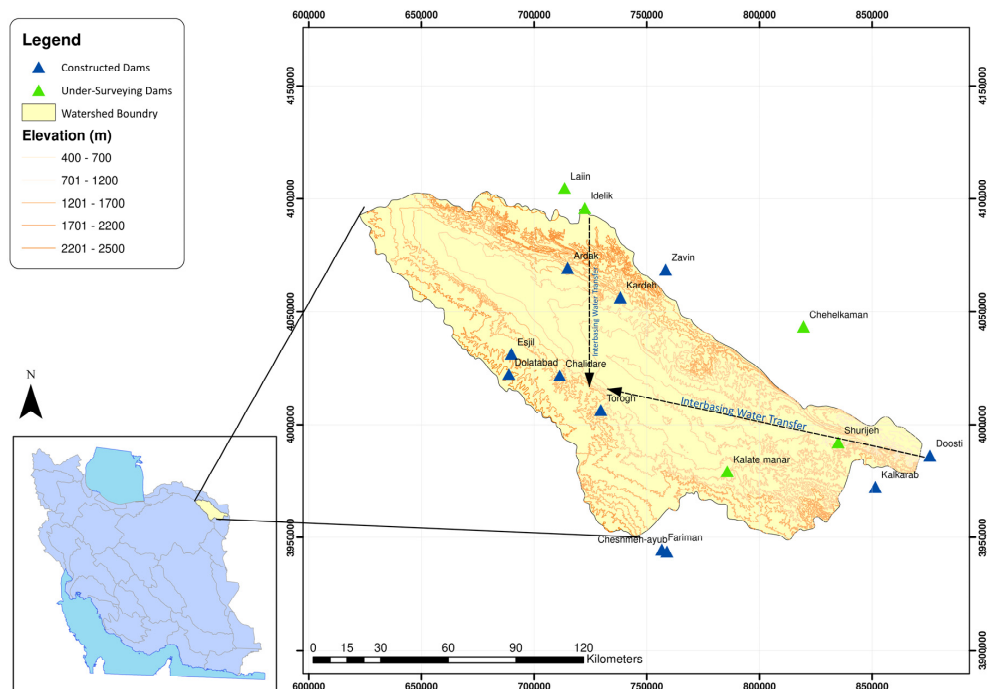
Figure 4. Location of Kashafroud in Iran and the existing and the under-studying water strategies.

2.2.5. Final Criteria Selection

Regarding Step 2 of the GDSS model (Figure 1), in order to consider the four sustainable development objectives for evaluating the five water strategies, the final criteria should be selected from the initial criteria. The first step in the survey process is an interview with the stakeholders, where the definitions of the initial criteria are explained. Next, the provided questionnaires are completed by the 21 members of the six stakeholders, in which the linguistic importance degrees of the initial criteria are assigned (see Appendix B, Table A4). In the end, the members' viewpoints of each of the six stakeholder's community are aggregated. The aggregated results related to the six stakeholders on the defuzzified weights of the initial criteria and the stakeholders' defuzzified normalized weights are presented in Figure 5.
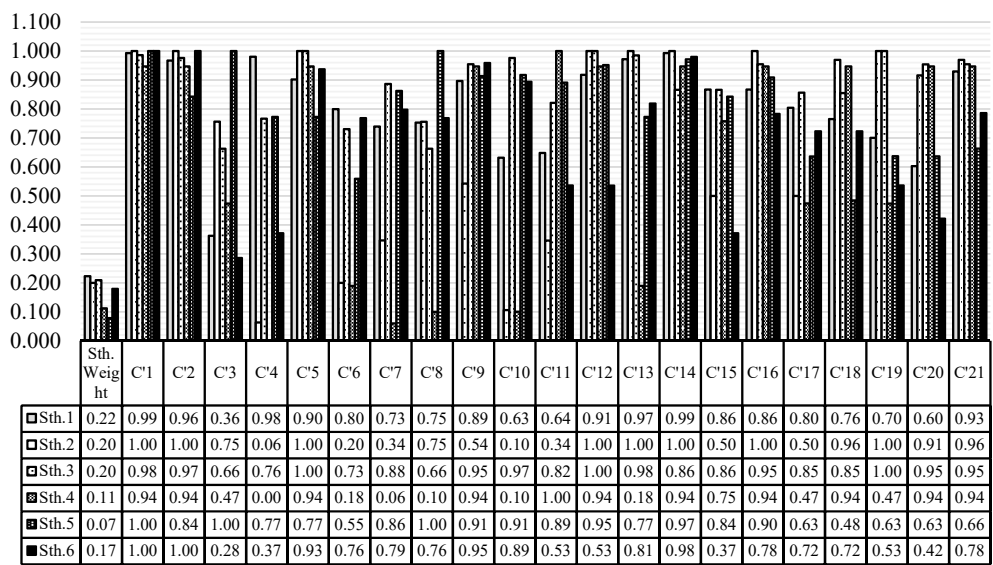

	Sth. Weight	C'1	C'2	C'3	C'4	C'5	C'6	C'7	C'8	C'9	C'10	C'11	C'12	C'13	C'14	C'15	C'16	C'17	C'18	C'19	C'20	C'21
☐ Sth.1	0.22	0.99	0.96	0.36	0.98	0.90	0.80	0.73	0.75	0.89	0.63	0.64	0.91	0.97	0.99	0.86	0.86	0.80	0.76	0.70	0.60	0.93
☐ Sth.2	0.20	1.00	1.00	0.75	0.06	1.00	0.20	0.34	0.75	0.54	0.10	0.34	1.00	1.00	1.00	0.50	1.00	0.50	0.96	1.00	0.91	0.96
☐ Sth.3	0.20	0.98	0.97	0.66	0.76	1.00	0.73	0.88	0.66	0.95	0.97	0.82	1.00	0.98	0.86	0.86	0.95	0.85	0.85	1.00	0.95	0.95
▦ Sth.4	0.11	0.94	0.94	0.47	0.00	0.94	0.18	0.06	0.10	0.94	0.10	1.00	0.94	0.18	0.94	0.75	0.94	0.47	0.94	0.47	0.94	0.94
▤ Sth.5	0.07	1.00	0.84	1.00	0.77	0.77	0.55	0.86	1.00	0.91	0.91	0.89	0.95	0.77	0.97	0.84	0.90	0.63	0.48	0.63	0.63	0.66
■ Sth.6	0.17	1.00	1.00	0.28	0.37	0.93	0.76	0.79	0.76	0.95	0.89	0.53	0.53	0.81	0.98	0.37	0.78	0.72	0.72	0.53	0.42	0.78

Figure 5. Assigned weights for the initial criteria by the stakeholders of the Kashafroud watershed.

The initial criteria weights are utilized to calculate the relevant group consensus measurements using Equation (1). The group consensus measurement results of the initial criteria are presented in Figure 6.
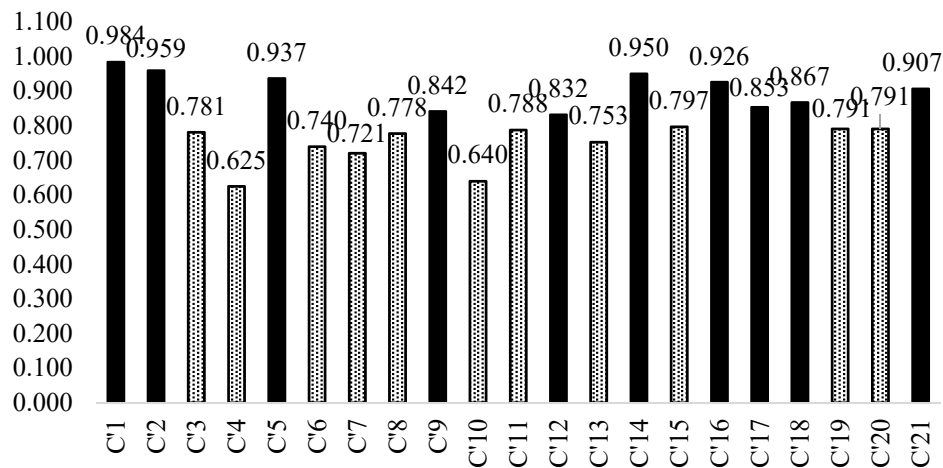
Figure 6. The group consensus measurements of the initial criteria for the Kashafroud watershed.

In order to select the final criteria from the 21 initial criteria, the group consensus measurements that are higher than the determined TLA (*TLA* = 0.800) are selected as the final criteria. According to Figure 6, the 10 black-filled criteria of C'_1, C'_2, C'_5, C'_9, C'_{12}, C'_{14}, C'_{16}, C'_{17}, C'_{18}, and C'_{21} have been selected as the final sustainable development criteria, which are the most preferable criteria in the group viewpoints for the decision-making process within the watershed. The final selected criteria that are marked by C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9, and C_{10}, are defined in Table 6 [82–85].

Table 6. The final sustainable development criteria for the Kashafroud watershed by the 2040 vision. *TWW* is the total water withdrawal (includes urban, agricultural, and industrial and water withdrawal); *TWS* is the total water storage; *EGW* is the exploitation from groundwater; *TEWR* is the total exploitation of water resources (*TWW* + environmental water withdrawal); *SAWD* is the supplied agricultural water demand; *AWD* is the agricultural water demand; *SWR* is the surface water resources; *RGW* is the renewable groundwater resources; *P* is the population; *SPWD* is the supplied potable water demand; *PWD* is the potable water demand; *SIWD* is the supplied industrial water demand; *IWD* is the industrial water demand; *SEWD* is the supplied environmental water demand; *EWD* is the environmental water demand; *GWD* is the groundwater discharge; *GWR* is the groundwater recharge; *PS* is the purified sewerage; *US* and *IS* are the urban sewerage and industrial sewerage, respectively; and *B* and *C* are the amount of benefit and cost values of the implementation of the water strategies, respectively.

Criterion	ID	Criterion Definition	Data Resource
Water stress	C_1	*TWW*/*TWS*	[81,86]
Groundwater dependency	C_2	*EGW*/*TEWR*	[71,75,76,78–81]
Percentage of water supply for agricultural demand	C_3	*SAWD*/*AWD*	[78,81]
Renewable water resources per capita	C_4	(*SWR* + *RGWR*)/*P*	[70,81,86]
Reliability for water supply	C_5	$0.25 \times \left(\frac{SAWD}{AWD} + \frac{SPWD}{PWD} + \frac{SIWD}{IWD} + \frac{SEWD}{EWD} \right)$	[71,78–81]
Groundwater unsustainability	C_6	*GWD*/*GWR*	[81,86]
Purified sewerage ratio	C_7	*PS*/(*US* + *IS*)	[71,79,81]
Potable water losses	C_8	Percentage of water distribution losses	[71]
Benefit per cost ratio	C_9	*B*/*C*	[77]
Social equity	C_{10}	$0.333 \times (0.970 \times \frac{SAWD}{AWD} + 1 \times \frac{SPWD}{PWD} + 0.970 \times \frac{SIWD}{IWD}$	[71,78–81]

2.2.6. Final Criteria Weights

Following Step 3, each stakeholder determines the importance degree for each selected criterion using linguistic variables (see Appendix B, Table A5). The linguistic variables are fuzzified and defuzzified. The defuzzified weights of the criteria in viewpoints of the stakeholders are presented in Figure 7.
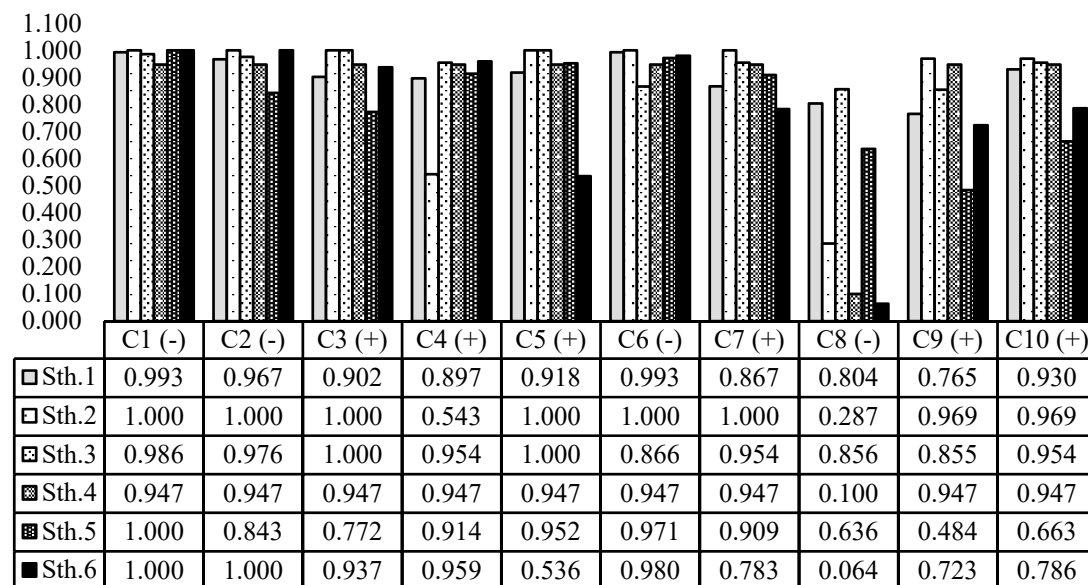

Figure 7. The defuzzified weights of the selected criteria in each individual stakeholder's viewpoint.

Finally, the criteria are weighted based on the entropy method. According to Step 4, the stakeholders' power weights are determined by using linguistic variables, which are finally defuzzified. Consequently, the final criteria weights in the individual stakeholders' viewpoints are presented in Figure 8.
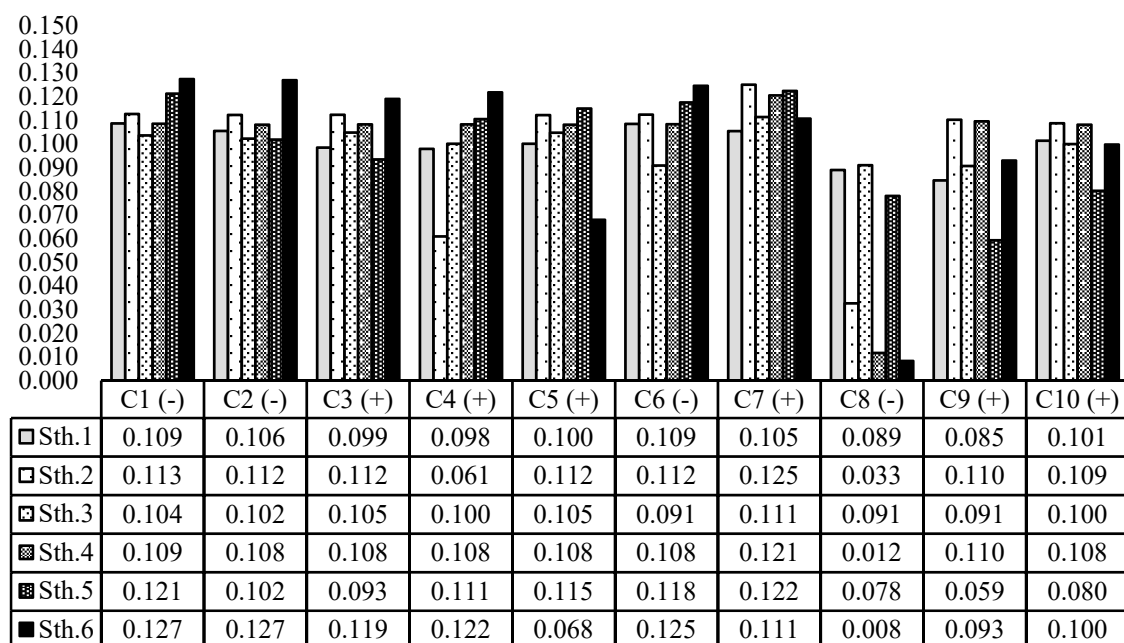

	C1 (-)	C2 (-)	C3 (+)	C4 (+)	C5 (+)	C6 (-)	C7 (+)	C8 (-)	C9 (+)	C10 (+)
Sth.1	0.109	0.106	0.099	0.098	0.100	0.109	0.105	0.089	0.085	0.101
Sth.2	0.113	0.112	0.112	0.061	0.112	0.112	0.125	0.033	0.110	0.109
Sth.3	0.104	0.102	0.105	0.100	0.105	0.091	0.111	0.091	0.091	0.100
Sth.4	0.109	0.108	0.108	0.108	0.108	0.108	0.121	0.012	0.110	0.108
Sth.5	0.121	0.102	0.093	0.111	0.115	0.118	0.122	0.078	0.059	0.080
Sth.6	0.127	0.127	0.119	0.122	0.068	0.125	0.111	0.008	0.093	0.100

Figure 8. The final weights of the selected criteria in each individual stakeholder's viewpoint.

The final criteria weights in the group viewpoint are represented in Figure 9.
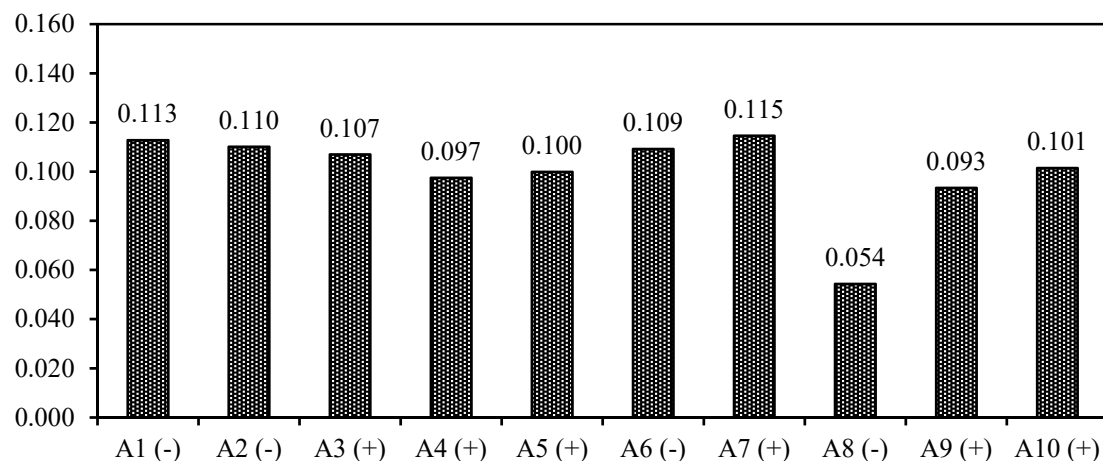
Figure 9. The final weights of the selected criteria in the group viewpoint.

2.2.7. Decision Matrix (Evaluation Matrix)

Regarding Step 5, the decision matrix is formed for evaluating the five water strategies with respect to the 10 selected sustainable criteria (see Table 6). The decision matrix elements are common among the six stakeholders. In the decision matrix, each evaluation value is the influence of implementing each water strategy on each criterion, which is obtained from MODSIM modeling outputs report [81], the data related to the hydrologic report [75], the hydrogeologic and budget reports [76,86], the socio-economic report [77], and the several demands reports [71,78–80] (see the data source in Table 6). Accordingly, the evaluation matrix of the water strategies with respect to the sustainable development criteria for the Kashafroud watershed is presented in Table 7 (see Appendix C, Table A6).

Table 7. Evaluation matrix of the water strategies with respect to the criteria for the Kashafroud watershed.

Selected Criteria	Dimension	S_1	S_2	S_3	S_4	S_5
$C_1{}^{(-)}$	Nondimensional	0.958	0.973	1.136	0.919	1.012
$C_2{}^{(-)}$	Nondimensional	0.753	0.742	0.704	0.728	0.742
$C_3{}^{(+)}$	Nondimensional	0.798	0.818	0.890	0.828	0.869
$C_4{}^{(+)}$	m^3/Person	269.8	269.8	251.9	253.4	245.0
$C_5{}^{(+)}$	Nondimensional	0.943	0.948	0.966	0.950	0.961
$C_6{}^{(-)}$	Nondimensional	1.027	1.027	1.133	0.980	1.081
$C_7{}^{(+)}$	Nondimensional	0.248	0.248	0.555	0.241	0.541
$C_8{}^{(-)}$	Nondimensional	0.232	0.232	0.232	0.171	0.171
$C_9{}^{(+)}$	Nondimensional	1.101	1.103	1.081	1.418	0.941
$C_{10}{}^{(+)}$	Nondimensional	0.915	0.921	0.944	0.925	0.938

It is noticeable that, in the decision matrix, some of the criteria, including C_3, C_4, C_5, C_7, C_9, and C_{10}, are positive (C^+), and the other criteria, including C_1, C_2, C_6, and C_8, are negative (C^-).
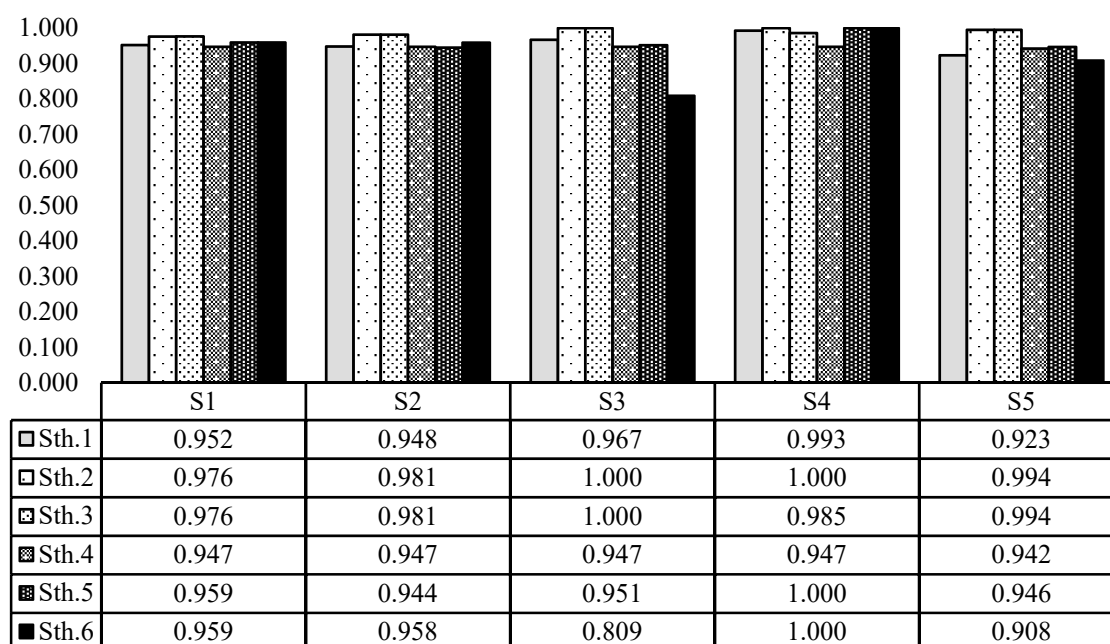
3. Results

3.1. Risk Analysis-Based Scores of the Water Strategies

According to Step 6, the decision matrix is first normalized; then, the weighted normalized decision matrix is formed for each of the stakeholders. Regarding Step 8, the weighted normalized decision matrix associated with each stakeholder is applied to implement the external risk analysis-based aggregation process. The scores of strategies in each stakeholder's viewpoint are calculated in several risk-taking cases. The results are presented in Figures 10 and 11 for the two risk-taking cases of completely risk-averse and completely risk-prone standpoints.
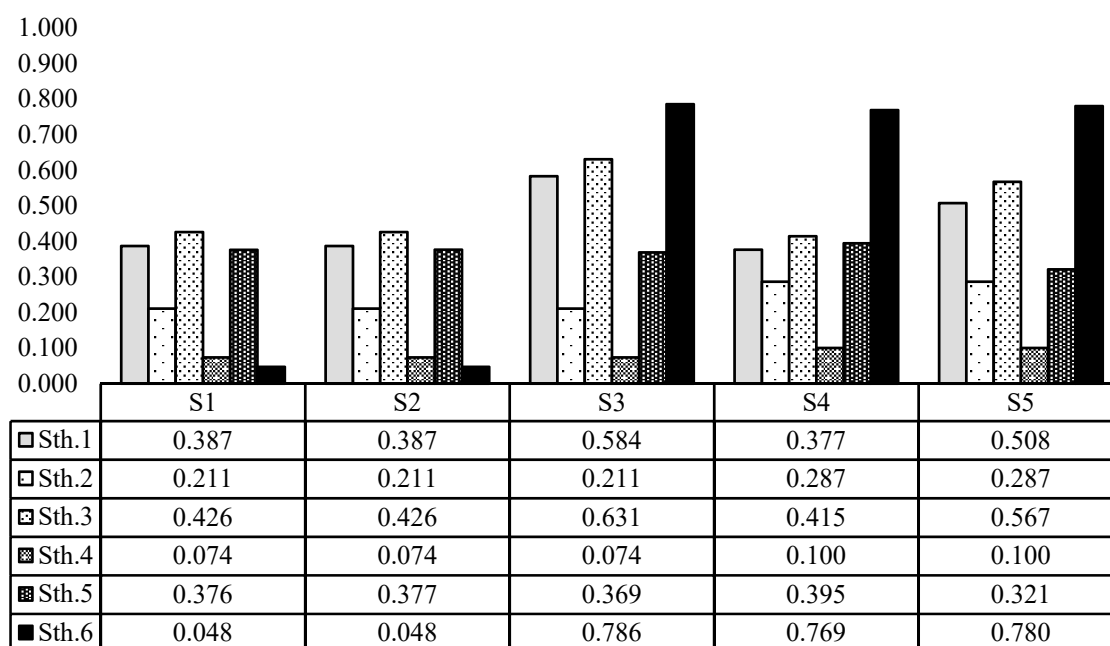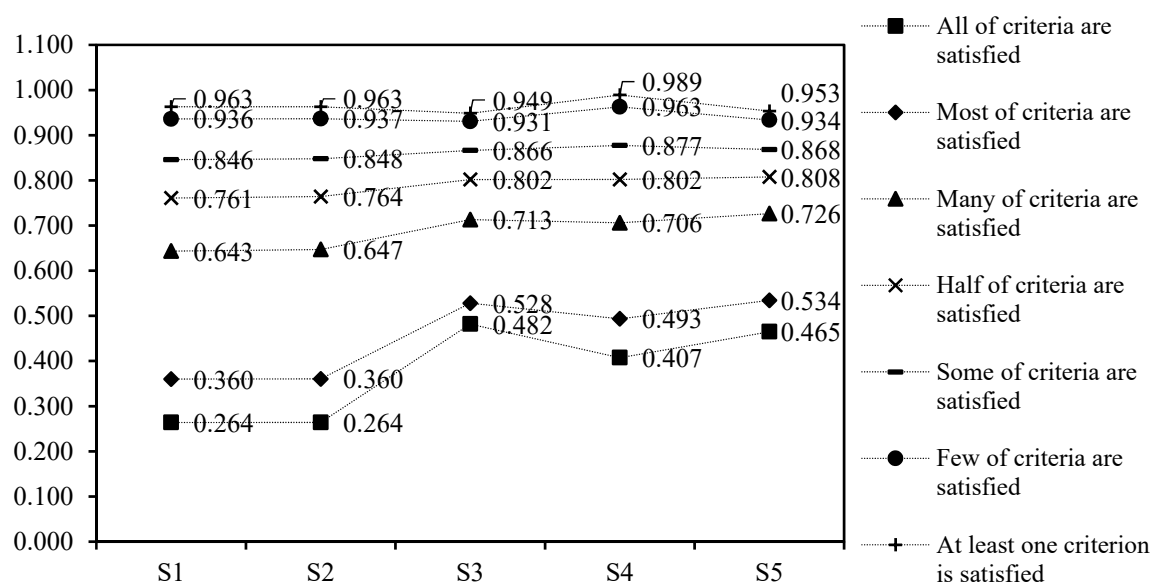
Figure 10. Scores of the water strategies in each stakeholder's viewpoint (satisfying all criteria).

|	S1	S2	S3	S4	S5
□ Sth.1	0.952	0.948	0.967	0.993	0.923
□ Sth.2	0.976	0.981	1.000	1.000	0.994
▣ Sth.3	0.976	0.981	1.000	0.985	0.994
▦ Sth.4	0.947	0.947	0.947	0.947	0.942
▦ Sth.5	0.959	0.944	0.951	1.000	0.946
■ Sth.6	0.959	0.958	0.809	1.000	0.908

Figure 11. Scores of the water strategies in each stakeholder's viewpoint (satisfying at least one criterion).

Following Step 9, the scores of water strategies in the viewpoint of a group of stakeholders are calculated based on the two types of EMOWA and IMOWA operators. Figures 12 and 13 represent the scores of strategies in each group viewpoint in several risk-taking attitudes, based on the EMOWA and IMOWA operators, respectively:

Figure 12. The external modified ordered weighted averaging (EMOWA) scores of the Kashafroud water strategies in the group viewpoint for the risk cases.
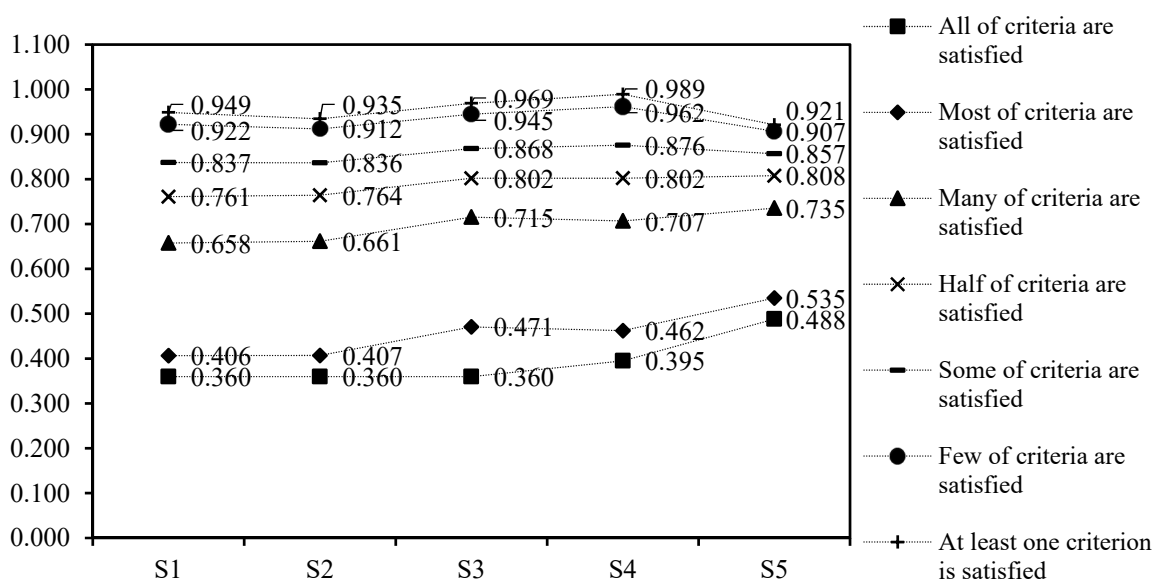
Figure 13. The internal modified ordered weighted averaging (IMOWA) scores of the Kashafroud water strategies in the group viewpoint for the risk cases.

3.2. Group Consensus Measurements of the Water Strategies

Regarding Step 10, the consensus measurements of water strategies in the viewpoint of a group of stakeholders are calculated based on the Euclidean Minkowski's distance-based method two types of EMOWA and IMOWA operators. According to the group decision-making amongst the stakeholders of the Kashafroud watershed, the TLA index is selected as the linguistic variable of "slightly high", which equals a numerical value of 0.800. Accordingly, the consensus measurement of each water strategy is compared with the numerical value of TLA.

Figures 14 and 15 represent the consensus measurements of water strategies in a group viewpoint in the several risk-taking attitudes, based on the EMOWA and IMOWA operators, respectively. The TLA of 0.800 is represented by the dashed line.
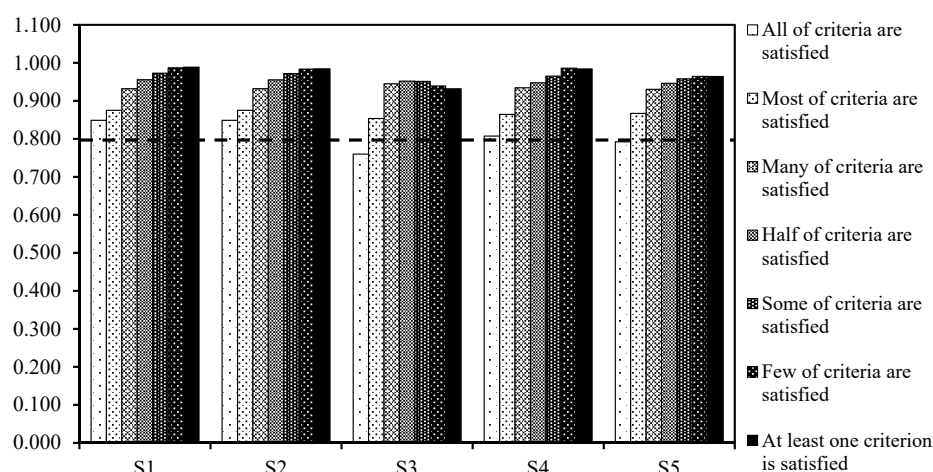
Figure 14. The EMOWA group consensus measurements of water strategies in the risk cases.
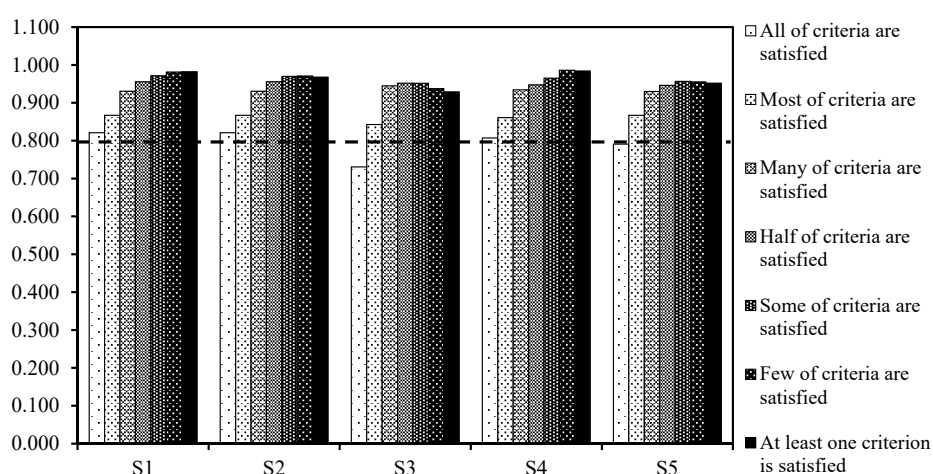

Figure 15. The IMOWA group consensus measurements of water strategies in the risk cases.

3.3. The Final Ranking of the Water Strategies

Finally, according to Step 11, the watershed strategies are ranked based on the group scores calculated by the two types of EMOWA and IMOWA operators in the several risk-taking cases, presented in Table 8. Additionally, the number of criteria that are satisfied in each case are specified [13].

Table 8. The final ranking of water strategies for the Kashafroud watershed in the risk-taking cases.

Type No. 1: EMOWA Operator							
Satisfaction of criteria by strategies	Satisfies at least one (1) criterion	Satisfies few of (2) the criteria	Satisfies some of (3) the criteria	Satisfies half of (5) the criteria	Satisfies many of (7) the criteria	Satisfies most of (9) the criteria	Satisfies all of (10) the criteria
S_1	2	3	5	5	5	5	5
S_2	3	2	4	4	4	4	4
S_3	5	5	3	3	2	2	1
S_4	1	1	1	2	3	3	3
S_5	4	4	2	1	1	1	2
Type No. 2: IMOWA Operator							
Satisfaction of criteria by strategies	Satisfies at least one (1) criterion	Satisfies few of (2) the criteria	Satisfies some of (3) the criteria	Satisfies half of (5) the criteria	Satisfies many of (7) the criteria	Satisfies most of (9) the criteria	Satisfies all of (10) the criteria
S_1	3	3	4	5	5	5	5
S_2	4	4	5	4	4	4	4
S_3	2	2	2	3	2	2	3
S_4	1	1	1	2	3	3	2
S_5	5	5	3	1	1	1	1

4. Discussion

Discussion about the results of the risk-based consensus-based GDSS modeling for the Kashafroud urban watershed is illustrated in four subjects, including 1—importance degrees of the criteria in the viewpoints of the group of stakeholders, 2—scores of water strategies in each stakeholder's viewpoint and the group of stakeholders' opinions, 3—group consensus measurements for the strategies, and 4—final ranking of the water strategies.

According to the results of criteria weights in group viewpoint (Figure 9), the stakeholders' group assigned the most weight to the criteria C_7 and C_1, respectively. In the viewpoint of the group, the priority of the criterion C_7 (purified sewerage ratio) in comparison with the other criteria shows that utilization of purified wastewater for some agricultural demands could reduce its withdrawal from groundwater resources, which instead be used to supply the increasing urban potable demand. Additionally, the relative priority of C_1 (water stress) emphasizes the importance of a close ratio between water withdrawal and renewable water resources in a semi-arid climate in order to control the withdrawal from other water resources. On the other hand, the group of stakeholders assigns the least weight for the criterion C_8 (potable water losses), because the criterion C_8 has no significant effect on water stress in comparison with the other factors.

Regarding the results related to the scores of water strategies in each stakeholder's viewpoint (Figures 10 and 11), in the completely risk-averse case, each stakeholder desires to select the strategy that satisfies all criteria. In this conservative viewpoint, half of the stakeholders choose the strategy S_3 as the more desirable strategy. These stakeholders have the supply management approach with an emphasis on utilization of purified wastewater for agricultural irrigation and dependency on water transfer from the Doosti Dam. Vice versa, in the completely risk-prone standpoint, each stakeholder desires to select the strategy that satisfies at least one criterion. Therefore, in this nonconservative standpoint, half of the stakeholders choose the strategy S_4 as the more desirable strategy. These stakeholders have just the demand management approach while considering the water transfer from the Doosti Dam. As it is expected from the risk analysis results, the scores of strategies in each stakeholder's viewpoint in the completely risk-prone viewpoint (completely optimistic viewpoint) are greater than the scores in the completely risk-averse viewpoint (completely pessimistic viewpoint). The completely optimistic viewpoint emphasizes on a fully positive and fully nonconservative approach of each stakeholder, while the completely pessimistic standpoint emphasizes on a fully negative and a fully conservative approach of each stakeholder.

With respect to the results of the group scores of water strategies (Figures 12 and 13), the group scores of strategies are increased from the completely risk-averse viewpoint to the completely risk-prone standpoint. Risk-averse cases have a conservative viewpoint and emphasize a pessimistic approach from stakeholders in the GDSS process, while the risk-prone cases have a nonconservative standpoint and emphasize an optimistic approach from stakeholders. For several risk-taking cases, the trend of changes for EMOWA scores is almost the same as the trend of changes for IMOWA scores, except for the completely risk-averse case. According to the EMOWA results, in the completely risk-averse viewpoint, strategy S_3 is selected as the more desirable strategy by the group. On the other hand, in the completely risk-averse viewpoint of the IMOWA results, strategy S_5 is chosen as the more desirable strategy by the group. It means that, for the Kashafroud watershed, the completely risk-averse viewpoint of the EMOWA operator emphasizes a supply management approach with dependency on water transfer from the Doosti Dam, whereas the completely risk-averse viewpoint of the IMOWA operator emphasizes a combined supply-demand management approach with no dependency on water transfer from the Doosti Dam. On the other hand, in accordance with the EMOWA and IMOWA results, in the completely risk-prone standpoint, strategy S_4 is chosen as the more desirable strategy by the group. For this watershed, the completely risk-prone viewpoint of the EMOWA and IMOWA operators emphasizes a demand management approach with dependency on the water transfer from the Doosti Dam.

Following the results of group consensus measurements (Figures 14 and 15), the consensus measurements of all water strategies in several risk-taking cases are higher than the selected TLA, except for the strategy S_3 in the completely risk-averse viewpoint (which has a consensus measurement with a really small distance to the selected TLA of 0.800). Therefore, a final group agreement amongst the stakeholders was reached. Additionally, according to the results of Figures 14 and 15, it is observed that the group consensus measurements have an increasing trend from a completely risk-averse viewpoint to a completely risk-prone standpoint. It is therefore more difficult to achieve group consensus by satisfying all criteria by the water strategies in the completely risk-averse viewpoint than accomplishing a group consensus by satisfying just one criterion by the strategies in the completely risk-prone standpoint. In addition, changing the Minkowski's parameter of q from 1 to infinity, the deviation and conflict between the individual and group viewpoints about the water strategies increased, which caused a decrease of group consensus measurements on strategies. After the achievement of the group consensus, the final ranking of water strategies can be implemented to determine the more desirable strategy in several risk-taking cases in both the EMOWA and IMOWA operators.

Consequently, according to the results of group scores achieved by the EMOWA and IMOWA operators, the final ranking of water strategies is determined in several risk-taking cases (Table 8). Regarding the EMOWA results, in the three risk-prone cases, the strategy S_4 is selected as the more desirable water strategy. In the neutral risk and the two risk-averse cases, the strategy S_5 is chosen as the more desirable strategy. Additionally, in the completely risk-averse case, the strategy S_3 is selected as the more desirable strategy. In accordance with the IMOWA results, in the three risk-prone cases, the strategy S_4 is selected as the more desirable water strategy, while, in the neutral risk and the three risk-averse cases, the strategy S_5 is chosen as the more desirable strategy.

5. Conclusions

In modeling the GDSS for effective urban watershed management, there are numerous stakeholders and beneficiaries with several opinions and preferences that should be used to evaluate water strategies with respect to sustainable development criteria for selecting the more desirable water strategy. The stakeholders' group may have several risk-taking attitudes, each of which risk-taking cases is related to satisfying the number of criteria by water strategies. The risk-taking attitudes vary from a completely risk-averse viewpoint to a completely risk-prone standpoint. The completely risk-averse viewpoint (completely conservative opinion) believes that all criteria should be satisfied by water strategies, while the completely risk-prone standpoint (completely nonconservative opinion) believes that at least one criterion can be satisfied by strategies. The other risk-taking attitudes are expressed between these two limited risk-taking cases. Accordingly, for analyzing the effect of risk-taking cases on the selection of the more desirable water strategy, the risk-based consensus-based GDSS model should be developed for effective urban watershed management.

In this research, in order to select the more desirable water strategy for the Kashafroud watershed, the risk-based EMOWA and IMOWA operators were proposed in the two types of external and internal aggregations to calculate the group scores of water strategies with respect to the criteria. These operators consider the importance degrees of criteria, the risk-taking degrees of the stakeholders' group, and the stakeholders' power weights simultaneously. Additionally, the group consensus-seeking process was implemented based on the weighted Minkowski's method, in which the group consensus measurements for strategies have been calculated using the squared mean deviation between the individual and group viewpoints of stakeholders. Finally, the ranking of the water strategies was determined in several risk-taking attitudes of the group of stakeholders with respect to the EMOWA and IMOWA scores for the strategies.

Therefore, the proposed methodology, including the main phases of water strategies' scoring, group consensus measuring, and the water strategies' ranking, was successfully developed for the study area of the Kashafroud watershed. The scoring results related to the EMOWA and IMOWA

operators represents that the group scores of the water strategies are dependent on the risk-taking attitudes of the stakeholders within the watershed. Accordingly, for each strategy, the group scores in the risk-prone cases (at least one, a few, and some of the criteria satisfied by the strategies) are greater than the group scores in the risk-averse situations (many, most, and all of the criteria satisfied by the strategies). In addition, the group consensus measuring results shows that the final agreement among the stakeholders for all strategies was almost fully achieved. According to the findings of each strategy, the group consensus measurements in the risk-prone cases are greater than the group consensus measurements in the risk-averse situations. Finally, regarding the ranking results of strategies, for the risk-averse viewpoint in the EMOWA results, the group of stakeholders has a conservative approach and tend to select the strategy of S_3 as a supply management strategy, which satisfies all sustainable development criteria, while, in the IMOWA results with the risk-averse viewpoint, the group of stakeholders tends to choose the strategy of S_5 as a combined supply-demand management strategy. For the risk-prone standpoint in both EMOWA and IMOWA results, the group of stakeholders have a nonconservative approach and like to select the strategy of S_4 as a demand management strategy, which satisfies at least one sustainable development criteria.

Besides the advantages of the proposed risk-based consensus-based GDSS model in this study, there are some issues that should be improved in future studies, which include:

- Improving the GDSS model for use of the other input variables in the MCDM process, including the combination of crisp and linguistic data, as well as fuzzy interval valued data.
- Considering the alternative generation process during the GDSS modeling by use of the design theory, such as the K-C and K-C-P methodologies.
- Modeling the other probable water strategies such as climate changes strategies; additionally, changes in the percentage of water supply for the agricultural demand with respect to more several criteria.
- Resolving probable conflicts among stakeholders within the GDSS model using the game-theoretical Nash Bargaining solution.

For future studies, it is suggested to develop this proposed risk-based consensus-based GDSS model for any other watershed management by generating several water strategies based on the stakeholders' group consensus, which considers the combination of agricultural, industrial, and environmental demands and climate changes conditions. Furthermore, a conflict resolution process among stakeholders within the risk-based consensus-based GDSS process for resolving the probable conflicts of preferences among the watershed stakeholders should be analyzed. Additionally, an analysis of the varieties of the Minkowski's parameter and its effect on the group consensus measurement should be studied for future research.

Author Contributions: Conceptualization, R.J.S. and A.P.N.; methodology, R.J.S.; software, R.J.S.; validation, R.J.S. and A.P.N.; formal analysis, R.J.S.; investigation, R.J.S. and A.P.N.; resources, R.J.S.; data curation, R.J.S. and A.P.N.; writing—original draft preparation, R.J.S.; writing—review and editing, A.P.N.; visualization, R.J.S. and A.P.N.; supervision, A.P.N.; project administration, R.J.S. All authors have read and agreed to the published version of the manuscript.

Appendix A

A.1. The Average 40-Year Long-Term Hydrological and Hydrogeological Budget of Kashafroud (1975–2015)

The summary of the results related to the average 40-year long-term hydrological and hydrogeological budget for the Kashafroud watershed (1975–2015) are presented in Table A1 [74–77].

Table A1. Long-term hydrological and hydrogeological budget of the Kashafroud watershed [74–77].

Hydrological Budget							
Mean annual precipitation (MCM)		Mean annual runoff (MCM)		Mean annual soil moisture (MCM)			
Plain	Highland	Plain	Highland	Plain		Highland	
				Evaporation	Infiltration	Evaporation	Infiltration
896	1953	21	342	758	117	1279	332
Hydrogeological Budget							
Mean annual groundwater recharge from (MCM)				Mean annual groundwater discharge by (MCM)		Mean annual changes in reservoir (MCM)	
Rainfall	Surface runoff	Agricultural reversible water	Urban and Industrial reversible water	Withdraw	Outflow from aquifer		
449	207	181	180	1105	31	−119	

A.2. The Estimated Water Consumptions and Predicted Water Demands for Kashafroud by the 2040 Vision

Additionally, for several urban, agricultural, industrial, and environmental water demands of the Kashafroud watershed, the current water consumptions have been specified, and the water demands by the 2040 vision have been predicted, which are presented in Table A2 [71,78–80].

Table A2. Water consumptions and water demands for the Kashafroud watershed by 2040 [71,78–80].

Current Water Consumptions						
Annual consumptions from surface water resources (MCM)			Annual consumptions from groundwater resources (MCM)			
Agricultural water	Urban water	Industrial water	Agricultural water	Urban water	Industrial water	
173	173.5	1.5	806	227	32	
Predicted Water Demands by the 2040 Vision						
Urban demand (MCM)	Equivalent Produced sewerage (MCM)	Agricultural demand (MCM)	Allocable sewerage for demand (MCM)	Industrial demand (MCM)	Equivalent Produced sewerage (MCM)	Environmental water demand (MCM)
489	382	806	404	90	52	43

Appendix B

B.1. Sample Questionnaire for the Selection of the Final Criteria

(1) Firstly, please overview the definitions of the initial criteria. After that, overview Table A3 containing the sustainable development objectives and the relevant initial criteria. Ultimately, give your viewpoint about the importance degree of each of the following criteria for the decision-making process and water resources planning and management in the study area of the Kashafroud urban watershed. (Please mark $\sqrt{}$ as a linguistic importance degree for each criterion within just one of the 4th to 12th columns of the table, according to the name of the criterion and the description of that corresponding criterion.)

- Please note that, in Table A3, the 21 initial criteria (taking into account the sustainability objectives including water resources sustainability, environmental sustainability, economic sustainability, and social sustainability) are specified and defined. Choose your priorities so that you can ultimately choose from all four objectives to be included in the final decision-making process.

Definitions of criteria:

- C'_1: (Urban water withdrawal + Agricultural water withdrawal + Industrial water withdrawal)/ (Total water storage);
- C'_2: (Exploitation from groundwater resources) / (Urban water withdrawal + Agricultural water withdrawal + Industrial water withdrawal + Environmental water withdrawal);
- C'_3: (Adjustable water potential from surface water resources—adjusted surface water resources by hydraulic structures) / (Surface water resources);
- C'_4: (Groundwater withdrawal) / (Renewable groundwater resources);
- C'_5: (Supplied agricultural water demand) / (Agricultural water demand);
- C'_6: (Supplied potable urban water demand) / (Potable urban water demand);
- C'_7: (Supplied industrial water demand) / (Industrial water demand);
- C'_8: (Supplied environmental water demand) / (Environmental water demand);
- C'_9: (Surface water resources + Renewable groundwater resources)/(Population);
- C'_{10}: (Sold urban water to urban water consumer) / (Urban water population);
- C'_{11}: (Industrial water withdrawal) / (Industrial employed population);
- C'_{12}: 0.25 × {(Supplied agricultural water demand) / (Agricultural water demand) + (Supplied potable urban water demand) / (Potable urban water demand) + (Supplied industrial water demand) / (Industrial water demand) + (Supplied environmental water demand) / (Environmental water demand)};
- C'_{13} (Qualitative): Balancing between the supply and withdrawal from surface water and groundwater resources;
- C'_{14}: (Groundwater discharge) / (Groundwater recharge);
- C'_{15}: (Entranced surface water + Transferred surface water) / (Surface water resources + Entranced surface water + Transferred surface water);
- C'_{16}: (Purified sewerage) / (Urban sewerage + Industrial sewerage);
- C'_{17}: (Total urban water withdrawal for water distribution network—sold urban water to urban water consumer) / (Total urban water withdrawal for water distribution network);
- C'_{18}: (Total benefit of implementation of water strategy) / (Total cost of implementation of water strategy);
- C'_{19} (Qualitative): Resolving conflicts among stakeholders in agricultural water, potable water, industrial water, and environmental water;
- C'_{20} (Qualitative): Creating job opportunities in agricultural, industrial, and service sectors during the implementation and operation periods of the strategies; and
- C'_{21}: 0.25 × {0.970 × (Supplied agricultural water demand) / (Agricultural water demand) + 1 × (Supplied potable urban water demand) / (Potable urban water demand) + 0.970 × (Supplied industrial water demand) / (Industrial water demand)}.

Table A3. Sample questionnaire for the linguistic importance degrees of the initial criteria.

1	2	3	4	5	6	7	8	9	10	11	12
Objective	Criterion	Definition	Linguistic Importance Degree								
			NI	VLI	LI	SLI	MI	SHI	HI	VHI	PI
Water resources sustainability	C'_1: Water stress										
	C'_2: Groundwater dependency										
	C'_3: Adjustable protential of Surface Water Resources										
	C'_4: Development of groundwater										
	C'_5: Percentage of water supply for agricultural demand										
	C'_6: Percentage of water supply for potable urban demand										
	C'_7: Percentage of water supply for industrial demand										
	C'_8: Percentage of water supply for environmental demand										
	C'_9: Renewable water resources per capita										
	C'_{10}: Potable water consumption per capita										
	C'_{11}: Industrial water consumption per capita										
	C'_{12}: Reliability for water supply										
	C'_{13}: Balancing between using surface water and groundwater										
	C'_{14}: Groundwater unsustainability										
	C'_{15}: Surface water dependency on other watersheds										
Environmental sustainability	C'_{16}: Purified sewerage ratio										
Economic sustainability	C'_{17}: Potable water losses										
	C'_{18}: Benefit per cost ratio										
Social sustainability	C'_{19}: Conflict resolution amongst water stakeholders										
	C'_{20}: Creating job opportunities										
	C'_{21}: Social equity										

NI: no importance, VLI: very low importance, LI: low importance, SLI: slightly low importance, MI: moderate importance, SHI: slightly high importance, HI: high importance, VHI: very high importance, and PI: perfect importance.

B.2. Stakeholders' Individual Viewpoints about the Importance Degree of the Initial Criteria

Table A4. The linguistic importance degrees of the initial criteria in the individual's viewpoints.

Member's ID	C'_1	C'_2	C'_3	C'_4	C'_5	C'_6	C'_7	C'_8	C'_9	C'_{10}	C'_{11}	C'_{12}	C'_{13}	C'_{14}	C'_{15}	C'_{16}	C'_{17}	C'_{18}	C'_{19}	C'_{20}	C'_{21}
Sth.$_{11}$	P	VH	N	VH	P	SH	SL	H	P	SH	SL	P	VH	P	SL	VH	H	SL	H	H	H
Sth.$_{12}$	P	P	M	VH	H	SL	L	L	SH	SL	H	M	SH	P	VL	M	M	VH	M	M	SH
Sth.$_{13}$	P	P	VL	VH	M	VH	VH	VH	H	M	VL	P	VH	P	SH	P	P	M	H	SL	VH
Sth.$_{14}$	P	VH	L	VH	H	VH	H	H	M	L	SL	VH	VH	P	H	M	SH	M	L	VL	H
Sth.$_{15}$	P	P	SL	H	P	VH	VH	SH	P	VH	VH	P	VH	P	VH	P	VH	VH	VH	M	P
Sth.$_{16}$	P	VH	H	VH	H	VH	VH	VH	P	VH	VH	VH	VH	P	H	VH	VH	H	SH	M	H
Sth.$_{17}$	VH	H	SH	VH	VH	VH	VH	VH	P	H	VH	VH	VH	VH	H	H	H	VH	SH	VH	P
Sth.$_{18}$	P	P	M	VH	P	VH	VH	VH	VH	VH	VH	P	VH	P	SL	P	P	P	VH	VH	P
Sth.$_{19}$	P	P	L	VH	P	L	M	VL	H	L	M	VH	VH	P	H	P	SL	VH	SL	H	VH
Sth.$_{21}$	P	P	M	VL	P	SL	SL	VH	L	L	SL	P	VH	P	M	P	M	P	H	VH	P
Sth.$_{22}$	P	P	M	VL	P	SL	M	M	P	L	SH	P	VH	P	M	P	VL	VH	VH	H	VH
Sth.$_{31}$	P	P	M	VH	P	VH	VH	M	P	VH	VH	P	VH	P	VL	P	P	VH	VH	H	P
Sth.$_{32}$	P	P	VH	VH	P	VH	VH	VH	P	VH	VH	P	VH	P	VH	P	P	P	VH	VH	P
Sth.$_{33}$	P	P	VL	M	P	VL	VH	H	P	VH	SH	P	VH	M	VH	P	M	VH	VH	M	P
Sth.$_{34}$	VH	H	VL	M	P	SH	M	SL	SH	H	M	P	VH	VH	VH	SH	H	M	SH	H	SH
Sth.$_{41}$	P	P	M	N	P	SL	VL	SL	P	L	VH	P	SL	P	SH	P	L	P	M	M	P
Sth.$_{51}$	P	H	H	M	M	L	VH	SL	VH	H	VH	H	M	VH	H	SH	SL	L	M	SH	M
Sth.$_{52}$	P	SH	H	VH	P	VH	SH	VH	H	VH	SH	P	VH	P	SH	P	P	SH	H	M	SH
Sth.$_{61}$	P	P	N	L	VH	H	VH	H	P	H	VH	SL	VH	P	SL	H	N	VH	VH	SL	M
Sth.$_{62}$	P	P	N	L	VH	H	VH	H	VH	H	VH	M	VH	P	SL	VH	N	P	VH	SL	VH
Sth.$_{63}$	P	P	H	VH	VH	M	M	M	VH	H	M	VH	M	VH	SH	M	SL	SL	SL	H	VH

B.3. Sample Questionnaire for Weighting the Final Criteria

(2) Please overview the Table A5 containing the final selected criteria. Give your viewpoint about the importance degree (linguistic weight) of each of the following criteria for the decision-making process and water resources planning and management in the study area of the Kashafroud urban watershed. (Please mark $\sqrt{}$ as a linguistic importance degree for each criterion within just one of the 4th to 12th columns of the table, according to the name of the criterion and the description of that corresponding criterion.)

Table A5. Sample questionnaire for the linguistic importance degrees of the final criteria.

1	2	3	4	5	6	7	8	9	10	11	12
Objective	**Criterion**	**Definition**	**Linguistic Importance Degree**								
			NI	VLI	LI	SLI	MI	SHI	HI	VHI	PI
Water resources sustainability	C'_1: Water stress										
	C'_2: Groundwater dependency										
	C'_5: Percentage of water supply for agricultural demand										
	C'_9: Renewable water resources per capita										
	C'_{12}: Reliability for water supply										
	C'_{14}: Groundwater unsustainability										
Environmental sustainability	C'_{16}: Purified sewerage ratio										
Economic sustainability	C'_{17}: Potable water losses										
	C'_{18}: Benefit per cost ratio										
Social sustainability	C'_{21}: Social equity										

Appendix C

Determination of the Water Strategies' Evaluation Values

In order to select the evaluation values of each water strategy with respect to the final sustainable development criteria for the risk-based GDSS model, the related variables have been extracted from the relevant IWRM project reports [71,74–77] and MODSIM modeling report [81], which have been provided by the Iran Water Resources Management Company and ToossAb Water Engineering Consultant Company and approved by the Iran Ministry of Energy. Indeed, the variables of the GDSS modeling for the Kashafroud watershed are related to the outputs of the IWRM project and MODSIM modeling project, which have been already analyzed for this study area.

The input data that should be entered into the MODSIM modeling includes the following:

1. Monthly data for the simulation of the model, including the data of the hydrometric stations related to the surface water, as well as the data of the aquifer unit hydrograph associated with the groundwater resources.
2. Monthly evaporation from the reservoir of each dam.
3. Monthly water withdrawal from the aquifer.
4. Monthly existing water consumptions for the base strategy, including urban, agricultural industrial, and environmental waters.
5. Estimated infiltration fraction (return flow) from urban, agricultural, and industrial consumptions.

Accordingly, the output data that are taken out from the MODSIM modeling includes the simulated results in hydrometric stations and aquifer unit hydrograph, which are compared with the observed data, based on an iterative calibration-validation process.

The parameters that are involved in the model calibration include the return water to aquifers from agricultural, urban, and industrial consumptions, the surface runoff infiltration values into the groundwater reservoirs, the outflow groundwater, and, if necessary, the efficiency of used water.

Additionally, the model calibration criterion for surface flows is primarily the hydrometric stations and the water resources budget data of the study area.

In addition, the model calibration criterion for the aquifers and groundwater reservoir is primarily the unit hydrograph of the aquifer and then the water resources budget data of the study area.

Accordingly, the model calibration is done in two parts: surface water and groundwater. In the surface water calibration, the output data from the station in the model is compared with the hydrometric station data within the watershed.

To calibrate and validate the outputs of the groundwater reservoir, it is done by calculating the changes in groundwater volume from the unit hydrograph of the aquifer. This is implemented for the modeling period. Then, the changes in the volume of the aquifer are compared with the changes in the volume of the groundwater reservoir in the simulated model. It should be noted that the calibration of the surface and groundwater due to the dependence of the parameters on each other should be performed simultaneously.

Ultimately, in order to determine the evaluation values of each water strategy with respect to each sustainable development criteria, the related data (see Table 6, Appendix B—Definitions of criteria) are extracted from the IWRM project reports [70,71,75–80,86], as well as the relevant variables are obtained from the outputs of the MODSIM modeling project report [81]. Accordingly, the detailed variables used for calculation of the evaluation values of the five water strategies with respect to the 10 final selected sustainable development criteria are presented in Table A6:

Table A6. The detailed variables for the determination of the evaluation matrix of the water strategies.

	S_1	S_2	S_3	S_4	S_5
C_1	$\frac{(488.2+880.3+71.5)}{(1503.3)}$	$\frac{(488.2+902.3+71.5)}{(1503.3)}$	$\frac{(488.2+981.9+71.5)}{(1356.7)}$	$\frac{(437.2+792.7+65.8)}{(1410.3)}$	$\frac{(437.2+831.7+65.8)}{(1319.4)}$
C_2	$\frac{(1092.45)}{(488.2+880.3+71.5+10.9)}$	$\frac{(1092.45)}{(488.2+902.3+71.5+10.9)}$	$\frac{(1092.45)}{(488.2+981.9+71.5+10.9)}$	$\frac{(951.19)}{(437.2+792.7+65.8+10.9)}$	$\frac{(999.09)}{(437.2+831.7+65.8+10.9)}$
C_3	$\frac{(880.3)}{(1103.4)}$	$\frac{(902.3)}{(1103.4)}$	$\frac{(981.9)}{(1103.4)}$	$\frac{(792.7)}{(956.8)}$	$\frac{(831.7)}{(956.8)}$
C_4	$\frac{(1533.8\times10^6)}{(5686046)}$	$\frac{(1533.8\times10^6)}{(5686046)}$	$\frac{(1432.2\times10^6)}{(5686046)}$	$\frac{(1440.8\times10^6)}{(5686046)}$	$\frac{(1392.9\times10^6)}{(5686046)}$
C_5	$0.25\times(0.798+1+1+0.973)$	$0.25\times(0.818+1+1+0.973)$	$0.25\times(0.890+1+1+0.973)$	$0.25\times(0.828+1+1+0.973)$	$0.25\times(0.869+1+1+0.973)$
C_6	$\frac{(1110.95)}{(1082)}$	$\frac{(1110.95)}{(1082)}$	$\frac{(1110.95)}{(980.4)}$	$\frac{(969.69)}{(989)}$	$\frac{(1017.59)}{(941.1)}$
C_7	$\frac{(105.858)}{(426.667)}$	$\frac{(105.858)}{(426.667)}$	$\frac{(236.976)}{(426.667)}$	$\frac{(94.445)}{(391.41)}$	$\frac{(211.775)}{(391.41)}$
C_8	0.232	0.232	0.232	0.171	0.171
C_9	1.101	1.103	1.081	1.418	0.941
C_{10}	$0.333\times$ $(0.97\times0.798+1\times1+0.97\times1)$	$0.333\times$ $(0.97\times0.818+1\times1+0.97\times1)$	$0.333\times$ $(0.97\times0.890+1\times1+0.97\times1)$	$0.333\times$ $(0.97\times0.828+1\times1+0.97\times1)$	$0.333\times$ $(0.97\times0.869+1\times1+0.97\times1)$

References

1. United Nations, Department of Economic Social Affairs, Population Division 2019. *World Population Prospects 2019: Highlights*, 1st ed.; United Nations: New York, NY, USA, 2019; pp. 1–2.

2. Bahri, A. *Global Water Partnership: Integrated Urban Water Management*, 1st ed.; Global Water Partnership: Stockholm, Sweden, 2012; pp. 11–12.

3. United Nations Development Programme 2006. *Global Partnership for Development: Annual Report 2006*, 1st ed.; United Nations: New York, NY, USA, 2006; pp. 1–2.

4. Simonovic, S.P. *Managing Water Resources: Methods and Tools for a Systems Approach*, 1st ed.; UNESCO Publishing: Paris, France; Earthscan James & James: London, UK, 2009; pp. 172–240.

5. Bender, M.J.; Simonovic, S.P. Consensus as the Measure of Sustainability. *Hydrol. Sci. J.* **1997**, *42*, 493–500. [CrossRef]

6. Parkinson, J.N.; Goldenfum, J.A.; Tucci, C. *Integrated Urban Water Management: Humid Tropics (Urban Water Series-UNESCO-IHP)*, 1st ed.; CRC Press: Boca Raton, FL, USA, 2009; p. 2.

7. Tahmasebi Birgani, Y.; Yazdandoost, F. An Integrated Framework to Evaluate Resilient-Sustainable Urban Drainage Management Plans Using a Combined-Adaptive MCDM Technique. *Water Resour. Manag.* **2018**, *32*, 2817–2835. [CrossRef]

8. Mianabadi, H.; Sheikhmohammady, M.; Mostert, E.; Van de Giesen, N. Application of the Ordered Weighted Averaging (OWA) Method to the Caspian Sea Conflict. *Stoch. Environ. Res. Risk Assess.* **2014**, *28*, 1359–1372. [CrossRef]

9. Minatour, Y.; Bonakdari, H.; Zarghami, M.; Ali Bakhshi, M. Water Supply Management Using an Extended Group Fuzzy Decision-Making Method: A Case Study in North-Eastern Iran. *Appl. Water Sci.* **2015**, *5*, 291–304. [CrossRef]

10. Prodanovic, P.; Simonovic, S.P. Comparison of Fuzzy Set Ranking Methods for Implementation in Water Resources Decision-Making. *Can. J. Civil. Eng.* **2002**, *29*, 692–701. [CrossRef]

11. Chitsaz, N.; Azarnivand, A. Water Scarcity Management in Arid Regions based on an Extended Multiple Criteria Technique. *Water Resour. Manag.* **2017**, *31*, 233–250. [CrossRef]

12. Anbari, M.J.; Tabesh, M.; Roozbahani, A. Risk Assessment Model to Prioritize Sewer Pipes Inspection in Wastewater Collection Networks. *J Environ. Manag.* **2017**, *190*, 91–101. [CrossRef]

13. Emrouznejad, A.; Marra, M. Ordered Weighted Averaging Operators 1988–2014: A Citation-based Literature Survey. *Int. J. Intell. Syst.* **2014**, *29*, 994–1014. [CrossRef]

14. Bouzarour-Amokrane, Y.; Tchangani, A.; Peres, F. A Bipolar Consensus Approach for Group Decision Making Problems. *Expert Syst Appl* **2015**, *42*, 1759–1772. [CrossRef]

15. Simonovic, S.P.; Bender, M.J. Collaborative Planning-Support System: An Approach for Determining Evaluation Criteria. *J. Hydrol.* **1996**, *177*, 237–251. [CrossRef]

16. Bender, M.J.; Simonovic, S.P. A System Approach for Collaborative Decision Support in Water Resources Planning. *Int. J. Technol. Manag.* **2000**, *19*, 546–556. [CrossRef]

17. Urtiga, M.M.; Morais, D.C.; Hipel, K.W.; Kilgour, D.M. Group Decision Methodology to Support Watershed Committees in Choosing Among Combinations of Alternatives. *Group Decis. Negot.* **2017**, *26*, 729–752. [CrossRef]

18. Dweiri, F.; Ahmed Khan, S.; Almulla, A. A Multi-Criteria Decision Support System to Rank Sustainable Desalination Plant Location Criteria. *Desalination* **2018**, *444*, 26–34. [CrossRef]

19. Kumar, A.; Sah, B.; Singh, A.R.; Deng, Y.; He, X.; Kumar, P.; Bansal, R.C. A Review of Multi Criteria Decision Making (MCDM) towards Sustainable Renewable Energy Development. *Renew Sust. Energ. Rev.* **2017**, *69*, 596–609. [CrossRef]

20. Roozbahani, A.; Ebrahimi, E.; Banihabib, M.E. A Framework for Ground Water Management based on Bayesian Network and MCDM Techniques. *Water Resour. Manag.* **2018**, *32*, 4985–5005. [CrossRef]

21. Tscheikner-Gratl, F.; Egger, P.; Rauch, W.; Kleidorfer, M. Comparison of Multi-Criteria Decision Support Methods for Integrated Rehabilitation Prioritization. *Water* **2017**, *9*, 68. [CrossRef]

22. Golfam, P.; Ashofteh, P.; Rajaee, T.; Chu, X. Prioritization of Water Allocation for Adaptation to Climate Change Using Multi-Criteria Decision Making (MCDM). *Water Resour. Manag.* **2019**, *33*, 3401–3416. [CrossRef]

23. Prodanovic, P.; Simonovic, S.P. Fuzzy Compromise Programming for Group Decision Making. *IEEE Trans. Syst. Man Cybern.-A* **2003**, *33*, 358–365. [CrossRef]

24. Bender, M.J.; Simonovic, S.P. A Fuzzy Compromise Approach to Water Resource Systems Planning Under Uncertainty. *Fuzzy Sets Syst.* **2000**, *115*, 35–44. [CrossRef]

25. Alhumaid, M.; Ghumman, A.R.; Haider, H.; Al-Salamah, I.S.; Ghazaw, Y.M. Sustainability Evaluation Framework of Urban Stormwater Drainage Options for Arid Environments Using Hydraulic Modeling and Multicriteria Decision-Making. *Water* **2018**, *10*, 581. [CrossRef]

26. Sapkota, M.; Arora, M.; Malano, H.; Sharma, A.; Moglia, M. Integrated Evaluation of Hybrid Water Supply Systems Using a PROMETHEE–GAIA Approach. *Water* **2018**, *10*, 610. [CrossRef]

27. Gigovic, L.; Pamucar, D.; Bajic, Z.; Drobnjak, S. Application of GIS-Interval Rough AHP Methodology for Flood Hazard Mapping in Urban Areas. *Water* **2017**, *9*, 360. [CrossRef]

28. Aschilean, I.; Giurca, I. Choosing a Water Distribution Pipe Rehabilitation Solution Using the Analytical Network. *Water* **2018**, *10*, 484. [CrossRef]

29. Fattahi, P.; Fayyaz, S. A Compromise Programming Model to Integrated Urban Water Management. *Water Resour. Manag.* **2010**, *24*, 1211–1227. [CrossRef]

30. Takahashi, R.H.C.; Deb, K.; Wanner, E.F.; Greco, S. A MCDM Model for Urban Water Conservation Strategies Adapting Simos Procedure for Evaluating Alternatives Intra-criteria. In Proceedings of the 6th International Conference on Evolutionary Multi-Criterion Optimization (EMO 2011), Ouro Preto, Brazil, 5–8 April 2011; Springer: Berlin, Heidelberg, 2011.

31. Roozbahani, A.; Zahraie, B.; Tabesh, M. PROMETHEE with Precedence Order in the Criteria (PPOC) as a New Group Decision Making Aid: An Application in Urban Water Supply Management. *Water Resour. Manag.* **2012**, *26*, 3581–3599. [CrossRef]

32. Roozbahani, A.; Zahraie, B. Tabesh, Integrated Risk Assessment of Urban Water Supply Systems from Source to Tap. *Stoch. Environ. Res. Risk Assess.* **2013**, *27*, 923–944. [CrossRef]

33. Abrishamchi, A.; Ebrahimian, A.; Tajrishi, M.; Marino, M.A. Case Study: Application of Multicriteria Decision Making to Urban Water Supply. *J. Water Res. Plan. Man.* **2005**, *131*, 326–335. [CrossRef]

34. Jesiya, N.P.; Girish, G. Groundwater Suitability Zonation with Synchronized GIS and MCDM approach for Urban and Peri-Urban Phreatic Aquifer Ensemble of Southern India. *Urban Water J.* **2018**, *15*, 801–811.

35. Qin, X.S.; Huang, G.H.; Chakma, A.; Nie, X.H.; Lin, Q.G. A MCDM-based Expert System for Climate-Change Impact Assessment and Adaptation Planning—A Case Study for the Georgia Basin, Canada. *Expert Syst. Appl.* **2008**, *34*, 2164–2179. [CrossRef]

36. Kim, Y.; Chung, E.-S.; Jun, S.-M.; Kim, S.-U. Prioritizing the Best Sites for Treated Wastewater Instream Use in an Urban Watershed Using Fuzzy TOPSIS. *Resour. Conserv. Recy.* **2013**, *73*, 23–32. [CrossRef]

37. Kumar, A.; Pandey, A.C. Geoinformatics based groundwater potential assessment in hard rock terrain of Ranchi urban environment, Jharkhand state (India) using MCDM–AHP techniques. *Groundw. Sustain. Dev.* **2016**, *2–3*, 27–41. [CrossRef]

38. Yu, L.; Lai, K.K. A Distance-based Group Decision-Making Methodology for Multi-Person Multi-Criteria Emergency Decision Support. *Decis. Support Syst.* **2011**, *51*, 307–315. [CrossRef]

39. Singh, R.K.; Choudhury, A.K.; Tiwari, M.K.; Shankar, R. Improved Decision Neural Network (IDNN) Based Consensus Method to Solve a Multi-Objective Group Decision Making Problem. *Adv. Eng. Inform.* **2007**, *21*, 335–348. [CrossRef]

40. Pluchinotta, I.; Kazakçi, A.O.; Giordano, R.; Tsoukiàs, A. Design Theory for Generating Alternatives in Public Decision Making Processes. *Group Decis. Negot.* **2019**, *28*, 341–375. [CrossRef]

41. Ullah, A.; Rashid, M.M.; Tamaki, J. On some Unique Features of C–K Theory of Design. *CIRP J. Manufact. Sci. Technol.* **2012**, *5*, 55–66. [CrossRef]

42. Agogué, M.; Kazakçi, A.O. 10 Years of C–K Theory: A Survey on the Academic and Industrial Impacts of a Design Theory. In *An Anthology of Theories and Models of Design; Philosophy, Approaches and Empirical Explorations*, 1st ed.; Chakrabarti, A., Blessing, L.T.M., Eds.; Springer: London, UK, 2014; pp. 219–235.

43. Hooge, S.; Béjean, M.; Arnoux, F. Organising for Radical Innovation: The Benefits of the Interplay between Cognitive and Organisational Processes in Kcp Workshops. *Int. J. Innov. Manag.* **2016**, *20*, 1–33. [CrossRef]

44. Vinogradova, I.; Podvezko, V.; Zavadskas, E.K. The Recalculation of the Weights of Criteria in MCDM Methods Using the Bayes Approach. *Symmetry* **2018**, *10*, 205. [CrossRef]

45. Zardari, N.H.; Ahmed, K.; Shirazi, S.M.; Bin Yusop, Z. *Weighting Methods and their Effects on Multi-Criteria Decision Making Model Outcomes in Water Resources Management*, 1st ed.; Springer: Cham, Germany, 2015; pp. 69–100.

46. Kandel, A. *Fuzzy Techniques in Pattern Recognition*, 1st ed.; John Wiley and Sons: New York, NY, USA, 1982; pp. 170–182.

47. Akter, T.; Simonovic, S.P.; Salonga, J. Aggregation of Inputs from Stakeholders for Flood Management Decision-Making in the Red River Basin. *Can. Water Resour. J.* **2004**, *29*, 251–266. [CrossRef]

48. Simonovic, S.P.; Akter, T. Participatory Floodplain Management in the Red River Basin, Canada. *Annu. Rev. Control.* **2006**, *30*, 183–192. [CrossRef]

49. Herrera, F.; Herrera-Viedma, E.; Verdegay, J.L. Direct Approach Processes in Group Decision-Making Using Linguistic OWA Operators. *Fuzzy Set Syst.* **1996**, *79*, 175–190. [CrossRef]

50. Mosadeghi, R.; Warnken, J.; Tomlinson, R.; Mirfenderesk, H. Comparison of Fuzzy-AHP and AHP in a Spatial Multi-Criteria Decision Making Model for Urban Land-Use Planning. *Comput. Environ. Urban Syst.* **2015**, *49*, 54–65. [CrossRef]

51. Zekai, S. *Fuzzy Logic and Hydrological Modeling*, 1st ed.; Taylor & Francis Group: New York, NY, USA, 2010; pp. 60–100.

52. Akter, T.; Simonovic, S.P. Aggregation of Fuzzy Views of a Large Number of Stakeholders for Multi-Objective Flood Management Decision Making. *J. Environ. Manag.* **2005**, *77*, 133–143. [CrossRef] [PubMed]

53. Ross, T.J. *Fuzzy Logic with Engineering Applications*, 3rd ed.; Wiley: Hoboken, NJ, USA, 2009; pp. 89–116.

54. Azarnivand, A.; Hashemi-Madani, F.S.; Banihabib, M.E. Extended Fuzzy Analytic Hierarchy Process Approach in Water and Environmental Management (Case Study: Lake Urmia Basin, Iran). *Environ. Earth Sci.* **2015**, *73*, 13–26. [CrossRef]

55. Shih, H.S.; Shyur, H.J.; Lee, E.S. An Extension of TOPSIS for Group Decision-Making. *Math. Comp. Model.* **2007**, *45*, 801–813. [CrossRef]

56. Llopis-Albert, C.; Merigo, J.M.; Liao, H.; Xu, Y.; Grima-Olmedo, J.; Grima-Olmedo, C. Water Policies and Conflict Resolution of Public Participation Decision-Making Processes Using Prioritized Ordered Weighted Averaging (OWA) Operators. *Water Resour. Manag.* **2018**, *32*, 497–510. [CrossRef]

57. Javidi Sabbaghian, R.; Zarghami, M.; Nejadhashemi, A.P.; Sharifi, M.B.; Herman, M.R.; Daneshvar, F. Application of Risk-based Multiple Criteria Decision Analysis for Selection of the Best Agricultural Scenario for Effective Watershed Management. *J. Environ. Manag.* **2016**, *168*, 260–272. [CrossRef]

58. Khakzad, H. OWA Operators with Different Orness Levels for Sediment Management Alternative Selection Problem. *Water Supp.* **2020**, *20*, 173–185. [CrossRef]

59. Zadeh, L.A. A computational approach to fuzzy quantifiers in natural languages. *Comput. Math. Appl.* **1983**, *9*, 149–184. [CrossRef]

60. Ben-Arieh, D.; Chen, Z. Linguistic-Labels Aggregation and Consensus Measure for Autocratic Decision Making Using Group Recommendations. *IEEE Trans. Syst. Man Cybern.-A* **2006**, *36*, 558–568. [CrossRef]

61. Bouzarour-Amokrane, Y.; Tchangani, A.P.; Peres, F. Defining and Measuring Risk and Opportunity in BOCR Framework for Decision Analysis. In Proceedings of the 9th International Conference on Modeling, Optimization and Simulation (MOSIM 2012), Bordeaux, France, 6–8 June 2012.

62. Tchangani, A.P.; Bouzarour-Amokrane, Y.; Peres, F. Evaluation Model in Decision Analysis: Bipolar Approach. *Informatica* **2012**, *23*, 461–485. [CrossRef]

63. Chiclana, F.; Taipa-Garcia, J.M.; del Moral, M.J.; Herrera-Viedma, E. A Statistical Comparative Study of Different Similarity Measures of Consensus in Group Decision Making. *Inform. Sci.* **2013**, *221*, 110–123. [CrossRef]

64. Wang, J.; Meng, X.; Dong, Z.; Lu, H.; Sun, J. A Consensus Degree based Multiple Attribute Group Decision Making Method. In Proceedings of the International Conference on Information and Automation (ICIA 2014), Hailar, China, 28–30 July 2014.

65. Dong, Y.; Zha, Q.; Zhang, H.; Kou, G.; Fujita, H.; Chiclana, F.; Herrera-Viedma, E. Consensus Reaching in Social Network Group Decision Making: Research Paradigms and Challenges. *Knowl.-Based Syst.* **2018**, *162*, 3–13. [CrossRef]

66. Kacprzyk, J.; Fedrizzi, M. A 'Soft' Measure of Consensus in the Setting of Partial (Fuzzy) Preferences. *Eur. J. Oper. Res.* **1988**, *34*, 316–325. [CrossRef]

67. Verma, D. *Decision Making Style: Social and Creative Dimensions.*, 1st ed.; Global India Publications: New Delhi, India, 2009; pp. 205–232.

68. Zarghami, M.; Szidarovszky, F. On the Relation between Compromise Programming and Ordered Weighted Averaging Operator. *Inform. Sci.* **2010**, *180*, 2239–2248. [CrossRef]

69. Javidi Sabbaghian, R.; Zarghami, M.; Sharifi, M.B.; Mianabadi, H. Developing a Distance-Based Group Consensus Model under Risk Assessment for Effective Watershed Management. In Proceedings of the 23rd International Conference on Multiple Criteria Decision Making (MCDM 2015), Hamburg, Germany, 2–7 August 2015.

70. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Population Studies, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2012.

71. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Urban and Rural Water Consumptions and Demands, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2012.

72. Davari, K.; Omranian Khorasani, H.; Shafi'ee, M.; Salarian, M. *The Process of Water Management, Revised Version for Kashafroud Watershed: Water and Sustainable Development*, 1st ed.; Khorasan Razavi Regional Water Co.: Mashhad, Iran, 2013; pp. 1–33.

73. Mesgaran, M.; Azadi, P. *A National Adaptation Plan for Water Scarcity in Iran: Stanford Iran 2040 Project*, 1st ed.; Stanford University: Stanford, CA, USA, 2018; pp. 1–36.

74. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Meteorology and Climatology Studies, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2012.

75. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Quantitative and Qualitative Surface Water, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2013.

76. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Quantitative and Qualitative Groundwater Studies, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2012.

77. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Socio-economic Studies, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2012.

78. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Agricultural Consumptions and Demands Studies, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2012.

79. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Industrial Consumptions and Demands Studies, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2012.

80. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Environmental Studies, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2013.

81. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Modeling of the Water Resources and Consumptions, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2013.

82. Vrba, J.; Lipponen, A. *Groundwater Resources Sustainability Indicators: Groundwater Working Group UNESCO, IAEA, IAH*, 14th ed.; UNESCO: Paris, France, 2007; pp. 7–27.

83. DiSano, J. *Indicators of Sustainable Development: Guidelines and Methodologies.*, 3rd ed.; United Nations Publications: New York, NY, USA, 2007; pp. 69–72.

84. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of Identifying and Determining the Criteria of the Water Resources and Consumptions, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2013.

85. United Nations Sustainable Development Solutions Network. *Indicators and a Monitoring Framework for the Sustainable Development Goals, A Report to the Secretary-General of the United Nations by the Leadership Council of the Sustainable Development Solutions Network*, 1st ed.; United Nations: New York, NY, USA, 2015; pp. 1–233.

86. Tooss Ab Consultant, Co. *Updating of Integrated Water Resources Management of Iran Project, The Eastern Basins of Iran: Report of hydrological-hydrogeological budget, Quaraqum Watershed*, 1st ed.; Tooss Ab Co.: Mashhad, Iran, 2015.