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An integrated decision-making framework for selecting the best strategies of water resources management in pandemic emergencies

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Abstract

In recent years, due to COVID 19 pandemic that has resulted in an unpredictable increase in water consumption, the global concerns about water resources management have been increased. Furthermore, it seems essential to focus on strategies enabling to decrease water consumption. So, the aim of this study is to identify and prioritize the potential strategies of water resources management during such pandemic. To do so, we develop a hybrid decision-making approach. At first, the potential strategies are identified by Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis while the relevant criteria are identified based on the literature review and experts' opinions. Afterwards, potential interrelationships between criteria are determined using fuzzy DEMATEL. Then, an integrated FBWM-FANP method is applied to calculate the global weights of criteria. Eventually, the fuzzy VIKOR is utilized to rank the potential strategies. Based on the obtained results, efficiency and economic measures are the most important criteria for selecting the strategies related to water resource management in COVID-19 pandemic. The strategy of advertising and informing about correct water consumption is the best strategy which indicates the power of advertising while it could be economic and efficient either.

1. Introduction

The role of water on human life and the whole universe is very important and vital. It is undeniable that human health and life depend entirely on water. Based on WHO, in 2019, more than a billion people do not have access to clean and healthy water and also more than 3.4 million people die each year from scarce and contaminated water sources [1]. Furthermore, urban water is more important compared to other types of water due to its necessity for a healthy lifestyle and also hygiene practices [2]. These statistics show the great importance of Water Resources Management (WRM) problem. WRM involves balancing the water supply-demand in different situations for all uses (drinking, industry, agriculture, and environment). Experts believe that hardware facilities and new technologies cannot be the only solution for a suitable WRM [3]. However, identifying the factors affecting the unbalanced supply-demand and the logical relationships between them are the most effective way of WRM [4].

Although many factors can affect the amount of water consumption such as population size, economics, and environmental conditions [5], the coronavirus (COVID-19) pandemic has had a significant effect on water consumption worldwide considering restrictions and lockdowns since April 2020. These restrictions have completely affected urban lives and people routines which in turn impact on consumption rate of different resources (i.e., energy, water, and food) [6,7]. Regarding water consumption, people's routines have been changed especially in sanitation and hygiene practices during the COVID-19 pandemic which has caused a rapid increase in water consumption since routine of hand-washing to prevent the infection was the most incredible change [8,9]. Besides, people staying at home again leads to more domestic water consumption because all the activities, which occurred previously outside the home, are now transmitted inside. Generally, Zambrano-Monserrate et al. [10] investigated the indirect effects of COVID-19 on the environment. They

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showed both positive and negative effects of the pandemic of coronavirus. They concluded that there was an improvement in environmental noise reduction and air quality. However, a reduction in recycling and increase of waste water were negative impacts during the short period of the pandemic. So, the future domestic water demand will increase in global cities during the pandemic and even several years later [11,12]. It should be noted that the increased amount of water consumption varies for different countries. For example, the Indian municipalities have reported a sharp increase in domestic water consumption more than 25% [13,14]. In addition, Rezayan and Rezayan [15] considered future water crisis in Iran. They concluded that Iran will face a water crisis by 2050 and it is very important to be ready for managing this crisis based on the expert's panel and Delphi method. So, they emphasized that some strategies that are able to defuse the crisis, for short or long-term postponement are necessary. In this regard, based on the report of Iran's Water Research Center, water consumption in Iran has increased about 40% within the three months from the beginning of this pandemic [16]. This increase is considerable given the critical condition of water resources and can lead to very serious problems soon. So, studying the changes in water consumption which are caused by this pandemic, can lead to important findings for decision-makers. Hence, government can choose effective strategies for dealing with this challenge.

One of the major challenges for decision-makers dealing with such problems as water resource management is adopting the appropriate strategies. The so-called SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis is a well-applied tool that helps decision-makers to provide strategic plans based on assessing both internal and external factors. On the other side, selecting the best strategy among the set of potential strategies is another challenge for decision-makers. To do this, different Multiple Criteria Decision Making (MCDM) techniques are frequently applied to evaluate the potential strategies [17,18].

Due to the importance of the aforementioned problem, this paper aims at investigating the potential strategies for water resource management under pandemic situations in Iran. Due to the limited water resources of Iran and the intensification of domestic water demand during the COVID-19 pandemic and even post-pandemic years, WRM is one of the most challenging tasks of the government in this period. Therefore, the evaluation of various strategies to manage water resources and their optimal use should be pursued by key decision-makers as one of the important directions of the next decade. So, in this study, we suggest some strategies based on the special situation in Iran during the COVID-19 pandemic for water resource management [19]. To achieve this aim, a combined SWOT-MCDM method is proposed to identify and prioritize existing improvement strategies. In this regard, by reviewing the literature as well as interviewing with experts, four components of SWOT analysis of the current situation of Iran during the COVID-19 pandemic are first identified. Since the current COVID-19 pandemic has changed the general situation, the opportunities and threats will be different compared to the normal situation. So, the COVID-19 outbreak influences the results of SWOT analysis. In addition, we apply the SWOT method in our methodology since it has a fundamental advantage over other methods due to the simultaneous consideration of both internal and external environments in formulating the selected strategies [13]. After reviewing the current situation, with regard to the opinions of experts, WRM strategies during the epidemic are presented. Since the simultaneous implementation of all strategies is impossible due to resource scarcity, a hybrid MCDM method is proposed for strategies evaluation. To do this, first relevant criteria are selected by interviewing experts and reviewing the literature. Then, the criteria interrelationships are analyzed through fuzzy DEMATEL. The advantage of this method is its clarity and transparency in reflecting the interrelationships between a wide range of components so that experts can express their views on the effects (direction and intensity of effects) between factors with more mastery [20,21]. In the next stage, the initial criteria weighs are calculated by Fuzzy Best-Worst Method (FBWM) and then using the Fuzzy Analytic Network Process (FANP) approach, the final weights of the criteria are calculated. The main reasons to combine FBWM and FANP are reducing the cognitive burden of required pairwise comparisons and increasing the reliability of the results while accounting for the non-linear decision structure [22]. Finally, after determining the weight of each criterion, the candidate strategies are weighted and prioritized by Fuzzy Vise Kriterijumska Optimizacija I Kompromisno Resenje (FVIKOR) due to its discriminating power. The compromise solution obtained by the FVIKOR method is agreed upon by the decision-makers. Under this strategy, the group utility is maximized and the individual effects are minimized [21]. Furthermore, the main questions of this study are as follows:

- What are the SWOT in Iran to manage water resources during the coronavirus epidemic?
- What is the situation in Iran in terms of SWOT strategic analysis in WRM during the COVID-19 pandemic?
- What are the evaluation criteria for finding optimal WRM strategies during the coronavirus epidemic?
- Which strategies are the best to optimally manage water resources during the coronavirus epidemic?

The rest of this research is structured as follows. The literature review is presented in Section 2. The methodology of research is given in Section 3. Section 4 presents the obtained results from implementing the proposed framework for the case study. Also, some managerial insights into the results are discussed in Section 5. Finally, some concluding remarks and suggestions for future studies are provided in Section 6.

2. Literature review

In this section, we review the relevant papers have focused on water resource management. For instance, Kalantari et al. [4] developed a sustainable framework for an integrated water resource management in Iran. They developed a framework with use of comparing, categorizing, and

analyzing different solutions based on expert opinions. Then, they presented some suggestions related to water management. Feizabadi and Gorji [11] analyzed the factors affecting the agricultural water management in Iran using the factor analysis approach. In their results, five influencing factors such as institutional and legislative, educational and promotional, economic, technical and farming systems were defined and also proposed useful strategies based on expert opinions such as Irrigation equipment conservation, farmer's knowledge promotion, and watercourse creating. Hadizadeh et al. [23] considered an integrated systems of agricultural water resources in Iran. First, they collected 347 questionnaires from paddy farmers to confirm or reject different proposed items. Then, factor analysis was used for validity test, in addition to the Bartlett and KMO tests. Finally, K-means clustering and ANOVA were used for clustering different factors. They expressed that five factors are affecting integrated management of agricultural water including the (i) Availability of irrigation infrastructure, (ii) Cropping pattern, (iii) Supportive role of local institutes, (iv) Irrigation experience, and (v) Traditional beliefs. Saatsaz [13] reviewed those studies related to water resource management in Iran. They focused on water resource management in different periods including the traditional, transitional, and modern periods. Their results showed that besides drought and global warming, there are some other reasons for increased water consumption in Iran such as industry's development, increasing population, and urbanization. They suggested some policies and strategies which are necessary in the modern era. Finally, they developed some strategies like deep-pumped well drilling, dam building, and inter-basin water transferring with can help Iran to cope with water insecurity and shortage. Babamiri et al. [24] analyzed sustainable management strategies for urban water distribution networks with the financial view. They used the system dynamics approach to evaluate different policies and financial strategies using several criteria such as financial, environmental, social, and service performance for Isfahan province in Iran. They concluded that the total amount of water volume does not decrease by penalizing higher blocks.

Chitsaz and Azarnivand [25] used a hybrid method based on the Best-Worst Method (BWM) and SWOT for finding the effective WRM strategies in the Yazd province of Iran. They applied a risk-based technique by considering the pessimistic, neutral, and optimistic scenarios. Damani and Hashmi [26] used the SWOT model to make a strategic analysis of water resource management in Iran. They collected the SWOT and calculated their scores. Finally, they resulted that their case study was in a competitive strategy state in the SWOT matrix. Petousi et al. [27] assessed water management situation through SWOT analysis in Greece. This study focused on the rational use of a special river. They used the SWOT matrix for strengths, weaknesses, opportunities, and threats of their case study and suggested some plans and strategies such as reducing irrigation water, wastewater recycling, and construction of small dams. Banihabib and Shabestari [28] used a fuzzy hybrid MCDM model to rank the agricultural water demand management strategies in arid areas. They provided some related strategies using the SWOT matrix and then prioritized them using a hybrid AHP-TOPSIS method in both fuzzy and non-fuzzy environment and compared their results. Nazari et al. [29] focused on irrigation water efficiency in Iran as an arid region. They considered 40 external and internal factors that had impacts on irrigation water management using SWOT and defined the most relevant measures such as political, economic, social, technological, environmental, and legal. They finally suggested some irrigation water management strategies to increase water security and also awareness of decision-makers about water resource development plans.

de Castro-Pardo et al. [30] focused on reviewing nearly 150 papers related to water ecosystem planning and management between 2000 to 2020 which had used various MCDM algorithms for the analysis. Their results showed that most of papers in this field only focused on investigating the factors impacting on water consumption and there were a few papers discussing on managerial aspects of water shortage issue. Yang et al. [31] focused on risk analysis in WRM. They evaluated the risks related to WRM considering uncertainties based on a Stochastic Multi-criteria Acceptability Analysis (SMAA) model in gray environment. Akbari et al. [32] proposed several strategies and policies for water resource management especially for desertification. They emphasized on drivers, pressures, states, impacts, and responses called DPSIR approach and then proposed 29 strategies whose priorities were determined through PROMETHEE method. Rubio-Aliaga et al. [33] suggested several WRM solutions especially in groundwater pumping for southeast of Spain. They then ranked these solutions through integrated AHP-TOPSIS method using some criteria. Their results indicated that using conventional diesel-based equipment and also solar PV power plants were the best strategies. In summary, Table 1 shows a summary of the literature review by which the research gaps are clarified.

According to Table 1, some papers only examined the factors affecting water management. For instance, Hadizadeh et al. [23] identified the factors affecting agricultural water management and proposed strategies such as optimizing planting patterns and irrigation, reforming regulatory approaches, and more effective training based on them. Nevertheless, their suggested strategies were not based on a systematic analytical method. In addition, although some papers have proposed the WRM strategies using SWOT especially for Iran, none of them examined the mentioned problem during COVID-19 pandemic. As mentioned before, the SWOT for WRM will be different during a special pandemic and usual situation. For instance, Damani and Hashmi [26] and Petousi et al. [27] used the SWOT approach to identify water consumption management strategies for a general situation in Iran and Greece. Nonetheless in their study, there were no evaluation for different suggested strategies. In this field, Babamiri et al. [24] studied some approaches optimizing urban water consumption by focusing on the financial perspective and concluded that the volume of water consumption will not be

Table 1. A summary of the literature review.

Authors	Aims	Case study	COVID-19 pandemic impact	Methods
Hadizadeh et al. [23]	Defining factors affecting the agricultural water management	Iran	×	K-means and ANOVA
Saatsaz [13]	Specifying factors related to water consumption and important strategies for WRM	Iran	×	Review paper
Babamiri et al. [24]	Analyzing strategies for urban water saving	Isfahan province in Iran	×	System dynamics
Chitsaz and Azarnivand [25]	Finding the effective WRM strategies	Yazd province of Iran	×	Best-Worst Method (BWM) and SWOT
Damani and Hashmi [26]	Strategic situation analysis of WRM	Iran	×	SWOT
Petousi et al. [27]	Specifying water management situation	Greece	×	SWOT
Banihabib and Shabestari [28]	Ranking the agricultural water demand management strategies	Iran	×	SWOT-AHP and TOSPIS
Nazari et al. [29]	Suggesting irrigation water management strategies	Iran	×	SWOT
This study	Proposing and ranking the WRM strategies based on special situation in COVID-19 pandemic period	Iran	✓	SWOT and FDEMATEL-FBWM-FANP-FVIKOR

reduced by adopting penal approaches. It is obvious that there is a need for a framework which is able to evaluate all proposed strategies generally not one by one. In this field, there are some studies in the field of WRM strategies analysis using combined approach of MCDM-SWOT based on some evaluation criteria. For example, Chitsaz and Azarnivand [25] combined BWM and SWOT methods to identify the best WRM strategy in Yazd province. Also, Banihabib and Shabestari [28] used AHP-TOPSIS methods for agricultural water demand management strategies prioritization. Although they used some evaluation criteria and an evaluation method for strategies, they did not consider the interrelationships between the criteria. So, this is the first study that examines WRM strategies while considering several qualitative criteria whose scores are extracted from the judgmental opinions of experts using fuzzy numbers. Furthermore, to fill these gaps, this study develops a novel hybrid decision-making framework by combining the strategic management and fuzzy MCDM approaches. In the proposed approach, the proposed strategies are determined by conducting a SWOT analysis.

In SWOT matrix, we identify and analyze the SWOT of potential WRM strategies in Iran during the COVID-19 pandemic by conducting structured interviews. Afterwards, the related criteria for strategies evaluation are first identified through examining the literature as well as extracting the experts' opinions and then the interrelationships between the criteria are recognized by applying the fuzzy DEMATEL method. Then, the initial weights of criteria are calculated using the FBWM. In the next stage, final weights of the criteria are measured by employing the FANP method while considering the interrelationships. Finally, the candidate WRM strategies are ranked by applying the FVIKOR approach. The combination of four MCDM techniques (i.e., FDEMATEL-FBWM-FANP-FVIKOR methods) associated with the SWOT analysis is the first study in the context of WRM strategy selection. The proposed framework of this study has several advantages: (1) we use a structured method (SWOT) to extract the feasible WRM strategies based on recent situations in COVID-19 pandemic, (2) we account for interrelationships between the strategies evaluation criteria, (3) the cognitive burden related to the pair-wise comparisons is considerably reduced by applying the FBWM within the framework of FANP, (4) during the ranking stage of alternatives, the group utility is maximized while the individual effects are minimized by employing FVIKOR, (5) a mixture of quantitative and qualitative judgmental data (i.e., expert subjective opinions) are utilized in the form of triangular fuzzy numbers.

3. Materials and methods

In this section, the case study is first explained. The case study is the water and wastewater organization in Iran which has the mission of supply, transfer, and continuous

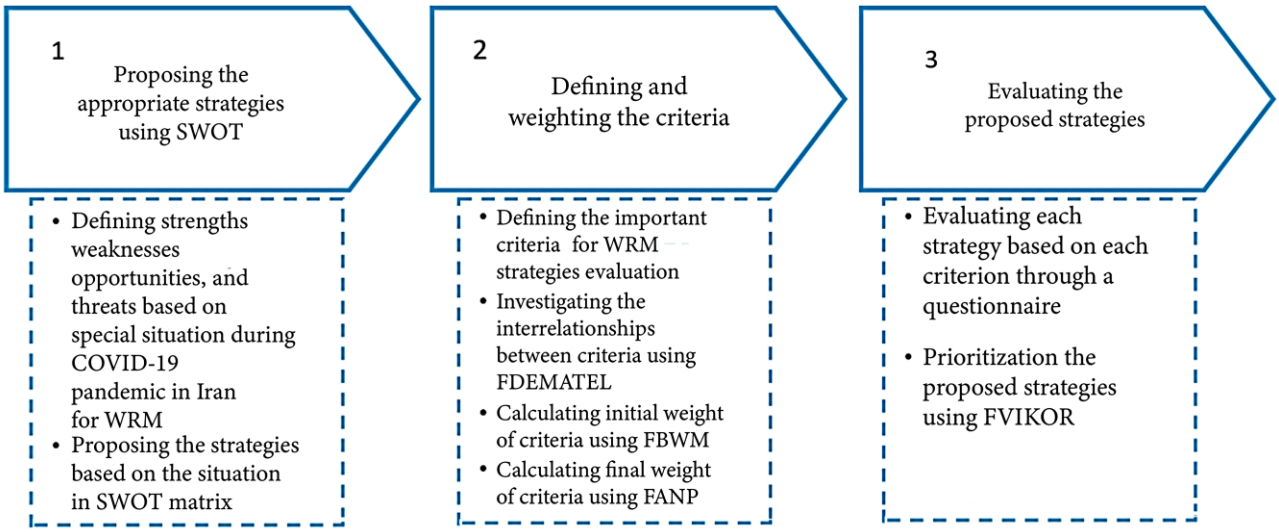

Figure 1. The proposed framework.

distribution of drinking water and collection, transfer, treatment, and sanitary disposal of wastewater in accordance with national and international standards, in order to develop municipal services. Since this organization is responsible for water supply in Iran, we considered it as the case study in order to be able to have the interviews with the experts who are working for this organization. There were ten experts of Iran water and wastewater organization including four managers and six data analysts who helped us in different steps of this study. This organization also tried to design some new strategies for WRM especially during the COVID-19 pandemic sine the sudden water consumption increase in this period as mentioned in Section 1 before. To help them in this field, in this study, the SWOT in the Coronavirus epidemic situation in Iran are first extracted from interviews and questionnaires distributed to experts. Afterwards, the main strategies are determined by applying SWOT method. For this, the SWOT of WRM in Iran were extracted considering the pandemic emergencies with great focus on COVID-19 pandemic. Then, the potential strategies considering the earlier SWOT matrix were proposed with the aim of decreasing the water crisis during the pandemic [34]. Consequently, some criteria were proposed by panel experts for evaluating the potential WRM strategies. However, these criteria are not independent and influence on each other. So, Fuzzy DEMATEL is used to figure out the interrelationships between the criteria. Using Fuzzy DEMATEL helps managers to focus more on implementing successful mission-oriented strategies via investigating the cause- and-effect relations among WRM criteria [35]. Then, an integrated FBWM-FANP method is applied to calculate the criteria weights. The main advantages of combining the two mentioned approaches are reducing/increasing the cognitive burden/reliability of calculation processes (by using FBWM), and incorporating the interrelationships between criteria (by using FANP) [36-38]. Finally, the potential strategies are ranked applying FVIKOR method. The main advantage of using this approach is maximizing the group utility and minimizing the individual effects [39]. The research framework is depicted in Figure 1. It should be noted that the basic definitions and mathematical expressions regarding to the methods applied in this research have been elaborated in the Supplementary data, Appendix A (Sections A.1 to A.5).

4. Implementation and results

This section is dedicated to presenting the obtained results in five parts: (i) SWOT, (ii) FDEMATEL, (iii) FBWM, (iv) FANP, and (v) FVIKOR.

4.1. SWOT analysis

The first and fundamental step of this study, after examining the theories and research literature, is to identify SWOT. In accordance with the current situation in Iran during 2021 and 2022 (during the COVID-19 outbreak), the SWOT analysis has been done whose results are shown in Figure 2. The sample size of experts used to identify SWOT criteria were twenty. In this regard, 4 of these experts were managers in the case study. Also, 12 of these people were university professors who had more than five years of experience in this research topics, and rest of them were executive directors in the municipality.

To analyze the current situation of Iran in WRM, the identified SWOT criteria should be evaluated and the existing strategic positions should be identified. In this regard, a questionnaire was designed and distributed to experts, and the weight and score of each of the above items were collected. Table 2 shows the strategic position analysis of the research. According to the findings of Table 2, the strategic position (i.e., SWOT matrix) of the case study is shown in Figure 3. However, according to the analysis of data which were collected through the expert survey questionnaire, Iran is in a competitive area during the COVID-19 pandemic. This result shows that Iran has reliable strengths and capabilities, but in its interactive environment, it faces many threats and challenges. Therefore, according to

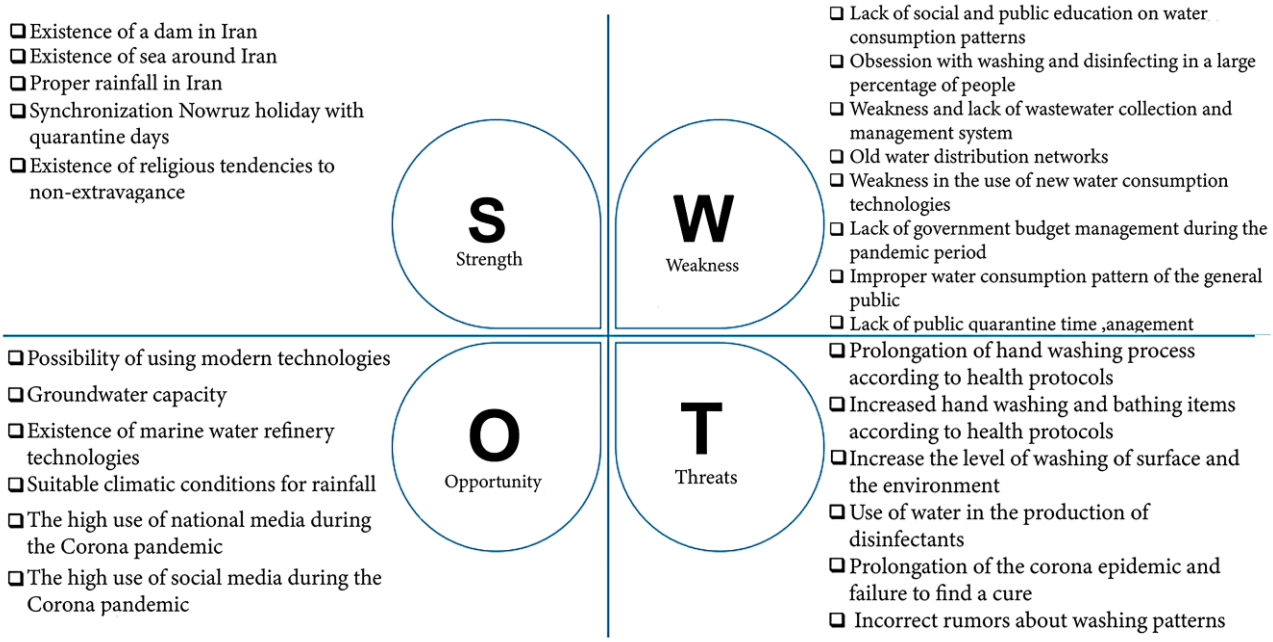

Figure 2. SWOT matrix of Iran water resources management in Covid-19 pandemic.

Table 2. SWOT analysis.

Code	Description Internal factors	Weight	Score	Weighted score
	Strengths			
S01	Existence of a dam in Iran	0.0832	3.1	0.2579
S02	Existence of sea around Iran	0.0556	3.2	0.1779
S03	Proper rainfall in Iran	0.1112	4.3	0.4782
S04	Synchronization Nowruz holiday with quarantine days	0.1388	3.8	0.5274
S05	Existence of religious tendencies to non-extravagance	0.1112	3.9	0.4337
	Weaknesses			
W01	Lack of social and public education on water consumption patterns	0.0636	1.7	0.10812
W02	Obsession with washing and disinfecting in a large percentage of people	0.0466	1.3	0.06058
W03	Weakness and lack of wastewater collection and management system	0.0847	2	0.1694
W04	Old water distribution networks	0.0807	1.9	0.15333
W05	Weakness in the use of new water consumption technologies	0.0636	1.7	0.10812
W06	Lack of government budget management during the pandemic period	0.0551	1.4	0.07714
W07	Improper water consumption pattern of the general public	0.0486	1.1	0.05346
W08	Lack of public quarantine time management	0.0571	1.3	0.07423
	Final weight of internal factors		**2.6795**	
	External factors **Opportunities**			
O01	Possibility of using modern technologies	0.0718	3.1	0.22258
O02	Groundwater capacity	0.0694	2	0.2082
O03	Existence of marine water refinery technologies	0.0718	3.1	0.22258
O04	Suitable climatic conditions for rainfall	0.0764	3.3	0.25212
O05	The high use of national media during the Coronavirus pandemic	0.0949	4.1	0.38909
O06	The high use of social media during the Coronavirus pandemic	0.0903	4.3	0.38829
	Threats			
T01	Prolongation of hand washing process according to health protocols	0.0903	1.1	0.09933
T02	Increased hand washing and bathing items according to health protocols	0.0891	1.15	0.102465
T03	Increase the level of washing of surfaces and the environment	0.0880	1.2	0.1056
T04	Use of water in the production of disinfectants	0.0880	1.4	0.1232
T05	Prolongation of the Coronavirus pandemic and failure to find a cure	0.0845	1.35	0.114075
T06	Incorrect rumors about washing patterns	0.0856	1.3	0.11128
	Final weight of external factors		**2.3388**	

Table 3. Interrelationships between criteria.

	Efficiency	Feasibility	Environmental	Economic	Cultural-social acceptance	Legal
Efficiency	0	1	0	1	1	0
Feasibility	1	0	0	1	0	0
Environmental	0	1	0	0	0	0
Economic	1	1	0	0	1	0
Cultural-social acceptance	1	0	0	0	0	0
Legal	1	1	0	1	0	0

Table 4. Determining the best and the worst criteria.

Criteria	D+R	The best criterion	The worst criterion
Efficiency	4.8454	Economic	Environmental
Feasibility	5.4485		
Environmental	3.8037		
Economic	6.4938		
Cultural-social acceptance	4.7398		
Legal	5.1803		

Figure 3. Iran position in WRM based on SWOT matrix.

this result, it can be stated that the maximum internal power and strengths should be used to optimally deal with environmental pressures and threats in this period. Given the country's strategic position in WRM, which is in a competitive area, the best strategies in this situation include using strengths to reduce the impact of threats and the proper use of opportunities.

4.2. Criteria identification

In this section based on the SWOT of Iran in the coronavirus pandemic, the following seven strategies were concluded through several interviews with expert which are related to the strategic position of Iran. Therefore, the strategies proposed in this study are:

- Strategy 1: Enforcing incentive policies;
- Strategy 2: Training for optimal water consumption;
- Strategy 3: Advertising and informing about correct water consumption;
- Strategy 4: Free distribution of disinfectants and hand gels;
- Strategy 5: Using new technologies in water consumption;
- Strategy 6: Repair and renovation of worn-out tools;
- Strategy 7: Enforcing punitive policies.

In addition, to analyze and evaluate the defined strategies, it is necessary to use criteria through which, the strategies can be evaluated. In this study, six criteria are considered which some of them have been proposed by Banihabib and Shabestari [28], and also some others were extracted from expert interviews. The criteria are as follows:

- Legal: How much each strategy is legal?
- Environmental: How much does each strategy protect natural resources?
- Economic: How much each strategy is economic?
- Cultural-social acceptance: how much the stakeholders and the public are willing to implement each strategy?
- Feasibility: How much each strategy could be executed under resource constraints?
- Efficiency: How much each strategy effect water resources protection?

Finally, Figure 4 shows the identified criteria and proposed strategies.

4.3. FDEMATEL results

In this section, the interrelationships among the criteria are identified by the FDEMATEL method. In this research, we use the outputs of the FDEMATEL to specify the best and worst criteria which are need for the next step of FBWM process. Since determining the best and the worst criteria is not easy especially when the decision-makers have different viewpoints. In this way, the criterion with the highest D+R is considered as the best, and the criterion with the lowest D+R is selected as the worst. The average of the experts' opinions based on the fuzzy numbers, the normalized fuzzy matrix, the fuzzy total relation matrix, and the crisp counterpart is given in the Supplementary data, Appendix B, Tables B.1-B.4. Eventually, the causal diagram is depicted in Figure 5. Based on the obtained results, the interrelationships among the criteria are given in Table 3. In this table, a_{ij} indicates that in what extent criterion i affects criterion j. On the other hand, the best and worst criteria have been determined in Table 4. As can be seen in Table 4, based on FDEMATEL results, the best criterion is economic and the worst one is environmental criterion.

4.4. FBWM results

In this section, the initial weights of the criteria are calculated by employing the FBWM. The average of Best-to-Others

Table 5. Results of the FBWM.

Criteria	Efficiency	Feasibility	Environmental	Economic	Cultural-social acceptance	Legal
Optimal weights	0.2226918	0.1900982	0.08679957	0.2284896	0.1142582	0.1576626
ξ^*= 0.4783140 *CI*=6.69 → *CR*=$\frac{0.4783140}{6.69}$ = 0.0715						

Table 6. Final weights of criteria using FANP.

Criteria	Efficiency	Feasibility	Environmental	Economic	Cultural-social acceptance	Legal
Final weight	0.252024	0.204014	0.10536	0.210855	0.111607	0.119263

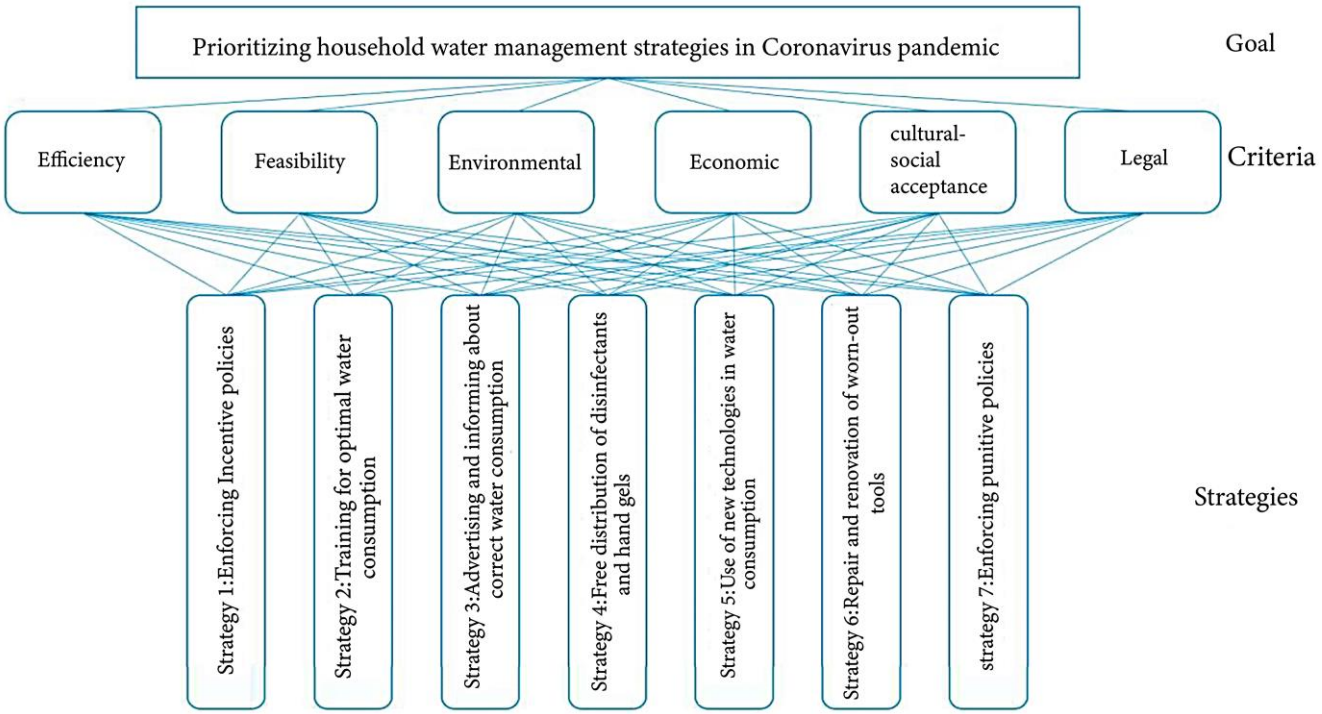

Figure 4. The hierarchical structure of decision-making problem.

and Others-to-Worst comparison vectors are presented in the Supplementary data, Appendix C, Tables C.1 and C.2. Finally, the initial weight of each criterion is presented in Table 5. As can be seen in this table, CR is close enough to zero which shows the reliability of the results.

4.5. FANP results

Eventually, in this section, the final weights of the criteria considering the interrelationships are calculated. To do this, we employ Super Decision software and we use "Misc → Direct data entry" toolbar in pairwise comparison section to enter the obtained results of the FBWM, directly. The decision tree of this research in Super Decision software has been depicted in the Supplementary data, Appendix D, Figure D.1. In addition, Table 6 shows the final weights of the criteria based on the output of the FANP.

Based on Table 6, efficiency is the first criterion which followed by economic, feasibility, legal, cultural-social acceptance, and environmental criteria. Now, with considering final weights of criteria, strategies' ranking can be done in the next section.

4.6. FVIKOR results

In this section, Fuzzy VIKOR method is applied to prioritize the proposed strategies of WRM proposed in Section 4.2.

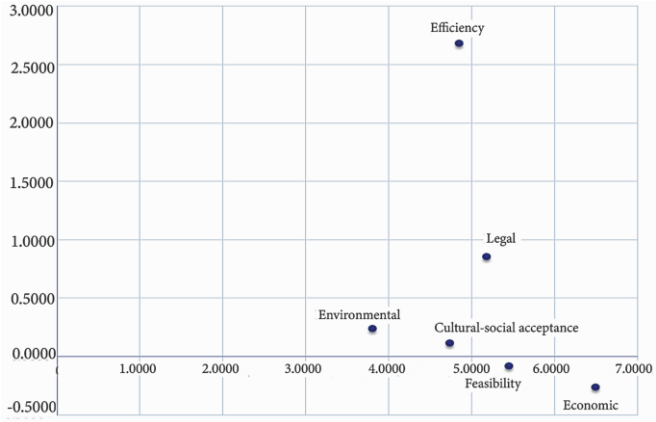

Figure 5. The causal diagram.

The details of implementing the FVIKOR method have been presented in the Supplementary data, Appendix E, Tables E.1 to E.5. Notably, S_i , R_i , and Q_i are calculated for each strategy (alternative) with considering v= 0.5 for the weights of individual utility and regret. Now, for analyzing the potential strategies, all three columns in Table 7 have been sorted ascending. The prioritization of all potential strategies is shown in Figure 6.

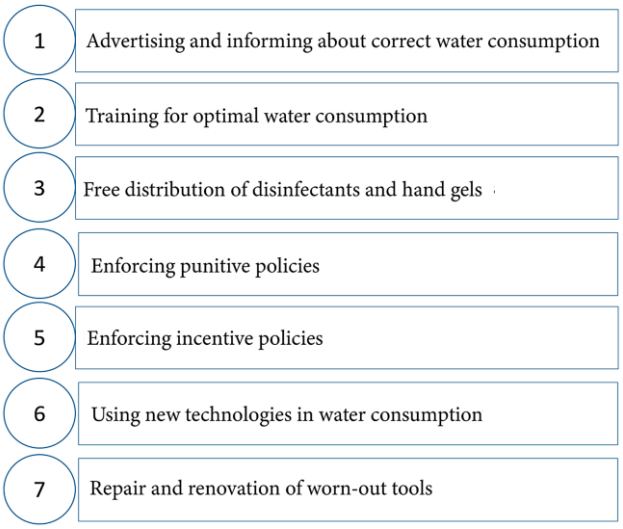

Figure 6. Prioritizing the potential WRM strategies during the pandemic.

Table 7. FVIKOR analysis.

Utility measure		Regret measure		Q-value	
S_6	0.123	R_6	0.093	Q_6	0
S_5	0.266	R_5	0.105	Q_5	0.126
S_7	0.301	R_1	0.111	Q_1	0.176
S_1	0.313	R_4	0.150	Q_7	0.355
S_4	0.478	R_7	0.174	Q_4	0.398
S_2	0.741	R_2	0.210	Q_2	0.748
S_3	0.894	R_3	0.262	Q_3	1

5. Managerial insights

WRM has been increasingly considered by researchers and experts during the last decades. The COVID-19 epidemic has affected water consumption rate and led to unprecedented disruptions for all countries. Since following the COVID-19 epidemic, the demand for water especially for sanitation has increased. For this reason, as the results of this study showed, in this period, the most important criterion for evaluating WRM strategies was the effectiveness of WRM strategies rather than their cost efficiency which usually was the most important criterion in previous studies. In other words, during this period, those strategies which have more effectiveness to WRM even if it is almost expensive, should be implemented. It does not mean that economic criterion is not important because it has the second importance weight and has the most impact on other criteria based on FDEMATEL output. Since the economic situation in many countries worldwide has been affected severely by COVID-19 outbreak, considering the strategies costs for senior government officials is actually important to evaluating WRM strategies. In other words, the economic criterion, although has not the highest importance among the criteria, it also has the most direct impact on other criteria of strategy evaluation. Besides, one of the criteria that is always considered in the evaluation of strategies, is the feasibility criterion. Since in the present case study, the feasibility of strategies implementation is very important, so it is very important to evaluate the strategies selected in accordance with the feasibility criterion. In addition to the above points, it is very important to pay attention to legal, cultural, and environmental criteria, which should always be considered in the evaluation of WRM strategies. Comparing with other studies, Feizabadi and Gorji [11] identified affecting criteria on agricultural water management such as institutional and legislative, educational and promotional, economic, technical, and farming systems. In addition, Babamiri et al. [24] considered several factors affecting the urban water distribution networks such as financial, environmental, social, and service performance and Nazari et al. [29] identified factors affecting the irrigation water management using SWOT which included political, economic, social, technological, legal, and environmental criteria.

After identifying and analyzing the evaluation criteria, water consumption management strategies were identified through structured interviews with experts and officials of relevant organizations and were finalized prioritized. In the current study, advertising and informing about water consumption, which has been selected as the top strategy, performs well in terms of efficiency due to its high impact on many peoples via media. It also is not much expensive and could be very feasible to inform people quickly via different Tv shows, which is why it is so important during an epidemic. Due to the quarantine laws and also due to the beginning of the new year's holidays in Iran, which was accompanied by the early months of the Coronavirus pandemic, a large population of people spent their time at home and as a result, the rate of watching national media, as well as the use of social media in the country, increased. Therefore, two strategies, "Advertising and informing about correct water consumption" and "Training for optimal water consumption" are the most important strategies among the strategies for managing water consumption in this special situation since they are easier than others in terms of efficiency, economic, and feasibility criteria. As mentioned before, one of the main reasons for the increase in water consumption during COVID-19 pandemic is hand washing and personal bathing increase in general, as well as rise in washing of the environment. Therefore, if disinfectants are more widely available to the public and various organizations, they can be used instead of washing with water. "Free distribution of disinfectants and hand gels" is the third important strategy considered by experts in the current situation. This strategy absolutely is effective and feasible but it is somehow expensive and based on the economic criterion it losts some score in prioritization. In addition, in most organizations and different societies in general, incentive and punitive policies can provide beneficial results in the short term. Therefore, the application of punitive policies for people who consume too much water and the defined margin of excess can have a direct impact on reducing short-term water consumption. It will also be important to implement incentive policies in this area to motivate people for more savings. Therefore, "enforcing punitive policies" and "enforcing incentive policies" are other strategies while they are less effective while they are economic and very feasible for deployment. But, for long term impacts, repairing and renovating worn-out tools, as well as the use of new technologies in water consumption are

the other potential strategies. According to estimates made in the relevant organizations; the average water loss in the world due to the deterioration of the distribution system is 12%, while it is 21% in Iran. Therefore, two other strategies considered by research experts include "use of new technologies in water consumption" and "repair and renovation of worn-out tools". They are the least important strategies which need more time while they are also so expensive. For comparing our results with those of similar studies, Feizabadi and Gorji [11] proposed the Irrigation equipment conservation and Saatsaz [13] suggested deep-pumped well drilling and dam building as the most important strategy for agricultural water management. However, we concluded that advertising and training are the most important strategies for domestic water management especially in COVID-19 pandemic situation. Also, Babamiri et al. [24] concluded that penalizing higher blocks was not an affecting strategy for water consumption management, which approves our results as enforcing punitive policies was at fourth rank which is considered as a moderate effective strategy Rubio-Aliaga et al. [33] suggested conventional diesel-based equipment and solar PV power plants as the best strategies for WRM while, based on our results, using new technologies and repairing the equipment were as the least important strategies since they need long time and in current pandemic crisis, they are not appropriate solutions.

In summary, we can conclude that the effectiveness is the most important criterion which should be considered while decision makers are selecting the most appropriate WRM strategies and policies especially during COVID-19 pandemic in order to quickly decrease the water consumption rate. The advertising, informing, and training are the most effective and feasible strategies to be deployed in this period while they need less cost compared to other strategies.

6. Conclusion and future studies

In this study, we aimed to provide a decision-making framework for evaluating and prioritizing potential Water Resources Management (WRM) strategies during the Coronavirus pandemic. This study also provided strategies for managing the volume of water consumption with short-term and long-term effects, taking into account the uncontrolled growth of domestic water consumption during the COVID-19 outbreak and the causes that lead to it. In this regard, there are factors and criteria considering the feasibility and acceptance of these strategies by the government and also the public [40,41]. Finally, six main criteria were identified as the final criteria after reviewing the literature as well as interviewing with experts. Then, the interrelationships between these criteria were determined using Fuzzy DEMATEL. Based on FDEMATEL results, the economic criterion was the most effective one and the environmental dimension was identified as the most impressive criterion. Afterwards, the weights of criteria were calculated using an integrated FBWM-FANP method. As results indicated, the efficiency and environmental criteria were the most and least important ones, respectively. In reviewing and identifying water consumption management and control strategies, seven strategies identified and then prioritized through FVIKOR. In summary, advertising and informing about correct water consumption and also training for optimal water consumption which could be carried out via advertising in media, are the two most important strategies that could be implemented in practice.

The most important limitations of this study were the difficulty of accessing to experts, especially in the case study organization for interviews and filling out the questionnaires. On the other hand, the scarcity of similar studies especially considering COVID-19 pandemic for the purpose of doing comparative analysis, was another limitation of this study. Suggestions for future studies could include examining the impact of implementing key strategies on household water consumption separately and together using the system dynamics approach, and presenting a mathematical model considering restrictions on the implementation of punitive and incentive policies. Ultimately, the root cause analysis of the causes of increased water consumption during the coronavirus pandemic could be carried out for finding more effective WRM strategies.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Fourth author

Sina Nayeri: Formal analysis; Methodology; Visualization

Supplementary data is available at

file:///C:/Users/SHAMILA/Downloads/Supplementary%20material-%20Ref.%20No%20SCI-2011-5077-3.pdf

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