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Modeling of decision-makers negotiations in reservoir operation with respect to water quality and environmental issues

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Abstract. Decision-makers have different and sometimes conflicting goals with utilities in operating dam reservoirs. As repeated interactions exist between decision-makers in the long-term, and the utility of each decision-making organization is affected not only by its selected strategy, but also by other rivals' strategies; selecting and prioritizing optimum strategies from a decision maker's point of view are of great importance while interacting with others. In this paper, a model based on a fuzzy set theory, for determining the priority of decision-makers' strategies in optimal qualitative-quantitative operation management of dam reservoir is presented. The fuzzy priority matrix is developed via defining membership functions of a fuzzy set for each decision maker's strategies, so that all uncertainties are taken into account. This matrix includes priorities assigned to possible combination for other decision makers' strategies in bargaining with each player's viewpoint. Here, the 15-Khordad Dam located in the central part of Iran, suffering from low water quality, was studied in order to evaluate the effectiveness of the model. Then, the range of quality of water withdrawal agreed by all decision-makers was determined using the prioritization matrix based on fuzzy logic. The results showed that the model proposed in the study had high effectiveness model.

Keywords: reservoir operation; prioritization of fuzzy strategies, conflict resolution, water quality

1. Introduction

Increasing water demands and lack of water resources on one hand, and the variety of preferences of organizations and departments on the other have made the determination of policies on optimal operating dam reservoirs and prioritization of them very important in analysis of water resources systems. Many researchers, like Sandara (2018), Stelson (2018) and Wang *et al*. (2018), worked on water and its application. Artificial neural network (ANN) simulation is used by Jokić *et al* (2018) to predict the dynamic change of permeate flux during wheat starch industry wastewater microfiltration with and without static turbulence promoter. In order to resolve the conflict between the managers involved in operating dam reservoirs, attempts are made while interacting with others to adopt the priority of their strategies in a way that all uncertainties and ambiguities in decision-making are provided by fuzzy logic. Game theory was used by Ganji *et al*. (2006, 2007) to resolve the conflict between water consumers. Based on the principles of game theory, the stochastic dynamic game model, Nash, was developed with complete information; it was assumed that decision-makers have enough information about random parameters related to operating reservoirs. The proposed model has been used in operating Zayandeh Rood Dam and results showed high effectiveness of the model in offering operating policies with regard to the interactions among consumers, organizations in charge of operating reservoirs and their favorites. A new structure was presented by Kerachian and Karamouz (2006, 2007) for optimal qualitative and quantitative operating of dam reservoirs and river-reservoir systems based on combining genetic algorithm optimization model with one-dimensional quality simulation model of reservoir and focusing on solving disagreements among decision-makers. The objective function of the model was analytic function, Nash, capable of meeting downstream water demand, storage capacity of reservoir, and water quality. The required time for running the model, which was presented by Kerachian and Karamouz (2006, 2007) declined in a researches conducted by Shirangi and Kerachian (2007) and Shirangi *et al*. (2008) through proposing a simplifying assumption and considering the same target function and proved that applying the assumption would not sacrifice the accuracy of calculations. Then, a two-dimensional optimal trade-off curve with quality and quantity goals were proposed by changing the target function and combining genetic algorithm optimization model with one-dimensional simulation model of reservoir. The curve was just the output of optimizing model and did not necessarily meet the decision-makers' utilities. Afterwards, the bilateral bargaining model, Young, was used for the first time to determine the optimal point on trade-off curve for considering the disagreements among all involved. The obtained point was accepted by all sides. According to the

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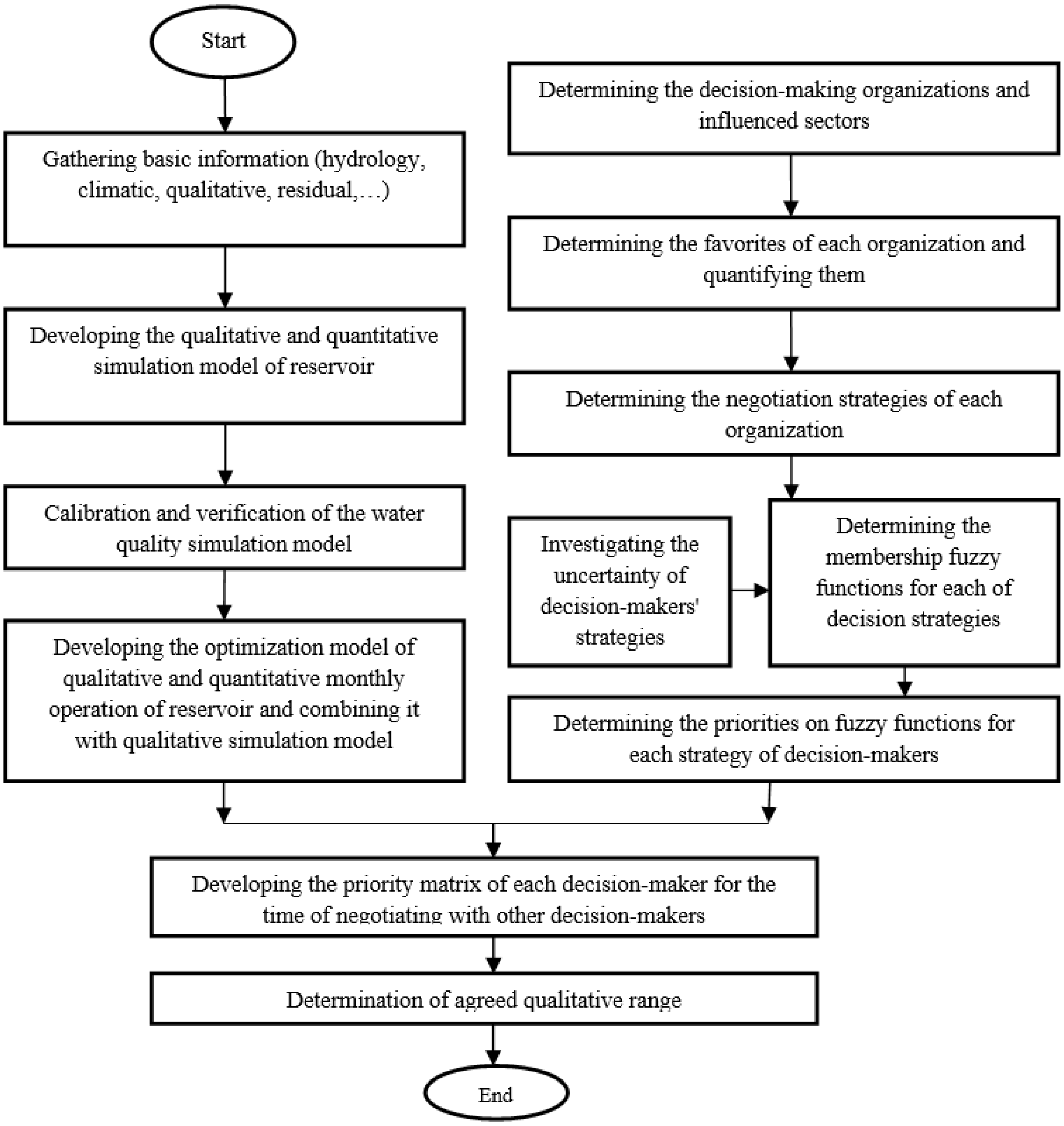


Fig. 1 Structure of proposed model for determining the priority matrix of each decision-maker in managing qualitative and quantitative operation of dam reservoirs

obtained optimal trade-off curve from Shirangi *et al*. (2008) model, the group n person conflict resolution theory was developed by Shirangi *et al*. (2016). They used Bayesian networks as a novel type of learning model to develop real-time operating rules. A new methodology based on differential evolutionary algorithm was presented by Soltani *et al*. (2008) for stochastic multi-purpose reservoir operation planning. In a study carried out by Soltani *et al*. (2010) the quality variables of dam reservoirs were simulated using Adaptive Neuro-Fuzzy Inference System (ANFIS). By combining it with a genetic algorithm, not only the required time for running the existing models decreased, but also setting policies and regulations for qualitative and quantitative operating of reservoirs was accelerated. A new methodology based on crisp and fuzzy Shapley games was developed by Sadegh *et al*. (2010) for optimal allocation of inter-basin water resources in Iran. The assessment of water transport projects impact on long term water supply in Zayandehrood basin by multi-period optimization analysis was presented by Karimi *et al*. (2011). It was a very important issue for water sector decision makers and water basin stakeholders. The utility and basic concept of game theory in water systems analysis was discussed by Madani (2010), illustrating the dynamic structure of water resource problems and game evolution which affect the behaviors of stakeholders in different periods of the conflict. Six stability definitions were reviewed and illustrated by Madani and Hipel (2011), applicable to finite strategy strategic non-cooperative water resources games, were applied to a range of generic water resources games to show how analytical results vary based on the applied stability definition. A game theory-reinforcement learning (GT-RL) method- for determining the optimal operation policies in multi-agent multi-reservoir systems was proposed by Madani and Hoshyar (2014) with respect to fairness and efficiency criteria. At the first step, the proposed method was applied to a hypothetical three-reservoir three-agent system to underline the utility of the GT-RL method in solving complex multi-agent multi-reservoir problems without a need for developing compound objectives and weight assignment. Two cooperative and non-cooperative methodologies were presented by Mahjouri and Ardestani (2011) for a large-scale water allocation problem in Southern Iran. They used optimization models having economic objectives with respect to the physical and environmental constraints of the system to determine the water shares of water users and their net benefits. Comparing the results of the two mentioned approaches showed the importance of acting cooperatively to achieve maximum revenue. Fuzzy cooperative games were used by Sadegh and Kerachian (2011) for optimal allocation of available water resources and associated benefits to water users in a river basin. Two fuzzy cooperative games were utilized by Abed-Elmdoust and Kerachian (2012) for modeling equitable and efficient water allocation among water users in both inter-basin and intra-basin water allocation problems. The proposed all-inclusive water allocation approach consists of three main steps, following Sadegh *et al*. (2010). The usefulness of the so-called methodologies was studied by applying them to three defined real life scenarios in a case study of water allocation in Iran. The results showed that the proposed methodologies are professionally appropriate to real-world uncertain problems regarding equitable and economic inter-basin and intra-basin water resources allocations. A new game theoretic methodology was presented by Poorsepahy-Samian *et al*. (2012) for water and pollution discharge permit allocation to agricultural zones in shared rivers. They used a new linear form for crop water production function in the objective function of the water allocation optimization models. Then, the total benefit produced by a coalition was distributed among its members using some solution concepts in cooperative game theory. The best water and discharge permit allocation strategies were also determined using the minimax regret theory. The proposed methodology was applied to the Karoon-Dez river system in the southwestern part of Iran. A methodology was presented by Sechi *et al*. (2013) based on cooperative game theory to allocate water service costs in a water resources complex system among different users and stakeholders. Fuzzy multi objective models were developed by Teegavarapu *et al*. (2013) for the optimum operation of a hydropower system. The models are used to a real-life hydropower reservoir system in Brazil. Singh *et al*. (2016) presented an overview of the different programming techniques used for the conjunctive use planning and management of irrigated agriculture. A new approach was developed by Dehghan Manshadi *et al*. (2015) based on cooperative games and virtual water concept for quantity-quality assessment of water transfer projects. The proposed model evaluates economic, equity and environment criteria to bring about sustainable development. To achieve equity and retrieve sufficient incentives for water users, cooperative game theory approaches were utilized for the reallocation of net benefits. The model was applied to a large scale case study of an inter-basin water transfer in central part of Iran, from Solakan to the Rafsanjan basins. In addition, using cooperative game theory, the net benefit of the project was realized twice the initial allocation. Uncooperative planar game theory model was proposed by Li *et al*. (2016) to aid the analysis of transboundary river water distribution scenarios, in which the concept of diplomatic cost was suggested originally. The Nash equilibrium solution was proved according to a Nikaido–Isoda function. Decision-making is an uncertain and stochastic process as it depends on the knowledge of decision-makers. Alizadeh *et al*. (2017) developed a new methodology based on multi-objective optimization model (NSGA-II), groundwater simulation model, M5P model tree, fallback bargaining procedures and social choice rules in order to determine the optimal groundwater management policies with an emphasis on the conflict resolution among stakeholders. Rashidi *et al*. (2018) used multiple criteria decision making method for selecting of sealing element for earth dams considering long and short terms goals. Yang *et al*. (2018) focuses primarily on the exploration of long-term operating rules for such an integrated system using implicit stochastic optimization (ISO), which can examine uncertainties in reservoir inflow and PV power. A new cooperative watershed management methodology was designed by Adhami *et al*. (2018) to develop the equitable and efficient Best Management Practices (BMPs) with participating all main stakeholders. The approach aimed at controlling total sediment yield, storm water and improving socio-economic status of the watershed, considering villagers, legislation and executive stakeholders with conflicting interests. They used the game theory as an alternative tool to analyze strategic managerial practices and measures among different demands in order to ensure achievement of the cooperative decision-making in sub-watershed and Best Co-Management Practices prioritization (BCMPs). In this paper, at the first time according to the obtained optimal trade-off curve from Shirangi *et al*. (2008) model and considering the fact that different decision-makers with different utilities could cause serious disagreements among the managers, the fuzzy prioritizing matrix is determined with regard to the interaction between parties and each decision maker's point of view so that all uncertainties are taken into consideration. This matrix includes priorities assigned to available strategies from each player for him against other negotiators' strategies. The 15-Khordad Dam with considerable quality problems is selected as the case study for this purpose. Then, range of water withdrawal quality that is agreed by all beneficiaries was determined by using the prioritization matrix based on fuzzy logic.

2. Methodology

Qualitative and quantitative programming and analyzing of water resources systems are very complicated due to various utilities of different decision-makers which cause conflicts and also multiplicity of goals and variables of decision-making along with various uncertainties. A two-dimensional optimal trade-off curve was demonstrated by Shirangi *et al*. (2008) regarding qualitative and quantitative purposes, through combining genetic algorithm optimization model with one-dimensional quality simulation model of reservoir. The presented trade-off curve was just an output of an optimal mathematics model and did not meet all decision-makers' demands and utilities; the bilateral bargaining model, Young, was used for the first time to determine the common point between two parties on the trade-off curve by choosing two decision-makers and defining their utilities. The obtained point was accepted by both decision makers. Since the conflict-resolving model is bilateral, just two sides may bargain while there might be several decision-makers with different strategies (which are often stochastic and uncertain) regarding the operation of dam reservoirs, and this is one the main limitations of the model.

Before entering into negotiations, how decision-makers choose their strategies and their advantages should be taken into account by negotiators as organizations do not often have a vivid picture of other sides' utilities. The structure of the proposed model for determining the priority of strategies in managing optimal qualitative and quantitative operation of reservoirs with fuzzy approach is shown in Fig. 1, indicating the informational demands, components, and path of the structure of the model. The structure may be studied in two parts. The first part which was done by Shirangi *et al*. (2008) includes codifying simulation models, optimizing operation of reservoirs and joining them. In the second part, the decision-making organizations, new influenced sectors and their utilities at the time of negotiations are identified, and then a new method for determining the priority of each decision maker's strategies is presented. Finally, through joining these two parts and based on the new proposed method, each negotiator knows the priority of their choices against other sides' strategies before the negotiations, so they will be able to take the best decision. The components of the methodology of the proposed model are described as follows:

2.1 Qualitative-quantitative simulation of reservoir model

Many researchers, like Lee *et al*. (2018), Haan *et al*. (2018), Jiang *et al*. (2018), Rojas-Serrano *et al*. (2015) and Lee *et al*. (2017) worked on quality of water and its application. The one-dimensional model developed by Kerachian and Karamouz (2006, 2007) is used to make the model of qualitative-quantitative simulation of reservoir so that it could be combined with the optimization model. The developed model is a one-dimensional simulation model on the basis of Water Quality for River-Reservoir Systems (WQRRS) model which could easily determine the quality of outflow and stored water for different policies of operation through chains of optimization. This model solves the equation of vertical spread and transmission of pollution by finite difference method. In this model, the reservoir is simulated in one-dimensional form and divided to some horizontal layers with certain volume, area and thickness. It is usually assumed that these layers are homogenous and fully mixed in one-dimensional modeling; on the other hand, the temperature and density of all points in each horizontal volume layer are supposed to be equal. Some limitations of the existing models such as those related to period of simulation (5 years for HEC5Q) are removed and time needed for calculations is decreased. Many researchers worked on water quality (Luo *et al*. 2017, Yang *et al*. 2017). Wu *et al*. (2017) reviewed the biological surveys of ballast water from major Chinese ports.

2.2 Optimization model

Solving the big problems of optimization for long-term planning is very time-consuming by genetic algorithm. To solve the problem, based on the idea presented by Shirangi *et al*. (2008), qualitative and quantitative optimization was divided into two phases. In the first phase, only quantitative uncertain optimization in long-term horizon was done. The target function of quantitative model is to maximize the supply and storage in the reservoir. Simulating the rules of uncertain operation obtained from the quantitative uncertain model, the time series of the volume and optimal outflow in a monthly period are yielded. In the second phase, considering the qualitative goals along with quantitative goals in one-year period which is repeated according to the years of planning, the optimization model solves the optimization problem. In fact, a thirty-year period is divided into thirty one-year periods. The main preference of this method is to decrease chromosome length and the number of genes, i.e. the number of genes is computed as follows:

$$NG = 12 \times n \tag{1}$$

In above-mentioned relation, NG is the number of each chromosome's genes and n is the number of dam gates. The monthly optimal outflow of gates could easily be obtained from the aforementioned model without sacrificing the accuracy.

2.3 The structure of fuzzy model

In game theory and multi-criteria decision-makings, some situations occur that players and decision-makers have to decide about based on their utilities and preferences which are influenced by strategies adopted by the rivals. Hence, reaching an agreement will be more difficult as the number of players increases since each organization takes optimizing its utilities into account. In most cases, some utility functions are set by the players to present their priorities, but there might be some uncertainties that could affect the result of the game considerably due to unawareness of players regarding each other's decisions. Of course, assuming the fact that each player knows that others do their best to progress, the degree of such uncertainties may be reduced. To face the existing uncertainties in target functions, a game called "ordinal game" was presented by Garagic and Cruz (2003) according to which players could organize their decisions regarding priorities against rivals' decisions and then start to play. They utilized fuzzy set theory in order to incorporate the players' heuristic knowledge of decision making into the framework of conventional game theory or ordinal game theory. However, the better solution is fuzzy mathematics. High compatibility of fuzzy theory with important sciences such as probability theory and the problems associated with decision-making with vague data, which are uncertain and sometimes stochastic, have made it crucial for solving the complicated problems of operating water resources such as dam reservoirs. In comparison with certain sets, fuzzy sets are vague bounded whose elements have one degree of membership which could vary between zero and one. Fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval $[0,1]$ as μ_A: $X \rightarrow [0,1]$. Membership functions assign the degree of membership of elements to the corresponding fuzzy sets. Assuming that decision-makers have different strategies in operating dam reservoirs and those strategies are uncertain, fuzzy theory may be used to simplify the modelling process. Considering the fuzzy strategies, decision makers are able to prioritize their decisions based on their rivals' chosen strategies and natural uncertainties of the decision space. In this paper, background information is assigned to each decision-maker which is expressed as a prioritization matrix. This matrix includes priorities assigned to available strategies of interacting with other sides based on each decision maker's viewpoint. If P is the set of all persons with Q decision-makers, C is the constraints of decision-making and X and U denote the sets of all available strategies and all players' priorities, respectively, two linguistic functions are defined as $L(X)$ and $L(U)$ to determine the limits of strategies and limits of priorities so that they would indicate the fuzzy aspect of strategies and priorities:

$$\begin{gathered} L(X) = \{\text{weak, medium, strong}\} \\ L(U) = \{\text{weak, medium-weak, medium-strong, strong}\} \end{gathered} \tag{2}$$

3. Case study

The 54-meter high 15-Khordad Dam was constructed across the Qomrood River in Markazi province near the cities of Delidjan and Mahallat to supply more than 8000 hectares of downstream agricultural lands with water, control floods, and provide water for the city of Qom. The location of dam is shown in Fig. 2.

Two years after coming into operation in 1995, the problems associated with the quality of reservoir water emerged. Particularly, an increase in the sanity of water was the most important problem as its Electrical Conductivity (EC) rose from 1000 *μmho*/*cm* in 1995 to 4000 *μmho*/*cm* in 2000. Successive droughts in recent years, thermal stratification and salinity, inappropriate operation, high evaporation rate of the lake, poor quality of entering water (especially from Shoor and Darbande Shoor Rivers) and low quality of geological structure are the effective causes in increasing the EC of the reservoir. The general information of the dam is shown in Table 1.

The dam was selected to permit comparison between the results of proposed models with those of previous models. The basin up to Abbas Abad hydrometric station occupies a total area of 10184 square kilometers and the main river is 166 kilometers in length. The average annual outflow is 177 million cubic meters, and the average discharge reaches 5.61 m^3/s. The discharge regime of Qomrood is flood and some of its tributaries including Darband, Khomain, and Khansar have snow regime, and others are influenced by rain regime. Since there are a lot of lands which are irrigated along the Qomrood River, water use increases in summer, and its discharge is affected by agricultural purposes from the middle of spring to late autumn.

Fig. 2 The 15-Khordad dam location in Iran

Table 1 The main characteristics of the 15-Khordad dam (Kerachian and Karamouz 2006)

Rank	Parameter	Value
1	Total volume	200 million m^3
2	Reservoir length at normal water level	12 *km*
3	Dead volume	35 million m^3
4	Foundation elevation	1,357.5[a]
5	Crest elevation	1,448.6 *m*[a]
6	Normal water level	1,440.5 *m*[a]
7	Spillway elevation	1,440.5 *m*[a]
8	Spillway capacity	1,417.6 m^3/s
9	Flood control bottom outlet elevation	1,408 *m*[a]
10	Flood control bottom outlet elevation capacity	94 m^3/s
11	Upper outlet (outlet 2) elevation	1,415 *m*[a]
12	Lower outlet (outlet 1) elevation	1,430 *m*[a]
13	Upper outlet capacity	8 m^3/s
14	Lower outlet capacity	8 m^3/s
15	Water surface area at normal water level	14 km^2
16	Minimum operational water level	1,420 *m*[a]

[a] From sea level

4. Results and discussion

4.1 Determination of prioritization matrix from the perspective of each decision maker

The 15-Khordad dam was studied by Shirangi *et al.* (2008). An optimal trade-off curve with quality and quantity

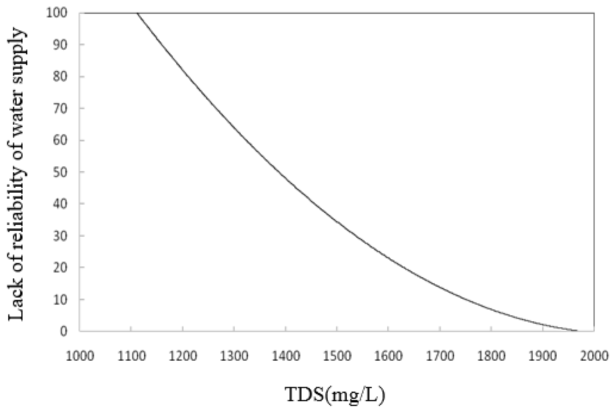
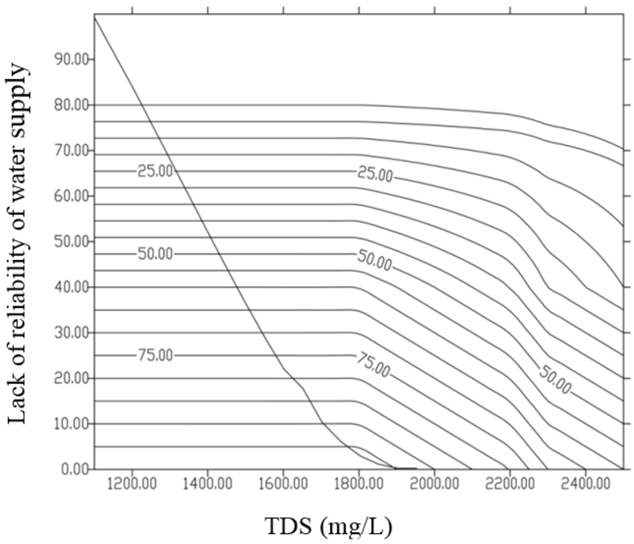
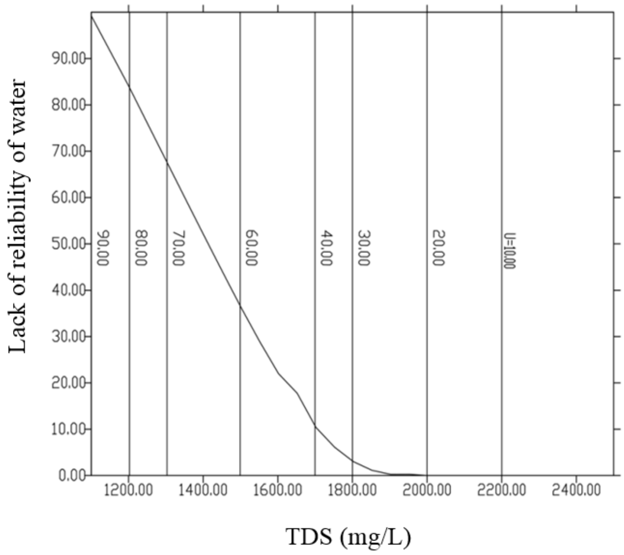


Fig. 3 The trade-off curve between the allocated water quality and the lack of reliability of water supply in thirty years (1968-1997) for the 15-Khordad dam (Shirangi *et al*. 2008)

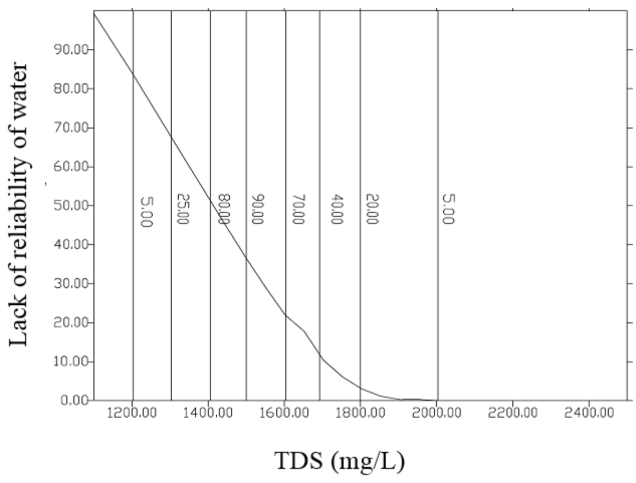
goals was presented for a thirty-year horizon (1968-1997) by combining genetic algorithm optimization model with one-dimensional quality simulation model of reservoir and using limit state. The trade-off curve that may be used to choose the best policies of quality management of reservoir or solve disagreements among the related parties is shown in Fig. 3. The horizontal and the vertical axes represent quality and quantity, respectively and the optimal percent of lack of supply is obtained for any given TDS. Nine months of the year (March to November) are allocated to optimization of the water quality in the proposed model, and the remaining three months (December to February) are smartly assigned by the model itself to remove salt and leach the reservoir and supply will be just from ground resources. It could be observed from the trade-off curve that the higher quality is the water, the fewer proportions of water are allocated to different organizations. The Organization of Agriculture, the Ministry of Energy and Domestic sector are the main decision-makers. From the viewpoint of agriculture, the assigned amount of water is of high importance and priority and improving quality should not result in reducing shares, and this will be the matter of negotiations. Quality is the top priority of domestic sector, and the Ministry of Energy takes economic benefits into consideration. So, it can be said that, however, the trade-off curve is composed of some optimal points that are the outputs of an optimized model and does not meet the favorites of the involved organizations. Since the favorites of the parties are different and sometimes contrary, disagreement will arise among the managers. Assuming that delegates argue the case rationally and take the benefits of their parties into account, presenting a method for prioritizing the fuzzy strategies against other decision-makers' strategies to achieve the objectives in negotiations is the main purpose of this paper. Of course, the Ministry of Industries and Mines and also Department of Environment are involved in exploiting the aforementioned dam, but as the amount of water consumed by them is not significant, they are not considered as the major decision-makers. So, it is supposed that they join a coalition with other major parties in negotiations.



(a) The utility curve for the agriculture sector (Kerachian and Shirangi 2008)



(b) The utility curve for the domestic sector (Kerachian and Shirangi 2008)



(c) The utility curve for the ministry of energy

Fig. 4 The utility curves

According to the given trade-off curve in Fig. 3 and interview with experts from all organizations involved, the Same-favorite points on the trade-off curve were obtained, and the expert's same-favorite curves were plotted by Kerachian and Shirangi (2008). The same-favorite curves of agriculture and domestic sectors are shown in Figs. 4(a) and 4(b). Fig. 4(a) shows that the percentage of lack of demand supply decreases, and consequently, the percentage of demand supply increases by increase in TDS and decrease of water quality (the zone below the curve). It is shown in Fig. 4(b) that by improving the quality of water, the utility of domestic sector enhances (the zone above the curve). Economy is the top priority of the Ministry of Energy as the middle zone of the curve shows its favorite. The same-favorite curve of Ministry of Energy sector is shown in Fig. 4(c). Increase in demand supply and decrease of water quality increases the costs as a result of poor quality and need for purification and vice versa; by decreasing demand supply and increasing quality, enough water is not provided, and compensation should be paid to consumers. So, the middle zone of the trade-off curve will be the favorite for the Ministry of Energy. Based on different favorites, each department does its best to give the most appropriate response to the rivals' strategies by choosing the best one.

The set of decision-makers in this problem includes three members as P = {Ministry of Energy, Domestic Sector, Agriculture} and the set *X* consists of the probable strategies. According to Table 2, two probable strategies are considered for each decision-maker. The first strategy for the Organization of Agriculture is to enter into negotiation alone, and the second is to form a coalition with the industry as both take the quantity of water into account. Similarly, the first strategy for the domestic sector is to enter into negotiation alone and the second is to form a coalition with the Department of Environment as the quality is of high importance for both. The first strategy for the Ministry of Energy is to prioritize the quality and the second is the quantity. The sets of all strategies, fuzzy priorities and linguistic functions are as follows:

$$X_1 = \{ Ag_{S1}, Ag_{S2} \}$$

$$X_2 = \{ U_{S1}, U_{S2} \}$$

$$X_3 = \{ W_{S1}, W_{S2} \}$$

$$L(X) = \{ strong, medium, weak \}$$

$$L(U) = \{ strong, strong-medium, medium, medium-weak, weak \}$$

$$U = \{ 0.25, 0.50, 0.75, 1.0 \}$$

where

X_1: Set of strategies of the Organization of Agriculture.

X_2: Set of strategies of the Domestic Sector.

X_3: Set of strategies of the Ministry of Energy.

Table 2 The probable strategies

Strategy number	Set of strategies for the organization of agriculture	Set of strategies for the domestic sector	Set of strategies for the ministry of energy
1	Bargaining with the domestic sector alone	Bargaining with the agriculture sector alone	Having qualitative viewpoint
2	Forming a coalition with the industry	Forming a coalition with the department of environment	Having quantitative viewpoint

Ag_{S1}, Ag_{S2}: The first and the second strategies of the Organization of Agriculture

U_{S1}, U_{S2}: The first and the second strategies of the Domestic sector

W_{S1}, W_{S2}: The first and the second strategies of the Ministry of Energy

$Ag_{S1}(W), Ag_{S2}(W)$: The first and second strategies of Organization of Agriculture in the weak zone

$Ag_{S1}(M), Ag_{S2}(M)$: The first and second strategies of Organization of Agriculture in the medium zone

$Ag_{S1}(S), Ag_{S2}(S)$: The first and second strategies of Organization of Agriculture in the strong zone

$U_{S1}(W), U_{S2}(W)$: The first and second strategies of Domestic sector in the weak zone

$U_{S1}(M), U_{S2}(M)$: The first and second strategies of Domestic sector in the medium zone

$U_{S1}(S), U_{S2}(S)$: The first and second strategies of Domestic sector in the strong zone

$W_{S1}(W), W_{S2}(W)$: The first and second strategies of Ministry of Energy in the weak zone

$W_{S1}(M), W_{S2}(M)$: The first and second strategies of Ministry of Energy in the medium zone

$W_{S1}(S), W_{S2}(S)$: The first and second strategies of Ministry of Energy in the strong zone

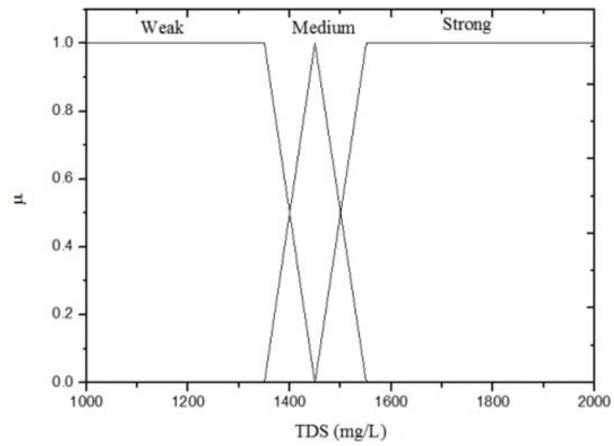
$L(x)$: The linguistic function that defines the limits of strategies

$L(U)$: The linguistic function that defines the limits of priorities

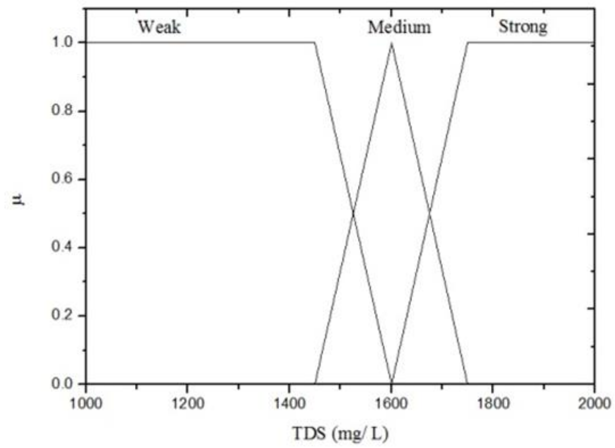
U : Set of decision-makers' all priorities from all probable strategies

Table 2 illustrates the strategies of each decision-maker. For each, the fuzzy membership functions are drawn and zoned according to the trade-off curve and demand supply, utility, and TDS as shown in Figure 5.

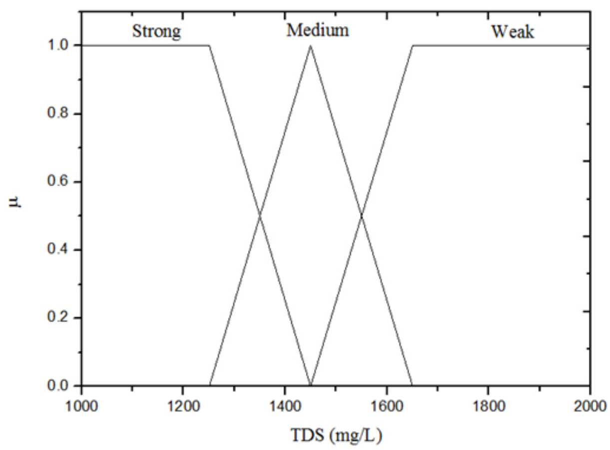
As the Organization of Agriculture takes quantity into consideration, the strong strategy is in the zone of high demand supply with TDS greater than 1450 as illustrated in Fig. 5 (a). Correspondingly, the medium strategy zone and the weak strategy zone cover $1350 \le TDS \le 1550$ and $TDS \le 1450$, respectively. The membership function of the



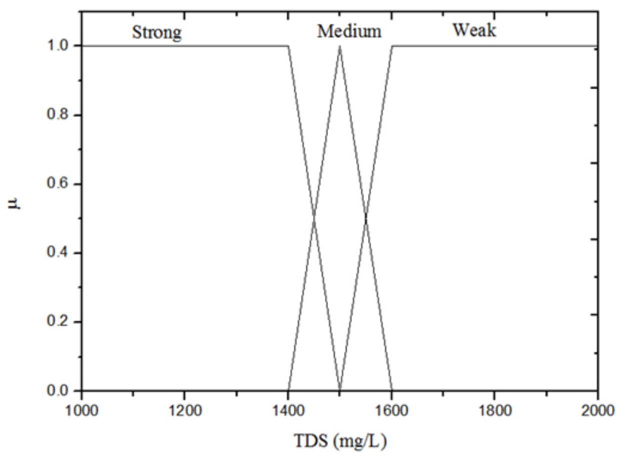
(a) The first strategy fuzzy diagram of the agriculture sector



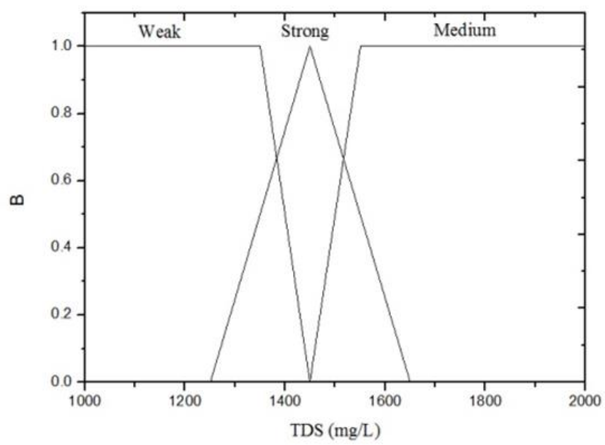
(b) The second strategy fuzzy diagram of the agriculture sector



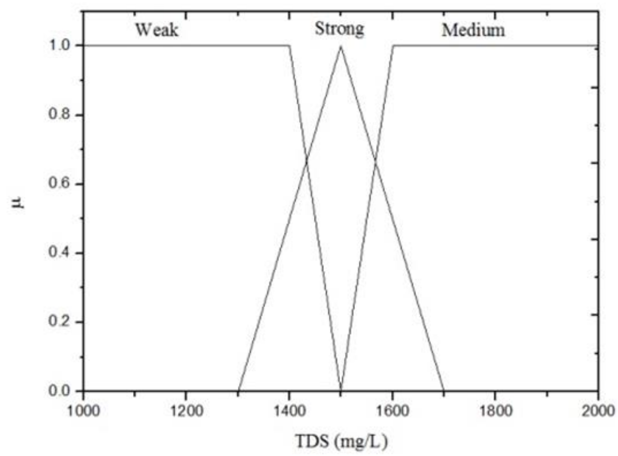
(c) The first strategy fuzzy diagram of the domestic sector



(d) The second strategy fuzzy diagram of the domestic sector



(e) The first strategy fuzzy diagram of the ministry of energy



(f) The second strategy fuzzy diagram of the ministry of energy

Fig. 5 The strategy fuzzy diagrams

second strategy of the Organization of Agriculture is shown in Fig. 5 (b). The fuzzy diagram deviates slightly to the right due to coalition with the industry. The industry takes quantity into account as well but receives smaller share of water than that of the Organization of Agriculture, so it cannot advance in negotiation alone. Forming a coalition with the industry, the Organization of Agriculture will be stronger in negotiation; hence, the second strategy should

Table 3 The values for the class of prioritizing each player's probable strategies from his viewpoint

	Agriculture sector		Domestic sector		Ministry of energy sector	
	Strategy number		Strategy number		Strategy number	
	1	2	1	2	1	2
a	0.25	0.25	1.00	1.00	0.25	0.25
b	0.5	0.5	0.75	0.75	0.75	0.75
c	0.75	0.75	0.5	0.5	1.00	1.00
d	1.00	1.00	0.25	0.25	0.5	0.5

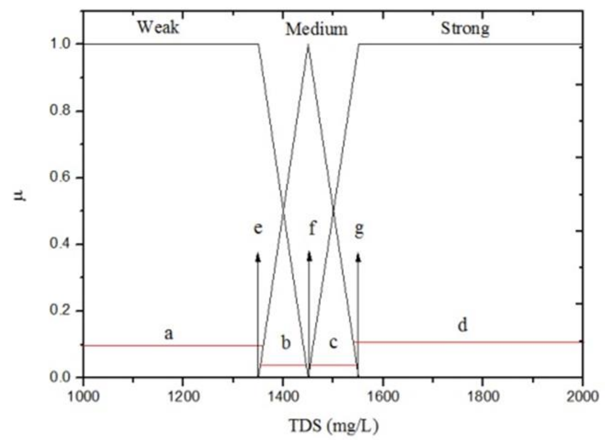


Fig. 6 The prioritizing method

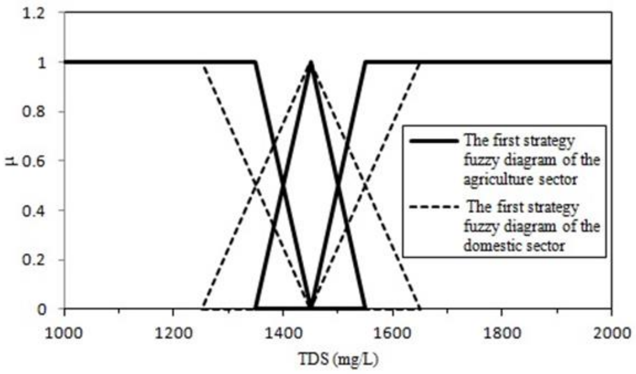
be adopted to meet the needs of the industry. Thus, the diagram of the second strategy deviates to the right. The zoning is reversed for the domestic sector due to consideration of quality as shown in Figs. 5(c) and 5(d). Fig. 5(e) shows the membership function for the first strategy of the Ministry of Energy. As the economy is the top priority and the middle zone of the trade-off curve is the favorite, $TDS \geq 1450$ and $TDS \leq 1450$ represent the medium and the weak zone, respectively. If $1250 \leq TDS \leq 1450$, the zone is strong-weak, and if $1450 \leq TDS \leq 1650$, the zone is strong-medium. Fig. 5(f) shows the membership function for the second strategy of the Ministry of Energy. Prioritizing the quality resulted in deviation to the right.

Thereafter, the priorities on fuzzy functions of each decision maker's strategies are determined to develop the priority matrix. According to Fig. 6 and interview with each party's expert, the priority classes of a, b, c, and d ranges are considered for each strategy. The priority class will be the average of the previous and the next priority at points, e, f and g that are the intersections of ranges. The ranges of priority are not equal in length since a decision-maker may assign a higher priority to a shorter range. The values of a, b, c and d are shown in Table 3 for each decision maker strategy. For example, they are 0.25, 0.5, 0.75 and 1 for the Organization of Agriculture.

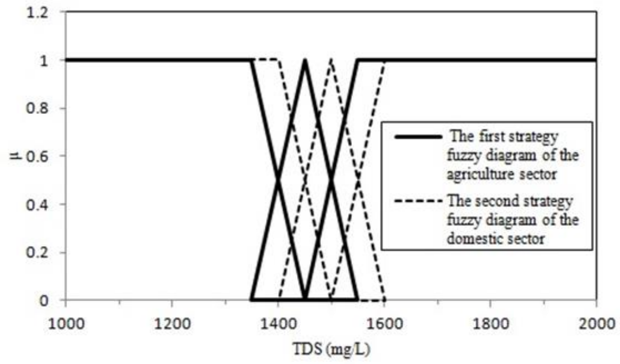
As there are three decision-makers and two strategies for each, the total number of strategies will be eight. It is very important which strategies are chosen by decision-makers. Therefore, the priority of each strategy may be obtained and organized in a priority matrix by overlapping the diagrams, determining the intersecting points and defining the priority class from each decision maker's viewpoint. Now, the priority matrix for the three mentioned decision-makers is arranged. Since the Organization of Agriculture and the Domestic Sector have two strategies, there will be four combos for probable strategies. These combos are shown in Figure 7. By overlapping the membership functions of strategies, obtaining the intersection points and using the diagrams in Figs. 5(e) and 5(f), the priority class of the points from the viewpoint of the Ministry of Energy is determined. Then, the priority matrix will be obtained from Table 4. According to this matrix, the priority of the first or the second strategy against rivals' strategies from the viewpoint of the Ministry of Energy is recognized. For example, if the Organization of Agriculture and the Domestic Sector enter into negotiation with the first strategy (Ag_{S1}), strong zone (S), the second strategy (U_{S2}) and weak zone (W), TDS will be 1650 at the intersection (Fig. 7(b)). Therefore, if the Ministry of Energy uses the first strategy (W_{S1}) (Fig. 5(e)), the priority of that TDS will be 0, 0.75 and 0 for weak (W), medium (M) and strong (S) zones, respectively (Path B in Table 4). Also, if the second strategy is chosen, TDS priority will be equal to 0, 1, and 1 for (W), (M), and (S) (Path B in Table 4), i.e. if the agriculture sector and the domestic sector choose the first strategy and the strong zone ($Ag_{S1}(S)$), and the second strategy and the weak zone ($U_{S2}(W)$) of the fuzzy membership function, respectively, the medium zone will be of high priority if the Ministry of Energy selects the first strategy. In the same way, if the second strategy is selected, strong or medium zones will be the best options. The priority of either the first or the second strategy for different zones from the viewpoint of the Ministry of Energy at the time of negotiation with agriculture and domestic sectors could be predicted from Table 4. Similarly, the priority matrix will be obtained for two other decision-makers as presented in Tables 5 and 6.

4.2 Determination of agreed qualitative range

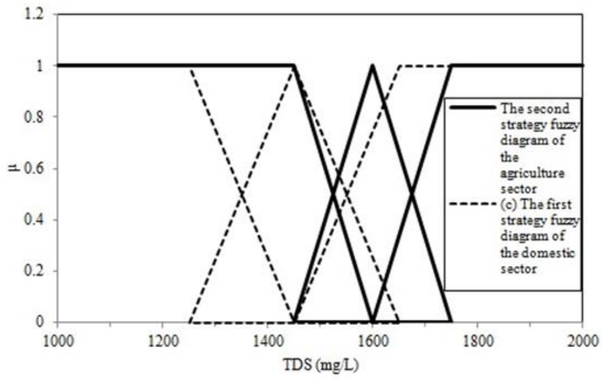
Decision-makers in conditions of negotiations are interested in choosing strategies that have the highest priority. The desirability of all decision-makers is avoiding any atmosphere of tension and conflict and it is emphasized that dialogue and negotiation is the best way to reach an agreement. Tables 4, 5 and 6 represent a prioritization matrix of each decision makers against the combination of different strategies of other decision-makers. Then, the range of water withdrawal quality which is agreed by all beneficiaries is determined using the prioritization matrix based on fuzzy logic for every decision maker. Table 6 indicates that the highest priority from the standpoint of domestic sector (number 1 in Table 6) happens just in the case that the decision maker uses the second strategy in the strong zone ($U_{S2}(S)$). In the following, If domestic sector implements the second strategy and strong zone ($U_{S2}(S)$) (Path B and D in Table 5) using Table 5, the highest priority from the standpoint of agriculture is devoted to selection of first strategy in the strong zone ($Ag_{S1}(S)$) which has priority 1. After determining the strategy with the highest priority from the perspective of domestic and agricultural sectors,



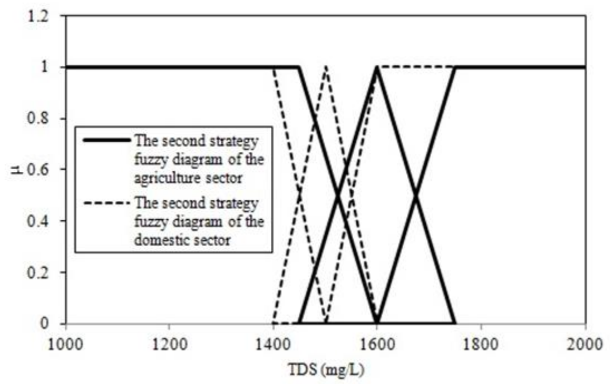
(a) The fuzzy diagram of combining the first strategy of the agriculture sector (solid line) with the first strategy of the domestic sector (dashed line)



(b) The fuzzy diagram of combining the first strategy of the agriculture sector (solid line) with the second strategy of the domestic sector (dashed line)



(c) The fuzzy diagram of combining the second strategy of the agriculture sector (solid line) with the first strategy of the domestic sector (dashed line)



(d) The fuzzy diagram of combining the second strategy of the agriculture sector (solid line) with the second strategy of the domestic sector (dashed line)

Fig. 7 The fuzzy diagrams of combining strategies of the agriculture sector (solid line) with strategies of the domestic sector (dashed line)

Table 4 The fuzzy prioritizing matrix from the ministry of energy viewpoint

Path	Strategies combination		$W_{S1}(W)$	$W_{S1}(M)$	$W_{S1}(S)$	$W_{S2}(W)$	$W_{S2}(M)$	$W_{S2}(S)$
		$Ag_{S1}(W) - U_{S1}(W)$	0	0	0	0	0	0
		$Ag_{S1}(W) - U_{S1}(M)$	0.75	0	0.75	0.75	0	0.75
		$Ag_{S1}(W) - U_{S1}(S)$	0.5	0	0	0.25	0	0
		$Ag_{S1}(M) - U_{S1}(W)$	0	1	1	0	1	1
A	$Ag_{S1} - U_{S1}$	$Ag_{S1}(M) - U_{S1}(M)$	0	0.875	0	0.75	0	0.75
		$Ag_{S1}(M) - U_{S1}(S)$	0.75	0	0.75	0.75	0	0.75
		$Ag_{S1}(S) - U_{S1}(W)$	0	0.75	0	0	1	1
		$Ag_{S1}(S) - U_{S1}(M)$	0	1	1	0	1	1
		$Ag_{S1}(S) - U_{S1}(S)$	0	0	0	0	0	0
		$Ag_{S1}(W) - U_{S2}(W)$	0	0	0	0	0	0
		$Ag_{S1}(W) - U_{S2}(M)$	0.75	0	0.75	0.75	0	0.75
		$Ag_{S1}(W) - U_{S2}(S)$	0.75	0	0.75	0.75	0	0.75
		$Ag_{S1}(M) - U_{S2}(W)$	0	1	1	0	1	1
B	$Ag_{S1} - U_{S2}$	$Ag_{S1}(M) - U_{S2}(M)$	0	1	1	0.75	0	0.75
		$Ag_{S1}(M) - U_{S2}(S)$	0.75	0	0.75	0.75	0	0.75
		$Ag_{S1}(S) - U_{S2}(W)$	0	0.75	0	0	1	1
		$Ag_{S1}(S) - U_{S2}(M)$	0	1	1	0	1	1
		$Ag_{S1}(S) - U_{S2}(S)$	0	1	1	0.75	0	0.75

Table 4 (continued)

Path		Strategies combination	$W_{S1}(W)$	$W_{S1}(M)$	$W_{S1}(S)$	$W_{S2}(W)$	$W_{S2}(M)$	$W_{S2}(S)$
C	$Ag_{S2}– U_{S1}$	$Ag_{S2}(W) – U_{S1}(W)$	0	1	1	0	1	1
		$Ag_{S2}(W) – U_{S1}(M)$	0	0	0.875	0.75	0	0.75
		$Ag_{S2}(W) – U_{S1}(S)$	0.5	0	0	0.25	0	0
		$Ag_{S2}(M) – U_{S1}(W)$	0	1	1	0	1	1
		$Ag_{S2}(M) – U_{S1}(M)$	0	1	1	0	1	1
		$Ag_{S2}(M) – U_{S1}(S)$	0	0	0	0	0	0
		$Ag_{S2}(S) – U_{S1}(W)$	0	0.5	0	0	0.5	0
		$Ag_{S2}(S) – U_{S1}(M)$	0	1	1	0	1	1
		$Ag_{S2}(S) – U_{S1}(S)$	0	0	0	0	0	0
D	$Ag_{S2}– U_{S2}$	$Ag_{S2}(W) – U_{S2}(W)$	0	1	1	0	1	1
		$Ag_{S2}(W) – U_{S2}(M)$	0	1	1	0.75	0	0.75
		$Ag_{S2}(W) – U_{S2}(S)$	0.75	0	0.75	0.75	0	0.75
		$Ag_{S2}(M) – U_{S2}(W)$	0	1	1	0	1	1
		$Ag_{S2}(M) – U_{S2}(M)$	0	1	1	0	1	1
		$Ag_{S2}(M) – U_{S2}(S)$	0	1	1	0.75	0	0.75
		$Ag_{S2}(S) – U_{S2}(W)$	0	0.5	0	0	0.5	0
		$Ag_{S2}(S) – U_{S2}(M)$	0	0	0	0	0	0
		$Ag_{S2}(S) – U_{S2}(S)$	0	0	0	0	0	0

Table 5 The fuzzy prioritizing matrix from the agriculture sector viewpoint

Path		Strategies combination	AgS1(W)	AgS1(M)	AgS1(S)	AgS2(W)	AgS2(M)	AgS2(S)
A	WS1– US1	WS1(W) – US1(W)	0	0	0	0	0	0
		WS1(W) – US1(M)	0.5	0.5	0	0.25	0	0
		WS1(W) – US1(S)	0.25	0	0	0.25	0	0
		WS1(M) – US1(W)	0	0	1	0	0.75	0.75
		WS1(M) – US1(M)	0	0.75	0.75	0.5	0.5	0
		WS1(M) – US1(S)	0	0	0	0	0	0
		WS1(S) – US1(W)	0	0	0.875	0.5	0.5	0
		WS1(S) – US1(M)	0	0.625	0	0.375	0	0
		WS1(S) – US1(S)	0.375	0	0	0.25	0	0
B	WS1– US2	WS1(W) – US2(W)	0	0	0	0	0	0
		WS1(W) – US2(M)	0.5	0.5	0	0.25	0	0
		WS1(W) – US2(S)	0.375	0	0	0.25	0	0
		WS1(M) – US2(W)	0	0	1	0	0.625	0
		WS1(M) – US2(M)	0	0.75	0.75	0.5	0.5	0
		WS1(M) – US2(S)	0	0.75	0.75	0.5	0.5	0
		WS1(S) – US2(W)	0	0	0.875	0.5	0.5	0
		WS1(S) – US2(M)	0	0	0.875	0.5	0.5	0
		WS1(S) – US2(S)	0.5	0.5	0	0.25	0	0
C	WS2– US1	WS2(W) – US1(W)	0	0.75	0.75	0.5	0.5	0
		WS2(W) – US1(M)	0.5	0.5	0	0.25	0	0
		WS2(W) – US1(S)	0.25	0	0	0.25	0	0
		WS2(M) – US1(W)	0	0	1	0	0.75	0.75
		WS2(M) – US1(M)	0	0	1	0.5	0.5	0
		WS2(M) – US1(S)	0	0	0	0	0	0
		WS2(S) – US1(W)	0	0	1	0.5	0.5	0
		WS2(S) – US1(M)	0	0.75	0.75	0.5	0.5	0
		WS2(S) – US1(S)	0.5	0.5	0	0.25	0	0

Table 5 (continued)

Path	Strategies combination		$Ag_{S1}(W)$	$Ag_{S1}(M)$	$Ag_{S1}(S)$	$Ag_{S2}(W)$	$Ag_{S2}(M)$	$Ag_{S2}(S)$
D	$W_{S2}– U_{S2}$	$W_{S2}(W) – U_{S2}(W)$	0	0	0	0	0	0
		$W_{S2}(W) – U_{S2}(M)$	0	0.625	0	0.375	0	0
		$W_{S2}(W) – U_{S2}(S)$	0.5	0.5	0	0.25	0	0
		$W_{S2}(M) – U_{S2}(W)$	0	0	1	0	0.625	0
		$W_{S2}(M) – U_{S2}(M)$	0	0	0.875	0.5	0.5	0
		$W_{S2}(M) – U_{S2}(S)$	0	0	0	0	0	0
		$W_{S2}(S) – U_{S2}(W)$	0	0	1	0.5	0.5	0
		$W_{S2}(S) – U_{S2}(M)$	0	0.75	0.75	0.5	0.5	0
		$W_{S2}(S) – U_{S2}(S)$	0.5	0.5	0	0.25	0	0

Table 6 The fuzzy prioritizing matrix from the domestic sector viewpoint

Path	Strategies combination		$U_{S1}(W)$	$U_{S1}(M)$	$U_{S1}(S)$	$U_{S2}(W)$	$U_{S2}(M)$	$U_{S2}(S)$
A	$W_{S1}–Ag_{S1}$	$W_{S1}(W) – Ag_{S1}(W)$	0	0.75	0.75	0	0	1
		$W_{S1}(W) – Ag_{S1}(M)$	0	0.75	0.75	0	0	0.875
		$W_{S1}(W) – Ag_{S1}(S)$	0	0	0	0	0	0
		$W_{S1}(M) – Ag_{S1}(W)$	0	0	0	0	0	0
		$W_{S1}(M) – Ag_{S1}(M)$	0.5	0.5	0	0	0.625	0
		$W_{S1}(M) – Ag_{S1}(S)$	0.5	0.5	0	0.5	0.5	0
		$W_{S1}(S) – Ag_{S1}(W)$	0	0.75	0.75	0	0	1
		$W_{S1}(S) –Ag_{S1}(M)$	0	0.625	0	0	0.75	0.75
		$W_{S1}(S) – Ag_{S1}(S)$	0.5	0.5	0	0.5	0.5	0
B	$W_{S1}–Ag_{S2}$	$W_{S1}(W) – Ag_{S2}(W)$	0	0.75	0.75	0	0	1
		$W_{S1}(W) – Ag_{S2}(M)$	0	0	0	0	0	0
		$W_{S1}(W) – Ag_{S2}(S)$	0	0	0	0	0	0
		$W_{S1}(M) – Ag_{S2}(W)$	0.5	0.5	0	0.5	0.5	0
		$W_{S1}(M) – Ag_{S2}(M)$	0.5	0.5	0	0.375	0	0
		$W_{S1}(M) – Ag_{S2}(S)$	0.25	0	0	0.25	0	0
		$W_{S1}(S) – Ag_{S2}(W)$	0	0.625	0	0	0.75	0.75
		$W_{S1}(S) –Ag_{S2}(M)$	0.5	0.5	0	0.5	0.5	0
		$W_{S1}(S) – Ag_{S2}(S)$	0.5	0.5	0	0.25	0	0
C	$W_{S2}–Ag_{S1}$	$W_{S2}(W) – Ag_{S1}(W)$	0	0.75	0.75	0	0	1
		$W_{S2}(W) – Ag_{S1}(M)$	0	0.75	0.75	0	0.75	0.75
		$W_{S2}(W) – Ag_{S1}(S)$	0.5	0.5	0	0	0.75	0.75
		$W_{S2}(M) – Ag_{S1}(W)$	0	0	0	0	0	0
		$W_{S2}(M) – Ag_{S1}(M)$	0.5	0.5	0	0.5	0.5	0
		$W_{S2}(M) – Ag_{S1}(S)$	0.5	0.5	0	0.375	0	0
		$W_{S2}(S) – Ag_{S1}(W)$	0	0.75	0.75	0	0	0.875
		$W_{S2}(S) –Ag_{S1}(M)$	0	0.5	0.5	0	0.75	0.75
		$W_{S2}(S) – Ag_{S1}(S)$	0.5	0.5	0	0.5	0.5	0
D	$W_{S2}–Ag_{S2}$	$W_{S2}(W) – Ag_{S2}(W)$	0	0.75	0.75	0	0	0.875
		$W_{S2}(W) – Ag_{S2}(M)$	0.5	0.5	0	0	0.75	0.75
		$W_{S2}(W) – Ag_{S2}(S)$	0	0	0	0	0	0
		$W_{S2}(M) – Ag_{S2}(W)$	0.5	0.5	0	0	0.5	0.5
		$W_{S2}(M) – Ag_{S2}(M)$	0.5	0.5	0	0.375	0	0
		$W_{S2}(M) – Ag_{S2}(S)$	0.25	0	0	0.25	0	0
		$W_{S2}(S) – Ag_{S2}(W)$	0.5	0.5	0	0	0.75	0.75
		$W_{S2}(S) –Ag_{S2}(M)$	0.5	0.5	0	0.5	0.5	0
		$W_{S2}(S) – Ag_{S2}(S)$	0.5	0.5	0	0.25	0	0

the highest priority from the standpoint of the Ministry is selection of the first strategy in the medium zone ($W_{S1}(M)$) or first strategy in the strong zone ($W_{S1}(S)$) as both of them have priority 1 for a combination of strategy $Ag_{S1}(S)$–$U_{S2}(S)$ and on the basis of path B from Table 4. The best strategy for decision-makers in the terms negotiation is as follows.

$Ag_{S1}(S)$–$U_{S2}(S)$–$W_{S1}(M)$, its common qualitative area according to Figure 5(a), 5(d) and 5(e) is $1450 \leq TDS \leq 1500$.

$Ag_{S1}(S)$–$U_{S2}(S)$–$W_{S1}(S)$, its common qualitative area according to Figure 5(a), 5(d) and 5(e) is $1450 \leq TDS \leq 1500$.

Range of $1450 \leq TDS \leq 1500$ provides the highest possible priority for all decision-makers and it is also accepted by all. Model is performed for each amount of TDS in the mentioned range and the volume of water withdrawal from each gate is obtained in each month. Given that the range $1450 \leq TDS \leq 1500$ has the highest priority for the stakeholders, the selecting any TDS value in this range will be favorable to each stakeholder. In the previous studies, only one TDS value was defined as the optimal quality of the stakeholders, which for it the reservoir water allocation is performed and the model did not have high flexibility under these conditions, while providing an appropriate range for the qualitative index of TDS is advantage of the proposed model in this paper. The optimum TDS value for stakeholders in the range $1450 \leq TDS \leq 1500$ is considered as threshold limit of TDS. Reservoir water allocation method in the model is as follows. Considering that in the15 Khordad dam quality/quantity annual operation model, 9 months (from December to March) is considered for optimization of water quality, and the model is intelligently dedicated the remaining 3 months (December, January, and February) to the salt discharge and reservoir leaching. The average TDS value can calculate during the 9-month period of the target year. According to the average TDS value, optimizing provision need to be made for threshold limit of TDS. The average TDS value is compared with threshold limit of TDS considered in the limit method. If the average TDS value during the 9-month period of the target year is greater than the threshold limit of TDS, the model intelligently considers zero as the percentage of provision for the input TDS. If the average TDS value is less than threshold limit of TDS, the TDS value will be monitored for each month because the TDS value per month can be greater than/less than threshold limit of TDS over the year. For months in which TDS value exceeds threshold limit of TDS, provision will not be made; otherwise, provision will be made based the downstream demand and the output value. In the conditions that water supply is not made through the reservoir, it is suggested to use alternative resources such as underground ones. The method proposed in this paper can be useful in many negotiations about systems of water resources which include multiple decision makers with different purposes and utilities. Specified negotiation stages and the possibility to select high-priority strategy for each decision maker at each stage of negotiations until determination of the final answer are considered as some of its advantages.

5. Summary and conclusion

Since there are several decision-makers with different prospects and priorities, taking decisions about operating water resources, especially dam reservoirs, is of high importance. Decision-making is an uncertain and stochastic process as it depends on the knowledge of decision-makers. Therefore, it is very important to determine the priority of strategies with regard to the rivals' strategies so that all uncertainties are considered. Each decision-maker has several strategies at the time of negotiation. In this paper, the priority fuzzy matrix was developed by defining fuzzy membership functions for each decision maker's strategies in a way that all uncertainties were taken into account. This matrix included priorities assigned to other decision makers' possible combination of strategies in negotiation with each player's viewpoint. Then, range of water withdrawal quality that is agreed by all beneficiaries was determined by using the prioritization matrix based on fuzzy logic. While the uncertain conditions prevailing in the atmosphere of talks are modeled by using this method, the possibility that the decision maker at each stage of talks knows their top priority against the strategy of the rivals, has been prepared. The advantages of this model include presence of several decision-making groups with unlimited members, different utilities and uncertainties of the problem. The 15-Khordad Dam which suffers from considerable quality problems was chosen as the case study for this purpose. It is concluded that the priority of each strategy may be determined for each negotiator using this method. In this paper, the type of game we study is non-cooperative game, in the sense that all players enter the game independently, and by choosing different strategies seek to maximize their individual utility, which eventually leads to a Nash equilibrium, but it is not ideal for them, determining the players' share with respect to Nash equilibrium will be future research goals.

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References

Abed-Elmdoust, A., and Kerachian, R. (2012), "Water resources allocation using a cooperative game with fuzzy payoffs and fuzzy coalitions", *Water Resour. Manag.*, **26**(13), 3961-3976.

Adhami, M., Sadeghi, S.H.R. and Sheikhmohammady, M. (2018), "Making competent land use policy using a co-management framework", *Land Use Policy.*, **72**, 171-180.

Alizadeh, M.R., Nikoo, M.R. and Rakhshandehroo, G.R. (2017), "Developing a multi-objective conflict-resolution model for optimal groundwater management based on fallback bargaining models and social choice rules: A case study", *Water Resour. Manag.*, **31**(5), 1457-1472.

Dehghan Manshadi, H.R., Niksokhan, M.H. and Ardestani, M. (2015), "Quantity-quality model for inter-basin water transfer system using game theoretic and virtual water approaches", *Water Resour Manag.*, **29**(13), 4573-4588.

Ganji, A., Khalili, D. and Karamouz, M. (2006), "Development of stochastic dynamic Nash game model for reservoir operation. I: The symmetric stochastic model with perfect information", *Adv. Water Resour*., **30**(3), 528-542.

Ganji, A., Khalili, D. and Karamouz, M. (2007), "Development of stochastic dynamic Nash game model for reservoir operation. II: The value of players' information availability and cooperative behaviors", *Adv. Water Resour.*, **30**(1), 157-168.

Garagic, D. and Cruz, J. (2003), "An approach to fuzzy noncooperative Nash games", *J. Optim. Theory Appl.*, **118**(3), 475-491.

Haan, T.Y., Shah, M., Chun, H.K. and Mohammad, A.V. (2018), "A study on membrane technology for surface water treatment: Synthesis, characterization and performance test", *Membr. Water Treat.*, **9**(2), 69-77.

Jiang, S.K., Zhang, G.M., Yan, L. and Wu, Y. (2018), "Treatment of natural rubber wastewater by membrane technologies for water reuse", *Membr. Water Treat.*, **9**(1), 17-21.

Jokić, A.I., Seres, L.L., Milović, N.R., Seres, Z.I., Maravić, N.R., Saranović, Z. and Dokić, L.P. (2018), "Modelling of starch industry wastewater microfiltration parameters by neural network", *Membr. Water Treat.*, **6**(1), 77-94.

Karimi, A., Nikoo, M.R., Kerachian, R. and Shirangi, E. (2011), "Assessment of water transport projects impact on long term water supply in Zayandehrood basin by multi-period optimization analysis", *Iran. Water Res. J*., **6**(11), 153-163.

Kerachian, R. and Karamouz, M. (2006), "Optimal reservoir operation considering the water quality issues: a stochastic conflict resolution approach", *Water Resour. Res.*, **42**(12), 1-15.

Kerachian, R. and Karamouz, M. (2007), "A stochastic conflict resolution model for water quality management in reservoir-river systems", *Adv. Water Res.*, **30**(4), 866-882.

Kerachian, R. and Shirangi, E. (2008), "A case study for conflict resolution in reservoir operation for water quantity and quality", *World Water and Environmental Resources Congress*, Hawaii, May.

Lee, C.S., Nam, Y.W. and Ki, D.I. (2017), "Economical selection of optimum pressurized hollow fiber membrane modules in water purification system using RbLCC", *Membr. Water Treat.*, **8**(2), 137-147.

Lee, J., Cha, H.Y., Min, K.J., Cho, J. and Park, K.Y. (2018), "Electrochemical nitrate reduction using a cell divided by ion-exchange membrane", *Membr. Water Treat.*, **9**(3), 189-194.

Li, B., Tan, G. and Chen, G. (2016), "Generalized uncooperative planar game theory model for water distribution in transboundary rivers", *Water Resour. Manag*., **30**(1), 225-241.

Luo, G., Li, W., Tan, H. and Chen, X. (2017), "Comparing salinities of 0, 10 and 20 in biofloc genetically improved farmed tilapia (Oreochromis niloticus) production systems", *Aquacult. Fisher.*, **2**(5), 220-226.

Madani, K. (2010), "Game theory and water resources", *J. Hydrology.*, **381**(3-4), 225-238.

Madani, K. and Hipel, K. (2011), "Non-cooperative stability definitions for strategic analysis of generic water resources conflicts", *Water Resour. Manag*., **25**(8), 1949-1977.

Madani, K. and Hooshyar, M. (2014), "A game theory reinforcement learning (GT-RL) method to develop optimal operation policies for multi-reservoir multi-operator systems", *J. Hydrology.*, **519**, 732-742.

Mahjouri, N. and Ardestani, M. (2011), "Application of cooperative and non-cooperative games in large-scale water quantity and quality management: A case study", *Environ. Monit. Assess.*, **172**(1-4), 157-169.

Poorsepahy-Samian, H., Kerachian, R. and Nikoo, M.R. (2012), "Water and pollution discharge permit allocation to agricultural zones: Application of game theory and min-max regret analysis", *Water Resour. Manag*., **26**(14), 4241-4257.

Rashidi, B. Shirangi, E. and Baymaninezhad, M. (2018), "Multiple criteria decision making method for selecting of sealing element for earth dams considering long and short terms goals", *Wind Struct.*, **26**(2), 69-74.

Rojas-Serrano, F., Álvarez-Arroyo, R., Pérez, J.I., Plaza, F., Garralón, G. and Gómez, M.A. (2015), "Ultrafiltration membranes for drinking-water production from low-quality surface water: A case study in Spain", *Membr. Water Treat.*, **6**(1), 77-94.

Sadegh, M., Mahjouri, N. and Kerachian, R. (2010), "Optimal inter-basin water allocation using crisp and fuzzy shapley games", *Water Resour. Manag*., **24**(10), 2291-2310.

Sadegh, M. and Kerachian, R. (2011), "Water resources allocation using solution concepts of fuzzy cooperative games: fuzzy least core and fuzzy weak least core", *Water Resour. Manag*., **25**(10), 2543-2573.

Sanada, K. (2018), "Real-time implementation of Kalman filter for unsteady flow measurement in a pipe", *J. Hydromechatronics*., **1**(1), 3-15.

Sechi, G.M., Zucca, R. and Zuddas, P. (2013), "Water costs allocation in complex systems using a cooperative game theory approach", *Water Resour. Manag*., **27**(6), 1781-1796.

Shirang, E. and Kerachian, R. (2007), "A simplified model for optimal reservoir operation considering the water quality issues", *Proceedings of CEMEPS/SECOTOX Conference*, Skiathos island, Greece, June.

Shirangi, E., Kerachian, R. and Shafai Bajestan, M. (2008), "A simplified model for optimal reservoir operation considering the water quality issues: Application of the Young conflict resolution theory", *Environ. Monit. Assess.*, **146**(1-3), 77-89.

Shirangi, E., khaleghi, S., Baghaei, F., Mansoori, A. and Pourmand, E. (2016), "Developing real time optimal reservoir operation rules using Bayesian networks: Application of group conflict resolution model", *J. Water Soil Resour. Conserv.*, **5**(3), 1-11.

Singh, A., Panda, S., Saxena, C., Verma, C., Uzokwe, V., Krause, P. and Gupta, S. (2016), "Optimization modeling for conjunctive use planning of surface water and groundwater for irrigation" *J. Irrig. Drain. Eng.*, **142**(3), 1-9.

Soltani, M.A., Karimi, A., Bazargan-lari, M.R. and Shirangi, E. (2008), "Stochastic multi-purpose reservoir operation planning by scenario optimization and differential evolutionary algorithm", *J. Appl. Sci*., **8**(22), 4186-4191.

Soltani, F., Kerachian, R. and Shirangi, E. (2010), "Developing operating rules for reservoirs considering the water quality issues: Application of ANFIS-based surrogate models", *Expert Syst. Appl.*, **37**(9), 6639-6645.

Stelson, K. (2018), "Academic fluid power research in the USA", *J. Hydromechatronics*, **1**(1), 126-152.

Teegavarapu, R.S., Ferreira, A.R. and Simonovic, S.P. (2013), "Fuzzy multiobjective models for optimal operation of a hydropower system", *Water Resour. Res.*, **49**(6), 3180-3193.

Wang, Z., Xie, Z. and Huang, W. (2018), "A pin-moment model of flexoelectric actuators", *J. Hydromechatronics*, **1**(1), 72-90.

Wu, H., Chen, C., Wang, Q., Lin, J. and Xue, J. (2017), "The biological content of ballast water in China: A review", *Aquacult. Fisher.*, **2**(6), 241-246.

Yang, G., Song, L., Lu, Q., Wang, N. and Li, Y. (2017), "Effect of the exposure to suspended solids on the enzymatic activity in the bivalve Sinonovacula", *Aquacult. Fisher.*, **2**(1), 10-17.

Yang, Z., Liu, P., Cheng, L., Wang, H., Ming, B. and Gong., W. (2018), "Deriving operating rules for a large-scale hydro-photovoltaic power system using implicit stochastic optimization", *J. Cleaner Product.*, **195**, 562-572.

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