

Evaluating the Relative Power of Water Users in Inter-Basin Water Transfer Systems

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Abstract One of the challenging issues in designing and operation of inter-basin water transfer systems is quantifying the relative power of water users. In this paper, a comprehensive set of criteria including regional gross income, water efficiency, presence of alternative water resources, self-sufficiency, existence of agricultural and industrial infrastructures, receiving political support of the government and parliament, and preference-based power is proposed to determine the power of water users in a quantitative way. Then, some well-known Multiple Criteria Decision Making (MCDM) methods, namely Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Evidential Reasoning (ER), Method for Order Preference by Similarity to Ideal Situation (TOPSIS) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE II), are utilized to evaluate the power of water users in inter-basin water allocation systems. In this paper, the Spearman's rank correlation coefficient and Kendall's coefficient of concordance are applied to compare the ranking outputs resulting from different MCDM methods. At last, the proposed approach is applied to a large-scale case study of water transfer from the Karoon River basin to the Rafsanjan plain in the central part of Iran.

Keywords Inter-basin water transfer · Power of water users · Multiple Criteria Decision Making (MCDM) · Evidential Reasoning (ER) · Analytical Network Process (ANP) · Analytical Hierarchy Process (AHP)

1 Introduction

Power is a basic concept in both physics and political science. In physics, power has a specific definition, however in the political science, it is inexplicit. The usual scientific definition of power faces many intangible problems when it is brought into the political and social sciences.

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Since the early 1930s, social scientists have had an operational definition of power as the ability of one party to move another party in an intended direction. It is noticeable that “move” states here not to physical movement but to change in thought, in position and action (Schelling 1960; Zartman 1974). There are two central difficulties in quantifying the power. First, resources are in various sizes and shapes, making it challenging to aggregate them in a single measure. Second, some resources are shapelessly, for example in moral rights or leadership, commitments, or obligations (Sheikhmohammady et al. 2012). Consequently, it would be very hard to have an accurate measurement of the power of water users in an inter-basin water transfer systems. Although lots of papers deal with inter-basin water transfer systems (e.g. Xuesen et al. (2009), Sadegh et al. (2010), Sadegh and Kerachian (2011), Abed-Elmdoust and Kerachian (2012), and Jafarzadegan et al. (2013a, b)), previous works related to investigating the political aspects of water resources management are restricted to some case studies (e.g. Endtner (1987), Dinar and Wolf (1994), Kucukmehmetoglu and Guldmann (2010), and Sheikhmohammady et al. (2012), and Abed-Elmdoust and Kerachian (2013)). The literature review submits that water is a distinct commodity with more than regular economic prices assigned to it. Thus, the addition of ideological and political considerations is important to any water transfer management decision making process (Dinar and Wolf 1994) and quantifying the relative power of water users is one of the most challenging issues in such considerations. Quantifying the relative power of water users are usually guided by multiple criteria such as economic independency and self-sufficiency, existence of agricultural and industrial infrastructures, and receiving political support of the government and parliament. Incorporating all these criteria in estimating the power of water users in an inter-basin water transfer problem makes MCDM an attractive approach. In this study, a set of criteria is proposed to tackle the challenging issue of determining the power of water users in an inter-basin water transfer system. Five different MCDM methods namely Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Evidential Reasoning (ER), Method for Order Preference by Similarity to Ideal Situation (TOPSIS) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE II) are utilized to estimate the relative weight of water users based on the selected criteria. The applicability and effectiveness of different MCDM methods for evaluating the relative power of water users are examined by applying them to a large scale water transfer project in Iran.

2 Major Criteria in Determining the Power of Water Users

The proposed hierarchy structure of criteria for determining the water users’ powers in an inter-basin water transfer problem is shown in Fig. 1. The main criteria, which are considered for determining the power of water users, are as follows:

2.1 Economic Power

To define and evaluate the economic power criterion, the following sub-criteria are considered:

2.1.1 Regional Gross Income (RGI)

The higher RGI, the better off the region is. RGI involves the aggregate value of things and facilities manufactured in the interior of a region (i.e. its Regional Gross Domestic Product (RGDP)), collected with its income expected from other regions (remarkably dividends and

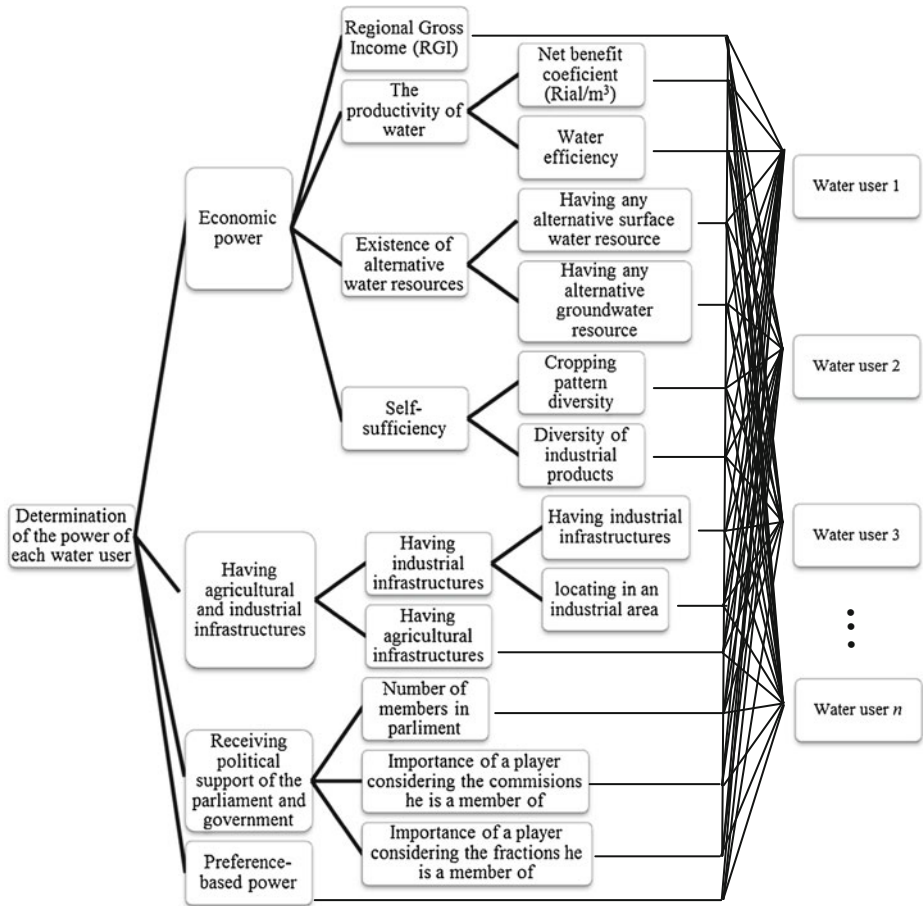


Fig 1 The proposed hierarchy structure of criteria for estimating the power of water users in inter-basin transfer systems

interest) minus similar costs and outgoings made to other regions. In other words, RGI is the worth of all income made by population of a region both in the interior and exterior of the region.

2.1.2 The Productivity of Waters

Whatever the amount of profit per unit of water (the rate of water efficiency) or Net benefit coefficient (Dollars/m³) is more in a region, it will be more concerned about getting more profit from common pool resources.

2.1.3 Existence of Alternative Water Resources

Regions having alternative water resources and are not dependent just on the disputed common pool resource may prefer to wait for future negotiations to attain better outcomes. Hence, the water users in these regions will be more powerful in negotiations.

2.1.4 Self-Sufficiency

Self-sufficiency of a water user can be dependent on the variety of his industrial and agricultural products. The more variety the water users have in their industrial and agricultural products, the more self-governing they might be.

2.2 Having Agricultural and Industrial Infrastructures

Having potential for water-related industrial and agricultural production and having enough infrastructures for that are important criteria which should be considered for estimating the power of a water user in a region.

2.3 Receiving Political Support of Government and Parliament

In addition to economic justification, government and parliament support in approving policies may be sturdily influenced by ethnic, demographic profile, geopolitical factors, and religious of the location of the water transfer project. These factors can be interrelated with the political trends of the authorities and their ethnic composition. So that a policy or project which is justified economically may be accepted in a region by the authorities; conversely, the same project with the same economic justification may not be welcomed in another region.

2.4 Preference-Based Power

Preference-based power is actually the amount of power that a water user has as being crucial to enter in different cooperative coalitions. The preference-based power of any water user can be measured in terms of to what extent he is vital in a cooperative coalition. If a water users' participation in a coalition leads a losing coalition change into a winning coalition, then that water user is considered as vital in that coalition. Some basic definitions are essential for calculating the vitalness score:

- **Group conflict:** at first, all water users define their own preferences about other water users and their policies. Formerly, based on these preferences, “ m -member group conflict” over n ranks (the number of ranks can be assume to be equal to the total number of water users since the water users are giving ranks to each other) is calculated using the following formula (Maoz 1995):

$$ConK = \frac{12 \sum_{h=1}^n \sum_{i=1}^{m-1} \sum_{q=i+1}^m (r_i^h - r_q^h)^2}{nm^2(n^2-1)} \quad (1)$$

where, $ConK$ is the index of group conflict in coalition K , r_i^h is rating assigned by water user h to water user i , r_q^h is rating assigned by water user h to water user q .

- **Coalition value:** using formula $EV_K = R_K(1 - ConK)$, coalition value is calculated (Maoz 1995). In this formula, R_K is the coalition's total resource derived from the sum of its individual members' resources. The conception of coalition value leads to coalition admissibility definition.
- **Coalition admissibility:** any water user can compare any coalition in which he is a member of and disregard the ones for which there is at least one suitable subset that gives a strictly greater expected value. Investigating admissibility is significant in water transfer

systems as it limits the number of possible coalitions. Furthermore, since in admissibility calculation, preferences ($1-ConK$) and resources (R_K) are applied conjointly, it signifies a way to make a distinction between the present theory and other theories which incorporate just resource-based powers.

- **Vital water user:** in this paper, following Maoz (1995), vitalness of a water user in any decision making is defined by means of the proportion of all admissible coalitions in which he is vital. Presence of a vital water user in the coalition makes this coalition win (gain more coalition value than some (not necessarily all) other coalitions), and its absence makes the coalition lose.

The vitalness score of water user i , which is the total number of times that the water user has helped the different coalitions to win in contest with their opponents (other coalitions), is denoted by VS_i' . The normalized vitalness score of water user i (preference-based power of water user i) is given by the following formula:

$$VS_i = \frac{VS_i'}{\sum_{i=1}^n VS_i'} \quad \forall i \tag{2}$$

where, n is the number of water users.

3 Multi Criteria Decision Making (MCDM) Methods

The Evidential Reasoning (ER) approach which uses the Dempster-Shafer theory (Dempster 1968) to arrive at a decision (Yang 2001), the AHP which is a structured procedure for establishing and evaluating multi criteria decision makings (Saaty 1980 and 2008), the ANP which uses a network with feedback attitude (Saaty 2005), the PROMETHEE II which offers a complete ordering of alternatives by pairwise comparison of the alternatives on each criterion (Leeneer and Pastijn 2002), and the TOPSIS in which the selected alternative has to be far from the negative-ideal solution as much as possible and close to the positive-ideal solution as much as possible (Hwang and Yoon 1981) are five selected MCDM methods which are applied to our case study.

4 Spearman’s Rank Correlation Coefficient and Kendall’s Coefficient of Concordance

Two coefficients, namely Spearman’s rank correlation coefficient and Kendall’s coefficient of concordance are used to compare the rankings obtained from the MCDM methods. The Spearman’s rank correlation coefficient (q) varies from -1 to 1 , in which number 1 represents perfect rank correlation. The Spearman’s rank correlation coefficient is calculated for ranking outputs of two MCDM methods denoted by $R' = \{r'_1 \dots r'_{nm}\}$ and $R'' = \{r''_1 \dots r''_n\}$ as follows (Sheskin 2004):

$$q = 1 - \frac{6 \sum_{i=1}^n d_i^2}{n(n^2-1)} \tag{3}$$

where, d_i is the difference of ranks between the two MCDM methods and n is the number of ranks which is equal to the number of water users.

The rankings resulted from the five MCDM methods are also compared using the Kendall's coefficient of concordance (z). Values of z range from 0 to 1, where number 1 represents perfect rank correlation. z is calculated as follows (Sheskin 2004):

$$z = \frac{\sum_{i=1}^n \left(s_i - \frac{\sum_{i=1}^n s_i}{n} \right)^2}{\frac{1}{12} k^2 (n^3 - n)} \quad (4)$$

where, k is the number of MCDM methods, which equals to 5 in this paper, s_i is the summation of all ranks assigned to an alternative i across all k MCDM methods and n is the number of alternatives.

5 Case Study

In order to evaluate the performance of the proposed methodology, a water transfer project from the great Karoon River to Rafsanjan plain in Iran is studied as a case study. The purpose of this project is to transfer water from Solegan reservoir, which will be constructed on one of the tributaries of the great Karoon River, to the Rafsanjan plain in the central part of Iran. The water users of the water donor basin include modern agro-industrial, old agro-industrial, and Khuzestan local agricultural sectors and the water user of the receiving basin is the Rafsanjan agricultural sector. In Fig. 2, the locations of the basin of origin and the water receiving basin in the study area are depicted. As shown in this figure, the donor basin is divided in to 5 sub-basins namely, *Gotvand*, *Shushtar*, *Ahvaz*, *Abadan*, and *Dezful*, each contains some regions. S , B , SB , and R denote respectively the sets of the sectors, the basins, the sub-basins, and the regions. These sets and their members are shown as follows:

$WU = \{\text{Khuzestan agricultural sector, Khuzestan modern agro-industrial sector, Khuzestan old agro-industrial sector, Rafsanjan}\}$, $B = \{\text{Donor basin, Receiving basin}\}$, $SB = \{\text{Gotvand, Shushtar, Ahvaz, Abadan, Dezful, Rafsanjan}\}$, $R = \{\text{Gotvand, Lali, Shushtar, Masjed soleyman, Ahvaz, Ramhormoz, Abadan, Shadegan, Mahshahr, Khoramshahr, Dezful, Andimeshk, Shush, Rafsanjan}\}$.

More details about the study area and the water transfer project can be found in Sadegh et al. (2010) and Mahjouri and Ardestani (2011).

6 Results and Discussion

6.1 Evaluating the Criteria

For evaluating the criteria, data and information which are gathered and disseminated by Statistical Center of Iran (SCI) are used. A complete set of data and information is available for sub-basins. Therefore, in order to evaluate the criteria related to a water user, the statistics related to its sub-basins should be considered. In this paper, to evaluate a criterion for a water user, the ratio of the sub-basin' water demand to

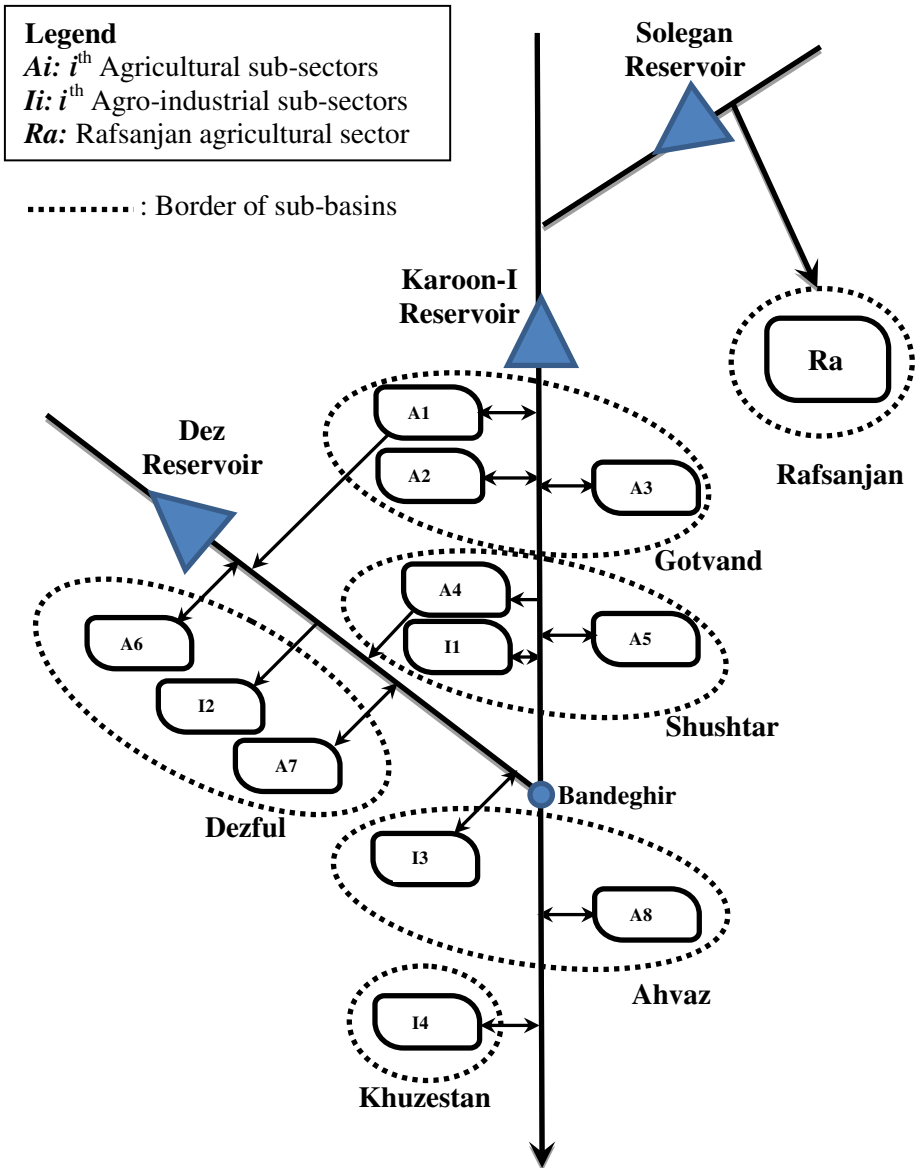


Fig. 2 The schematic locations of the water donor and the water receiving basins in the study area in Iran

demand of the water user is considered. This ratio can be considered as the ratio of the value of the criterion for the sub-basin and the water user:

$$Share_{ji} = \frac{\sum_{v=1}^{NSS_{ij}} D_{vi}}{\sum_{j=1}^{NSB_i} \sum_{v=1}^{NSS_{ij}} D_{vi}} \quad \forall i, j \quad (5)$$

$Share_{ji}$ denotes the share of sub-basin j from the total demand of water user i . NSS_{ij} is the number of sub-sectors of water user i located in sub-basin j . NSB_i denotes the number of sub-basins of water user i . D_{vi} is the demand of sub-sector v of water user i . The parameter $Share_{ji}$ will be used in evaluating different criteria in the next sub-sections. Table 1 presents the share of each sub-basin from the total water demand of water users.

6.1.1 RGI in the Study Area

In this paper, the household income is used for estimating the RGI. The RGI of region k is calculated using the data presented in Table 2 and the following formula:

$$RGI_k^R = NHU_k \times AIUH_k + NHR_k \times AIRH_k \quad \forall k \in R \tag{6}$$

where, NHU_k denotes the number of households in urban areas of region k , NHR_k denotes the number of households in rural areas region k . $AIUH_k$ denotes the average income of urban households in region k . $AIRH_k$ denotes the average income of rural households in region k .

The number of households in the urban and rural areas of each region, the average income of urban and rural households, and the RGI calculated for each region are presented for the year 2006 in Table 2. The RGI of each sub-basin j is calculated using the following formula:

$$RGI_j^{SB} = \sum_{k=1}^{NR_j} RGI_k^R \quad \forall j \tag{7}$$

where, NR_j is the number of regions of sub-basin j . The RGI of the water user i (RGI_i^{WU}) is calculated using the information presented in Table 2 and the following formula:

$$RGI_i^{WU} = \sum_{j=1}^{NSB_i} RGI_j^{SB} \times Share_{ji} \quad \forall i \tag{8}$$

Table 1 The share of each sub-basin from the total demand of water user

Sub-basins	Agricultural (A_i) and industrial (I_i) sub-sectors	Annual water demand (million m ³)	The ratio of each sub-sector's water demand to the total water demand of each water user	The share of each sub-basin
Gotvand	A1	583	4.37	18.19
	A2	566	4.25	
	A3	1275	9.57	
Shushtar	A4	5401	40.52	45.73
	A5	694	5.21	
Dezful	A6	1396	10.47	15.34
	A7	649	4.87	
Ahvaz	A8	2764	20.74	20.74
Sum of the annual agricultural water demands		13328	100	100
Shushtar	I1	5996	62.19	62.19
Dezful	I2	2005	20.79	20.79
Ahvaz	I3	1408	14.60	14.60
Abadan	I4	233	2.42	2.42
Sum of the annual industrial water demands		9642	100	100

Table 2 The Regional Gross Income (RGI) of each region in 2006

Sub-basin	Region	The number of households in the urban areas (NHU)	The number of households in the rural areas (NHR)	The average income of urban households (AIUH) (Rials)	The average income of rural households (AIRH) (Rials)	RGI of each region (RGI_k^R) (Rials)
Rafsanjan	Rafsanjan	42477	29428	65509108	39128830	3.93411E+12
Gotvand	Gotvand	4426	16465			9.34199E+11
	Lali	3047	3341			3.30336E+11
Shushtar	Shushtar	21555	16465			2.05631E+12
	Masjed Soleiman	22608	11200			1.91927E+12
Ahvaz	Ahvaz	225330	49233			1.66876E+13
	Ramhormoz	14144	11574			1.37944E+12
	Azadegan	12294	9779			1.18801E+12
Abadan	Abadan	49998	8932			3.62482E+12
	Shadegan	8613	15218			1.15969E+12
	Mahshahr	42800	10739			3.22399E+12
	Khoramshahr	26670	5948			1.97987E+12
Dezful	Dezful	26568	26164			2.76421E+12
	Andimeshk	62252	7530			4.37271E+12
	Shush	13172	20327			1.65826E+12

where, $Share_{ji}$ is the share of sub-basin j from the water user i calculated by Eq. 5. The RGI of the four water users are presented in Table 3.

6.1.2 Having Industrial Infrastructures

The number of employees water user i has in industries is a measure for determining if water user is located in an industrial area or not. Consequently, we can estimate to what extend each water user is located in an industrial area and has industrial infrastructures. This criterion is calculated using the data presented in Table 4 and the following formula:

$$NEI_i^{WU} = \sum_{j=1}^{NSB_i} NEI_j^{SB} \times Share_{ji} \quad \forall i \quad (9)$$

Table 3 The RGI of the four water users in 2006

Sub-basin	RGI of each sub-basin (RGI^{SB}) (Rials)	Standardized RGI ^{SB}	Water user	RGI of water user (RGI^{WU})
Rafsanjan	3.9341E+12	0.15	Agricultural sector	40.31
Gotvand	1.2645E+12	0.00	Agro-industrial sector	42.12
Shushtar	3.9756E+12	0.15	Rafsanjan	17.6
Ahvaz	1.9255E+13	1.00		
Abadan	9.9884E+12	0.48		
Dezful	8.7952E+12	0.42		

Table 4 Percentage of employees in industries for different sub-basins and water users

Sub-basin	Number of employees in industries (NEI_{SB})	Number of employees in industries (Standardized)	Water user	Percentage of employees in industries (PEI_{WU})
Rafsanjan	13088	0.24	Agricultural sector	37.18
Gotvand	2161	0.00	Agro-industrial sector	38.94
Shushtar	12189	0.22	Rafsanjan	23.88
Ahvaz	47845	1.00		
Abadan	39794	0.82		
Dezful	21389	0.42		

where, NEI_i^{WU} denotes the number of employees in industries related to water user i . NEI_j^{SB} denotes the number of employees in industries in sub-basin j .

6.1.3 The Number of Members in Parliament

The study area has 19 members in Iran parliament. The percentage of the members in the parliament is calculated for water user i using the following formula:

$$PMP_i = \sum_{j=1}^{NSB_i} NMP_j \times Share_{ji} \quad \forall i \quad (10)$$

PMP_i denotes the percentage of members of parliament who are related to the water user i . NMP_j denotes the number of members in parliament who are related to sub-basin j . The percentages of the members in the parliament are presented in Table 5 for all water users.

6.1.4 The Power of the Water users' Commissions and Fractions in the Parliament

There are 9 different commissions and 15 different fractions in the parliament of Iran. The relative powers of these commissions and fractions in national decision-making have been estimated and presented in Table 6. A representative of water user in the parliament is the

Table 5 The percentage of members in Iran's parliament

Sub-basin	Number of members in parliament (NMP)	Water user	Percentage of members in the parliament (PMP)
Rafsanjan	1	Agricultural sector	42.58
Gotvand	2	Agro-industrial sector	42.08
Shushtar	2	Rafsanjan	15.34
Ahvaz	5		
Abadan	6		
Dezful	3		

Table 6 The power of water users' commissions (POC^{WU}) and fractions (POF^{WU}) in Iran parliament

Sub-basin	Number of members in the eighth Parliament	The power of commissions (POC^{SB})	The power of fractions (POF^{SB})	Water user	The power of commissions (POC^{WU}) (Eq. 11) (Standardized)	The power of fractions \times (POF^{WU}) (Eq. 12) (Standardized)
Rafsanjan	1	0.17	0.15	Agricultural sector	45.18	46.05
Gotvand	2	0.31	0.28	Agro-industrial sector	45.90	42.85
Shushtar		0.31	0.28	Rafsanjan	8.92	11.10
Ahvaz	5	1.92	1.77			
Abadan	6	2.03	1.88			
Dezful	3	1.61	0.47			

member of a commission and a fraction. Therefore, the power of water user i 's commissions in parliament is calculated using the data presented in Table 6 and the following formula:

$$POC_i^{WU} = \sum_{j=1}^{NSB_i} POC_j^{SB} \times Share_{ji} \quad \forall i \tag{11}$$

where, POC_i^{WU} denotes the power of water user i 's commissions in the parliament. POC_j^{SB} denotes the power of sub-basin j 's commissions estimated based on the number of members sub-basin j has in different commissions of Iran parliament considering the importance and influence of those commissions. The necessary information was retrieved from the parliament website (<http://www.majlis.ir/>). The power of water user i 's fraction in parliament is also calculated using the data presented in Table 6 and the following formula:

$$POF_i^{WU} = \sum_{j=1}^{NSB_i} POF_j^{SB} \times Share_{ji} \quad \forall i \tag{12}$$

where, POF_i^{WU} denotes the power of fractions for water user $i=POF_j^{SB}$ denotes the power of sub-basin j 's fraction estimated based on the number of members sub-basin j has in different fractions of Iran parliament considering their importance and influence of those fractions. The power of water users' commissions and fractions in the Iran parliament are presented in Table 6.

6.1.5 Preference-Based Power of the Water Users

In our case study, the four water users can bring their water rights into different coalitions. Table 7 shows admissibility of coalitions in the inter-basin water transfer problem. In this paper, it is assumed that the water in the main river of the donor basin can be controlled using a reservoir. Therefore, a water right allocation model is developed in order to share water among the competing users. In this paper, water right allocation to the water users is performed utilizing a genetic algorithm (GA) model.

Table 8 shows all possible contests among all admissible coalitions, the total vitalness scores of the four water users and also the preference-based power of each water user. As

Table 7 Admissibility of coalitions in the inter-basin water transfer problem

Type of coalition	Coalition	Resources	Group conflict (Eq. 1)	Expected value	Admissibility
One-member	{1}	14.19	0.0	14.2	yes
	{2}	17.01	0.0	17.0	yes
	{3}	129	0.0	129.0	yes
	{4}	142.8	0.0	142.8	yes
Two-member	{1,2}	31.2	0.025	30.4	yes
	{1,3}	143.19	0.044	136.9	yes
	{1,4}	156.99	0.006	156.0	yes
	{2,3}	146.01	0.056	137.8	yes
	{2,4}	159.81	0.019	156.8	yes
	{3,4}	271.8	0.038	261.6	yes
Three-member	{1, 2, 3}	160.2	0.056	151.3	yes
	{1, 2, 4}	174	0.022	170.1	yes
	{1, 3, 4}	285.99	0.039	274.9	yes
	{2, 3, 4}	288.81	0.050	274.4	yes
Grand Coalition	{1, 2, 3, 4}	303	0.047	288.8	yes

Number 1: Modern agro-industrial sector, Number 2: Old agro-industrial sector, Number 3: Khuzestan agricultural sector, Number 4: Rafsanjan agricultural sector

shown in this table, Rafsanjan agricultural sector (water user 4) has the highest preference-based power.

6.2 Estimating the Total Power of Each Water User in the Study Area

The estimated values for the criteria shown in Fig. 1 are presented in Table 9. The relative weight vector of the sub-criteria in the last level of the hierarchy structure is determined by using comparison matrices provided by some experts. This weight vector, which is presented in Table 9, is held constant for each MCDM method.

The power (relative weight) and the rank of each water user (alternative in the MCDM models) resulted from the five MCDM methods are presented in Table 10. Values of

Table 8 Contests among all admissible coalitions, the total vitalness scores of the four water users, and the preference-based power of each water user in the four-player inter-basin water transfer project in Iran

	{}	{1}	{2}	{3}	{4}	{1,2}	{1,3}	{1,4}	{2,3}	{2,4}	{3,4}	vitalness score	Preference-based power
{1}	N	*	N	N	N	*	*	*	1	N	N	1	0.05
{2}	1	N	*	N	N	*	1	N	*	*	N	2	0.11
{3}	3	N	N	*	N	1	*	N	*	N	*	4	0.21
{4}	6	3	2	N	*	1	N	*	N	*	*	12	0.63

N Row water user has not helped the column coalition to win in contest with any of other coalitions

* Irrelevant contest

Numbers 1, 2, 3, and 6 The number of times that the row water user has helped the column coalition to win in contest with other coalitions

{ } Contest of individual water users with different coalitions

Table 9 List of all criteria and sub-criteria which are considered for evaluating the water users' powers, their relative weights (numbers in parentheses), and their estimated values

Goal	Criteria	Sub-criteria	Water users				
			Khuzestan modern agro-industrial sector	Khuzestan old agro-industrial sector	Khuzestan local agro-industrial sector	Rafsanjan agricultural sector	
Determination of the power of each water user	Economic power (0.25)	Regional Gross Income (RGI)-(Standardized) (0.53)	21.06	21.06	40.31	17.6	
		Water efficiency (0.29)	3300	3000	2800	11277	
	Existence of alternative water resources (0.11)	Water efficiency-(%) (0.5)	60	55	37	36.5	
		Having any alternative surface water resource-(%) (0.5)	91	91	95.88	1.14	
		Having any alternative groundwater resource-(%) (0.5)	9	9	4.12	98.86	
	Determination of the power of each water user	Self-sufficiency (0.07)	Cropping pattern diversity (0.67)	6	6	8	1
			Diversity of industrial products (0.33)	7	7	0	0
Having industrial and agricultural infrastructures (0.25)		Having industrial infrastructures-(Normalized) (0.33)	1	1	0	0	
		Having agricultural infrastructures (0.67)	38.18	38.18	37.64	24.18	
		Number of members in parliament-(Standardized, between 0 and 100) (0.33)	1	1	1	1	
Receiving political support of the parliament and government (0.25)	Importance of a water user considering the commissions he is a member of-(Standardized, between 0 and 100) (0.33)	42.08	42.08	42.58	15.34		
	Importance of a water user considering the fractions he is a member of-(Standardized, between 0 and 100) (0.33)	57.25	57.25	61.52	14.84		
	Reference-based power (0.25)	42.85	42.85	46.05	11.1		
			0.05	0.11	0.21	0.63	

Table 10 Relative power (Relative weight, *W*) and rank (*R*) of each water user

Water user	MCDM method									
	AHP		ANP		ER		TOPSIS		PROMETHEE II	
	<i>W</i>	<i>R</i>	<i>W</i>	<i>R</i>	<i>W</i>	<i>R</i>	<i>W</i>	<i>R</i>	<i>W</i>	<i>R</i>
Khuzestan modern agro-industrial sector	19	3	19.5	3	21	4	15	4	30.48	3
Khuzestan old agro-industrial sector	17	4	18.5	4	23	3	17	3	29.52	4
Khuzestan local agricultural sector	31	2	26	2	47	1	24	2	36.42	1
Rafsanjan agricultural sector	33	1	36	1	46	2	44	1	34.06	2

Spearman’s rank correlations, which are in the range of [0.93–1], are given in Table 11. The strength of agreement, measured with Kendall’s coefficient of concordance (*z*) are presented in Table 11. As shown in this table, the values of the Kendall’s coefficients of concordance (*z*) are consistent with the values of the Spearman’s rank correlation coefficients (*q*).

7 Summary and Conclusions

In this paper, a new framework was presented for evaluating the power of water users in inter-basin water transfer systems. For this purpose, a comprehensive set of criteria influencing the power of water users including s regional gross income, water efficiency, presence of alternative water resources, self-sufficiency, existence of agricultural and industrial infrastructures, receiving political support of the government and parliament, and preference-based power was proposed to determine the power of water users in a quantitative way.

This study also explored the agreement between different MCDM methods used for an inter-basin water transfer project. Some well-known Multiple Criteria Decision Making (MCDM) methods, namely Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Evidential Reasoning (ER), Method for Order Preference by Similarity to Ideal Situation (TOPSIS) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE II), were utilized to evaluate the power of water users in inter-basin water allocation systems.

In this paper, the Spearman’s rank correlation coefficient and Kendall’s coefficient of concordance were applied to compare the ranking outputs resulting from different MCDM methods. At last, the proposed approach for determining the power of water users was applied to a large-scale case study of water transfer from the Karoon River basin to the Rafsanjan plain

Table 11 Spearman’s rank correlation (*q*) and Kendall’s coefficient of concordance (*z*) in the inter-basin water transfer problem

	AHP		ANP		ER		TOPSIS		PROMETHEE II	
	<i>q</i>	<i>z</i>	<i>q</i>	<i>z</i>	<i>q</i>	<i>z</i>	<i>q</i>	<i>z</i>	<i>q</i>	<i>z</i>
AHP	–	–	1	1	0.93	0.8	0.97	0.9	0.97	0.9
ANP	–	–	–	–	0.93	0.8	0.97	0.9	0.97	0.9
ER	–	–	–	–	–	–	0.97	0.9	0.97	0.9
TOPSIS	–	–	–	–	–	–	–	–	0.93	0.8

in the central part of Iran. The results of the five MCDM methods were almost alike. Khuzestan modern agro-industrial sector was ranked 3 by ANP, AHP, and PROMETHEE II methods and 4 by TOPSIS and ER methods. Khuzestan old agro-industrial sector was ranked 4 by ANP, AHP, and PROMETHEE II methods and 3 by TOPSIS and ER methods. Khuzestan local agricultural sector was ranked 2 by ANP, AHP, and TOPSIS methods and 1 by PROMETHEE II and ER methods. Rafsanjan agricultural sector was ranked 1 by ANP, AHP, and TOPSIS methods and 2 by PROMETHEE II and ER methods. By utilizing the proposed methodology for determining the power of stakeholders, non-cooperative behaviour of water users in inter-basin water transfer systems can be studied in future works. If the power of water users is being considered as a criterion in water allocation problems, a sub-criteria of “Regional socioeconomic deprivation” should be added to the hierarchical structure for evaluating the water users’ powers. In this manner, the deprived areas can also be considered in allocation of a limited amount of water.

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