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Social Planner's Solution for the Caspian Sea Conflict

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Abstract This paper evaluates the proposed alternatives for sharing the Caspian Sea from the social planner's or systems-level perspective with respect to the stakeholders' utilities from the oil and natural gas resources of the sea. Different multi-criteria decision-making methods, namely dominance, maximin, lexicography, simple additive weighting, and TOPSIS are applied to determine the social planner's ranking of these alternatives. Results suggest the Condominium governance regime as the most promising division method. Bankruptcy rules and cooperative game theory methods can be considered as the other socially optimal resolutions to the conflict over sharing the Caspian Sea energy resources among its five littoral countries. Consideration of these methods in negotiations may help with resolving the existing deadlock, which has been in place for two decades.

Keywords Conflict resolution · Multi-criteria · Decision-making · Social planner · Caspian Sea

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1 Introduction

Prior to collapse of the Soviet Union in 1991, the Caspian Sea (Fig. 1) was governed based on the two historic treaties between Tehran and Moscow in 1921 and 1940 (Ahmadov 2002). These treaties ceded free shipping and transport to both riparian states; but they did not address the rights for exploitation of energy resources of the Caspian Sea. Determining a new legal regime that delineates the territorial borders along with the right to access to the natural resources has been the source of conflict among the current five littoral countries of the Caspian Sea: Azerbaijan, Iran, Kazakhstan, Russia and Turkmenistan. The discovery of abundant oil and gas resources in the Caspian Sea has significantly added to the complexities of this conflict, especially with the Newly Independent States of Azerbaijan, Kazakhstan, and Turkmenistan in desperate need of accessing Caspian Sea's valuable oil and natural gas resources (Sheikhmohammady et al. 2011). Pipeline transit opportunities and strategic importance of the Caspian Sea are the other important factors that make finding a fair governance regime even more difficult (Kaliyeva 2004). The major reasons for continuation of disagreement over legal regime of the Caspian Sea include (Sheikhmohammady and Madani 2008a; Sheikhmohammady et al. 2011):

Fig. 1 Caspian Sea and its littoral states

1. Presence of several disputants with quite distinct expectations: Five countries are engaged in negotiations. This is a relatively large number of beneficiaries for an international trans-boundary water resource conflict, making a compromise solution less likely when the interests of the parties and their proposed solutions to the problem are highly different;
2. Interference of external powers and beneficiaries: The United States, European Union, China, and Turkey along with multinational oil companies have different interests in this problem, trying to impact the negotiations in different ways; and
3. Ambiguity of the geographical classification of the Caspian Sea: Existing international conventions are not readily applicable to the Caspian Sea as the international scientific and political communities have not yet developed a consensus over classifying the Caspian Sea as a sea or a lake. If Caspian Sea is to be considered a lake, a Condominium regime might be applicable under which no country has exclusive right and a joint sovereignty will govern the lake. However, being the largest enclosed water body on earth by area and having oceanographic characteristics that are typical of seas put applicability of the Condominium regime into question (Sheikhmohammady and Madani 2008a). As a sea, Caspian Sea could be divided using equidistance median lines, based on the International Law of the Seas. Under this law, also referred to as the 'sectorial division" method, each country has exclusive rights within its maritime boundaries (Ahmadov 2002).

During almost two decades of negotiations, five major governing/sharing methods have been proposed by the riparian states (Kaliyeva 2004; Sheikhmohammady and Madani 2008a):

- C: Condominium status applying to both the surface and the seabed;
- Dm: Division based on the International Law of the Seas;
- De: Equal division, allocating 20 % of the sea and the seabed to each state;
- Ds: Division based on the old Soviet maps; and
- DC: Division of the seabed based on the International Law of the Seas with Condominium status on the sea surface.

The negotiating parties have different preferences over the suggested governance methods with respect to their national economic, political, military, and strategic interests. Relying on other abundant energy sources and not in immediate need of the energy sources of the Caspian Sea, Iran and Russia have shown more interest in the Condominium governance. On the other hand Azerbaijan, Kazakhstan, and Turkmenistan with urgent need of access to valuable energy resources favour methods that provide exclusive rights. Over the two decades of negotiations, the negotiating powers have strategically made some changes in their positions. For example, in 2000, Iran declared that it only accepts resolutions that leads to at least 20 % of the Caspian Sea surface and its subjacent bed, resulting in consideration of the equal division (De) method as one of the division alternatives. However, Azerbaijan and Kazakhstan strongly objected this resolution. In response, Russia proposed a dual division method (DC), which is more acceptable than Iran's suggested method to the Newly Independent States. Yet, none of the proposed methods has received enough support from all negating parties and the conflict has remained unresolved since the start of negotiations in 1993.

The Caspian Sea transboundary water conflict has been the subject of few recent studies, which can be divided into two categories. The first category includes the studies that used descriptive approaches to identify the most likely outcome of the negotiations under different scenarios/conditions. Sheikhmohammady and Madani (2008a) applied different fallback bargaining methods (Brams and Kilgour 2001) to identify the likely outcome of the on-going negotiations. Under this descriptive approach it was assumed that Caspian Sea negotiators bargain over the solution to the conflict, starting with their most preferred outcome and then falling back, in lockstep, to less preferred outcomes until there is one solution that receives enough support by the parties. Due to differences in rationales of the fallback bargaining methods, the study could not find a unique solution to the problem, implying that the practical outcome is highly sensitive on how negotiators might pursue the bargaining procedure (Sheikhmohammady et al. 2011). Nevertheless, the authors discussed that given the earlier agreement of the negotiating parties, which mandates that the legal regime should be unanimously acceptable by all littoral states; unanimity fallback bargaining method might be the most promising method to be used by the parties. Under this rule the minimum support level would be reached after multiple fallbacks, which seems to be unrealistic as some parties might leave negotiations if there is no compromise after few fallbacks, as suggested by the fallback bargaining with impasse method. This method suggested that the parties cannot agree over any of the five proposed division rules (Sheikhmohammady and Madani 2008a; Sheikhmohammady et al. 2011). In the same study Sheikhmohammady and Madani (2008a) applied different social choice methods or voting rules to identify the most likely outcome of the negotiations if the parties try to select the final outcome using one of the common voting rules. Under this descriptive approach the likely outcome of voting procedure was identified based on six well-known social choice rules. Except for the plurality rule, which suggested both Condominium governance (C) and division based on the Soviet maps (Ds) as the solution under voting, all other rules unanimously suggested Ds as the solution. Nevertheless, the authors discussed that outcome prediction based on social choice rules might not be valid in practice, as the nature of international Caspian Sea negotiations is much more complex than what captured by social choice methods. Furthermore, these methods did not consider how unequal powers of the parties might affect the outcome of negotiations (Sheikhmohammady and Madani 2008a; Sheikhmohammady et al. 2011). To address the effect of unequal powers of the parties (military, economic, political, etc.) on the outcome of negotiations (Sheikhmohammady and Madani 2008b) proposed a new descriptive conflict resolution approach. By considering the negotiators' powers as an important determining factor in predicting the outcome their Asymmetric Multilateral Negotiations model suggested division based on the International Law of the Seas (Dm) as the most likely resolution of the conflict. Their results suggest that the final outcome of Caspian Sea negotiations may not necessary match the outcome selected by voting rules as the parties can influence the negotiation process using their powers.

The second group of Caspian Sea conflict studies includes the studies that use normative approaches to prescribe the optimal resolution for this transboundary water resource conflict. Sheikhmohammady and Madani (2008c) suggested considering the Caspian Sea conflict as a bankruptcy problem in which the total beneficiaries' claims of oil and gas is more than the amount of available oil and gas. Three bankruptcy solutions, namely the Proportional (P), Constrained Equal Award (CEA), and Adjusted Proportional (AP) rules (Dagan and Volji 1993) were then used to prescribe fair allocations of the available gas and oil resources to the parties. In another study, Madani and Gholizadeh (2011) suggested resolving the conflict within a cooperative game theory framework. They suggested the 1940 treaty between Iran and the USSR as the basis for estimation of the non-cooperative (status-quo) resource shares of the parties, i.e. the values of oil and gas resources within the 10-mile distance from the shoreline of each country. The Nash-Harsanyi, Shapely, Nucleolus, and τ-value solution methods were then used to estimate the fair and efficient shares of the parties under cooperation, i.e., values of the total oil and gas resources each country should receive under a cooperative resolution to the conflict.

Rouhani et al. (2010) developed the Caspian Sea Negotiation Support System (NSS) to facilitate estimation of countries' shares under different division scenarios and developing optimal marine boundaries for sharing the Caspian Sea. Their study results suggest a high sensitivity of negotiators' utilities to division rules due to the non-uniform distribution of oil and gas fields. They conclude that developing any resolution to the conflict must be based on the value of resources in seabed and the countries' utilities. This was indeed ignored by the descriptive studies of Caspian Sea conflict, which did not consider the parties' oil and gas utilities from the five suggested division solutions. In these studies, the preference orders of the countries over the five proposed solutions were speculated based on the history of the conflict and the information revealed by the negotiating parties over the course of negotiations since 1993. On the other hand, the perspective studies of the conflict, which were considered the values of oil and gas resources to suggest optimal resolution, did not compare their suggested schemes with the five solutions proposed by the negotiators. Therefore, these solutions may not be necessarily preferred by the parties to the solutions, which are under consideration in negotiations.

To bridge the gap of previous studies of the Caspian Sea conflict this study establishes a firm basis for comparison of the solutions that have been proposed so far by the negotiation parties as well as the independent researchers. First, the preference orders of the countries over the proposed solutions are determined based on the value of oil and gas resources each country receives under different division rules or resource allocation schemes. The overall order of the proposed solutions is then determined from a systems (impartial social planner) perspective, using a range of multi-criteria decision-making (MCDM) methods. Finally, to understand how the negotiators' powers might affect the system's solution, weighted ranking of the division alternatives are developed.

2 Multi-Criteria Decision-Making (MCDM)

MCDM methods have been widely used in the operations research literature over the past decades (Wallenius et al. 2008). Given that water resources management problems often involve conflicts among the objectives of a single decision-maker in charge of a water system or interests of multiple stakeholders (Madani 2010; Madani and Lund 2011) the water resources literature include numerous applications of MCDM methods

Table 1 Total value (in $ billion) of the allocated oil and gas to each country under different division methods

Division method	Country				
	A	I	K	R	T
C	$2,702	$2,702	$2,702	$2,702	$2,702
DC	$2,448	$821	$5,968	$790	$3,485
De	$2,296	$1,856	$4,587	$933	$3,841
Dm	$2,448	$821	$5,968	$790	$3,485
Ds	$2,580	$526	$5,968	$790	$3,648
AP	$1,895	$1,984	$4,831	$1,984	$2,818
CEA	$2,580	$2,702	$2,764	$2,702	$2,764
P	$1,960	$2,052	$4,533	$2,052	$2,915
Nash–Harsanyi	$2,593	$2,728	$2,821	$2,593	$2,778
Nucleolus	$2,593	$2,728	$2,821	$2,593	$2,778
Shapely	$2,593	$2,728	$2,821	$2,593	$2,778
τ-Value	$2,593	$2,728	$2,821	$2,593	$2,778

as suggested by the reviews by Cohon and Marks (1975), Romero and Rehman (1987), Hipel (1992), Figueira et al. (2005), Hajkowicz and Collins (2007), and Wallenius et al. (2008).

The Caspian Sea transboundary water resource conflict can be considered as a multi-decision-maker single-criterion problem in which the countries determine the quality of each division alternative based on the economic values of their oil and gas shares. In such a situation each party prefers the alternative under which it obtains the highest share value. It is noteworthy that given that the oil and gas resources of Caspian Sea are non-uniformly distributed in the seabed, the utility or value of each county's oil and gas share varies under the five proposed division methods by the countries. Table 1 indicates the value of oil and gas resources each country receives under different division methods. These values have been estimated based on the value of gas and oil resources that each country would own under different division methods. Readers interested in calculation details may consult Sheikhmohammady (2009), Madani and Gholizadeh (2011), Sheikhmohammady et al. (2011), Imen et al. (2012). Given that the four game theory methods, i.e., Nash-Harsanyi, Shapely, Nucleolus, and τ-value yield the same share values, hereafter they are considered as a single division alternative, recognized as "Cooperative GT". The Dm and DC also yield similar gains since they apply the same principle to divide the seabed. Therefore, they are also considered as one alternative, recognized as "DC or Dm".

Multi-decision-maker single-criterion problems are normally converted to multi-criteria single-decision-maker problems to be solved by MCDM methods (Hipel 1992; Madani and Lund 2011). Based on a similar approach, the five negotiating countries are considered as five criteria, which the impartial social planner considers to determine the optimal alternative among the suggested division rules. Thus, utilities of the countries under different division rules (Table 1) correspond to the performances of the alternatives under different criteria.

Here, five different MCDM methods are used to determine the overall ranking of the proposed solutions in Table 1 and identify the system's level optimal resolution of the conflict. The first three methods, i.e., dominance (Fishbrun 1964), maximin (Wald 1945), and lexicographic (Tversky 1969) are recognized as non-interactive (non-compensatory) methods, while the other two, i.e., simple additive weighting (Churchman and Ackoff 1954), and TOPSIS (Hwang and Yoon 1981) are considered as interactive (compensatory) methods.

2.1 Non-interactive (Non-compensatory) Methods

2.1.1 Dominance

Dominance (Fishbrun 1964) is one of the oldest yet most fundamental concepts of decision-making. Application of Dominance method requires a pairwise comparison of all alternatives to identify the least dominated option (Figueira et al. 2005). In other words, the alternative that has a better performance than others in most of the pair-wise comparisons under all criteria is considered to be the optimal solution. Example applications of the Dominance method in environmental and water resources context include Matthews (2001), Greening and Bernow (2004), and Mokhtari et al. (2012). According to this method, the cooperative game theory method is the social planner's optimal division scheme for resolving the Caspian Sea conflict. The overall social planner's ranking of the proposed Caspian Sea division rules are as follows:

$$\text{Cooperative GT} > \text{C} > \text{CEA} > \text{De} > \text{Ds} > \text{Dm} = \text{DC} > \text{P} > \text{AP} \tag{1}$$

2.1.2 Maximin

The Maximin method (Wald 1945) tries to avoid the worst possible performance (Linkov et al. 2005). Therefore, based on this method, alternatives are ranked based on their weakest attribute and the alternative with the maximum lowest performance is selected as the optimal solution. In other words, this method maximizes the minimum satisfaction of all countries. The overall social planer's ranking of eight Caspian Sea division alternatives based on the Maximin method is as follows:

$$\text{C} > \text{Cooperative GT} > \text{CEA} > \text{P} > \text{AP} > \text{De} > \text{Dm} = \text{DC} > \text{Ds} \tag{2}$$

2.1.3 Lexicographic

The Lexicographic method (Tversky 1969) satisfies the most important decision-maker. So, once the criteria are ordered according to their importance, the alternative

Table 2 Normalized performances

Division method	Country				
	A	I	K	R	T
C	0.142	0.176	0.079	0.186	0.108
DC or Dm	0.128	0.053	0.175	0.054	0.140
De	0.120	0.121	0.134	0.064	0.154
Ds	0.135	0.034	0.175	0.054	0.146
AP	0.099	0.129	0.141	0.136	0.113
CEA	0.135	0.176	0.081	0.186	0.111
P	0.103	0.134	0.133	0.141	0.117
Cooperative GT	0.136	0.177	0.083	0.178	0.111

with the highest performance under the most important criterion is selected as the optimal alternative. In case of a tie, which is likely in problems with several alternatives, performances of tying options under the next most important criterion determine the best alternative. The procedure will continue, in case of another tie, until a unique winner alternative can be identified (Linkov et al. 2005).

Given the description of this method, the first step is to determine the importance and weight of each criterion (country). If the decision criteria (countries) are equally important, the entropy weighting method can be utilized to assign a weight to each criterion considering the dispersion of the performances of alternatives under that criterion (Chan et al. 1999; Yaghoubi et al. 2011). In this case, the entropic weights do not necessary reflect the weights of the criteria (countries) in reality. Nevertheless, calculating weights is an essential step when using the Lexicographic method.

Based on this method, the performance matrix of alternatives should be normalized first using Eq. 3:

$$P_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \tag{3}$$

where for $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$: P_{ij} is the normalized payoff of alternative i under criterion j; r_{ij} is the performance of alternative i under criterion j; and m and n are the number of alternatives and criteria, respectively.

Table 2 shows the normalized utilities of the countries from the proposed division methods.

The entropy of normalized performances under a given criterion (E_j) is calculated using Eq. 4:

$$E_j = -k \sum_{i=1}^{m} P_{ij} . \ln P_{ij} \tag{4}$$

where: $k = \frac{1}{\ln m}$

Table 3 Entropy, d_j, and weight of each criterion

	Country				
	A	I	K	R	T
Entropy	0.996	0.951	0.978	0.949	0.996
d_j	0.004	0.049	0.022	0.051	0.004
Weight	0.028	0.375	0.170	0.393	0.035

The entropic weight of each criterion (W_i) can be calculated then using Eq. 5:

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{5}$$

where: $d_j = 1 - E_j$

Table 3 presents the calculated E_j, W_j and d_j for the five negotiating countries. As discussed, calculation of these weights is essential to determination of the optimal solution based on the Lexicographic method. These weights are only based on the dispersion of the utilities and do not represent the actual power of parties in negotiation. Based on the entropic weights, Russia is the most important country (criterion) here. Since the Condominium governance regime (C) and Constrained Equal Award (CEA) equally yield the highest utility to this country, their performance under the next most important criterion (Iran) should be considered. Therefore, Constrained Equal Award (CEA) is the optimal social planner solution of the problem based on the Lexicographic method. The overall ranking of all alternatives based on this method is determined as follows:

$$\text{CEA} > \text{C} > \text{Cooperative GT} > \text{P} > \text{AP} > \text{De} > \text{Dm} = \text{Dc} > \text{Ds} \tag{6}$$

2.2 Interactive (Compensatory) Methods

2.2.1 Simple Additive Weighting

Under the SAW method (Churchman and Ackoff 1954), weighted performances of alternatives under all criteria are the touchstones of comparison (Triantaphyllou 2000). Based on this method, a comparison index of an alternative (SAW_i) is calculated using Eq. 7:

$$SAW_j = \sum_{j=1}^{n} W_j \times r_{ij} \tag{7}$$

Table 4 presents the weighted performances of alternatives and the value of comparison index for each option. The higher the comparison index of an alternative, the better the alternative. The overall social planner's ranking of the division alternatives based on SAW method is as follows:

Table 4 Weighted performances and comparison index of division alternatives based on the SAW method

Division method	Country					
	A	I	K	R	T	SAW
C	75.66	1,013.25	459.34	1,061.89	94.57	2,704.70
DC or Dm	68.54	307.88	1,014.56	310.47	121.98	1,823.42
De	64.29	696.00	779.79	366.67	134.44	2,041.18
Ds	72.24	197.25	1,014.56	310.47	127.68	1,722.20
AP	53.06	744.00	821.27	779.71	98.63	2,496.67
CEA	72.24	1,013.25	469.88	1,061.89	96.74	2,714.00
P	54.88	769.50	770.61	806.44	102.03	2,503.45
Cooperative GT	72.60	1,023.00	479.57	1,019.05	97.23	2,691.45

Table 5 Normalized performances for the TOPSIS method

Division method	Country				
	A	I	K	R	T
C	0.398	0.459	0.214	0.481	0.303
DC or Dm	0.361	0.140	0.473	0.141	0.391
De	0.338	0.316	0.364	0.166	0.431
Ds	0.380	0.089	0.473	0.141	0.410
AP	0.279	0.337	0.383	0.353	0.316
CEA	0.380	0.459	0.219	0.481	0.310
P	0.289	0.349	0.359	0.365	0.327
Cooperative GT	0.382	0.464	0.224	0.461	0.312

$$\text{CEA} > \text{C} > \text{Cooperative GT} > \text{P} > \text{AP} > \text{De} > \text{Dm} = \text{DC} > \text{Ds} \tag{8}$$

2.2.2 Technique for Order Preference by Similarity to an Ideal Solution

The TOPSIS method (Hwang and Yoon 1981) selects the alternative that has the minimum relative performance distance from the ideal performance as the best alternative. The first step is to normalize the performances using Eq. 9. Table 5 presents the normalized utilities of the negotiators from the proposed division rules.

$$N_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} \tag{9}$$

Second, the weighted normalized performance of each alternative under each criterion (V_{ij}) is calculated using Eq. 10. Table 6 presents the weighted normalized utilities of the negotiators from the proposed division rules.

$$V_{ij} = N_{ij}.W_{ij} \tag{10}$$

Table 6 Weighted normalized performances for the TOPSIS method

Division method	Country				
	A	I	K	R	T
C	0.0110	0.1721	0.0365	0.1890	0.0105
DC or Dm	0.0099	0.0523	0.0806	0.0552	0.0135
De	0.0093	0.1182	0.0619	0.0652	0.0149
Ds	0.0105	0.0335	0.0806	0.0552	0.0141
AP	0.0077	0.1264	0.0652	0.1387	0.0109
CEA	0.0105	0.1721	0.0373	0.1890	0.0107
P	0.0080	0.1307	0.0612	0.1435	0.0113
Cooperative GT	0.0105	0.1738	0.0381	0.1813	0.0108

Table 7 The best and worst performances of the alternatives under each criterion

	Country				
	A	I	K	R	T
Best performance	0.0110	0.1738	0.0806	0.1890	0.0149
Worst performance	0.0077	0.0335	0.0365	0.0552	0.0105

Third, the best and the worst performances of the alternatives under each criterion(V_j^+ and V_j^-, respectively) are determined based on the weighted normalized decision matrix (Table 6). Table 7 shows the best and worst utilities that each country can gain.

Fourth, distances of each alternative from the best and the worst scenario are calculated using Eqs. 11 and 12, respectively.

$$d_i^+ = \left[\sum_{j=1}^{n}\left(V_{ij} - V_j^+\right)^2\right]^{0.5} \tag{11}$$

$$d_i^- = \left[\sum_{j=1}^{n}\left(V_{ij} - V_j^-\right)^2\right]^{0.5} \tag{12}$$

Finally, the relative distance (CL_i^+) of each alternative is calculated:

$$CL_i^+ = \frac{d_i^+}{d_i^+ + d_i^+} \tag{13}$$

The alternative with the minimum relative distance is the best option based on the TOPSIS method. Table 8 presents the distances of the proposed division rules from the best and worst utilities (presented in Table 7) as well as the relative distance of each alternative. The overall social planner's ranking of the proposed Caspian Sea division rules based on the TOPSIS method is as follows:

Table 8 Distances of the proposed division rules from the best (ideal) and worst (anti-ideal) utilities and the relative distances of the division rules

Method	Distance from the best utilities	Distance from the worst utilities	Relative distance
C	0.044	0.192	0.187
DC or Dm	0.180	0.048	0.790
De	0.136	0.089	0.605
Ds	0.193	0.044	0.814
AP	0.070	0.128	0.356
CEA	0.043	0.192	0.184
P	0.065	0.133	0.329
Cooperative GT	0.043	0.188	0.187

Table 9 Ranking orders based on different MCDM methods

Method	Ranking order
Dominance	Cooperative GT > C > CEA > De > Ds > Dm = DC > P > AP
Maximin	C > Cooperative GT > CEA > P > AP > De > Dm = DC > Ds
Lexicographic	CEA > C > Cooperative GT > P > AP > De > Dm=Dc > Ds
SAW	CEA > C > Cooperative GT > P > AP > De > Dm = DC > Ds
TOPSIS	CEA > Cooperative GT > C > P > AP > De > Dm = DC > Ds

$$\text{CEA} > \text{Cooperative GT} > \text{C} > \text{P} > \text{AP} > \text{De} > \text{Dm} = \text{DC} > \text{Ds} \tag{14}$$

2.3 Final Ranking of the Alternatives

Table 9 summarizes the overall ranking orders of the eight proposed alternatives for sharing the Caspian Sea based on the five different MCDM methods used in this study. Due to the subjectivity of the optimality notion and the differences between basic rationales of MCDM methods, the ranking orders based on the MCDM methods are not consistent. Therefore, there is a need for developing the final ranking of the division rules based on the results presented in Table 9.

Borda count or score (Borda 1781) can be used in order to establish the final overall ranking of the division rules. Based on this method, each alternative will be assigned a score based on its rank under each MCDM method. Alternatives will be then ranked according to their accumulated score (Young 1995; Shih et al. 2007; Sheikhmohammady and Madani 2008a; Shalikarian et al. 2011). Table 10 shows the scores assigned to each alternative under different criteria. In this case, scores are equal to the ranks of the alternatives under different MCDM methods. The sum of the scores (last column in Table 10) for each alternative is an indicator of its desirability. The lower the Borda score, the higher the desirability of an alternative. Based on Table 10, the final overall ranking of the alternatives is as follows:

Table 10 Borda scores of different division methods

	Dominance	Maximin	Lexicographic	SAW	TOPSIS	Borda score
C	2	1	2	2	3	10
DC = Dm	6	7	7	7	7	34
De	4	6	6	6	6	28
Ds	5	8	8	8	8	37
AP	8	5	5	5	5	28
CEA	3	3	1	1	1	9
P	7	4	4	4	4	23
Cooperative GT	1	2	3	3	2	11

$$\text{CEA} > \text{C} > \text{Cooperative GT} > \text{P} > \text{De} > \text{AP} > \text{Dm} = \text{DC} > \text{Ds} \tag{15}$$

The overall ranking suggests that the Constrained Equal Award (CEA) is the social planner's optimal solution for sharing the oil and natural gas resources of the Caspian Sea. After that, the Condominium regime and the cooperative game theory methods seem promising solutions for solving the conflict.

2.4 Power Effects

So far, in determining the social planner's solution it has been assumed that the negotiators are equally powerful (have equal weights). Only for the MCDM methods, which require weighting of the criteria (countries), entropic weights were used based on the dispersion of the performances of alternatives under that criterion. However, in practice parties may influence the negotiations and change the negotiations direction outcomes using their political, economic, and military powers (Sheikhmohammady and Madani 2008b; Sheikhmohammady et al. 2012). Therefore, the power effects should be considered to determining a social planner's solution that is practical.

Considering economic independence, military conditions, US support, and political influence as some of the major factors affecting negotiators' powers in the Caspian Sea conflict (Table 11) Sheikhmohammady and Madani (2008b) applied the Data Envelopment Analysis (DEA) to estimate the powers (weights) of the five negotiators (Table 12). The higher the power of a negotiator, the more influential is this negotiator in changing the outcome of negotiations in its favour. Based on the estimated powers Russia and Turkmenistan are the most and the least powerful negotiators in the Caspian Sea negotiations, respectively (Sheikhmohammady et al. 2012).

To examine if the social planner's ranking order can be influenced by negotiators' powers the estimated powers (Table 12) are used to re-determine the rankings of the proposed division rules. Given that only the Lexicographic, SAW, and TOPSIS methods consider weights in determining the best solution, powered rankings can be only developed using these methods by replacing the entropic weights with the estimated weights. Table 13 indicates the results of MCDM analysis after consideration of powers. Comparison of the ranking orders under

Table 11 Power factors and representative indices in Caspian Sea negotiations (after Sheikhmohammady and Madani 2008b)

Factor	Indicator
Economic independence and self sufficiency	GNI/capita
	Net trade/GDP
	GDP/claimed Caspian Sea oil and natural gas
Military status	Yearly military expenditures
	Military expenditures/GDP
	Active troops/population
	Nuclear power status
US support	US financial support
	US political support
Political influence and structure	Political influence
	Democracy level

Table 12 Normalized powers (weights) of negotiating countries based on the estimated powers by Sheikhmohammady and Madani (2008b)

	Country				
	A	I	K	R	T
Weight	0.180	0.167	0.164	0.367	0.119

Table 13 Powered ranking of Caspian Sea division methods under different MCDM methods

Method	Resulting ranking
Lexicographic	C > CEA > Cooperative GT > P > AP > De > Ds > Dm = DC
SAW	C > CEA > Cooperative GT> P > AP > De > Dm = DC > Ds
TOPSIS	CEA > C> Cooperative GT > P >AP > De > Dm = DC > Ds

the same methods in Tables 9 and 13 shows that powers can change the ranking orders in favour of more powerful negotiators. For example, on average, alternative C is ranked higher, when powers are considered, as this alternative is the most favourite option of the most powerful negotiators (Russia and Azerbaijan). This, indeed, underlies the importance of considering powers of negotiators in determining the social planner's solution to resource sharing problems.

To determine the final powered ranking Borda scores are calculated based on the ranking orders presented in Table 13. Table 14 indicates the Borda scores of the proposed division rules under powers. Based on these scores, the final overall powered ranking of the alternatives is as follows:

$$\text{C} > \text{CEA} > \text{Cooperative GT} > \text{P} > \text{AP} > \text{De} > \text{Dm} = \text{DC} > \text{Ds} \tag{16}$$

Table 14 Powered Borda score of different division methods

	Lexicographic	SAW	TOPSIS	Borda score
C	1	1	2	4
DC = Dm	8	7	7	22
De	6	6	6	18
Ds	7	8	8	23
AP	5	5	5	15
CEA	2	2	1	5
P	4	4	4	12
Cooperative GT	3	3	3	9

The weighted analysis indicated that consideration of powers can change the order of the alternatives in favour of more powerful countries. The final ranking of the division rules suggests that the Condominium (C) governance is the system's level's optimal solution when powers are considered. The bankruptcy and cooperative game theory solutions are the other promising socially optimal alternatives that can be considered by the negotiating parties.

3 Conclusions

Through application of multi-criteria decision-making (MCDM) methods this study provides valuable insights into the Caspian Sea conflict—one of the world's major transboundary water resources conflicts that have remained unresolved since 1993. Given the highlighted importance of consideration of the negotiators' utilities from the valuable oil and gas resources of the Caspian Sea by former studies, this paper established a firm basis for comparison of the division methods which have been proposed for resolving the conflict by the negotiating parties or independent researchers.

Assuming that riparian countries represent the decision-making criteria, various MCDM methods were used to determine the social planner's optimal solution of the decision-making problem. Knowledge of the system's optimal solution to the problem and ranking order of the available options can be helpful to impartial third parties and mediators (such as the United Nations) to facilitate developing a compromise resolution to the conflict. It should be noted that implementation of the system's optimal solution might be challenging in practice when parties base decisions on individual rationality as opposed to group rationality (Madani and Dinar 2012a), find the optimal solution unfair (Madani and Dinar 2012b), try to influence the negotiations using their power, or take advantage of issue-linkage and "strategic loss" opportunities (Madani 2011) (e.g. Iran might link the Caspian Sea negotiations with the nuclear power negotiations that it is currently involved in to gain more support from Russia). Nevertheless, a powerful facilitator can benefit from identification of optimal and inferior solutions to encourage the negotiating parties to be more supportive of the optimal solutions and disregard the inferior options.

To ensure that the findings of the study are reliable in practice, the overall ranking of the alternatives were developed with and without consideration of the negotiators' powers. Results show that consideration of powers changes the ranking order of the alternatives in favour of more powerful countries. Generally, the Condominium regime, Constrained Equal Award (CEA) bankruptcy rule, and cooperative game theory methods are promising socially optimal resolutions to the conflict. Other bankruptcy rules also have a potential to resolve the conflict. These results have an important policy implication for this international water conflict, suggesting that bankruptcy rules and cooperative game theory allocation schemes must be seriously considered in negotiations. Inclusion of these new alternatives in negotiations may result in deviating from the existing deadlock that has resulted in failure of negotiations since for almost two decades.

Like all modeling studies, this study is associated with limitations. Therefore, study results should be interpreted noting the associated simplifications (Madani and Hipel 2011). Despite their limitations, simple decision analysis models can provide useful policy insights as long as their caveats are not overlooked (Madani 2013). This study ignored the continuous geopolitical and socio-economic volatility in the region with significant implications for the Caspian Sea conflict and effects on the bargaining power and position of the negotiators. Future studies may address the limitations of this study and consider some additional factors with potential effects on Caspian Sea negotiations, such as: instability of the oil and gas markets, linkage of the Caspian Sea conflict with other conflicts that the bargaining parties are involved in (e.g., Iran's nuclear negotiations); effects of external powers (e.g., US, China, EU, and Turkey); effects of current sanctions on Iran's negotiating power; possibility of formation of coalitions during negotiations to strengthen bargaining power; military, political, and environmental utility from different division methods (in this study utilities were calculated only based on the economic values of oil and gas resources); and practicality of the suggested division rules (e.g. implementation of the Condominium governance regime in the Caspian Sea case could have dramatic transaction costs.)

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