Chapter 11
Bargaining Under Uncertainty: A Monte-Carlo Fallback Bargaining Method for Predicting the Likely Outcomes of Environmental Conflicts

Kaveh Madani, Laleh Shalikarian, Ahmed Hamed, Tyler Pierce, Kondwani Msowoya and Christopher Rowney

Abstract This chapter develops a method for analyzing bargaining problems in which the bargainers are uncertain about the performance of alternative bargaining outcomes. Monte-Carlo selection is combined with fallback bargaining (FB) in order to map the stochastic bargaining problem into many deterministic bargaining problems which can be analyzed using various fallback bargaining methods, namely unanimity FB, q-approval FB, and FB with impasse. The proposed method is applied to the California's Sacramento-San Joaquin Delta benchmark problem. In this problem the stakeholders need to reach an agreement over a water export strategy to address the current crisis in the Delta. This problem is modeled here as a bargaining game in which the environmentalists and water exporters develop a resolution through a bargaining process while the performances of different water export alternatives are uncertain. The analysis results are consistent with the findings of other studies using different decision analysis methods to analyze this multi-decision maker problem. Construction of a peripheral canal or a dual conveyance is expected if the parties change their cooperation attitudes, trying to benefit from a low level of cooperation in solving the Delta problems.

Keywords Fallback bargaining · Conflict resolution · Monte-Carlo multi-criteria decision analysis · Uncertainty · Stochastic decision making · Sacramento-San Joaquin delta · California

K. Madani (✉)
Centre for Environmental Policy, Imperial College London, London SW7 1NA, UK
e-mail: k.madani@imperial.ac.uk

L. Shalikarian
School of Civil Engineering, University of Tehran, Tehran, Iran

A. Hamed · T. Pierce · K. Msowoya · C. Rowney
Department of Civil, Environmental, and Construction Engineering,
University of Central Florida, Orlando, FL 32816, USA

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11.1 Introduction

Decision making for optimal management of water and environment is challenging due to presence of multiple stakeholders with different interests, championing conflicting objectives and solution alternatives (Mirchi et al. 2010). Selection of the optimal management strategies becomes even more challenging with the uncertainties due to imperfect foresight and the changing environment. Bargaining is used as a group decision-making method to develop consensus among environmental stakeholders and resolve environmental conflicts (Bruce and Madani 2014). In a successful bargaining process at least one party falls back in order for a settlement to be reached.

Fallback bargaining (FB) (Brams and Kilgour 2001) is a method for predicting the likely outcome of bargaining procedures. FB simulates the behavior of bargaining parties who fallback in lockstep from their most preferred solution or alternative to a less desired solution until an agreement is reached. For instance, let's assume two parties who rank a set of alternatives: A, B, C, D, and E, differently. The two parties are tasked with choosing a single alternative out of the choices given. Party 1's order of preference is D, C, B, A and E ($P_1 = D > C > B > A > E$) and would choose alternative D if it were the single decision maker. However, party 2's preference order is B, A, E, D, and C ($P_2 = B > A > E > D > C$) and would choose alternative B on its own. In this case, the two parties do not agree on their most preferred alternative and must, therefore, compromise to reach an implementable solution. In a bargaining process, these parties need to fallback in lockstep to their second choices (C and A) because they cannot agree on their first choices (D and B). As there is still no common alternative, the parties fallback once more to their third choices (B and E). As party 2 has already shown a preference for alternative B and party 1 now reveals alternative B as an acceptable solution out of those remaining, alternative B is the winning choice. As the winning choice's lowest position, among the bargainers involved, is on the third tier, this is considered a depth three agreement. This common agreement, which becomes the winning outcome of the procedure, leads to Pareto-optimal outcome that maximizes the bargainers' minimum satisfaction (Brams and Kilgour 2001).

FB methods can be used as a practical and useful method to simulate the decision making process involving multiple decision makers (Sheikhmohammady and Madani 2008). As game-theoretic methods, these methods help developing a reliable understanding and interpretation of stakeholders' behaviors in multi-decision-maker hydro-environmental management problems which usually involve conflicts (Madani 2010, 2013). Given that water and environmental problems often involve uncertainty it is important to develop a method which takes into account the effects of uncertainty on the decision making process. Therefore, the main purpose of this chapter is to develop a method for dealing with uncertainty in performances of different alternatives in group decision making using bargaining. For this purpose FB is combined with Monte-Carlo selection. The resulting method determines the ranking distribution of each alternative, reflecting their potential for being selected

as the best alternative and their degree of ranking robustness. The proposed method is applied to the Sacramento-San Joaquin Delta conflict as a benchmark stochastic multi-participant decision making problem to predict the likely outcome of this group decision making process in which the parties are not necessarily willing to implement the social planner (system's optimal) solution and have shown interest in adopting a non-cooperative bargaining approach for decision making, resulting in a stable outcome (Read et al. 2014). It must be noted that although parties do not fully cooperate to implement the social planner's solution (Madani et al. 2014a) or the socially optimal solution selected through social choice (voting) methods (Madani et al. 2014b), involvement in a bargaining approach implies existence of a low level of cooperation. This level of cooperation is required for parties to get involved in a bargaining process and can result in outcomes, which are Pareto-superior to what can be obtained through a fully non-cooperative conflict resolution process (Madani and Lund 2011; Madani and Hipel 2011).

Located at the confluence of the Sacramento and San Joaquin Rivers, the California's Sacramento-San Joaquin Delta is a major source of water supply for the state of California. The Delta supplies water to 25 million urban residents and approximately two million acres of farmland. It is home to a variety of native endangered and threatened species and has a unique ecosystem with more than 750 species of flora and fauna (Lund et al. 2007, 2010; Tanaka et al. 2011). Despite the Delta having a rich agricultural land that contributed over $500 million crop value in 1990s, it is exceptional in that it is a source of fresh water for the state of California. The Delta intercepts 40 % of the runoff from California's total land area and about 50 % of the state's total stream flow. The current state of the Delta is notably different from its original 500,000 acres of tidal marshland. Land subsidence of the islands, diverse agricultural activities, recreation and growing urbanization are some of the current characteristics associated with the Delta. These traits, in addition to sea level rise, earthquakes, climate change, floods, invasive species and a perpetual decline in native species have led to a general conclusion that the current use of Sacramento-San Joaquin Delta's land and water is unsustainable. Reliability and sustainability of the Delta is further threatened by water export from the Delta (Lund et al. 2007, 2010; Suddeth et al. 2010).

Considering the multiplicity of stakeholders' interests in the Delta, espousing new strategies to secure the Delta against current threats and to prevent tragic outcomes for the Delta's future would not be convenient (Madani and Lund 2012). To solve the Delta problem, Lund et al. (2010) suggested four options for central water export. These are: (1) continuing the Delta export as usual (CDE), (2) constructing a peripheral canal to convey water around the Delta (PC), (3) constructing a dual conveyance system for water transfers (DC) and (4) stopping the water export (SE).

To evaluate the aforementioned options, two important criteria representative of a variety of the main stakeholder interests in the Delta were considered, namely; economic performance and environmental sustainability (Lund et al. 2010). Performance of each of the four suggested options was evaluated according to these two criteria through survey from experts (Lund et al. 2008), as shown in Table 11.1. Cost (economic performance) of each alternative is a major concern for the Delta

Table 11.1 Performance range of Delta water export strategies under economic and environmental sustainability criteria (Lund et al. 2008, 2010)

Water export alternative	Cost (billion $/year)	Fish survival
CDE	0.55–1.86	5–30
PC	0.25–0.85	10–40
DC	0.25–1.25	10–40
SE	1.25–2.5	30–60

water exporters. Construction costs, maintenance costs and costs of failure of the alternative constitute the overall cost of an alternative. It is assumed that environmentalists are supposed to be mainly concerned about the fish survival. Therefore, fish (delta smelt) survival is considered to be a rational performance indicator of environmental sustainability of each of the four water export options (Lund et al. 2008).

In this study, we employ three FB methods, namely (1) Unanimity Fallback Bargaining, (2) q-Approval Fallback Bargaining, and (3) Fallback Bargaining with Impasse, to determine a possible settlement to California's Sacramento-San Joaquin Delta conflict over selection of a water export strategy.

In the next section of this chapter we formulate the Delta FB problem as a deterministic bargaining problem involving two bargainers. Then we introduce and apply FB methods in order to find the possible outcome(s) of the deterministic bargaining procedure. We also combine Monte-Carlo selection with FB methods in order to examine whether or not the resolution (outcome) differs when uncertainties are involved. This process helps to ensure reliability of the predicted outcome in face of the given uncertainties in the performance values. The last section of the chapter concludes.

11.2 Deterministic Fallback Bargaining

As indicated by the values in Table 11.1, the performance of each alternative is subject to uncertainties. To illustrate the FB methods, the Delta problem is first solved in a deterministic form. Performance averages are used so as to imply how, on average, decision makers might rank the alternatives. The matrix below presents the performance averages of the alternatives in cardinal form. Each column represents the performance values considered by one of the two main decision makers in the Delta problem. The first column (cost indicated by C) represents the utility of the water exporters from each alternative and the second column (fish survival indicated by FS) represents the utility of the environmentalists.

$$Performance_{cardinal} = \begin{array}{c} \\ CDE \\ PC \\ DC \\ SE \end{array} \begin{array}{c} \begin{array}{cc} \text{C} & \text{FS} \end{array} \\ \begin{bmatrix} 1.205 & 17.5 \\ 0.550 & 5.0 \\ 0.750 & 25.0 \\ 1.875 & 45.0 \end{bmatrix} \end{array}$$

Given that FB methods consider ordinal (ranking) information for determining the solution, the above cardinal matrix can be simplified to an ordinal matrix presented below. The ordinal matrix illustrates stakeholders' preferences over the possible Delta export alternatives. In the ordinal preference matrix, a higher rank (1 = highest rank) of an alternative by a decision maker reflects its higher desirability for that decision maker. Here, the water exporters prefer a lower cost and the environmentalists prefer a higher fish survival rate.

$$Performance_{Ordinal} = \begin{array}{c} \\ CDE \\ PC \\ DC \\ SE \end{array} \begin{array}{c} \begin{array}{cc} C & FS \end{array} \\ \begin{bmatrix} 3 & 3 \\ 1 & 2 \\ 2 & 2 \\ 4 & 1 \end{bmatrix} \end{array}$$

The Delta problem is considered as a bargaining problem in which stakeholders bargain based on their preferences over the water export alternatives. For such a problem FB methods can be applied to predict plausible outcome(s) (Sheikhmohammady and Madani 2008). However, to develop a compromise, they have to fall back in lockstep to a less preferred alternative until alternative with sufficient support is reached (Brams and Kilgour 2001). Based on the FB method applied, the definition of sufficient support varies. In the following sections, three different FB methods are defined and applied to the deterministic Delta decision making problem.

11.2.1 Unanimity Fallback Bargaining

The depth of agreement is the level of support at which a compromise set is acceptable (Sheikhmohammady et al. 2010). In Unanimity FB (UFB) (Brams and Kilgour 2001), the stakeholders indicate their support for the alternatives. The alternative(s) which receives all stakeholders' support with the highest possible quality is the selected outcome. If a decision rule other than unanimity is used, the selected outcome may differ. The outcome of UFB is Pareto-optimal, but not necessarily unique. The alternative(s) selected under UFB is at least average in each bargainer's ranking order (Brams and Kilgour 2001). The compromise set under the UFB method exactly includes the alternatives which maximizes the minimum satisfaction over all bargainers (Brams and Kilgour 2001; Sheikhmohammady and Madani 2008). The number of supporters for the water export alternatives in the Delta problem is presented in Table 11.2. In this problem SE, stopping the water export, is the most preferred alternative by the environmentalists. In the second level of preference, they prefer PC, constructing a peripheral canal to convey water around the Delta and DC, constructing a dual conveyance system for water transfers, equally. On the other hand, the water exporters place PC at their first preference level and DC at their second preference level. Therefore, under the UFB method, alternatives PC and DC are suggested as the most possible outcomes of the Delta bargaining problem because both options reach universal support at the second level.

Table 11.2 Number of supports for each alternative at different preference levels

Alternative	1st	2nd	3rd	4th
CDE	0	0	2	2
PC	1	2	2	2
DC	0	2	2	2
SE	1	1	1	2

11.2.2 q-Approval Fallback Bargaining

q-Approval FB selects the alternative(s) receiving the support of at least q bargainers ($1 \leq q \leq n$) as the most possible bargaining outcome, where n is the number of bargainers required for acceptance at the highest possible level (Brams and Kilgour 2001). If an alternative is accepted by at least q bargainers it is added to the compromise set. q-Approval may be appropriate for a bargaining situation in which there are multiple winners and one wishes to achieve proportional representation. Under q-Approval FB, ties are broken according to the quality of support and this method seeks to maximize the minimum dissatisfaction of q most satisfied bargainers. Therefore, under this method, when more than one alterative receive the minimum required level of support at a given preference level, the alternative with the strongest quality of support (highest number of supporters) is the winner (Brams and Kilgour 2001).

In the Delta problem $n = 2$, so q can be either 1 or 2. In the case when $q = 1$, the alternative(s) which receive at least one support at the highest quality should be selected based on 1-Approval FB. For the environmentalists SE is the most preferred alternative. For the water exporters, however, PC is the most preferred alternative as indicated in Table 11.2. Therefore, SE and PC are the most likely outcomes of the Delta problem under the 1-Approval FB method. In this case, since both alternatives have one supporter, there is no need for breaking ties and both alternatives should be selected as winners. When $q = 2$ for q-Approval, the problem becomes the same as UFB and PC and DC are the most likely bargaining outcomes.

11.2.3 Fallback Bargaining with Impasse

Additional data might be obtainable whereby bargainers could make use of an "impasse" in their rankings, indicating an outcome below which they would prefer no agreement (Brams and Kilgour 2001). The impasse itself could then become the fallback outcome, foreclosing any agreement and choosing to walk away (Behmanesh et al. 2013). Each bargainer's impasse level is indicated by "*I*" in his preference ranking. Beside the other alternatives to agree upon, a new alternative to the bargainers is presented with the permission to impasse (IMP). In a situation in which the bargainer prefers "no agreement" over an alternative, IMP may be

chosen, and it is considered as an arbitrary point below which a bargainer would not descend (Brams and Kilgour 2001; Sheikhmohammady and Madani 2008). Therefore, when a bargainer realizes that descending from some alternative is not beneficial, IMP or no agreement may be selected. IMP can be ranked at any level after the most preferred alternative.

After letting the parties add IMP to their preference matrices, the problem can be solved using UFB or q-Approval FB. Therefore, the FB with impasse method produces a set of Pareto-optimal alternatives, which can include IMP. This set maximizes the minimum satisfaction of the bargainers. However, with addition of IMP, the selected Pareto-optimal excludes certain alternatives that, without IMP, might have been considered satisfactory (Brams and Kilgour 2001). In the Delta Problem, reliable information about how the stakeholders might rank IMP in their preference matrix is missing. Therefore, for illustration purposes, it is assumed that IMP could be placed at any level lower than the first preference level by the decision makers. For cost, IMP can be positioned at level two through five, establishing four unique orders. Whereas for fish survival, IMP can only be placed at level 2, 3 and 4 of the alternatives given that PC and DC have the same ordinal rank. Therefore, 12 different combinations (4 orders for cost and 3 orders for fish survival) can be generated to analyze the Delta problem using FB with impasse. Since IMP can rank from 2 to 4 under the fish survival criterion and 2–5 under the cost criterion in this problem, 12 different ordinal preference matrices can be generated to represent the Delta decision making problem if impasse is allowed. This is based on different possible combinations of the preference orders of the two bargainers over the 5 possible alternatives under consideration (CDE, PC, DC, SE, and IMP). Since the most likely position of the IMP option in the bargainers' preference order is unknown, it is assumed that all 12 ordinal preference matrices are equally likely. FB methods can be used to determine the most likely outcome(s) for each of the 12 bargaining games. The probability of being selected as the resolution of the bargaining game is then calculated for each alternative through dividing the number of times it is selected as the bargaining solution by 12. Given that the solution based on 1-Approval FB is not practical in a bargaining problem with two members, it is reasonable to use UFB (same as 2-approval FB in this case) to determine the likely outcome of the bargaining problem with impasse.

Table 11.3 shows the probability of being selected as the bargaining resolution for each alternative for the bargaining game with impasse, using the UFB method. Given that ties are possible, the selection probabilities exceed 100 %. The most likely outcomes are PC and DC which have the highest probability of being an outcome, 67 and 50 %, respectively. It is noteworthy that IMP is also a likely outcome of the

Table 11.3 Outcomes of the Delta bargaining problem involving IMP

Alternative	Probability of being an outcome under UFB (%)
CDE	0
PC	67
DC	50
SE	8
IMP	25

Table 11.4 FB outcomes in the deterministic mode

FB method	Likely outcomes
UFB	PC, DC
1-Approvall FB	PC, SE
FB with impasse	PC, DC

bargaining process one-fourth of the time. This result is consistent with the findings of Madani and Lund (2011, 2012), suggesting that "no resolution" is a weak equilibrium (likely outcome) of the Delta conflict in absence of willingness to cooperate.

The likely outcomes of the Delta's deterministic bargaining game under different FB methods are summarized in Table 11.4. PC is the most likely bargaining outcome, followed by DC. The 1-Approval FB does not simulate the bargaining process realistically and therefore may not be a reliable method in predicting the outcome of the Delta bargaining game. Reaching an agreement between two equally powerful bargainers is possible only when both parties support the final resolution. Therefore, SE is not likely to be the final outcome of the Delta bargaining problem.

11.3 Stochastic Fallback Bargaining

Although taking performance averages may simplify the analysis of stochastic data in group decision making problems, the final results may not be reliable as it overlooks the robustness of the selected outcomes (Madani et al. 2014b). To deal with the uncertainty in performance ranges of the alternatives in the Delta problem Madani and Lund (2011) suggested a Monte-Carlo game theory approach. Based on this procedure, random preference matrices are generated based on a Monte-Carlo selection method and then solved according to non-cooperative game theoretical concepts. Similarly, Monte-Carlo multi-criteria decision making (MCDM) and Monte-Carlo social choice making methods were respectively developed by Mokhtari et al. (2012) and Madani et al. (2014b) to evaluate the sensitivity of the Delta problem's solutions to different levels of cooperation. Based on the same concept, a Monte-Carlo FB approach is used here to account for the uncertainty in the decision making problem's input variables and to evaluate the robustness of the likely outcomes.

In each round of a Monte-Carlo selection the Delta problem is solved using different FB methods. As done by Madani and Lund (2011), for illustration purposes, uniform probability distributions are used in the Monte-Carlo selection process to generate random performance numbers out of the performance ranges in each round of the Monte-Carlo selection. The resulting deterministic problem is then used using different FB methods. The probability of being selected as the outcome of the bargaining process is updated for each alternative in each round. Table 11.5 shows the likelihood of each alternative being selected as the bargaining solution according to UFM, 1-Approval FB, and FB with impasse. Given that 1-Approval FB is not practical in a 2-bargainer problem, it can be concluded from the results

that PC and DC are the most likely outcomes if parties decide to select the water export alternative through a bargaining process. When impasse is allowed, the bargaining process the parties might not settle over any of the four suggested alternatives.

In addition to calculating the winning probability for each alternative, i.e. probability of being selected as the best alternative (Table 11.5), ranking distribution of each alternative can be determined in order to evaluate the robustness of winning probabilities (Madani et al. 2014b). To determine the ranking distribution of alternatives, the alternatives must be fully ranked in each round of Monte-Carlo selection. Therefore, once the bargaining solution is determined in a given round under a given FB method, rank 1 is assigned to this alternative. This alternative is then removed and the FB analysis is continued with the remaining alternatives to determine the next best alternative (rank 2). This process is continued until all alternatives are ranked in a given round of Monte-Carlo selection. Through repetition of this process in each round of Monte-Carlo selection, the overall probability of ranking at each level can be determined for each alternative. The resulting ranking distribution

Table 11.5 Probability of being selected as the bargaining outcome under different bargaining methods

	CDE (%)	PC (%)	DC (%)	SE (%)	IMP (%)
UFB	15	52	50	1	–
1-Approval FB	3	69	33	90	–
FB with impasse	1	47	42	1	16

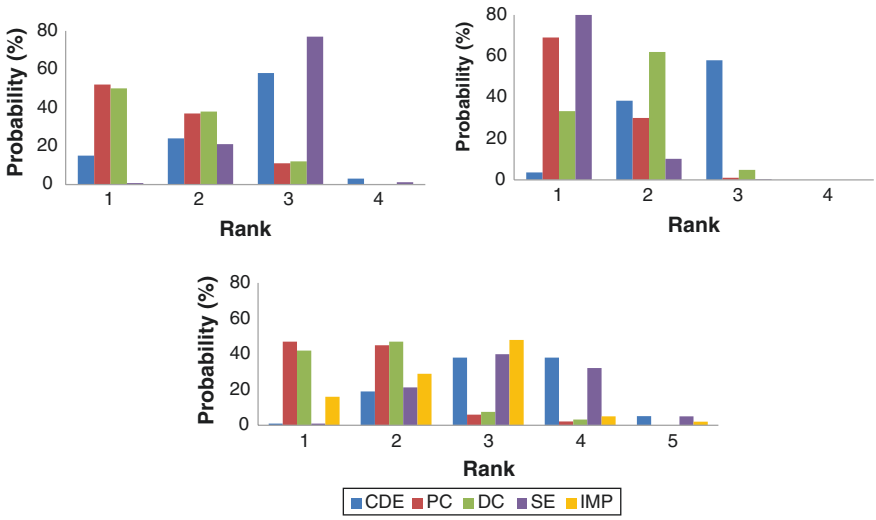

Fig. 11.1 Ranking distributions of water export alternatives based on the UFB (*top-left*), 1-Approval FB (*top-right*) and FB with impasse (*bottom*) methods

reflects the degree of ranking robustness for each alternative (Madani et al. 2014b). Ideally, one would prefer a narrower (more robust) probability distribution.

Figure 11.1 shows the ranking distributions of different water export alternatives in the Delta problem under the UFB (top left), 1-Approval FB (top right) and FB with impasse (bottom). As an example of robust ranking one can refer to SE under 1-Approval FB. This alternative has a narrow distribution, concentrated in the first and second levels. On the other hand, a good example of non-robust ranking is CDE under the UFB or FB with impasse methods. The ranking distribution of this alternative is wide and covers all ranking levels, so, it can be considered as a risky option. Given that 1-Approval FB is not realistic in the Delta case, based on Fig. 11.1, PC and DC are the most likely and robust outcomes if the water export alternative were to be selected through a bargaining process.

Table 11.6 compares the results obtained in this study with previous studies that used different decision analysis methods to study the Delta's benchmark problem. This table reflects the sensitivity of the results to the cooperation strategy of the

Table 11.6 Different approaches to solve the Delta problem

Cooperation strategy	Method (rule)	Ranking
Fully non-cooperative (Madani and Lund 2011)	Game theory (weak equilibrium)	CDE > PC > DC > SE
Partially cooperative (low level cooperation)	Fallback bargaining (unanimity)	PC > DC > CDE > SE
	Fallback bargaining (1-Approval)	SE > PC > DC > CDE
	Fallback bargaining (with impasse)	PC > DC > IMP > CDE > SE
Cooperation through coalition formation (Madani and Lund 2011)	Game theory (strong equilibrium)	PC > DC > CDE > SE
Partially cooperative (high level of cooperation) (Madani et al. 2014b)	Social choice (Borda score)	PC > DC > SE = CDE
	Social choice (condorcet choice)	PC > DC > CDE > SE
	Social choice (plurality)	SE > PC > DC > CDE
	Social choice (median voting)	PC > DC > CDE > SE
	Social choice (majoritarian compromise)	PC > DC > CDE > SE
	Social choice (condorcet practical)	PC > DC > CDE > SE
Fully cooperative (Mokhtari et al. 2012)	MCDM (lexicographic)	PC > DC > SE > CDE
	MCDM (SAW)	PC > DC > SE > CDE
	MCDM (TOPSIS)	PC > DC > SE > CDE
	MCDM (MAXIMIN)	PC > DC > CDE > SE
	MCDM (dominance)	PC > DC > CDE > SE
Fully cooperative (Rastgoftar et al. 2012)	Fuzzy (centroid deffuzification)	PC > DC > SE > CDE

Delta's decision makers. Under the fully non-cooperative case, which has been the status of the problem for decades, CDE is the most likely equilibrium of the game, i.e. water export will continue using the existing water export facilities. However, once the parties decide to change their cooperation strategies, even low levels of cooperation can result in CDE becoming an inferior and less likely outcome. Under cooperation, PC and DC are the most likely resolutions of the Delta's conflict.

11.4 Conclusions

This study suggested a method for analyzing bargaining problems in which the parties are uncertain about the performance of alternative bargaining outcomes. The suggested method ranks the likely outcomes of the bargaining process and determines the ranking robustness. To show the usefulness of the suggested method, this method was applied to solve the Sacramento-San Joaquin's Delta conflict as a benchmark stochastic multi-decision maker problem. To explore the most likely outcomes of this problem in which parties have to agree over an alternative for continuation of water export from the Delta, this problem was modeled as a bargaining procedure in which two bargainers, representing the main Delta interests, have to reach an agreement over a water export alternative. Three different FB methods were used to solve the benchmark problem. Given that the Delta problem has only two main decision makers, the q-approval FB method was not found to be appropriate. Nevertheless, this method is applicable in bargaining problems that involve more decision makers.

Overall the results suggest that building a peripheral canal or dual conveyance system are the most likely and robust outcomes of the Delta problem if the decision were to be made through bargaining. When parties are allowed to choose no-agreement as an additional option, selection of this option is more likely than continuation of water export as usual or stopping delta export. Findings of the study were consistent with those of previous studies of the Delta benchmark problem that used different decision analysis methods. Results suggest that except a fully non-cooperative case, which results in no resolution or in continuation of the status quo, building a peripheral canal or dual conveyance is likely in other cases, even if the level of cooperation among stakeholders is low.

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