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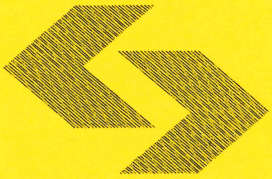

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ON SOME PROCEDURES SUPPORTING MULTICRITERIA COOPERATIVE DECISIONS

Lech KRUŚ*

Abstract. The paper deals with cooperation problems in the case of several parties having different sets of criteria measuring their payoffs. It presents interactive procedures supporting multicriteria analysis and procedures aiding consensus seeking through a mediation process. Using ideas of the game theory, a mathematical model describing cooperation situations and deriving possible payoffs of parties can be constructed. The model is base for the analysis made. Solution concepts developed in the cooperative game theory are applied in the mediation process. Using the procedures a computer-based system supporting analysis carried on by the parties can be constructed, so that the final decision about the cooperation can be made consciously.

Keywords: multicriteria analysis, cooperative games, computer-based systems, utility theory, mediation

1. Introduction

In the paper support of cooperative decisions with use of computer based systems is discussed. Mathematical modeling, the theory of cooperative games, methods of multicriteria analysis, methods of utility function and computational methods of optimization create the theoretical basis for the support.

Let several parties consider realization of a joint project. They negotiate participation in the costs of the project as well as in the profit expected after the project realization. Each party has its own, different vector of criteria, characterizing the party's payoff from the project and has own independent preferences among the criteria. The problem is considered in the space being Cartesian product of the multicriteria spaces of the parties as the multicriteria bargaining problem. The computer based system should aid the decision analysis of the problem. It should also support selection of the solution being fair and acceptable by all the parties. The mentioned solution includes engagements of the parties in the project and allocation of the benefits from the project.

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Iterative procedures aiding multicriteria analysis and supporting a mediation process leading to a consensus in the negotiation are presented in the paper. They are inspired by the single negotiation text procedure proposed by R. Fisher, which is frequently applied in international negotiations.

The proposed approach includes construction of substantive model of the decision situation, application of the interactive procedures and construction of the computer based system supporting the decision analysis made by each party. In the procedures cooperative mediation proposals are derived taking into account the criteria and the preferences of the parties. The mediation proposals are derived on the base of solution concepts of the cooperative games extended on the multicriteria case. Combining multicriteria analysis and the mediation process with application of the solution concepts taken from the game theory seems to be original element of the work in comparison to other papers dealing with computer-based support in negotiations. The system is treated only as an analytical tool. The final decisions are made by the parties, and the parties are also responsible for the decisions. The computer-based system implementing the procedures can be considered as a third party aiding concession seeking. Parties engaged in a cooperation problem, using the system, can learn the nature of the problem and learn possible mediation proposals to make the final decision consciously.

The application area includes among others analysis of cooperation in the case of innovative activities, education systems and cost allocation problems. The references attached include among others selected papers dealing with computer-based support in negotiations [3, 6-10, 12-19], relating to the multicriteria decision analysis [11-14, 17, 19, 26, 27, 35-37], to the utility function approach [5, 20-23, 30, 31, 33, 34] and to the game theory [4, 24, 28, 30, 32].

2. Some basic notions regarding negotiations

2.1. Third party aid

Parties can negotiate directly or can accept third party aid. The third party aid can be made by a facilitator, a mediator or an arbitration. According to definitions made by Raiffa [29] a *facilitator* is a person who arranges for the relevant parties to come to the negotiating table. The facilitator may choose not to get involved in the actual process of negotiation, but he may play a facilitating role in implementing the agreement. A *mediator* is an impartial outsider who tries to aid the negotiators in their quest to find a compromise agreement. The mediator can help with the negotiation process, but he does not have the authority to dictate a solution. An *arbitrator* (or arbiter), after hearing the arguments and proposals of all sides and after finding out "the facts," may also try to lead the negotiators to devise their own solutions or may suggest reasonable solutions; but if these preliminary actions fail, the arbitrator has the authority to impose a solution. The negotiators might voluntarily submit their dispute for arbitration, or the arbitration might be imposed on them by some higher authority. A *roles manipulator* is given the authority to alter or constrain the process of negotiation - or, put another way, to modify the rules of the game.

2.2. BATNA concept

Each party before the negotiations should derive its Best Alternative To Negotiated Agreement abbreviated further as BATNA (see Fisher, Ury [1]). In the negotiations a party can compare analyzed proposals to the derived BATNA.

Let us look at a simple two parties - one issue bargaining when a buyer and a seller negotiate price of a commodity. The seller and the buyer have reservation prices, r_s and r_k respectively, based on (BATNA concept) – the best alternatives to the negotiated agreement. The agreement is possible if there exists agreement zone : $r_s < r_k$.

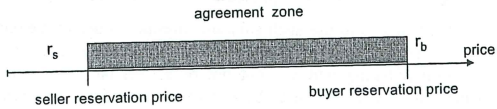

Figure 1. One issue bargaining

The buyer will not agree for the price higher than r_b and respectively the seller will not agree for the price lower than r_s. In this zone the bargainers can settle an agreement price but might not come to any agreement, even if the zone is not empty.

2.3. Classical cooperative games

The cooperation situations are modeled in the cooperative game theory: as so called bargaining problem for two and more players, and as models of the cooperative games in which the players can create different coalitions. The classical axiomatic theory of bargaining has been developed by Nash [24], Raiffa [28], Kalai, Smorodinsky [4], Roth [30], Thomson [32], and many others. The classical bargaining problem in the case of two and many issues is formulated in the theory in terms of utilities. Two parties (players) can reach any of the payoffs from the agreement set S, if they unanimously agree. The disagreement point d defines payoffs of the players in the case when they do not reach such an agreement. It is derived on the base of BATNA concept, in particular it can be the status quo point.

A solution of the bargaining problem is considered as a method to choose a point from the set S, accepted by rational players. Different solution concepts are proposed under different set of axioms (assumed properties describing feeling of fairness) the solution should fulfill. The argumentation for acceptation of the solution concept by the players is the following: if rational players agree on a selected set of axioms- principles and accept them as fair, why they should not accept the solution concept which fulfills the axioms.

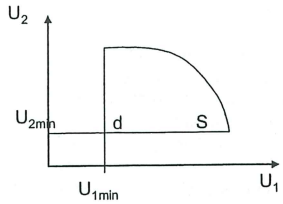

Figure 2. Classical representation of the bargaining problem

It seems be reasonable to use such solution concepts to derive mediation or arbitration proposals in negotiations and also in the case when a decision maker would like to propose cooperative solution taking into account not only own but also partners' benefits. An example of the last case is considered by Kulikowski and Krus [23], referring to a private high school, deriving and proposing the tuition level which is beneficial not only for the school but also for students.

2.4. Mediation process using Single Negotiation Text (SNT) procedure

The SNT procedure proposed by Roger Fisher, has been effectively applied in the Camp David negotiations. In the Camp David, USA, 1978, Jimmy Carter invited Monachem Begin representing Israel and Anwar el Sadat representing Egipt, to negotiate conditions of Middle East peace. The opponents started form very hard positional negotiations, so that the negotiations have failed after few rounds without any progress.

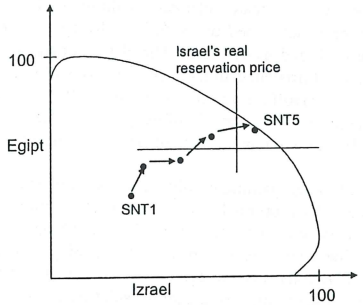

Figure 3. Steps in the single negotiation text procedure applied in the Camp David negotiations

Then a different approach has been applied proposed by Roger Fisher, who was an adviser of Jimmy Carter. According to the approach opponents should not discuss tasks independently nor formulate and consider counterproposals. They obtain and analyze, in

consecutive rounds, proposals prepared by the mediator. In each round they work on the same "single" text. On the base of their opinions and suggestions, the mediator prepares improved proposal being analyzed in the next round.

In the Camp David summit Jimmy Carter was a mediator, who presented successive proposals prepared by a team of advisers. Progress of the negotiations is presented schematically in Figure 3 (see Raiffa [29]). Achievements in terms of utilities of the opponents are measured in the scales of 100% of their wishes. The negotiation has started form SNT1 proposal. After several rounds the opponents have exceeded their real reservation prices, and finally have reached an agreement. Characterizing shortly the SNT procedure: it is multi round process, Single Negotiation Text is analyzed in each round and we can observe progression in the space of utilities.

3. Problem formulation

To describe the cooperation situation an extension of the classical bargaining problem is considered in the case of n decision makers (DM) called further players, each having multicriteria payoffs. Each DM (player) $i = 1,...,n$, has defined:

- a vector of decision variables $x_i \in \boldsymbol{R}^{ki}$, where ki is number of the variables of the player i,
- a vector of criteria (to be maximized) $y_i \in \boldsymbol{R}^{mi}$, where mi is number of criteria of the player i.

A mathematical model describing the decision situation is given, defining:

- a set of admissible decisions $X^0 \subset R^K$, where $R^K = R^{k1} \times ... \times R^{kn}$ is the space of decisions of all the players,
- a space of payoffs of all the players $R^M = R^{m1} \times ... \times R^{mn}$, it is the Cartesian product of the multicriteria spaces of the players' payoff,
- a function $F : X^0 \rightarrow R^M$ defining vectors of the players' payoffs for given values of decision variables. In the case of continuous function F and compact set X^0, the set of attainable payoffs $Y^0 = F(X^0)$ is also compact.

It is assumed that each player has his own reservation point $d_i \in R^{mi}$ assumed in his multicriteria space on the base of the BATNA concept. Then the Multicriteria Bargaining Problem (MBP) can be defined by the disagreement point $d = (d_1, ...d_n) \in R^M$, and the agreement set S consisting of the points of the set $Y^0 \subset R^M$ dominating the point d. Each point of the agreement set can be reached if all the players unanimously agree, i.e the problem consists in selection of the point from the set S, which could be accepted by all the players.

Let us see the following facts regarding the problem formulation. Each DM (player) has his own set of criteria, in general different. The set of the attainable payoffs Y^0 is considered in the space R^M being Cartesian product of individual multicriteria spaces of the players. The set is in general not given explicitly. However multicriteria payoffs of each player can be derived by a computer-based system for given values of the decision variables of all the players, using model relations.

An example of multicriteria bargaining problem is presented in Figure 4 in the case of two players. Player 1 has criteria y_{11} and y_{12}. player 2 has only one criterion y_{21}

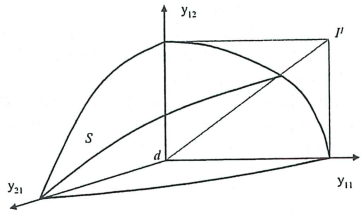

Figure 4. An example of multicriteria bargaining problem

The disagreement point d is based on BATNA of each player. In general case derivation of the disagreement point may also require additional multicriteria analysis made by each player. The agreement set S is defined by model relations, and in general is not known explicitly. The ideal point in the criteria space of the player 1 is also shown denoted by I^I.

4. Procedures supporting analysis and consensus seeking

4.1. Multicriteria analysis

Each player starts independently from interactive multicriteria analysis of the problem. The analysis is called unilateral, as the player looks for the outcome being the best from the point of view of his own preferences about criteria. During the analysis he can obtain information about possible outcomes for different assumptions about his preferences. He has also to make assumptions about the counter players' outcomes or counter players' preferences. The analysis can be made applying the reference point approach developed by Wierzbicki [32-34] with use of the order approximation functions. According the approach the player assumes reference points in the space of his criteria and the system generates respective outcomes which are Pareto optimal in the set S. For some number of reference points assumed by a player, a characterization of the Pareto frontier of the set S can be obtained.

Outcomes characterizing the Pareto frontier in the case of i-th player are derived by:

$$\max_{x \in X_0} [s\ (y_i(x), y_i^*)] \tag{1}$$

where:
y* is a reference point assumed by the player in the space $\boldsymbol{R}^{mi}$,
$y_i(x)$ defines vector of criteria of the i-the player, which are dependent on the vector x of decision variables, by the model relations,

$s(y,y^*)$ is the order approximating achievement function.

The function

$$s(y_i, y_i^*) = \min_{1 \le j \le mi} [a_j(y_{ji} - y^*_{ji}) + a_{mi+1} \sum_{i=1}^{mi} a_j(y_{ji} - y^*_{ji})], \quad (2)$$

states an example of the achievement function suitable in this case, where $y_i^* \in R^{mi}$ is a reference point, a_j, $1 \le j \le mi$, are scaling coefficients, and $a_{mi+1} > 0$ is a small parameter.

The assumed reference points and the obtained Pareto outcomes are stored in a data base, so that a characterization of the Pareto frontier can be made and analyzed by the player.

Figure 5 presents results of the unilateral, interactive analysis made by the player 1 in his criteria space for two different assumptions about the second player outcomes: 1-st - for the counter player's outcomes assumed on the level of d, and 2-nd - for the counter player's aspirations assumed by the player 1.

Using the reference point approach the player can generate a number of such characterizations of the Pareto frontier. At the end, the player is asked to indicate the preferred outcome.

The unilateral analysis is made by each player. Information about the indicated preferred outcomes of all the players are collected.

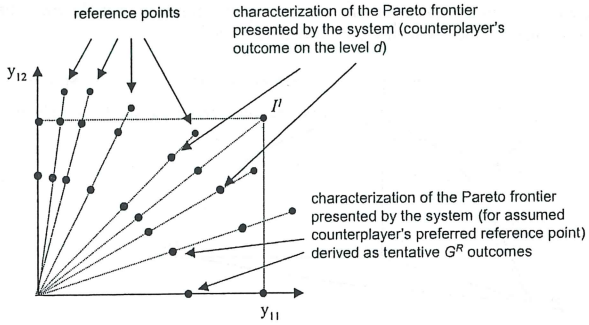

Figure 5. Characterizations of the Pareto frontier obtained during unilateral analysis

4.2. Supporting mediation process

A procedure supporting mediation process has been proposed under inspiration of the Single Negotiation Text (SNT). It consists of sequence of rounds $t=1,2,\ldots T$. Rules of the procedure can be point out as follows:

- in each round each player supported by the computer based system makes interactive unilateral analysis in his criteria space and indicates a required

improvement direction of his outcome according to his preferences among the criteria,

- the computer-based system generates consecutive mediation proposals on the base of the improvement directions indicated by all players,
- each player analyzes the proposals and corrects required improvements of his outcome and the system generates new improved mediation proposal.

The consecutive mediation proposal d^t is generated in the round t on the base of the players indications, according to the scheme:

$$d^0=d,$$

$$d^t=d^{t-1}+\alpha^t \cdot [G^t - d^{t-1}], \text{ for } t=1, 2, \ T, \tag{3}$$

where $\alpha^t=\min\{\alpha^{1t}, ...,\alpha^{mt}\}$, α^{it} is so called confidence coefficient assumed by the player i in the round t, $0 < \varepsilon < \alpha^{it} < 1$, G^t is the game solution calculated in the round t, for example the Raiffa solution, generalized on multicriteria case.

In the Cartesian product of multicriteria spaces of the players' payoffs a point is derived which is a composition of the preferred outcomes indicated by the players after the unilateral analysis. This point denoted by U^R in Figure 6 is called the relative utopia point. It relates to aspirations of the players. In fact it is derived according to the players preferences expressed after the unilateral analysis. In general it is different than the ideal point defined by the maximal values of criteria in the S set.

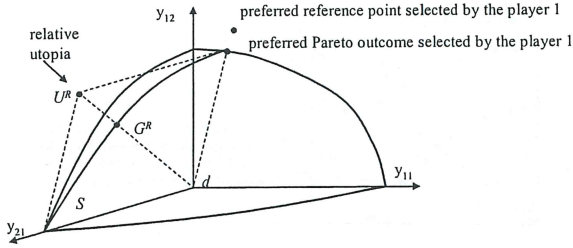

Figure 6. Relative utopia and generalized Raiffa solution

The generalized Raiffa solution G^R is the maximal point in S, on the line linking the disagreement point d and the relative utopia U^R. Each player assuming the confidence coefficient relatively small, less then 1, can limit increase of the payoffs of all the players in the given round as it is presented in Figure 7. A tentative mediation proposal is derived according to the formula (6).

The tentative mediation proposal derived in the round t is treated as the disagreement point d^t in the next round $t+1$. Next, unilateral analysis is made by each player who explores the set of points belonging to S and dominating the d^t point. It is illustrated by Figure 8.

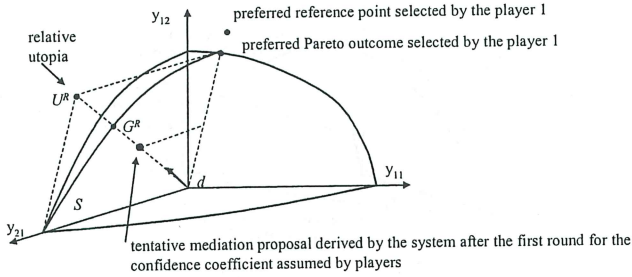

Figure 7. Tentative mediation proposal

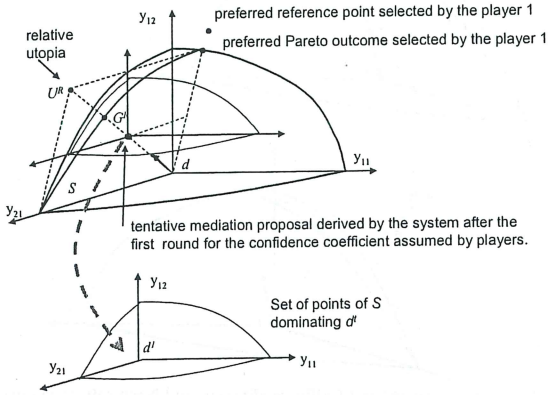

Figure 8. The mediation proposal is treated as the disagreement point in the problem analyzed in the next round.

4.3. Mediation proposals based on different game solution concepts

Comparison of solution concepts in multicriteria bargaining problem is presented in Figure 9. The preferred outcome selected by a player defines a direction in his multicriteria space. The directions of all players define a hyperplane in the Cartesian

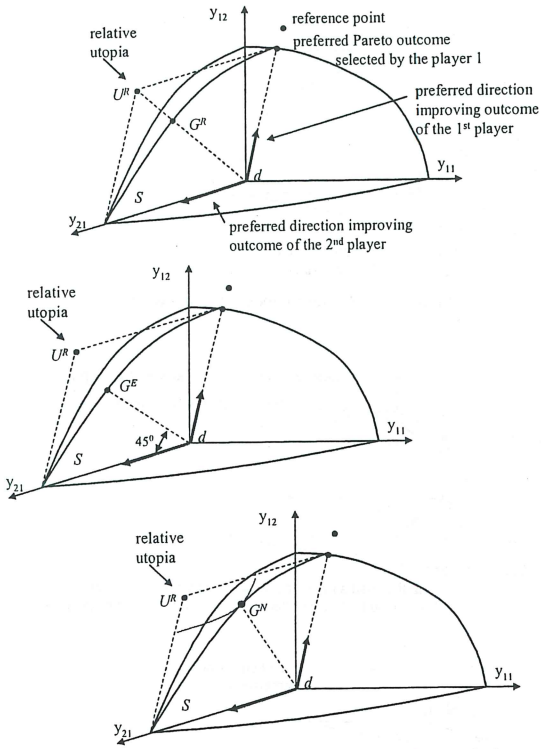

Figure 9. Generalized Raiffa, egalitarian and Nash solution concepts in multicriteria game

product of the spaces. The relative utopia and generalized Raiffa solutions lay in the hyperplane. Other theoretical solutions of the game theory laying on the hyperplane can be considered based for example on the egalitarian concept or Nash cooperative solution concept.

The egalitarian solution (denoted by G^E) maximizes gain of equal coordinates. It satisfies axioms of weak Pareto optimality, symmetry, strong monotonicity.

The Nash cooperative solution G^N maximizes the product of the payoffs increases. It satisfies the axioms of Pareto optimality, symmetry, scale invariance, independence of irrelevant alternatives (see Nash [24]).

Mentioned before generalized Raiffa solution concept satisfies axioms of weak Pareto optimality, symmetry, scale invariance, restricted monotonicity (Krus, Bronisz [13]).

Figure 10 presents the case of three parties, each having only one criterion y_1, y_2, y_3 respectively, when the Raiffa solution is only weakly Pareto point, even if the set S is convex. Imai [3] proposed the way to improve the solution to the Pareto optimal one, so that no player loose. The idea can be generalized on multicriteria case as it is proposed here.

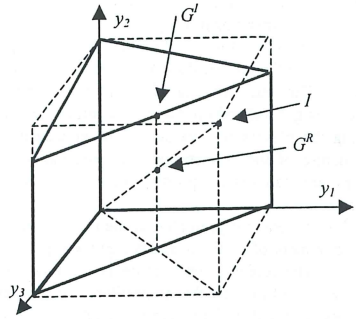

Figure 10. Raiffa and Imai solution concepts in a three party bargaining problem

Given multicriteria bargaining problem (S,d). An affine transformation $L:\boldsymbol{R}^M \rightarrow \boldsymbol{R}^M$ is introduced satisfying for $k\in[1,\ldots M]$: $L_k(z)=(z_k-d_k)/(u_k-d_k)$, where u_k is k^{th} coordinate of the relative utopia vector U^R.

Let $>^{\text{lex}}$ be lexicographic ordering on $\boldsymbol{R}^M$ i.e. for any $z,y\in\boldsymbol{R}^M$ $z>^{\text{lex}} y$ if and only if there is $k \in[1,\ldots\text{M}]$ satisfying $z_k>y_k$ and $z_i=y_i$ for $i<k$. Also let P: $\boldsymbol{R}^M \rightarrow \boldsymbol{R}^M$ be such that for $z\in\boldsymbol{R}^M$, there is a permutation on $[1,\ldots,\text{M}]$, π, with $P(z)=\pi^*z$ and $P_1(z)\leq P_2(z)\leq\ldots\leq P_M(z)$.

The solution concept is proposed in the form

$$G^I(S,d,U^R)=\{z\in S: P[L(z)]>^{\text{lex}} P[L(y)] \text{ for any } y\in S\} \qquad (4).$$

The solution is Pareto optimal in S. If the generalized Raiffa-Kalai-Smorodinsky solution G^R is Pareto optimal then $G^I=G^R$.

In Figure 10 the agreement set S has the form of the prism drown in bold lines. The Raiffa solution concept G^R is defined by the intersection of the line linking the ideal I and the disagreement pint d, with the frontier of the prism. It is only weekly Pareto point. The Imai concept G^I is Pareto optimal. It improves the payoff y_2 of the 2-nd party, not decreasing payoffs of the 1-st and the 3-rd party. In the multicriteria case discussed here, the generalized Imai solution is based not on the Ideal point but on the Relative Utopia point which depends on preference of the players. Therefore the solution is looked for in the interactive multi round procedure.

5. Final remarks

In the paper procedures aiding multicriteria analysis and supporting consensus seeking a are proposed. The procedures can be implemented in a computer-based system . The cooperation problem is formulated with use of the game theory ideas. The multicriteria analysis of the problem is made independently by parties with use of the reference point approach. Each player assuming reference point in the space of his criteria can generate with use of the system a set of outcomes characterizing Pareto frontier of possible outcomes. It is made by solving maximization problems with specially constructed achievement functions. The system generates also Pareto optimal compromise outcomes. They are derived taking into account the information on the parties preferences expressed in a special interactive process. The outcomes satisfy axioms of cooperative solutions formulated in the theory of games generalized on the multicriteria case. They can be treated as mediation proposals aiding the players in looking for the consensus. Parties using the system can understand the nature of the cooperation problem, can learn what their real preferences among the criteria are, can analyze possible outcomes, and can make the final decision about cooperation consciously.

The paper continues the line of research presented in the references [12-19]. It is a part of the research including development of methods and computer experiments in the case of different cooperation problems. The research includes decision situation described by the multicriteria bargaining problems, but also by the multicriteria noncooperative games, the multicriteria cooperative games with and without side payments. In the research the utility function approach, being an alternative to the direct multicriteria analysis, is also developed. In particular concepts proposed by R. Kulikowski [20-23] are applied to support decision analysis taking into account the presence of risk. The concepts extend ideas developed in the papers [5, 25, 31, 33, 34]. They are applied among others in the case of financial analysis [20, 22], analysis of innovative activities [16, 21] and analysis of education decisions [23].

References

[1] Fisher R., Ury W., *Getting to Yes*, Hougton Mifflin, Boston, 1981.

[2] Imai H., Individual Monotonicity and Lexicographic MaxMin Solution, *Econometrica*, Vol. 51 (1983), No. 2, 389-401.

[3] Jarke, M., M.T. Jelassi, M.F. Shakun, Mediator: Towards a negotiation support system, *European Journal of Operational Research*, Vol. 31 (1987), 314—334.

[4] Kalai E., M. Smorodinsky, Other Solutions to Nash's Bargaining Problem, *Econometrica*, Vol. 43 (1975), 513-518.

[5] Kahneman D., Tversky A., Prospect theory: an analysis of decision under risk. *Econometrica,* Vol. 47 (1979), No. 2.

[6] Korhonen, P., H. Moskowitz, J. Wallenius, S. Zionts, An Interactive Approach to Multiple Criteria Optimization with Multiple Decision Makers, *Naval Research Logistics Quarterly*, Vol. 33 (1986), 589-602.

[7] Kersten, G.E., A Procedure for Negotiating Efficient and Non-Efficient Compromises, *Decision Support Systems*, (1988). No. 4 , 167-177.
[8] Kersten G., W. Michalowski, S. Szpakowicz, Z. Koperczak, Restructurable Representations of Negotiations, *Management Sci.*, Vol. 37 (1991), No. 10, 1269-1290.
[9] Kersten G., Szapiro. T., Generalized Approach to Modeling Nego-tiations, *European Journal of Operation Research*, 26 (1986).
[10] Kersten, G., Noronha S.J., WWW-based Negotiation Support: Design, Implementation and Use, *Decision Support Systems*, 25 (1999), 2
[11] Kostreva M. M., W .Ogryczak, A.Wierzbicki, Equitable Aggregations and Multiple Criteria Analysis, *European Journal of Operational Research*, Vol. 158 (2004), 362-377.
[12] Kruś L., Some Models and Procedures for Decision Support. in Bargaining, in: P. Korhonen, A. Lewandowski, J. Wallenius (eds.), *Multiple Criteria Decision Support*, Springer Verlag, Berlin, 1991.
[13] Kruś L., Bronisz P., Some New Results in Interactive Approach to Multicriteria Bargaining, in J. Wessels, A.P. Wierzbicki, (eds), *User-Oriented Methodology and Techniques of Decision Analysis and Support*, Springer Verlag, Berlin, 1993.
[14] Kruś L., Multicriteria Decision Support in Negotiations, *Control and Cybernetics*, Vol. 25 (1996), No. 6, 1245-1260.
[15] Kruś L., Bronisz, P., Cooperative game solution concepts to a cost allocation problem, *European Journal of Operational Research*. Vol. 122 (2000), No. 2, 258-271.
[16] Kruś L., A System Supporting Financial Analysis of an Innovation Project in the Case of Two Negotiating Parties, *Bull. of Polish Academy of Sci., Ser. Techn.*, Vol. 50 (2002), No. 1, 93-108.
[17] Kruś L., *Multicriteria* Decision Support in Bargaining, a Problem of Players Manipulations, in: T. Trzaskalik, J. Michnik, (eds), *Multiple Objective and Goal Programming*, Physica Verlag, Springer, Berlin, 2002.
[18] Kruś L., A Computer Based System Supporting Analysis of Cooperative Strategies, in: L. Rutkowski, J. Siekmann, R. Tadeusiewicz, L. Zadeh, (eds), *Artificial Intelligence and Soft Computing – ICAISC 2004*, Lecture Notes in Computer Science, Springer, Berlin, 2004.
[19] Kruś L. A multicriteria approach to cooperation in the case of innovative activity, *Control and Cybernetics*, Vol. 33 (2004), No.3.
[20] Kulikowski R., Portfolio optimization: two factors utility approach, *Control & Cybernetics*, (1998) No. 3.
[21] Kulikowski R., URS methodology – a tool for stimulation of economic growth by innovations, *Bulletin of the Polish Academy of Sciences, Sci. Tech.*, Vol. 50 (2002), No. 1.
[22] Kulikowski R., On general theory of risk management and decision support systems, *Bulletin of the Polish Academy of Sciences, Sci. Tech.*, Vol. 51 (2003) No. 3.
[23] Kulikowski R., L. Kruś, Support of education decisions, in: J. Kacprzyk, D. Wagner (eds.) *Group Decisions and Voting*, Akad. Oficyna Wyd. EXIT, Warszawa, 2003.
[24] Nash J., The Bargaining Problem. *Econometrica*, Vol. 18 (1950), 155--162.
[25] von Neumann J., Morgenstern O., *Theory of games and economic behavior*. Princeton Univ. Press, 1953.

[26] Ogryczak W., Multiple criteria optimization and decisions under risk, *Control and Cybernetics*, Vol. 31 (2002), No. 4.
[27] Ogryczak W., *On Nucleolar Refinement of the Reference Point Method*, Paper presented at MCDM Workshop, Ustroń, 2007 (submitted to the MCDM workshop proceedings),
[28] Raiffa H., Arbitration Schemes for Generalized Two-Person Games, *Annals of. Math. Studies*. (1953) No. 28, 361-387, Princeton.
[29] Raiffa H., *The Art and Science of Negotiations*, Harvard Univ. Press, Cambridge, 1982.
[30] Roth, A. E., *Axiomatic Models of Bargaining*. Lecture Notes in Economics and Math. Systems. Vol 170 (1979), Springer Verlag, Berlin.
[31] Savage L. J., *The foundations of statistics*. New York, Wiley, 1954.
[32] Thomson W., Two Characterization of the Raiffa Solution. *Economic Letters*. Vol. 6 (1970), 225-231.,
[33] Tversky A., Kahneman O., The framing of decisions and the psychology of choice, *Science*, Vol. 211 (1981), 453-480.
[34] Tversky A., Utility theory and additivity analysis of risky choices, *Experimental Psychology*, Vol. 75 (1967), 27-37.
[35] Wierzbicki, A. P, On the Completeness and Constructiveness of Parametric Characterization to Vector Optimization Problems, *OR-Spectrum*, Vol. 8 (1986), 73--87.
[36] Wierzbicki, A. P., Kruś, L., Makowski, M., The Role of Multi-Objective Optimization in Negotiation and Mediation Support. *Theory and Decision*, special issue on "International Negotiation Support Systems: Theory, Methods, and Practice", 34, (1993), 2.
[37] Wierzbicki A. P., M. Makowski, J. Wessels, *Model-based Decision Support Methodology with Environmental Applications*, Kluwer Academic Press, Dordrecht, Boston, 2000.