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A MODEL TO SUPPORT NEGOTIATIONS ON THE ELECTRICITY MARKET

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Abstract

Liberalization on the electricity market in Poland is related to the possibility of free choice of electricity supplier. On a liberalized market, suppliers have to compete to gain new customers and retain the old ones. The suppliers have to satisfy the customers' needs − which are more and more complex − and customize their approach. Therefore, negotiations of electricity sale conditions become an usual practice.

The purpose of this study is to propose a way of supporting the negotiation process of electricity sale conditions between a supplier and a customer. To solve this problem, the scoring method has been used.

Keywords: electricity, active and passive negotiation support, negotiation offer evaluation system, scoring method, SAW.

1 Introduction

Nowadays we see a progressing process of liberalization on the electricity market in Poland. According to the principle of TPA (Third Party Access), starting with 2007 every consumer of electricity in Poland can freely choose the supplier. On the other hand, suppliers of electricity have to compete with each other to gain new consumers and retain the old ones. For this reason, negotiations of conditions of offers to sell electricity become a common practice.

The purpose of this study is to present a proposal for supporting the negotiation process of conditions of electricity sales between a supplier and a consumer. A sample negotiation problem from the electricity market is presented.

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The paper consists of few main sections. First few sections are the introduction of basic concepts related to the electricity market, the negotiation problem, and the system of evaluation of negotiation offers. There's also a description of the algorithm of the method used to construct such a system, which is the scoring method.

The next sections contains the description of a sample application of the scoring method on the electricity market to the construction of an offer evaluation system. The section contains also the description of assumptions regarding the elements of the negotiation problem and the evaluation of negotiation offers. Furthermore, examples of passive and active negotiation process support are presented, together with the author's proposal of suggesting a non-dominated negotiation compromise.

Passive negotiation support means that information on the negotiation process in progress is elaborated and visualized, without suggesting any solutions. Active support, on the other hand, is related to a recommendation of negotiation compromises (Wachowicz, 2013).

The last section is a summary with conclusions and future research directions.

2 Problem formulation and a system for negotiation offer evaluation

Negotiation analysis was introduced in the 1980s, when a formal description and assumptions of a negotiation process were suggested. This description became a basis for the construction of models describing negotiation processes (Raiffa, 1982; Kopańska-Bródka, Wachowicz, 2013). Nowadays, to support the negotiation process, tools based on the following are used:

- game theory (Brams, 1990, cited in: Kopańska-Bródka, Wachowicz, 2013);
- decision-making theory (Raiffa et al., 2002, cited in: Kopańska-Bródka, Wachowicz, 2013);
- mathematical programming (Kersten et al., 1991, cited in: Kopańska-Bródka, Wachowicz, 2013).

Selected papers dealing with negotiations on electricity markets focus on the problem of automation of this process through the notion of multi-agent systems with defined negotiation strategies and bidding rules (Kaleta et al., 2009; Brazier et al., 2002).

First, we have to define three basic categories related to the electricity market and used in the present paper. An energy supplier is a business entity (an energy-trading company) which sells and buys energy on the market. In this paper, the role of the market is played by the Polish Energy Exchange (PEE)[1]. The cus-

[1] Detailed information on the PEE is available on the web page www.tge.pl.

tomer purchases energy for further resale, and is interested in purchasing a forward contract for the supply of electricity. The customer is not a direct participant in the market, and that is why he/she wants to purchase from a supplier.

The negotiation problem consists of three main elements: negotiation issues, together with the levels of their implementation, and variants of agreement. Given the set G of J negotiation issues $G = \{g_1, g_2, \ldots, g_J\}$, $j = 1, \ldots, J$, with the levels of implementation defined for each issue, we can also define the set of agreement variants $A = \{a_1, a_2, \ldots, a_I\}$, $i = 1, ..., I$. The set A consists of vectors of implementation levels of the negotiation issues from the set G: $a_i = [x_{i1}, x_{i2}, \ldots, x_{iJ}]^T$ [2].

The negotiation issues in the classical decision problem represent the criteria, while the variants of agreement correspond to decision variants. The elements of a negotiation issue are the subject of discussions and are determined by both parties during the pre-negotiation stage.

The negotiation problem thus defined can undergo further evaluation. The evaluation can be related to negotiation issues, levels of their implementation, and − as a consequence − agreement variants. As a result we obtain a system of negotiation offer evaluation with a defined vector of weights of negotiation issues[3] $w = [w_1, w_2, \ldots, w_J]^T$ and a vector of evaluations of all agreement variants $V = [v(a_i)]^T$, $i = 1, \ldots, I$ (Wachowicz, 2013).

The system of negotiation offer evaluation enables each negotiator to sort out the information on the problem. In this system, the negotiators' preferences are presented explicitly as evaluations and weights. Finally, on the basis of this system both passive and active negotiation process support is made possible at the stage of actual negotiations.

Moreover, such a system allows for a quick and unique evaluation and comparison of negotiation offers; it also allows to preserve the negotiator's rational way of thinking. A negotiation offer evaluation system makes it also possible to justify the decision to suggest the next offer in response to the moves of the other party (Simoms, Tripp, 2003, after: Wachowicz, 2013).

The offer evaluation system is constructed separately by each negotiator at the pre-negotiation stage. To construct such a system we can use the scoring method.

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[2] These are not the only elements of the problem indicated in the literature, cf. Wachowicz (2013).

[3] Not all methods of construction of offer evaluation systems require the evaluation of how essential a given negotiation issue is. An example is the ELECTRE TRI method, see Roy (1971), after: Wachowicz (2013).

3 The scoring method

The scoring method (Trzaskalik, ed., 2014) is a modification of the Simple Additive Method (SAW) and is used to construct systems of negotiation offer evaluation. In the literature it is pointed out that other multi-criteria methods can be used, such as BIPOLAR, VIKOR, TOPSIS, AHP and their later modifications (see Keeney, Raiffa, 1976; Saaty, 1980; Hwang, Yoon, 1981; Konarzewska-Gubała, 1989; Opricovic, 1998; Wachowicz et al., 2012). The SAW method is one of the simplest and most often used multi-criteria methods. It was introduced by Churchman and Ackhoff in 1954 (Churchman, Ackhoff, 1954, after: Trzaskalik, ed., 2014). Its algorithm consists of three steps:

1. Assignment of the weights w_j [0, P] to the negotiation issues[4]. The most essential issues receive the highest weights. We also assume that $\sum_{j=1}^{J} w_j = P$.
2. The individual evaluation of k implementation levels within the negotiation issues $v_j\left(x_j^k\right) \in \left[0; w_j\right]$. The most essential levels receive the highest evaluations.
3. Calculation of the global evaluations of agreement variants based on the multi-attribute value function $v(a_i) = \sum_{j=1}^{J} v_j\left(x_j^{a_i}\right)$. The most favorable variants receive the score P, while the least favored ones, the score 0 (Wachowicz, 2013).

4 An example of a negotiation issue

A customer wants to purchase energy in the form of forward contracts for further resale. Moreover, he/she wants to actively manage the purchase price of his/her volume. That is why the customer decided to negotiate a dynamic purchase, that is, one where he/she decides when and what share of volume to purchase by submitting a purchase order to the potential supplier. The total power of contracts within this dynamic purchase is 10 MW for baseload supply (BASE–Y_15) and 4 MW for peakload supply (PEAK5–Y_15)[5].

For the purpose of this paper we make certain assumptions as to the elements of the negotiation problem and the offer evaluation system.

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[4] In the scoring method, points are assigned as weights and evaluations. The value P is determined by the customer and the supplier separately. Usually, P is set to 100 which means that weights are assigned as points from the interval [0, 100]. One should note that evaluations from the range between 0 and 100 are assigned also in the SMART method.

[5] Definitions of forward contracts for baseload supply and peakload supply can be found in Kudyba (2014).

The individual negotiation issues with their weights and the implementation levels with the scores assigned do not change during the negotiation. Otherwise, the set of non-dominated compromises would change in time. If during the negotiation the negotiators decided to include a new issue into the discussion, it would mean that the offer evaluation system would have to be constructed anew.

The negotiators do not have information on weights and scores of their opponents. If a negotiator had information on the preferences of his/her opponents, he/she could influence the choices of the other party's consecutive offers. Such a situation is undesirable, since it is not in agreement with the general principles of conducting business.

It is assumed, however, that the information on weights and scores of both negotiators can be voluntarily passed on to a third party (an arbitrator) and used only to support the negotiation process.

5 Problem definition

In the pre-negotiation stage the parties agreed as to the following issues:

- maximal power of the standard product ordered in a single purchase order;
- pricing method or the method of setting the purchase price on the market at the time of purchase;
- mark-up of the supplier who fulfills the contract.

The parties agreed that one purchase order can include the purchase of both products at the same time[6]. For instance, if a 5 MW volume is selected for both products, the customer receives 5 MW of baseload power and 4 MW of peakload power. The next orders will concern baseload supply only. The customer cannot contract for more than 10 MW of baseload power and 4 MW of peakload power. It has been agreed that the power interval will be negotiated in the range from 1 MW to 10 MW. The essential options within this negotiation issue are 1.5 MW and 10 MW.

The second negotiation issue concerns the method of setting the purchase price of the volume in each purchase order, which is a qualitative issue. The price itself is of course a strictly quantitative issue, but this issue consists in the method of agreeing on the price, and not in its specific value. The parties agreed to discuss the following proposal:

- the settlement occurs according to the price of sale offer posted on the exchange quotation board at the time when the decision of purchase is made;

[6] That is, contracts denoted BASE-Y_15 and PEAK-Y_15.

- the settlement occurs according to the average price of transactions on the PEE before 12:00; the customer can submit the purchase order by 12:30 on the same day;
- the settlement occurs according to the average price of transactions on the PEE on the day preceding the submission of the order; the customer can submit the purchase order by 8:00 on the following day;
- the settlement occurs according to the average price of transactions on the PEE on the day preceding the submission of the order; but the customer can decide to submit the order during the entire day following the publication of the average transaction price.

One should note that in this negotiation issue there are no intermediate options.

The last issue to be negotiated is the supplier's profit margin. The margin suggested by the supplier is the markup on the liquidity risk related to the volatility of prices on the market for products being ordered. When a customer submits a purchase order of a volume, the supplier is not always able to buy the product immediately, and price quotations change in time. Hence the margin as a markup for the liquidity risk calculated on the basis of price volatility.

The analysis of price volatility concerned BASE–Y_15 and PEAK5–Y_15 products. To measure volatility, standard deviation of the logarithmic returns was used. The supplier assumed a uniform risk calculation as the average of markups for base and peakloads, weighted by the joint power of standard products.

Daily return volatility for the BASE–Y_15 product is 0.47%, which gives the markup of 0.79 PLN/MWh assuming the settlement rate of 169.37 PLN/MWh. Analogously, the return volatility for the PEAKS–Y_15 product is 0.64%, which gives the markup of 1.40 PLN/MWh assuming the settlement rate of 202.02 PLN/MWh. The average markup weighted with the total volume of orders is 0.88 PLN/MWh[7].

On the basis of liquidity analysis the supplier obtains information on the number of days needed to purchase the given power, depending on the settlement methods selected. The number of days taken into account in the calculation of the markup for risk depending on the settlement option selected and the volume ordered is presented in Table 1. The values of markup for 1-, 2-, 3-, and 4-day risk are 0.88, 1.25, 1.53, and 1.77 PLN/MWh, respectively.

On the basis of the calculations of each markup the supplier knows that selecting the fourth method of settlement and the maximal power of the order of 10 MW, the markup for the service equal to 1.77 PLN/MWh should protect

[7] One should note that the daily mark-up was calculated on the basis of daily price volatility, while mark-ups for longer periods will be calculated using the square root principle, described in Marcinkowska (2009).

him/her from price volatility. For the purpose of the negotiation process, these amounts have been rounded up to integers. The supplier's margin will be fixed as a value from the interval between 1.00 and 2.00 MWh with the accuracy of 0.01 PLN/MWh. The essential options in this case are 1.00, 1.50, and 2.00 MWh[8].

Table 1: Number of days for the calculation of markup for volatility risk depending on the option

t-day markup	Settlement 1	Settlement 2	Settlement 3	Settlement 4
1 MW	1	2	2	3
2 MW	1	2	2	3
3 MW	1	2	2	3
4 MW	1	2	2	3
5 MW	1	2	2	3
6 MW	2	3	3	4
7 MW	2	3	3	4
8 MW	2	3	3	4
9 MW	2	3	3	4
10 MW	2	3	3	4

Source: Author's own elaboration.

6 Construction of systems of negotiation offer evaluation

After having agreed on negotiation issues and options within each issue, both parties begin to prepare their systems of negotiation offer evaluation. It is assumed that the threshold value P is 100 points. The evaluations assigned to the essential options are listed in Table 2[9].

Table 2: Evaluations of the individual options assigned by each party in the negotiation process

Negotiation issue	Essential option	Supplier's evaluations	Customer's evaluations
Maximal volume in a single order	1 MW	**40**	0
	5 MW	30	20
	10 MW	0	**30**
Settlement method	Settlement 1	**30**	0
	Settlement 2	25	10
	Settlement 3	5	30
	Settlement 4	0	**40**
Supplier's profit margin	2,00	**30**	0
	1,50	11	25
	1,00	0	**30**

Source: Author's own elaboration.

[8] Evaluations of the intermediate options (between the essential options) are based on linear approximation.

[9] Boldface denotes the weights assigned to each negotiation issue.

The issue of power in the order submitted: The customer assessed the importance of this issue to be 30 points, while the supplier 40 points. From the point of view of the customer a high power of the order increases the chances of flexible management of purchase cost: the higher the power, the greater the chance of purchasing the entire volume in shorter time. The rate of increase of the score for powers from 1 MW to 5 MW is greater: it is equal to 20 pts, while the increase of score for powers from 5 MW to 10 MW is equal to 10 pts. A smaller power in a single order means less problems for the supplier with the purchase on the market and that is why the supplier evaluates options with lower powers higher.

The issue of the settlement method: The most important issue for the customer (its weight is 40 pts) who evaluates highest a settlement based on the average price over the transactions from day $t - 1$ (also 40 pts). In this case the customer has the opportunity to watch the prices on the next day, and therefore to check whether the current price tendency is favorable for him/her or not. The least preferred is the first method since it is tied to the current price and does not allow to forecast its further increase or decrease. For the supplier, the importance of this issue is 30 pts, and the preferred settlement method is the first one, although the second one is also acceptable. On the other hand, the third and fourth methods are evaluated much lower. What is appealing in these two methods for the customer is at the same time less so for the supplier.

The issue of the supplier's margin is just as essential for the supplier as the issue of settlement. The highest score is assigned to the highest profit margin, that is, 2.00 PLN/MWh. This score decreases to 11 pts for the margin of 1.50 PLN/MWh and is 0 pts for the margin of 1.00 PLN/MWh. For the customer the margin is as essential as the power ordered; he/she prefers most the margins from the range between 1.00 to 1.50 PLN/MWh, assigning to them scores from 30 pts to 25 pts. Further on, the score decreases gradually to 0 for the highest profit margin of 2.00 PLN/MWh.

One should note that Table 2 contains only the essential options for each negotiation issue, on the basis of which the systems of negotiation offer evaluation of both negotiators were constructed.

There are several power variants to be negotiated in the orders, of value from 1 MW to 10 MW; there are thus ten possibilities. In the settlement issue there are only four options; no intermediate variants are possible. The supplier's margin, on the other hand, is a value from the range between 1.00 and 2.00 PLN/MWh, determined with the accuracy of 0.01 PLN/MWh, and therefore there are as many as 101 implementation levels for this issue. The evaluations of all the options which are not deemed essential have been determined using linear interpolation.

The negotiation space for the problem is presented in Figure 1.

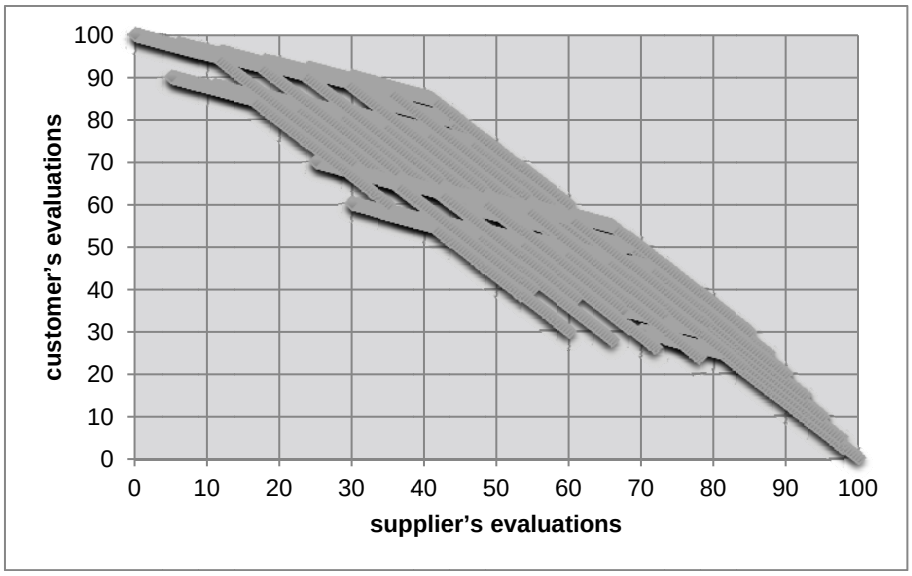

Figure 1. Negotiation space for the problem under discussion

Source: Author's own elaboration.

7 The phase of actual negotiations

In the phase of actual negotiations the supplier put forward seven offers, while the customer six. The compromise was reached in the 13th round. The first offer came from the supplier: it was one of the most favorable ones, that is, an offer of 1 MW of power with the first settlement method and the profit margin of 1.90 PLN/MWh. This offer scored 96.2 pts, according to the supplier's offer evaluation system. The customer countered with an offer evaluated at 94 pts: an order for 7 MW of power with the fourth settlement method and the profit margin of 1.00 PLN/MWh.

In the third negotiation round the supplier suggested a modification of his offer, with the profit margin lowered by 0.10 PLN/MWh, and the settlement method changed to the second one. The evaluation of his offer falls from 96.2 pts to 87.4 pts. The customer, on the other hand, evaluates the supplier's offer at 20 pts, which is an increase of 15 pts as compared to the customer's evaluation of the previous offer by the supplier. In response to that, the customer suggests an offer with the profit margin higher by 0.35 PLN/MWh as compared with his previous offer (which was an order of 7 MW with the fourth settlement method and the profit margin of 1.00 PLN/MWh). The implementation levels of the other issues remained unchanged.

The supplier gives up the profit margin and the minimal power in the order, but returns to the suggestion to use the first settlement method, and puts forward an offer of 3 MW with settlement #1 and margin 1.70. In the sixth round the customer did not make any concessions as regards the settlement method, but lowered the power and the margin down to the values of 5 MW and 1.40, respectively. These concessions, in turn, resulted in the next offer on the part of the supplier: the same power of 5 MW and a more favorable second settlement method, but the margin higher by 0.20 PLN/MWh, that is, equal to 1.90 PLN/MWh. The supplier, based on the analysis of liquidity risk, knows that such parameters of the order and settlement are safeguarded by the margin proposed.

In the eighth round the customer decided to increase the power to 7 MW and the margin, to 1.55 PLN/MWh at the expenses of the settlement method. He chose method #3, less profitable for him. In response, the supplier suggested the same volume and price algorithm, but a lower markup 1.80 PLN/MWh, which covers the potential liquidity risk. The customer counters with an offer of profit margin lower by 0.10 PLN/MWh, but insists on the third settlement method.

In the eleventh round the supplier agrees to the power and margin, but the settlement method remains a contentious issue. The customer suggest a higher margin to compensate for the settlement method and as a result, in the 13th round, the supplier − satisfied with the power at the level of 5 MW and a higher profit margin of 1.80 PLN/MWh − agrees to the third settlement method. According to his analysis, this margin will cover the liquidity risk as high as four days.

In the 13th round the parties achieved a compromise, whereby the customer will be able to order a maximum of 5 MW of power by 8 am, the price will be equal to the average over the transactions on the PEE on the previous day plus the profit margin of 1.80 PLN/MWh.

The compromise was assigned the score of 57.4 pts by the supplier. From the point of view of the customer's evaluation system, the compromise was worth 60 pts. The list of all the offers analyzed in the actual negotiation phase is presented in Table 3.

Table 3: Evaluation of each option by both parties participating in the negotiation process

Negotiation round	**Offer maker**	**Offer: power/settlement method/margin**	**Global score of the offer from the supplier's point of view**	**Global score of the offer from the customer's point of view**
1	2	3	4	5
Round 1	Supplier	1 MW/Settlement 1/1,90	96,2	5
Round 2	Customer	7 MW/Settlement 4/1,00	18	94
Round 3	Supplier	1 MW/Settlement 2/1,80	87,4	20
Round 4	Customer	7 MW/Settlement 4/1,35	25,7	90,5
Round 5	Supplier	3 MW/Settlement 1/1,70	83,6	25

Table 3 cont.

1	2	3	4	5
Round 6	Customer	5 MW/Settlement 4/1,40	38,8	86
Round 7	Supplier	5 MW/Settlement 2/1,90	81,2	35
Round 8	Customer	7 MW/Settlement 3/1,55	35,9	76,5
Round 9	Supplier	5 MW/Settlement 2/1,80	77,4	40
Round 10	Customer	5 MW/Settlement 3/1,70	53,6	65
Round 11	Supplier	5 MW/Settlement 2/1,70	73,6	45
Round 12	Customer	5 MW/Settlement 3/1,80	57,4	60
Round 13	Supplier	5 MW/Settlement 3/1,80	57,4	60

Source: Author's own elaboration.

8 Negotiation process support

Using the information from the offer evaluation system, both parties can use tools which allow for active and passive negotiation process support.

An example of passive support is the use of negotiation history plots (Wachowicz, 2013). Plots of negotiation history for the supplier and the customer in the problem analyzed are presented in Figures 2 and 3.

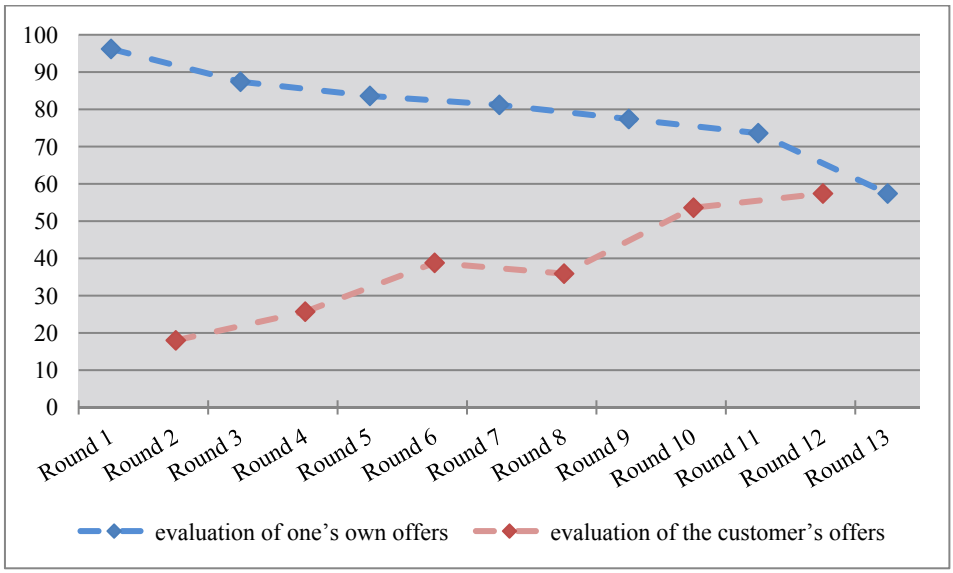

Figure 2. Plot of negotiation history from the supplier's point of view

Source: Author's own calculations.

In the negotiation history plot accessible to the supplier we can see the scores of the agreement variants suggested by the supplier and by the customer[10]. The customer's agreement variants are evaluated according to the supplier's evaluation system. Using this plot, the potential supplier can obtain information as to the customer's response to the offers suggested.

From the point of view of the supplier one can note that the dynamics of his/her compromises is relatively constant: the supplier made the greatest concessions at the beginning and the end of the negotiations. The supplier started the negotiations with an offer evaluated at 96.2 pts and ended with a compromise evaluated at 57.4 pts. The concession scale is therefore 38.8 pts. Worth noting are the supplier's evaluations assigned to the customer's offer. In round 6, the customer suggested an offer evaluated at 38.8 pts, in the next round the supplier countered with an offer evaluated at 81.2 pts (a score lower by 2.4 pts as compared with round 5). In response, in round 8, the customer came up with an offer evaluated by the supplier at 35.9 pts (that is, lower by 2.9 pts as compared with the offer from round 6). This reversal of the evaluation trend does not mean that the customer changed his/her attitude to a tougher one or to non-cooperative behavior, the more so that the same offers are evaluated at 86 and 76.5 pts in the customer's evaluation system. In reality, therefore, the customer made a concession of 9.5 pts between rounds 6 and 8.

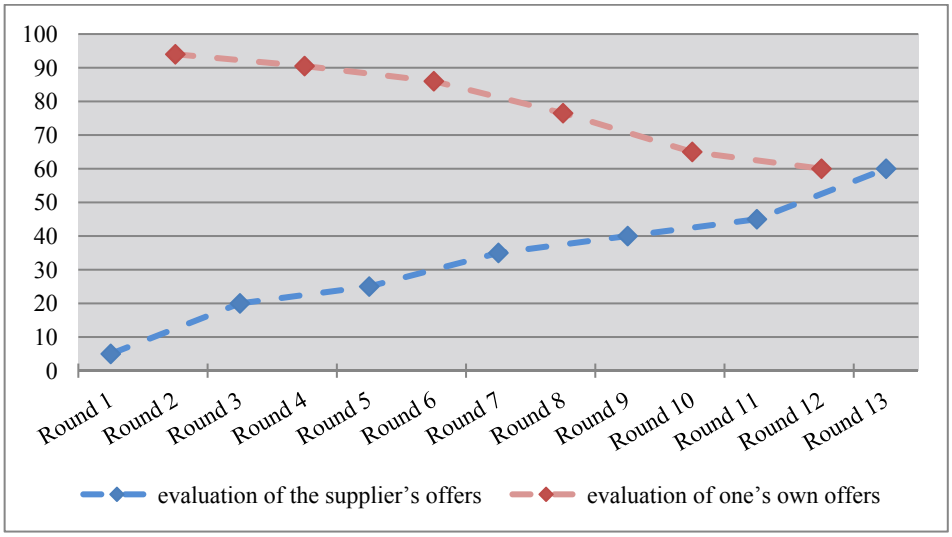

Figure 3. Plot of negotiation history from the point of view of the customer

Source: Author's own calculations.

[10] One should point out that the supplier has no access to the customer's evaluations.

The concession scale of the supplier's offers from the point of view of the customer is 55 pts. The first offer scored 5 pts, while the compromise 60 pts. The customer's range of concessions for round 6 did not exceed 5 pts. In the second half, however, the customer was more inclined to make concessions: in rounds 8 and 10 the scores of offers were lowered by 10 pts on the average.

Active support of the negotiation process consists in suggesting non-dominated negotiation compromises. If the compromise S^{sq} worked out by the parties[11] is not a non-dominated compromise, one can suggest to them a new, non-dominated solution S_i^*.

This way, the selection of the compromise suggested will exhaust the negotiation capabilities of both parties (in the negotiation parlance: the entire negotiation pie will be consumed). The negotiating parties do not have to and do not always agree to select a new, non-dominated negotiation compromise (Wachowicz, 2013).

The compromise reached by the supplier and the customer in the example analyzed is a dominated solution S^{sq} = (57.4; 60)[12]. Active support can include a suggestion to both parties to select instead a non-dominated compromise from among those situated within the domination cone[13].

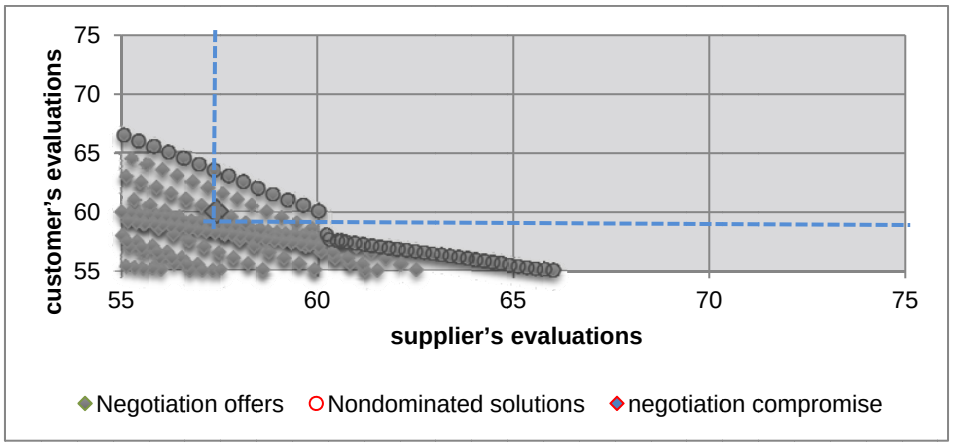

Figure 4. Compromise of the negotiators against non-dominated solutions in the negotiation space

Source: Author's own elaboration.

[11] The *status quo* point, according to game theory and Nash's arbitration scheme is the result of a game in the case when the players have not reached an agreement on their own, see Nash (1950). In negotiation analysis the possibility of using a dominated negotiation compromise was analyzed, instead of a *status quo* point (cf. Kopańska-Bródka, Wachowicz, 2013). So does also the present author.

[12] This compromise is shown in Figure 4.

[13] The domination cone is marked in Figure 4 by a dashed line.

When we deal with a concrete proposal of a dominated compromise, it is easy to identify non-dominated solutions situated within the domination cone. In our case, however, a problem appears: that of the criterion which should be used when selecting the specific non-dominated solution to be presented to the negotiating parties. Various approaches to solve this problem are suggested in the literature[14]. One can use the Euclidean or the taxicab metric which measures the distances between the compromise and the non-dominated solutions within the domination cone. When metrics are used, the recommendation concerns the selection of the solution closest to the compromise in the sense of the metric applied (Wachowicz, 2013).

Another solution proposed is Raiffa's solution of balanced increments. This solution consists in using both negotiators' potential to determine the bliss point $S^* = \left(s_1^*, s_2^*\right)$ on the basis of the status quo $S^{sq} = \left(s_1^{sq}, s_2^{sq}\right)$. In particular, as the point S^{sq} one can take the compromise reached by the parties during the actual negotiation phase.

If the criteria are maximized, S^{sq} lies below the effective limit, while S^* lies above it. The intersection of the straight line determined by these two points with the effective limit is the recommended non-dominated solution $S^{rec} = \left(s_1^{rec}, s_2^{rec}\right)$. This solution can be suggested to the negotiators to improve the joint result. The idea of determining the coordinates of the points S^* and S^{rec} using the negotiation potentials is presented in Figure 5.

Incremental analysis assumes that mixed strategies are recommended as non-dominated negotiation compromises (Kopańska-Bródka, Wachowicz, 2013; Raiffa, 1953).

When the possibility of selecting mixed negotiation compromises is excluded, the use of the effective limit can cause problems. It may be impossible to determine negotiation potentials according to Raiffa's algorithm, since a non-dominated compromise, allowing to determine the point S^* uniquely, does not always exist. This situation is shown in Figure 6.

[14] Suggesting non-dominated negotiation compromises is related to the notion of fair solution. Various approaches to this can be found in: Zeuthen (1930); Nash (1953); Brams (1990); Raiffa et al. (2002).

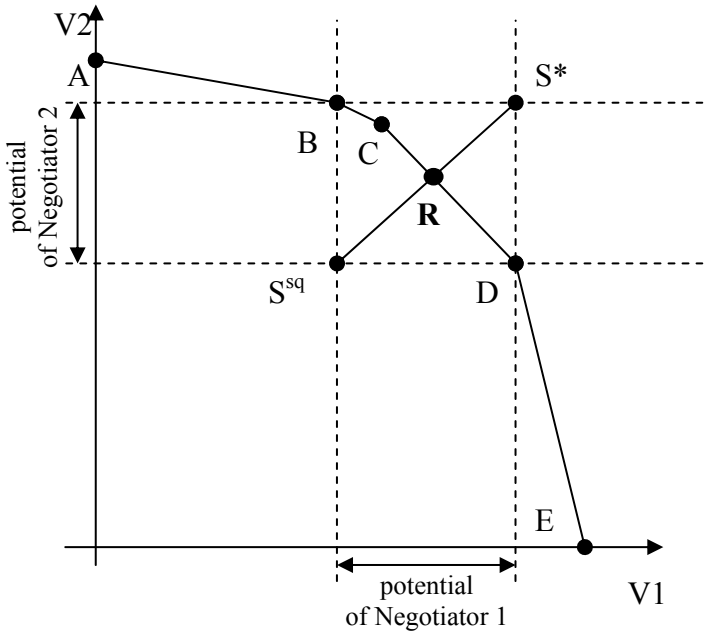

Figure 5. Balanced increment solution based on negotiation potential

Source: Kopańska-Bródka, Wachowicz (2013).

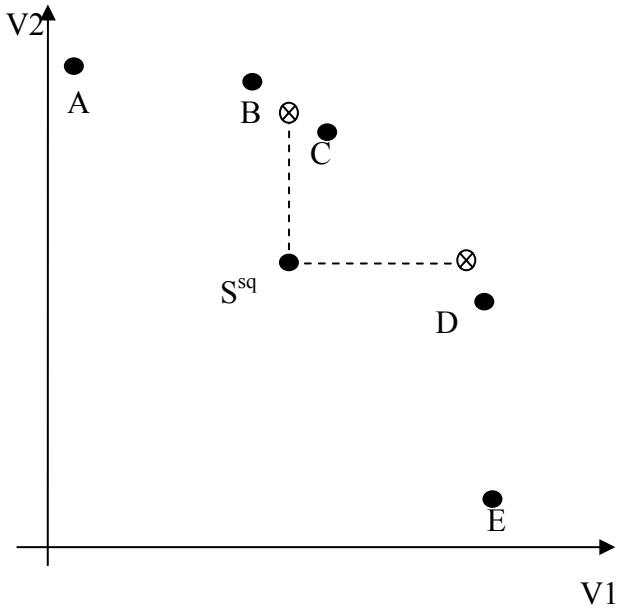

Figure 6. Balanced increment solution in the discrete case

Source: Author's own elaboration based on: Kopańska-Bródka, Wachowicz (2013).

The set of non-dominated solutions in Figure 6 consists of five points *A* through *E*. It can be seen that it is not possible to determine negotiation potentials uniquely. When determining the potential for the first negotiator (scores V1) it is not obvious to which point, *B* or *C*, the straight line from S^{sq} should be drawn. The choice of either point influences the coordinates of S^{*} and therefore the recommended compromise S^{rec}.

This problem can be solved using linear interpolation between the points analyzed. One should keep in mind, however, that the interpolated points between *B* and *C* represent mixed negotiation compromises. As a result, the recommended solution can also be a mixed compromise, which is not always acceptable for the negotiators, since it follows from the detailed characteristics of the negotiation problem. The characteristics of the criterion related to the determination of the settlement method for the purchase order excludes the possibility of recommendation of mixed negotiation compromises.

The classic version of the balanced increment solution can be applied despite these problems. Instead of selecting the determined mixed compromise one can select another pure compromise closest to the mixed one.

The effective limit of the problem analyzed is formed by the straight lines through the points listed in Table 4[15].

Table 4: Points on the effective limit

Points	Scores	
	supplier	customer
A	100	0
B	90	20
C	85	30
D	66	55
E	41	85
F	30	90
G	0	100

Source: Author's own elaboration.

The recommended point is the mixed compromise S^{rec} = (59,61(6);62,66). It lies between two non-dominated points *D* and *E*. These compromises differ only by the implementation of the settlement method. S^{rec} has been determined according to the idea of balanced increments as the intersection of the line through *D* and *E* $v^K = 1{,}2v^S + 134{,}2$ with the line perpendicular to it and passing through

[15] For a detailed algorithm calculating the effective limit using analysis of critical ratios, see Raiffa et al. (2002); Wachowicz (2013).

S^{sq} and the bliss point located above the effective limit $v^K = 1{,}2v^S - 8{,}88$. The variables $v^K$and v^S represent the evaluations of the customer and supplier, respectively.

While rejecting at first the possibility of accepting mixed compromises, one should note that the lines through the point S^{sq} which determine the negotiation potentials are identical with the domination cone for this point. The dominated compromise S^{sq} reached by the negotiators[16] is overlapped by the domination cone which determines the distance from all the non-dominated points included in the cone. The distance is understood here as the difference between the evaluations assigned to non-dominated solutions and those assigned to the compromise S^{sq}. Distances can be interpreted as improvements of the results of each negotiator achievable by selecting any available non-dominated solution. The interpretation of distances refers to Raiffa's potentials.

As the criterion for the recommendation of a non-dominated solution we take the quotient of the improvements of the results as close to 1 as possible. The formula for the improvement quotient (also called increment ratio) can be written as follows:

$$\frac{s_{i1}^0 - s_1^{sq}}{s_{i2}^0 - s_2^{sq}} \to 1,\ s_{i2}^0 - s_2^{sq} \neq 0 \tag{1}$$

where:

$S^{sq} = \left(s_1^{sq}, s_2^{sq}\right)$ is the dominated compromise achieved by the negotiators;

$S_i^0 = \left(s_{i1}^0, s_{i2}^0\right)$ is the *i*th non-dominated solution.

The denominator and numerator of the improvement quotient show how much the evaluations of both negotiators will increase if a specific suggested compromise is chosen. One can say that the increment ratio of evaluations of both parties is an indicator of the improvement of the solution. If this measure is exactly equal to 1, this means that the selection of a new non-dominated compromise will improve the evaluations of both negotiators by the same number of points. In this case one should choose that compromise for which the quotient is as close to 1 as possible. The quotient value greater than 1 means that the improvement of the compromise is more favorable for the negotiator whose evaluations are calculated in the numerator of formula (1). The quotient value smaller than 1 means that the improvement is more favorable for the negotiator whose evaluations are calculated in the denominator of this formula.

[16] Kopańska-Bródka, Wachowicz (2013) also suggest using the compromise achieved by the negotiators instead of point S^{sq}.

The improvement quotient described by formula (1) has a construction flaw: It can be calculated only if the difference of evaluations in the denominator is non-zero. The zero value would mean that the choice of a non-dominated compromise is not related to an increase in evaluation for one negotiator. Moreover, a quotient with 0 in the denominator would be undetermined. To avoid this situation, the difference of evaluations in the denominator must be positive. The construction of the index is therefore sensitive to the order of negotiators. One would have to choose that order for which this quotient can be determined[17].[2]

The ratio of evaluation increments is related to the notion of the proportion of the potential (Raiffa et al., 2002) (POP). The POP indices are calculated separately for each negotiator, taking into accounts the reservation values of each party[18]. The calculation of the improvement quotient, as opposed to POP, requires only points S^{sq} and S^0_i. The quotient itself is calculated jointly for both negotiators.

Within the cone of dominating solutions there are seven non-dominated points denoted from S^0_1 to S^0_7 with the coordinates: S^0_1 = (60; 60), S^0_2 = (59.62; 60,5), S^0_3 = (59.24; 61), S^0_4= (58.86; 61.5), S^0_5 = (58.48; 62), S^0_6 = (58.1; 62.5) and S^0_7 = (57.72; 63). The detailed results of the potential recommendation using various selection criteria are shown in Table 5. Four criteria of the selection of non-dominated compromise were analyzed: taxicab metric, Euclidean metric, Raiffa's balanced increment solution, and the notion of improvement quotient.

Table 5: Evaluations of each option by both negotiating parties

No	Evaluations supplier	Customer	Taxicab metric	Euclidean metric	Raiffa's approach	Improvement quotient
S^0_1	60	60	**2,60**	2,60	2,69	0,00
S^0_2	59,62	60,5	2,72	2,28	2,16	0,23
S^0_3	59,24	61	2,84	**2,09**	1,70	0,54
S^0_4	58,86	61,5	2,96	**2,09**	1,38	**1,03**
S^0_5	58,48	62	3,08	2,27	**1,31**	1,85
S^0_6	58,1	62,5	3,20	2,60	1,53	3,57
S^0_7	57,72	63	3,32	3,02	1,93	9,37

* The values in this column are the distances of the points S^0_1 through S^0_7 from the compromise recommended by the balanced increment solution with the coordinates (59.61(6); 62.66). The distances have been calculated using the Euclidean metric.

** The numerator contains the differences of the customer's evaluations, the denominator – those of the supplier.

Source: Author's own calculations.

[17] In future research it is planned to eliminate this flaw by applying the minimum and maximum functions.

[18] Reservation values: *cf.* Kopańska-Bródka, Wachowicz (2013).

Suggesting non-dominated compromises on the basis of the taxicab metric consists in proposing the point S_1^0 as the closest to the compromise achieved by the negotiators. The selection of the Euclidean metric, on the other hand, changes this recommendation to points S_3^0 and S_4^0 as the least removed from the compromise achieved. The point closest to the mixed compromise calculated by means of Raiffa's approach is S_5^0.

Recommending point S_4^0 agrees with the idea of the improvement quotient. Worth noting is the non-dominated compromise S_1^0, from the point of view of the notion of the improvement quotient. This point, although recommended on the basis of the Euclidean metric, is at the same time evaluated as the worst one by the improvement quotients. This is because the selection of S_1^0 is related to an improvement of the result from 57.4 to 60 pts only for the supplier. Therefore, these measures exclude a point at which the improvement will not occur for one of the parties.

9 Summary

In the era of liberalization of the energy market in Poland an individual approach to each customer, especially to an industrial one, and negotiations of the conditions of agreement will become standard. For that reason it is justified to use methods supporting negotiations in this area.

The scoring method, being a modification of one of the simplest multicriteria method, is relatively simple. Nonetheless, the evaluations of negotiation issues and of levels of their implementation are critical for the negotiators. Their results interweave throughout the entire negotiation process and, as a result, influence the negotiation compromise.

The notion of the increment quotient proposed here is a simple and fairly intuitive measure which explicitly shows the improvement of the results of both negotiators. However, it is not always possible to calculate it because of its quotient construction. Further research will include a modification of its construction so as to eliminate the indefinite symbols in the result.

Moreover, the improvement of the result by the same number of points, that is, absolutely, does not have to mean the same improvement relatively. For that reason, in future research, a construction of this index for relative (percentage-wise) improvement will be considered.

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