Group Decision Making for Selection of Supplier Under Public Procurement

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Abstract. The article deals with problem of group decision making for selection of supplier under public procurement. For the goal, a generalized algorithm for multi-attributes group decision-making is proposed. The distinguish feature of the described algorithm is consideration of knowledge and experience of each expert from the group by using of weighted coefficients. Simple additive weighting and weighted product model are modified to cope with the differences in experts' knowledge and experience. The applicability of proposed group decision making algorithm is illustrated by using of new modified utility functions for simple additive weighting and weighted product model. The numerical testing considers a real-life problem for selection of the most preferable supplier of personal computers under a public procurement. The results demonstrate the flexibility of proposed approach when using a group of experts with different expertise.

Keywords: Multi-attribute group decision making · Simple additive weighting Weighted product model · Optimization techniques · Pure integer linear model

1 Introduction

In the contemporary economics, proper supplier determination becomes a key strategic decision for success of different business activities. The process of selection takes into account two major factors: the presence of useful information for evaluation of parameters and corrupt behavior possibility [10]. The supplier selection problem is recognized as a complex problem consisting of both quantitative and qualitative criteria [4, 9]. In most cases, these evaluation criteria are in conflict. The availability of qualitative and quantitative criteria, require they to be evaluated simultaneously in decision making process [12]. To be more transparent, the selection process should involve a group of experts with different skills, experience and knowledge capable to evaluate all of the criteria [2, 8]. All of these considerations received relatively large amount of attention in both academia and industry by proposing of different approaches to tackle with problems of selection [5, 10]. This requires involving different analysis and techniques to support business decision making processes [2]. Using of business

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intelligence tools improve decision making and optimize business processes that contribute to the business competitiveness.

The supplier selection for the goal of public procurement is an important case of group decision making where spending of funds has to be public. An increased interest in public procurement is observed over the last few decades, as the purchase of goods by the public sector is increased [7]. The public procurements are to be transparent and in accordance to legislation, administrative regulations and should follow particular public procurement procedures. Different mathematical methods and models are proposed for supplier selection in procurement environment. Systematic reviews of literature for application of decision making techniques in supplier selection are given in [3, 11]. Compensatory strategies in decision making rely on rational decision choices based on multi-attribute utility models [6]. These utility models represent the preferences of the expert and very often are expressed as a sum of the utilities that each criterion determines [5]. Most commonly used method based on compensatory strategy is simple additive weighting (SAW). The SAW does not consider the different preferential levels and preferential ranks for each decision maker's assessment of alternatives in a decision group [1]. A very similar to SAW is weighted product model (WPM) where the main difference is that instead of addition in the model utility function multiplication is used [13]. The key idea of the both methods based on multi-attribute utility theory relies on construction of utility function used to evaluate given alternatives toward performance criteria.

In the article, the multi-attribute utility theory is used to formulate a combinatorial optimization decision making model in group environment. The proposed model is applied for supplier selection under a public procurement. The final choice relies on evaluations of group of experts capable to estimate given set of alternatives in respect of predefined quality and quantity indicators. The proposed in the article modeling approach takes into account the difference in knowledge and experience of expert within the group.

The rest of the article is structured as follows: Sect. 2 describes the problem for supplier selection. Section 3 is focused on generalized algorithm for group decision making considering the differences in experts' knowledge and expertise. Section 4 describes application of the proposed modification of SAW and WPM for group decision making while Sect. 5 presents obtained results, and conclusions are given in Sect. 6.

2 Problem Description

The considered decision making problem consists in selection of the most preferable supplier for delivery of personal computers (PCs) in accordance to a public procurement. There exist a number of suppliers with different PCs offers and the choice must be done by a group of different experts which are relevant to the problem. The experts in the group have expertise in different (but related to the problem) fields. This means that their evaluations are with different importance accordingly to their relevance to the problem. Each supplier (vendor) is considered as possible alternative that can be described by different parameters expressed as evaluations criteria. The most preferred alternative should be determined by considering all of the above considerations.

3 Generalized Algorithm for Group Decision Making

To support the business decision making processes by business intelligence, a generalized algorithm for group decision making considering the differences in experts' knowledge and expertise is proposed. This algorithm is composed of nine stages as shown in Fig. 1.

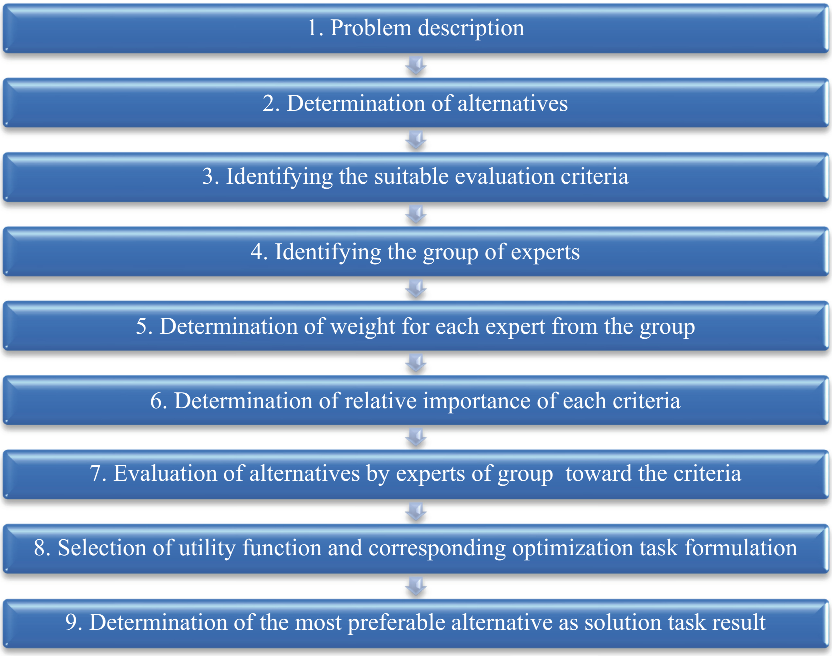

Fig. 1. Generalized algorithm for group decision making

The first stage concerns the description of the existing group decision making problem. The 2-nd stage considers the determination of a set of acceptable alternatives appropriate to cope with the goal of problem. Next stage is focused on determination of important criteria for evaluation of the alternatives. Stage 4 deals with determination of relevant group of competent experts in the area of the problem. On 5-th stage the corresponding weighted coefficients for the experts' knowledge and experience are to be set. Next stage requires determination of relative importance between criteria by assigning of corresponding weighted coefficients in accordance to the point of view of each expert. On the 7-th stage the evaluation of alternatives toward criteria from all experts are to be done. At this stage, normalization may be needed depending on the units of dimension for evaluation criteria. The applied normalization transforms experts' evaluations are in the range of 0 to 1 in dimensionless units.

The stage 8 concerns the choice of proper utility function and formulation and solving of corresponding optimization task. This task should incorporate the information from the above stages including: (1) weights for experts from the group, (2) performance of alternatives in accordance to the evaluation criteria, (3) weights for relative importance of evaluation criteria. In the last stage, the solution of the optimization task will give information for the best alternative performance considering different point of view of the experts.

In the article, two types of utility functions based on SAW and WPM are used to define corresponding combinatorial optimization models for group decision making. The proposed mathematical pure integer linear model based on modification of SAW is as follows:

$$\text{maximize}\left(\sum_{i=1}^{M}\sum_{k=1}^{K}\sum_{j=1}^{N} w_j^k a_{i,j}^k \lambda^k x_i\right) \tag{1}$$

subject to

$$\sum_{j=1}^{N} w_j^k = 1, \forall k = 1,\ 2, \ldots, K \tag{2}$$

$$\sum_{k=1}^{K} \lambda^k = 1 \tag{3}$$

$$\sum_{i=1}^{M} x_i = 1,\ x_i \in \{0,\ 1\} \tag{4}$$

where w_j^k are coefficients for relative importance between criteria for k-th expert point of view, $a_{i,j}^k$ represents the i-th alternative evaluation to j-th criterion from k-th expert. The following sets are used in this formulation are: (1) set of alternatives to get the final selection $\{i = 1, 2, \ldots, \mathrm{M}\}$; (2) set of evaluation criteria $\{j = 1, 2, \ldots, \mathrm{N}\}$; (3) set of experts $\{k = 1, 2, \ldots, \mathrm{K}\}$; (4) set of decision variables $\{x_i\}$ assigned to each alternative; (5) set of weighted coefficients for experts $\left\{\lambda^k,\ k = 1, 2, 3,\ \ldots, \mathrm{K}\right\}$ representing their level of expertise and knowledge.

The proposed modification of WPM for group decision making is as follow:

$$\text{maximize}\left(\sum_{i=1}^{M}\sum_{k=1}^{K} x_i \lambda^k \prod_{j=1}^{N} (a_{i,j}^k)^{w_j^k}\right) \tag{5}$$

subject to the same restrictions (2)–(4).

Here multiplication $\prod_{j=1}^{N}\left(a_{i,j}^{k}\right)^{w_j^k}$ expresses the performance of *i-th* alternative toward *j-th* evaluation criteria accordingly *k-th* expert' opinion.

The group decision making process is managed by a leader of higher management responsible to organize overall decision making process including: identification of possible alternatives and determination of essential criteria for evaluation of alternatives. He also determines the weighted coefficients that express the knowledge and experience of group members or uses the values provided by other competent authorities for the purpose of considered problem. The leader is authorized to make the final decision or to propose most appropriate alternative to higher management. The distribution of responsibilities between leader and group members in the group decision-making process are illustrated in Fig. 2.

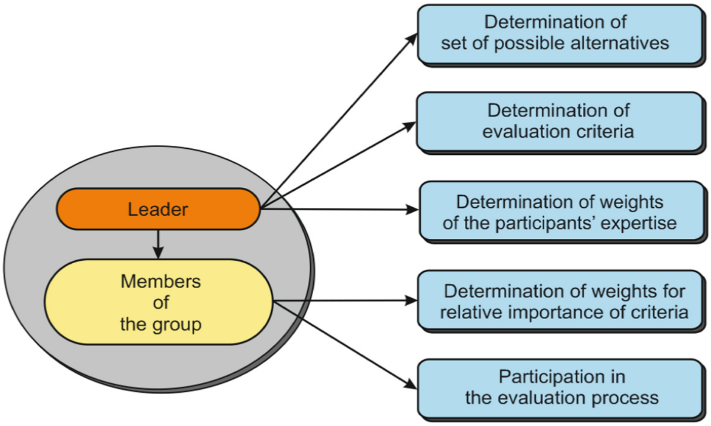

Fig. 2. Distribution of responsibilities between leader and group members

All of the described above data are used to formulate a combinatorial optimization task (on stage 8), which decision determines the most preferable alternative (on stage 9).

4 Numerical Testing

Three offers from different suppliers for delivery of PCs are considered as three possible alternatives (A-1, A-2, A-3). Each supplier is evaluated by 12 quality and numeral criteria: (1) technical performance; (2) bid price; (3) price breaks and quantity discounts; (4) payment terms – possibility of deferred payment; (5) warranty; (6) out-of-warranty service; (7) number of available repair shops; (8) availability of experienced staff; (9) certifications; (10) previous experience; (11) lead time; (12) customer recommendations.

The criterion for technical performance of PCs incorporates processor type, core and frequency, memory frequency, type and volume, graphics resolution and available ports, keyboard type and existence of installed operating system. The bid price criterion is related with the price for a single unit and the offered price for PCs delivery as a whole. The criteria for payment terms and price breaks and quantity discounts consider the possibility of different payment options – payment on delivery, in advance or deferred payment as well as the possibility for decreasing of cost per unit of goods for certain quantity. The criteria for warranty terms and out-of-warranty service conditions are used to guarantee as much as possible flawless working of purchased PCs. The criteria for number of repair shops and experienced staff examine how quick and qualitative will be handling of possible problems. Availability of certifications and previous experience are indicators for reliability of the supplier. Lead time is essential criterion as it determines the needed time between the initiation of contract and delivery. Last but not least, for evaluation criterion is information about satisfaction of other customers and their recommendations.

The group of five authorized experts relevant to the problem (excluding leader of the group) are selected to evaluate the alternatives: financial consultant (E-1), two IT specialists (E-2 and E-3), system administrator (E-4), and manager (E-5). Each expert of the group determines the importance of all criteria by assigning of corresponding weighted coefficients in accordance to his point of view.

All of the described data together with normalized evaluation scores from experts' point of view toward the performance of alternatives in accordance to the given criteria are shown in Table 1.

Table 1. Modified weighted decision matrix

Experts	Alternatives	Evaluation criteria											
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Criteria weights		0.08	0.10	0.09	0.09	0.08	0.07	0.08	0.08	0.09	0.08	0.07	0.10
E-1	A-1	0.76	1.00	0.72	0.82	0.76	0.56	0.69	1.00	0.68	0.66	0.66	0.56
	A-2	0.83	0.88	0.78	0.93	0.77	0.58	0.65	0.93	0.79	0.76	0.68	0.55
	A-3	0.81	0.90	0.76	1.00	0.72	0.66	0.72	0.92	0.74	0.75	0.70	0.63
Criteria weights		0.11	0.07	0.07	0.06	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.09
E-2	A-1	0.81	0.85	0.73	0.67	0.67	0.89	0.73	0.67	0.74	0.85	0.80	0.93
	A-2	0.84	0.78	0.76	0.65	0.77	0.91	0.75	0.69	0.78	0.82	0.81	0.85
	A-3	0.82	0.74	0.73	0.72	0.72	0.82	0.78	0.65	0.79	0.78	0.73	0.91
Criteria weights		0.15	0.06	0.06	0.06	0.11	0.10	0.09	0.09	0.06	0.06	0.07	0.09
E-3	A-1	0.86	0.81	0.78	0.77	0.95	0.82	0.84	0.82	0.81	0.76	0.96	0.79
	A-2	0.72	0.79	0.76	0.81	0.83	0.76	0.70	0.81	0.78	0.79	0.89	0.82
	A-3	0.81	0.78	0.79	0.69	1.00	0.80	0.79	0.88	0.83	0.72	1.00	0.76
Criteria weights		0.13	0.06	0.06	0.06	0.12	0.11	0.09	0.08	0.06	0.07	0.08	0.08
E-4	A-1	1.00	0.85	0.61	0.62	0.95	0.93	0.73	0.73	0.94	0.85	0.85	0.93
	A-2	0.88	0.74	0.66	0.66	0.96	1.00	0.75	0.79	0.88	1.00	0.92	0.88
	A-3	0.92	0.76	0.73	0.75	0.83	0.91	0.78	0.76	1.00	0.88	0.78	0.90
Criteria weights		0.10	0.10	0.10	0.10	0.10	0.06	0.06	0.07	0.06	0.09	0.10	0.06
E-5	A-1	0.92	0.79	0.88	0.73	0.83	0.78	1.00	0.73	0.72	0.76	0.63	0.84
	A-2	0.78	0.88	1.00	0.72	0.84	0.71	0.88	0.74	0.75	0.78	0.68	1.00
	A-3	0.84	0.76	0.82	0.68	0.88	0.73	0.91	0.79	0.81	0.82	0.69	0.86

5 Results and Discussion

The numerical testing is based on a real-life problem for selection of supplier for PCs under public procurement procedure. The flexibility of proposed approach is illustrated by using of different sets of weighted coefficients for importance of experts' opinions in the group. The data from Table 1 are used to formulate the corresponding optimization tasks. Their solution results are shown in Table 2.

Table 2. Solution results

Sets	Coefficients for expertise of the group members					Selected alternative by modified SAW	Selected alternative by modified WPM
	E-1	E-2	E-3	E-4	E-5		
Set-1	0.20	0.20	0.20	0.20	0.20	A1	A3
Set-2	0.25	0.10	0.15	0.25	0.25	A3	A3
Set-3	0.27	0.12	0.13	0.18	0.30	A2	A3

Using of different weighted coefficients for expertise of group members' influence essentially the final selection of the most preferable alternative. The consideration of equal expertise for all group members (set-1) leads to choice of alternative A-1 for modified SAW and A-3 for modified WPM. The weighting coefficients from set-2 put more weights on opinions of experts E-1, E-4 and E-5 followed by the importance of experts E-2 and E-3. In this case, the defined preferable alternative is A-3 for both models. When the major attention is paid on opinions of experts E-5 and E-1 and lees on experts E-2, E-2 and E-4, the most preferable alternative is A-2 for modified SAW and A-3 for modified WPM.

From Table 2 it is seen that the modified SAW is more sensitive than modified WPM in determination of different choices of alternatives when different weighted coefficients for expertise of the experts are defined. Additional experiments are to be done to prove this fact. Nevertheless, both proposed modifications of SAW and WPM could be used for group decision making to determination of the most preferable alternative.

6 Conclusions

Two of the most widely used methods for group decision making (SAW and WPM) are modified by introducing a weighting coefficients of group decision making experts' opinions. The key idea of the proposed approach relies on construction of utility functions used to evaluate potential alternatives toward performance criteria taking into account the differences in knowledge and experience of the group experts. The including of weighting coefficients for expertise of each group members' adds flexibility in group decision making process. Using of these coefficients allow determination of optimal alternative in accordance to the experts competency and conforms better to the organization goals.

The described modifications of SAW and WPM are implemented in a generalized algorithm for group decision-making. The practical usability of the described approach was confirmed by numerical testing on an example of real-life problem for PCs supplier selection under public procurement requirements.

Future studies need to be done to make a more robust comparison of the practical application of the modified SAW and WPM methods. It is also interesting how similar modifications of other group decision methods will perform in practice.

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