

Original scientific paper

**SUPPLIER RANKING IN MINING SYSTEMS IN TERMS OF QUALITY,
CASE STUDY: PUBLIC COMPANY FOR UNDERGROUND COAL
EXPLOITATION RESAVICA**

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Received: September 15, 2019

Accepted: October 8, 2019

Abstract The aim of this paper is to show the application of multi-criteria analysis (PROMETHEE method) in the selection of the suppliers which are working in the mining systems, specifically in the Public Company for the Underground Exploitation of Coal Resavica (PCUEC Resavica)- Serbia. The company ranking was done in terms of quality according to seven criteria. The criteria cover the most prominent aspects of the quality management of suppliers. Accordingly, 5 suppliers were taken into consideration. In ranking process the expert knowledge of the specialists from PCUEC Resavica was used. Firstly, the determination of the importance and the impact of certain criteria to the process of the suppliers selection was done, and after that the assessment of the suppliers according to each criteria is performed by company experts. PROMETHEE method is used for final ranking of the suppliers. Obtained results show that applied combined method gives excellent results and it can be used for solving a large scale of complex problems in mining systems.

Keywords: supplier selection; production systems; ranking; mining systems; PROMETHEE

1 INTRODUCTION

Suppliers selection is one of the most important task for mining managers with aim to create a long-term sustainability and stability of the company. Strategic decision include forming the optimal supply chain with the suppliers who is able to follow a change in innovation in the phase of designing new products (Croom, 2001), to provide the constant supply of the raw materials, spare parts, etc. The proper choice of suppliers has important impact on organization because it can reduce the operative costs and improve the quality of its final products (Zeydan et al., 2011). Also, if the strategic relationship

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with suppliers is established, a long term competitive advantage and improvement of organizational performances can be achieved (Lima et al., 2013). The supplier selection process implies application of different statistical techniques, as well as the Multi-Criteria Decision Making methods (Wu and Olson, 2008; Chai et al., 2013). Generally, the suppliers selection process can be seen through following phases: defining the need for a new supplier, defining the criteria for decision making, choice of the best ranking supplier and continuous monitoring, assessment, and evaluation of the chosen supplier. There are many studies that show different methods for the supplier selection in different contexts (Mafakheri et al., 2011; Vanteddu, 2011; Lin, 2012; Ekici, 2013; Qian, 2014).

The multi-criteria analysis methodology represents a good basis for solving proposed problem. This methodology allows to managers to obtain a priority list, based on ranking the alternatives by many different, opposite and often contradictory criteria at the same time. Also, the decision maker must have a big amount of relevant data for analysis in order to obtain the correct results. The most well-known methods are analytic hierarchy process (AHP), analytic network process (ANP), TOPSIS and PROMETHEE. PROMETHEE method has many advantages compared with other methods. The most important advantage is its capacity for obtaining results in the contradictory condition and criteria.

The basic aim of this paper is to solve the suppliers selection problem by applying the PROMETHEE method based on the expert knowledge of specialists from mining company for ranking of their suppliers in terms of quality. The researches has been done in the PCUEC Resavica (case study).

The ranking process is done by Decision Lab software which supports PROMETHEE method and enables sensitivity analysis. Also, this software supports the visual tool called GAIA plan for identification of conflicts among criteria and for grouping of the alternatives (Albadvi et al., 2007).

2 SUPPLIERS MANAGING IN MINING SYSTEMS

The growth in demand of mining products lead to a higher development of mining technique, such as machines and equipment, and more complex their maintenance respectively. In accordance to that, the contemporary mining systems require more compound and detailed planning and control of all technical, technological and other processes. All this requires the procurement of appropriate equipment, raw materials, energy, spare parts, etc. But it is not an easy task, followed by the right quality, the right price, the deadlines, etc. This complex process is accompanied by great risks, which is why it is of the utmost importance for the mining company to do the right research to find the optimal solution for the selection of reliable potential suppliers. Consequently, the process of identifying reliable suppliers and selecting them is very demanding process. Many experts consider suppliers selection as one of the most complex activities in the procurement sector (Xia and Wu, 2007).

According to De Boer et al. (2007) supplier selection process has several phases such as defining problem, formulating criteria, identifying potential suppliers, and making a final decision. The quality of the final selection depends largely on the quality of all the steps involved in this process. Thus, the first step in the process of the suppliers selection is defining what we want to accomplish with the supplier selection. The decision to choose a supplier is much more complicated due to the fact that different criteria have to be taken into account in this decision-making process. Also, the performance of suppliers vary from criteria to criteria (Liu and Hai, 2005). Since that this process is followed by uncertainty, companies have the tendency to manage their suppliers in different way such as forming supplier-supplier link, evaluation of suppliers, supplier selection, organizations of suppliers, coordination of suppliers, etc. (Jain et al., 2009). Strategic assessment of supplier includes the monitoring and consideration of supplier's practice such as management, quality, finance, etc. as well as, supplier's ability – technical skills, co-design ability, the reducing cost ability, etc. (Dowlatshahi, 2000). Mining companies can achieve the competitive advantage, lower exploitation costs, enhance the maintenance of the equipment, etc. by managing of the suppliers. In this way, mining companies can increase the reliability in the work and enhance the profit. In order to do that, mining companies must select the best suppliers and maintain long-term and profitable relationships with them, with aim to achieve the growth and to survive in the market.

3 PROMETHEE METHOD

PROMETHEE is a ranking method based on the selection of the best preference function and the weight coefficients for each criteria. Preference function determines the way of ranking a certain alternative according to another alternative and translates the deviation between them. PROMETHEE method has at his disposal 6 forms of preference (Usual, U – shape; V- shape; Level, Linear, Gaussian). Each form depends on two indifference thresholds (Q and P). Threshold (Q) represents the maximum deviation which the decision maker sees as unimportant, while the indifference threshold (P) represents the minimum deviation which is considered to be important for the decision maker. Threshold Q must not be higher than P. Gaussian threshold (s) is the intermediate value of P and Q thresholds.

PROMETHEE method calculates the positive-entrance flow (Φ^+) and the negative-exit flow (Φ^-) for each alternative according to the outranking relations, in accordance with weight coefficients for each criterion. The positive preference flow shows the significance of a certain alternative, i.e. the higher value ($\Phi^+ \rightarrow 1$), the more significant is the alternative. The negative preference flow (Φ^-) shows how a certain alternative is preferred in accordance with the other alternatives. The smaller value of the exit flow ($\Phi^- \rightarrow 0$) indicates more significant alternative.

Complete ranking (PROMETHEE II) is based on the value of the net flow (Φ), which represents the difference between the positive and the negative preference flow. The best ranked alternative is the one with the highest value of the net flow.

4 CASE STUDY

Public Company for the Underground Exploitation of Coal Resavica (PCUEC Resavica)- Serbia is a very complex system for coal exploitation and processing in Serbia. This system has eight mines located in central part of Serbia (Figure 1).



Figure 1. Mines of PCUEC Resavica

The complex system like this demands a wide range and reliable suppliers which can meet its needs. This task is very difficult and it is necessary to apply a certain model that can evaluate and assess the suppliers in order to obtain their rank. In this paper is proposed the model of supplier selection according to the provided quality of services and goods to PCUEC Resavica. The model consists several phases – Figure 2.

Creation of selection committee is the first step. It consists of procurement experts and technical executives from the company. They identify the criteria and determine their impact, as well as the supplier's assessment of each criteria.

Criteria identification is next step, which is extremely important for supplier selection. The criteria represent one of the most important factors for the process of supplier

ranking. In this paper, the focus is on the quality of services and goods provided by suppliers to PCUEC Resavica. The reason is that quality is the most important in procurement process according to experts in PCUEC Resavica, and it slowly suppresses other criteria such as price, service, etc. The quality can be defined as level of satisfaction, requirements, and expectations of services and goods provided by suppliers. The most important criteria of quality defined by selection committee are: shelf life (C1), status of the ISO certificate (C2), quality management (C3), product performance and compatibility with standards (C4), product rejection degree at the initial quality control (C5), degree of repaired and returned products (C6) and product corrections according to the feedback from the buyers (C7).

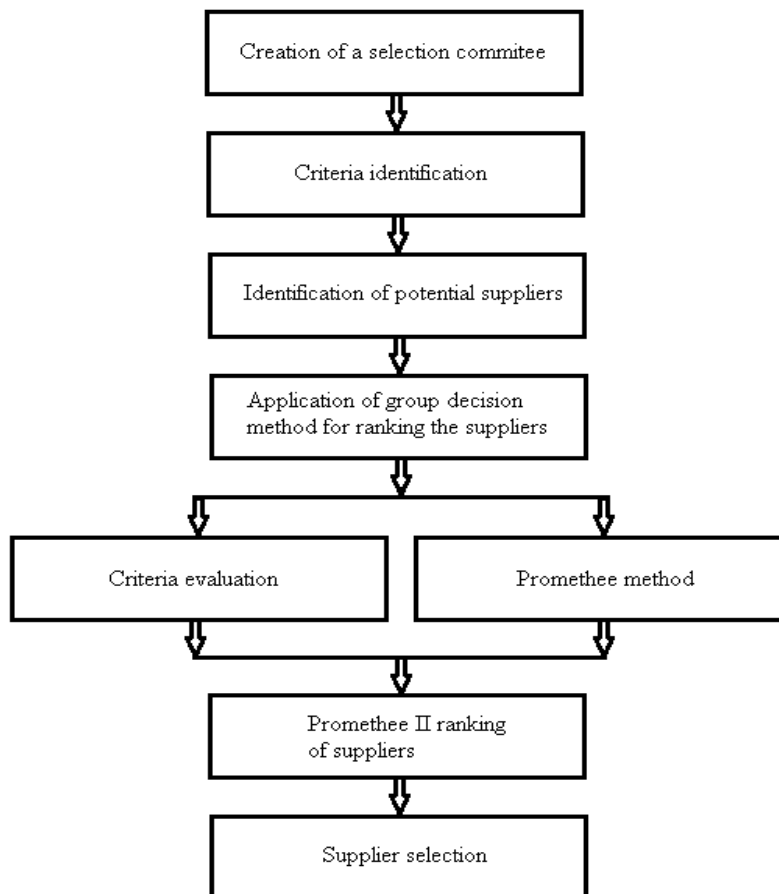


Figure 2. Proposed model for supplier selection

Identification of potential suppliers is next step of a selection model. For supplying of the PCUEC Resavica apply several suppliers. In this paper are identified five potential suppliers which are labeled 1; 2; 3; 4 and 5.

The next step is application of group decision method for ranking the suppliers. This is the most important, but also the most complex stage of the proposed decision model. This is executed by ten experts from PCUEC Resavica (E1 – E10) who are directly involved with suppliers and who use the products and services provided by the suppliers (members of the selection committee – managers, supervisors, employees in the procurement departments, employees in the manufacturing and maintenance sectors).

Their first task was to evaluate criteria, i.e. to determine the weight coefficients which represent their magnitude of the impact to the result of ranking of the suppliers. The weight coefficients of the criteria is determined by each expert, by filling the table grading the importance of the criteria from 0 to 1, where the sum of all weight coefficients should be 1. Table 1 shows results of evaluation of the criteria, as well as the middle value of their weight coefficients.

Table 1. Value of criteria weight coefficients obtained from experts, as well as their middle value

Expert Criteria	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	Middle value
C1	0,25	0,15	0,2	0,2	0,2	0,25	0,2	0,15	0,15	0,1	0,185
C2	0,1	0,15	0,15	0,1	0,1	0,15	0,2	0,15	0,1	0,2	0,140
C3	0,1	0,2	0,15	0,15	0,1	0,2	0,25	0,2	0,1	0,2	0,165
C4	0,15	0,2	0,2	0,25	0,3	0,15	0,1	0,2	0,35	0,2	0,210
C5	0,2	0,1	0,1	0,1	0,1	0,05	0,05	0,1	0,1	0,1	0,100
C6	0,1	0,1	0,1	0,1	0,1	0,15	0,05	0,05	0,1	0,1	0,095
C7	0,1	0,1	0,1	0,1	0,1	0,05	0,15	0,15	0,1	0,1	0,105
Sum	1	1	1	1	1	1	1	1	1	1	1

Table 1 clearly shows the criteria C4 (product performance and compatibility with standards) has the highest influence on the result of ranking since its weight coefficients is 0,210. On the other side, the criteria C6 (degree of repaired and returned products) has the lowest influence on ranking results, since its weight coefficients is 0,095

After criteria evaluation, the PROMETHEE method is used for evaluation of the suppliers. Due to the qualitative or uncertain structure (assessment of suppliers) of the decision process, the appropriate qualitative five levels scale is used to enable quality comparison of the suppliers. Table 2 shows the qualitative scale with the numeral value for each qualitative mark.

Table 2 Qualitative scale

Qualitative value	Very low	Low	Middle	High	Very high
Numeral value	1	2	3	4	5

In order to create the evaluation matrix for PROMETHEE method, the evaluation of the suppliers in respect to the criteria has to be done. This is done by the same ten experts from the PCUEC Resavica. They have filled the table thus assessing the suppliers with marks given in Table 2. Table 3 shows the results of suppliers assessments expressed through the middle value of all marks based on the marks given by all the experts.

After evaluation of the suppliers, the evaluation matrix for PROMETHEE method is created (Table 4). The level shape of preference function is chosen according to the qualitative character of data for criteria and alternatives. The indifference and preference thresholds (Q and P) values are chosen in 5% and 30% zones, respectively.

Table 3 Middle value of suppliers marks in respect to the criteria

Supplier Criteria	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
C1	3,3	3,7	3,8	4,4	4,4
C2	3,4	4,5	4,5	4,9	4,9
C3	3,4	4,4	4,1	4,3	4,2
C4	3,2	4,2	4,1	4,4	4,2
C5	3,5	4,0	4,0	4,1	3,8
C6	3,2	3,7	4,2	4,0	3,9
C7	3,7	3,9	4,2	4,2	4,2

Table 4 Evaluation matrix

Criteria	C1	C2	C3	C4	C5	C6	C7
Max/min	max	max	max	max	max	max	max
Weight coeff.	0,185	0,140	0,165	0,210	0,100	0,095	0,105
Function of preference	Level	Level	Level	Level	Level	Level	Level
Supplier 1	3,3	3,4	3,4	3,2	3,5	3,2	3,7
Supplier 2	3,7	4,5	4,4	4,2	4,0	3,7	3,9
Supplier 3	3,8	4,5	4,1	4,1	4,0	4,2	4,2
Supplier 4	4,4	4,9	4,3	4,4	4,1	4,0	4,2
Supplier 5	4,4	4,9	4,2	4,2	3,8	3,9	4,2

Base on evaluation matrix, the software Decision Lab is used for evaluation of the suppliers (alternatives). Table 5 shows the value of the positive (Φ^+), negative (Φ^-) and net flows (Φ) for suppliers ranking, taken from the Decision Lab software.

Table 5 PROMETHEE preference flows

Alternatives	Φ^+	Φ^-	Φ
Supplier 1	0,0000	0,1631	-0,1631
Supplier 2	0,0381	0,0000	0,0381
Supplier 3	0,0175	0,0000	0,0175
Supplier 4	0,0669	0,0000	0,0669
Supplier 5	0,0406	0,0000	0,0406

The complete ranking of suppliers is done by PROMETHEE II (Figure 3). Here, the values of the flows (Φ) from the last column of Table 5 are used for ranking.

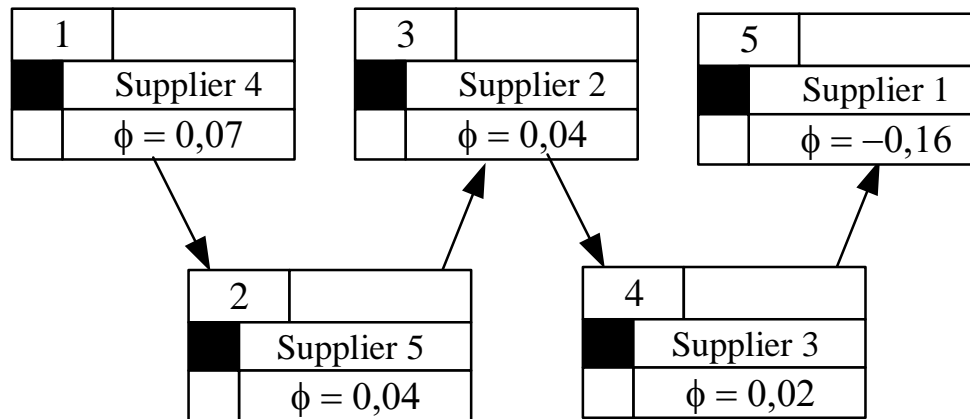


Figure 3 PROMETHEE II complete suppliers ranking

According to PROMETHEE II complete ranking, the best alternative is supplier 4. The other suppliers are ranked in this order: supplier 5, supplier 2, supplier 3 and supplier 1 (Figure 3).

The last step of the proposed model is supplier selection. On the basis of realized complete procedure defined by the applied model of decision making, i.e. choosing the best supplier in terms of quality of goods and services for PCUEC Resavica, it was decided that the best one is supplier 4. So, for future procurement supplier 4 is finally selected.

5 THE ANALYSIS OF OBTAINED RESULTS

The analysis starts from criteria. All criteria can be divided into two global groups in terms of their importance for suppliers ranking. The first group of criteria is consisted of most influential criteria – C4 (product performance and compatibility with standards), followed by C1 (shelf life), C3 (quality management) and C2 (status of the ISO certificate). It means that for PCUEC Resavica experts the most important aspects are to get the adequate products, immediately usable, without the need for refinement, alteration and return to the supplier. Otherwise, this represents an additional obligation, while waiting for the right product, and part of the production suffers as a result.

The second group of criteria consists of less influential criteria (about 10% for each one) – C7 (product corrections according to the feedback from the buyers), C5 (product rejection degree at the initial quality control) and C6 (degree of repaired and returned products). This indicates that product corrections, product rejections and production return are much less acceptable by experts. According to this, for experts are much more important the criteria that enable the selection of better suppliers – criteria from first group.

As far as suppliers are concerned, the best one is supplier 4. This supplier has the best marks from the aspect of the criteria C4 (product performance and compatibility with standards) and C5 (product rejection degree at the initial quality control). From the aspect of the rest of the criteria, this supplier has got good marks which are mostly in the same level comparing with the second ranked supplier 5.

On the second place in ranking is supplier 5. This supplier has a bit weaker, or almost the same marks, compared with the first ranked supplier in all criteria.

The third place is taken by the supplier 2. It is the best according to the criteria quality management (C3). From the aspect of the other criteria, it was is rated lower than the top two ranked suppliers.

Supplier 3 is on the fourth place. It is the best, or shares the first place with the other suppliers in in term of criteria C6 (degree of repaired and returned products) and maintenance C7 (product corrections according to the feedback from the buyers).

The last place is taken by the supplier 1, which is the lowest rated in terms of all the criteria.

Based on the obtained results, the advantage needs to be given to the supplier 4 which is the best compared with the other suppliers.

6 CONCLUSION

In this paper is applied PROMETHEE decision method for ranking of the suppliers in PCUEC Resavica in terms of the quality of their goods and services. Based on ranking results, the best suppliers is selected in order to provide a long-term sustainability and stability of the company. In this process are analyzed five suppliers (supplier 1, 2, 3, 4 and 5) in terms of seven criteria for ranking – shelf life (C1), status of the ISO certificate (C2), quality management (C3), product performance and compatibility with standards (C4), product rejection degree at the initial quality control (C5), degree of repaired and returned products (C6) and product corrections according to the feedback from the buyers (C7).

Based on the obtained results by PROMETHEE method, it is selected the best suppliers, which is supplier 4. The most influential criteria for ranking is the criteria C4 (product performance and compatibility with standards).

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