XVII International Scientific Conference on Industrial Systems (IS'17)
Novi Sad, Serbia, October 4. – 6. 2017.
University of Novi Sad, Faculty of Technical Sciences,
Department for Industrial Engineering and Management
Available online at http://www.iim.ftn.uns.ac.rs/is17

SUPPLIER EVALUATION CRITERIA: AHP ROUGH APPROACH

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Abstract

Logistics subsystem of procurement causes high expenses with significant influence on supply chain management (SCM). Therefore, it is necessary to optimise first phase of logistics in order to reach operational efficiency. To take into account these aspects this paper proposes methodology for defining the most important criteria for the supplier evaluation and selection. From a set of twenty criteria that were established i.e. four sets of criteria: finances, logistics, quality and communication and business which containing its sub-criteria we allocated the most important for supplier selection. Analytic Hierarchy Process (AHP) based on rough numbers is presented to determine the weight of each evaluation criterion. For criteria evaluation we used knowledge from the expert from the field. The efficacy of the proposed evaluation methodology is demonstrated through its application in the company for the production of wire. Experimental results show that the proposed approach can provide significantly influence the reduction of costs, increase competitiveness and

satisfaction of end users, which is the goal of each participant in the supply chain.

Key words: *Logistics, Rough AHP, Supplier criteria*

1. INTRODUCTION

Multi-criteria analysis is rapidly expanding, especially during the past several years, and therefore, great number of problems is being solved nowadays using methods from that area. It is being used for solving problems of diferent nature, it is also greatly accepted and used in the area of logistics, where certain decisions are being made exactly on the base of multi-criteria methods. [1]
There is a great number of methods belonging to the area of multi-criteria decision making, and the most often used, at least when dealing with supplier choice, are the AHP. That was confirmed in [2] where author was concluded that AHP and their integrated methods are most preferred among researchers. Integration of AHP with other methods is very often where authors using AHP for detemination criteria weights and other for evaluation. Example of integration AHP with other methods can find in next research [3,4,5,1], while in twoo last years few researcher use new method (Best Worst method) [6] for weights of criteria [7,8].
The correct choice of a set of criteria and the quantification of their relative weight are of fundamental importance to the alignment of purchasing decisions with strategic and performance objectives of the buying organization. [9] According [10] most firms regard the use of supplier selection criteria as an important part of their supplier selection process.
This paper is structured as follows. Section 2 show the fundamentals of rough sets theory, operations with rough numbers and rough Analytic Hierarchy Process. Section 3 describes main part of this paper: practical example and show results of proposed model. Section 4 show sensitivity analysis. This section also show discussion and stability of model. Section 5 sets out the conclusions and the paper concludes with the references.

2. METHODS

2.1 Rough set theory

Due to the complexity and uncertainty of numerous real indicators in the process of multi-criteria decision-making, as well as the occurrence of the ambiguity of human thinking, there are difficulties in presenting information about the attributes of decisions through accurate (precise) numerical values. These uncertainties and ambiguities are commonly exploited through application of rough numbers [11,12].

In addition to the fuzzy theory, a very suitable tool for the treatment of uncertainty without the impact of subjectivism is rough set theory, which was first introduced in [13]. From the beginning until today, the theory of rough sets has evolved through solving many problems by using rough sets [14,15,16] and through the use of rough numbers as in [17,18].

In the theory of rough sets only the internal knowledge is used, i.e. operational data, and there is no need to rely on the models of assumptions. In other words, in the application of rough sets, instead of various additional/external parameters, we use exclusively the structure of the data provided [19]. In rough sets measurement of uncertainty is based on the uncertainty that is already contained in the data [14]. This leads to objective indicators that are contained in the data. In addition, the theory of rough sets is suitable for application in the sets that are characterized by a small number of data, and for which statistical methods are not suitable [20].

2.2 Operations with rough numbers

In rough set theory, any vague concept can be represented as a pair of precise concepts based on the lower and upper approximations [20] as shown in Figure 1.

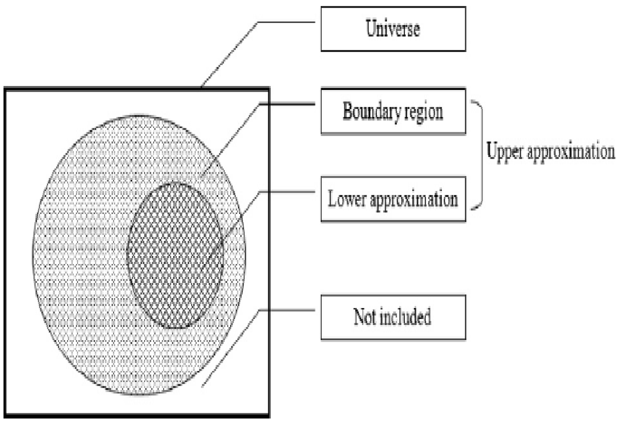

Figure 1. Basic notions of rough set theory [21]

Suppose U is the universe which contains all the objects, Y is an arbitrary object of U, R is a set of t classes (G_1;G_2; ... ;G_t) that cover all the objects in U, R (G_1;G_2; ... ;G_t). If these classes are ordered as G_1<G_2<...<G_t, then $\forall Y \in U, G_q \in R, 1 \le q \le t$ the lower approximation $(\underline{Apr}(G_q))$, upper approximation $(\overline{Apr}(G_q))$ and boundary region $(Bnd(G_q))$ of class G_q are according [12] defined as:

$$\underline{Apr}(G_q) = \cup\{Y \in U/R(Y) \le G_q\} \tag{1}$$

$$\overline{Apr}(G_q) = \cup\{Y \in U/R(Y) \ge G_q\} \tag{2}$$

$$Bnd(G_q) = \cup\left\{Y \in \frac{U}{R(Y)} \ne G_q\right\} = \left\{Y \in \frac{U}{R(Y)} \ge G_q\right\} = \cup\{Y \in U/R(Y) \le G_q\} \tag{3}$$

Then G_q can be represented by a rough number $(RN(G_q))$, which is determined by its corresponding lower limit $(\underline{Lim}(G_q))$ and upper limit $(\overline{Lim}(G_q))$, where:

$$\underline{Lim}(G_q) = \frac{1}{M_L}\sum R(Y)|Y \in \underline{Apr}(G_q) \tag{4}$$

$$\overline{Lim}(G_q) = \frac{1}{M_U}\sum R(Y)|Y \in (\overline{Apr}(G_q) \tag{5}$$

$$RN(G_q) = [\underline{Lim}(G_q), \overline{Lim}(G_q)] \tag{6}$$

where M_L, M_U are the number of objects that contained in $\underline{Apr}(G_q)$ and $\overline{Apr}(G_q)$, respectively.

Obviously, the lower limit and upper limit denote the mean value of elements included in its corresponding lower approximation and upper approximation, respectively. Their difference is defined as rough boundary interval $(IRBnd(G_q))$:

$$IRBnd(G_q) = \overline{Lim}(G_q) - \underline{Lim}(G_q) \tag{7}$$

Operation for two rough number $RN(\alpha) = [\underline{Lim}(\alpha), \overline{Lim}(\alpha)]$ and $RN(\beta) = [\underline{Lim}(\beta), \overline{Lim}(\beta)]$ according [22] are:

Addition (+) of two rough numbers $RN(\alpha)$ and $RN(\beta)$

$$RN(\alpha) + RN(\beta) = [\underline{Lim}(\alpha) + \underline{Lim}(\beta), \overline{Lim}(\alpha) + \overline{Lim}(\beta)] \tag{8}$$

Subtraction (-) of two rough numbers $RN(\alpha)$ and $RN(\beta)$

$$RN(\alpha) - RN(\beta) = [\underline{Lim}(\alpha) - \overline{Lim}(\beta), \overline{Lim}(\alpha) - \underline{Lim}(\beta)] \tag{9}$$

Multiplication (×) of two rough numbers $RN(\alpha)$ and $RN(\beta)$

$$RN(\alpha) \times RN(\beta) = [\underline{Lim}(\alpha) \times \underline{Lim}(\beta), \overline{Lim}(\alpha) \times \overline{Lim}(\beta)] \tag{10}$$

Division (÷) of two rough numbers $RN(\alpha)$ and $RN(b)$

$$RN(\alpha) \div RN(\beta) = [\underline{Lim}(\alpha) \div \overline{Lim}(\beta), \overline{Lim}(\alpha) \div \underline{Lim}(\beta)] \tag{11}$$

Scalar multiplication of rough number $RN(\alpha)$, where μ is a nonzero constant

$$\mu \times RN(\alpha) = [\mu \times Lim(\alpha), \mu \times \overline{Lim}(\alpha)] \tag{12}$$

2.3 Rough Analytic Hierarchy Process

The procedure of the rough AHP is described as follows [12]:

Step 1: Identify the evaluation objective, criteria and alternatives. Construct a hierarchical structure with the evaluation objective at the top layer, criteria at the middle and alternatives at the bottom.

Step 2: Conduct AHP survey and construct a group of pair-wise comparison matrices. The pair-wise comparison matrix of the eth expert is described as:

$$B_e = \begin{bmatrix} 1 & x_{12}^e & \cdots & x_{1m}^e \\ x_{21}^e & 1 & \cdots & x_{2m}^e \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1}^e & x_{m2}^e & \cdots & 1 \end{bmatrix} \quad (13)$$

where $x_{gh}^e (1 \le g \le m, 1 \le h \le m, 1 \le e \le s)$ is the relative importance of criterion *g* on criterion *h* given by expert *e*, *m* is the number of criteria, *s* is the number of experts.Calculate the maximum eigenvalue λ_{max}^e of B_e, then compute the consistency index

$CI = (\lambda_{max}^e - n)/(n-1)$

Determine the random consistency index (*RI*) according to *n*. Compute the consistency ratio *CR=CI/RI.*

Conduct consistency test. If *CR < 0,1*, the comparison matrix is acceptable. Otherwise, experts' judgments should be adjusted until *CR < 0,1*

Then the integrated comparison matrix $\tilde{B}$ is built as:

$$\tilde{B} = \begin{bmatrix} 1 & \tilde{x}_{12}^e & \cdots & \tilde{x}_{1m}^e \\ \tilde{x}_{21}^e & 1 & \cdots & \tilde{x}_{2m}^e \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1}^e & \tilde{x}_{m2}^e & \cdots & 1 \end{bmatrix} \quad (14)$$

where $\tilde{x}_{gh} \{x_{gh}^1, x_{gh}^2, \ldots, x_{gh}^s\}$, $\tilde{x}_{gh}$ is the sequence of relative importances of criterion *g* on criterion *h*.

Step 3: Construct a rough comparison matrix.

Translate the element x_{gh}^e in $\tilde{B}$ into rough number $RN(x_{gh}^e)$ using Equations (1) - (6):

$$RN(x_{gh}^e) = [x_{gh}^{eL}, x_{gh}^{eU}] \quad (15)$$

where x_{gh}^{eL} is the lower limit of $RN(x_{gh}^e)$ while x_{gh}^{eU} is the upper limit.

Then the rough sequence $RN(\tilde{x}_{gh})$ is represented as:

$$RN(\tilde{x}_{gh}) = \{[x_{gh}^{1L}, x_{gh}^{1U}], [x_{gh}^{2L}, x_{gh}^{2U}], \ldots, [x_{gh}^{sL}, x_{gh}^{sU}]\} \quad (16)$$

It is further translated into an average rough number $RN(x_{gh})$ by rough arithmetic Equations (8) - (12):

$$RN(x_{gh}) = [x_{gh}^L, x_{gh}^U] \quad (17)$$

$$x_{gh}^L = \frac{x_{gh}^{1L} + x_{gh}^{2L} + \cdots + x_{gh}^{sL}}{s} \quad (18)$$

$$x_{gh}^U = \frac{x_{gh}^{1U} + x_{gh}^{2U} + \cdots + x_{gh}^{sU}}{s} \quad (19)$$

where x_{gh}^L is the lower limit of $RN(x_{gh})$ and x_{gh}^U is the upper limit.

Then the rough comparison matrix M is formed as:

$$M = \begin{bmatrix} [1,1] & [x_{12}^L, x_{12}^U] & \cdots & [x_{1m}^L, x_{1m}^U] \\ [x_{21}^L, x_{21}^U] & [1,1] & \cdots & [x_{2m}^L, x_{2m}^U] \\ \vdots & \vdots & \ddots & \vdots \\ [x_{m1}^L, x_{m1}^U] & [x_{m2}^L, x_{m2}^U] & \cdots & [1,1] \end{bmatrix} \quad (20)$$

Step 4: Calculate the rough weight wg of each criterion:

$$w_g = \left[\sqrt[m]{\prod_{h=1}^m x_{gh}^L}, \sqrt[m]{\prod_{h=1}^m x_{gh}^U}\right] \quad (21)$$

$$w_g' = w_g / \max(w_g^U) \quad (22)$$

where w_g' is the normalization form.

Finally, the criteria weights are obtained.

3. NUMERICAL EXAMPLE

The main activity of the company which is the subject of research is the production of wire. The aim of this paper is to determine the most important criteria for suppliers evaluation in the mentioned company. Figure 2 presents the criteria finance, logistics, quality and communications and business, and each of these criteria contains five subcriteria which are also shown in the figure below each criterion. Review the given criteria for suppliers evaluation through literature is presented in the paper [23].

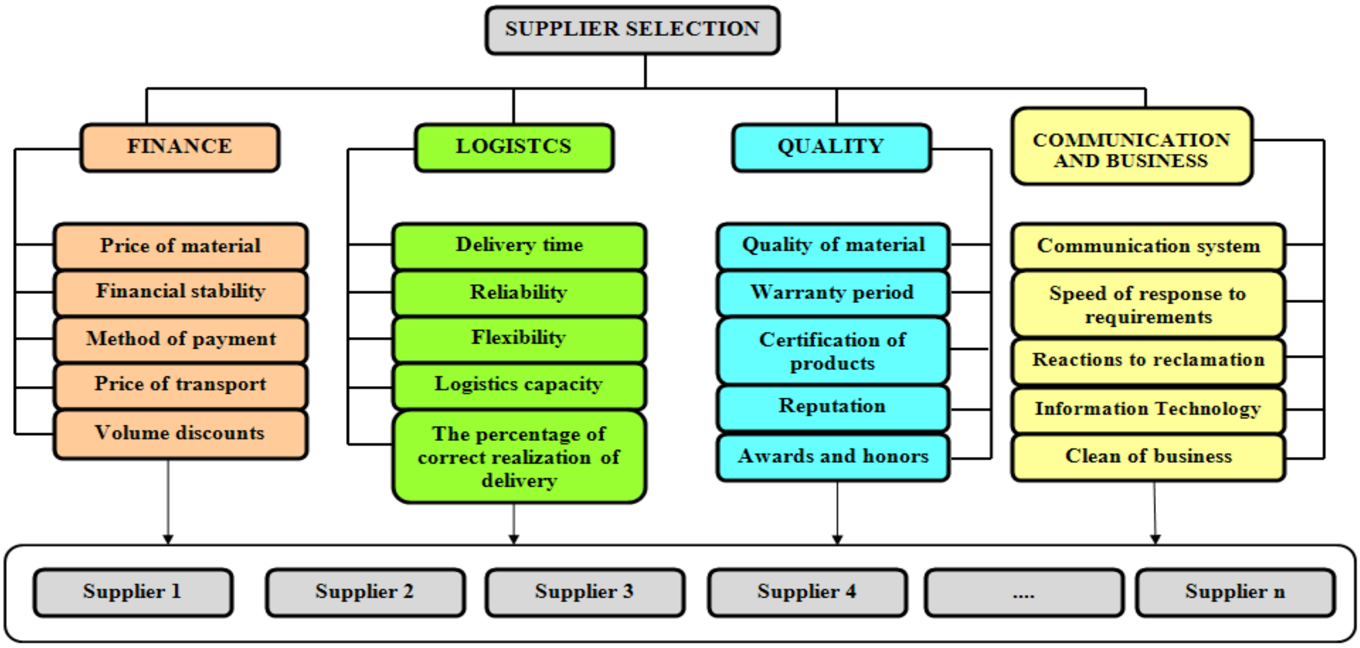

Figure 2. Criteria for supplier selection [24]

Collect individual judgments and construct a group of pairwise comparison matrices. Take the consistency examination until all the comparison matrices can pass through. Integrate individual comparison matrices to generate an integrated comparison matrix. The individual pair-wise comparison matrices for subcriteria of group logistics are as follows:

$$B_1 = \begin{bmatrix} 1 & 3 & 4 & 1/3 & 4 \\ 1/3 & 1 & 3 & 1/4 & 3 \\ 1/4 & 1/3 & 1 & 1/5 & 1 \\ 3 & 4 & 5 & 1 & 5 \\ 1/4 & 1/3 & 1 & 1/5 & 1 \end{bmatrix}, CR = 0{,}046 < 0{,}10$$

$$B_2 = \begin{bmatrix} 1 & 4 & 4 & 3 & 5 \\ 1/4 & 1 & 1 & 1/3 & 3 \\ 1/4 & 1 & 1 & 1/3 & 3 \\ 1/3 & 3 & 3 & 1 & 4 \\ 1/5 & 1/3 & 1/3 & 1/4 & 1 \end{bmatrix}, CR = 0{,}045 < 0{,}10$$

$$B_3 = \begin{bmatrix} 1 & 1 & 3 & 4 & 5 \\ 1 & 1 & 3 & 4 & 5 \\ 1/3 & 1/3 & 1 & 3 & 4 \\ 1/4 & 1/4 & 1/3 & 1 & 3 \\ 1/5 & 1/5 & 1/4 & 1/3 & 1 \end{bmatrix}, CR = 0{,}047 < 0{,}10$$

Obviously CRe < 0,1 (e= 1, 2, 3), all the comparison matrices are acceptable. Then the integrated comparison matrixgenerated by combining with the above three individual comparison matrices.

$$B = \begin{bmatrix} 1,1,1 & 3,4,1 & 4,4,3 & 1/3,3,4 & 4,5,5 \\ 1/3,1/4,1 & 1,1,1 & 3,1,3 & 1/4,1/3,4 & 3,3,5 \\ 1/4,1/3,1/3 & 1/3,1,1/3 & 1,1,1 & 1/5,1/3,3 & 1,3,4 \\ 3,1/3,1/4 & 4,3,1/4 & 5,3,1/3 & 1,1,1 & 5,4,3 \\ 1/4,1/5,1/5 & 1/3,1/3,1/5 & 1,1/3,1/4 & 1/5,1/4,1/3 & 1,1,1 \end{bmatrix}$$

Translate the elements in $\tilde{B}$ into rough numbers and correspondingly the original integrated comparison matrix $\tilde{B}$ is converted into a rough comparison matrix.
Take as an example $\tilde{x}_{12} = \{3,4,1\}$

$$\underline{Lim}(1) = 1, \quad \overline{Lim}(1) = \frac{1}{3}(3+4+1) = 2{,}67$$

$$\underline{Lim}(3) = \frac{1}{2}(1+3) = 2, \quad \overline{Lim}(3) = \frac{1}{2}(3+4) = 3{,}5$$

$$\underline{Lim}(4) = \frac{1}{3}(3+4+1) = 2{,}67, \quad \overline{Lim}(4) = 4$$

Thus, x_{12}^{e} can be expressed in rough number:

$$RN(x_{12}^{1}) = RN(3) = [2;3{,}5]$$

$$RN(x_{12}^{2}) = RN(4) = [2{,}67;4]$$

$$RN(x_{12}^{3}) = RN(1) = [1;2{,}67]$$

According to Equations (17) - (19)

$$x_{12}^{L} = \frac{x_{12}^{1} + x_{12}^{2} + x_{12}^{s}}{s} = \frac{2 + 2{,}67 + 1}{3} = 1{,}89$$

$$x_{12}^{U} = \frac{x_{12}^{1} + x_{12}^{2} + x_{12}^{s}}{s} = \frac{3{,}5 + 4 + 2{,}67}{3} = 3{,}39$$

Thus the rough sequence $\tilde{x}_{24}$ in $\tilde{B}$ is transformed into a rough number $RN(x_{24}) = [1{,}59; 3{,}93]$.

The transformation of other elements in $\tilde{B}$ are implemented in the same way.
Then, the rough comparison matrix is obtained:

$$M = \begin{bmatrix} [1,1,1] & [1{,}89;3{,}39] & [3{,}45;3{,}89] & [1{,}48;3{,}31] & [4{,}45;4{,}89] \\ [0{,}36;0{,}76] & [1,1,1] & [1{,}89;2{,}78] & [0{,}69;2{,}23] & [3{,}22;4{,}11] \\ [0{,}26;0{,}30] & [0{,}40;0{,}70] & [1,1,1] & [0{,}55;1{,}95] & [1{,}89;3{,}39] \\ [0{,}58;1{,}95] & [1{,}43;3{,}31] & [1{,}59;3{,}93] & [1,1,1] & [3{,}5;4{,}5] \\ [0{,}21;0{,}23] & [0{,}26;0{,}32] & [0{,}36;0{,}73] & [0{,}23;0{,}29] & [1,1,1] \end{bmatrix}$$

Calculate rough weights of the criteria using Equations (21) and (22).

$$w = \{[2{,}12;2{,}92];[1{,}09;1{,}79];[0{,}64;1{,}07];[1{,}36;2{,}58];[0{,}40;0{,}44]\}$$
$$w' = \{[0{,}73;1];[0{,}37;0{,}61];[0{,}22;0{,}37];[0{,}47;0{,}88];[0{,}14;0{,}15]\}$$

Rough weights of main criteria are:

$$w' = \{[0{,}66;0{,}99];[0{,}58;0{,}1];[0{,}45;0{,}90];[0{,}18;0{,}23]\}$$

so weights of subcriteria logistics have final values as follow:

$$w' = \{[0{,}42;1];[0{,}22;0{,}61];[0{,}13;0{,}37];[0{,}27;0{,}88];[0{,}08;0{,}15]\}$$

After decribed methodology is obtained values for all twenty criteria that is shown in Figure 3.

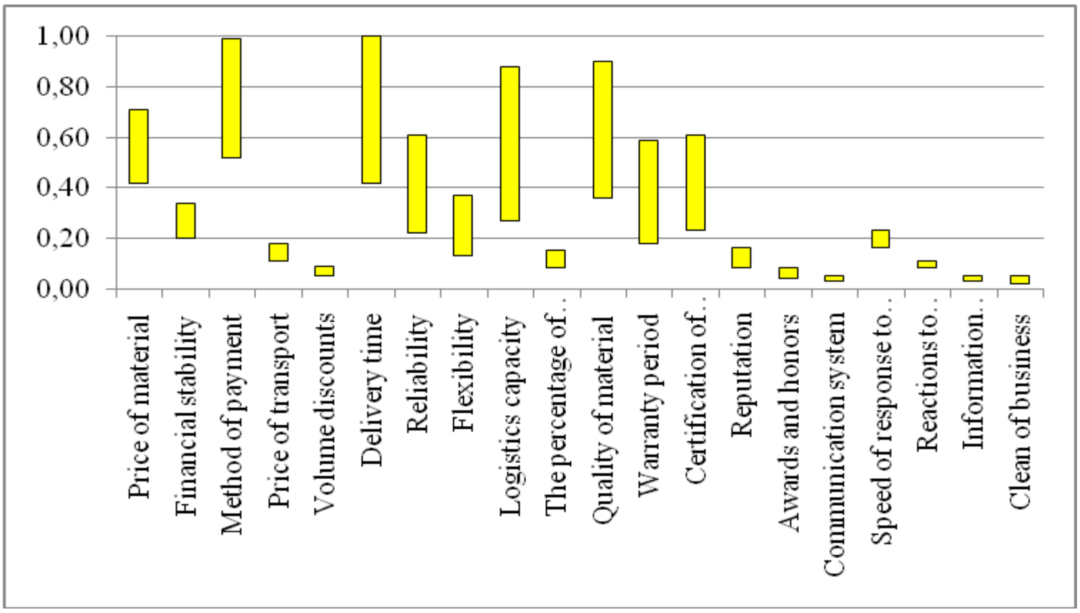

Figure 3. Values of all criteria in rough numbers

On Figure 3 can see that method of payment, delivery time, quality of material and logistics capacity are most important in company which is subject of research. This criteria are very important because company exports her products on international market. On fifth place is criterion price of material, while sertification of product, reliability and warranty period are on sixth, seventh and eight place respectively. Other criteria are less important.

4. SENSITIVITY ANALYSIS

After obtained results is made sensitivity analysis that include comparison values of criteria using fuzzy Analytic Hierarchy Process.

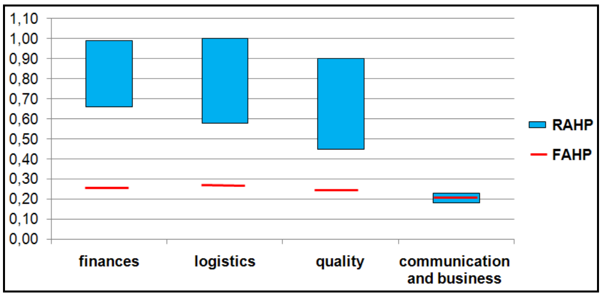

Figure 4. Values of main criteria using FAHP and RAHP

On Figure 4 are shown values of main criteria obtained using Fuzzy AHP and Rough AHP, while in Table 1 is presented all results of sensitivity analysis including all twenty criteria.

Table 1. Results of sensitivity analysis

	FAHP		RAHP	
	Value	Rank	Value	Rank
Price of material	0,068	3	(0,42;0,71)	5
Financial stability	0,059	7	(0,20;0,34)	9
Method of payment	0,078	1	(0,52;0,99)	1
Price of transport	0,042	11	(0,11;0,18)	12
Volume discounts	0,018	15	(0,05;0,09)	16
Delivery time	0,066	4	(0,42;1)	2
Reliability	0,054	8	(0,22;0,61)	7
Flexibility	0,052	9	(0,13;0,37)	10
Logistics capacity	0,059	7	(0,27;0,88)	4
The percentage of correct realization of delivery	0,041	12	(0,08;0,15)	14
Quality of material	0,074	2	(0,36;0,90)	3
Warranty period	0,061	6	(0,18;0,59)	8
Certification of products	0,063	5	(0,23;0,61)	6
Reputation	0,041	12	(0,08;0,16)	13
Awards and honors	0,016	16	(0,04;0,08)	17
Communication system	0,033	14	(0,03;0,05)	18
Speed of response to requirements	0,061	6	(0,16;0,23)	11
Reactions to reclamation	0,045	10	(0,08;0,11)	15
Information Technology	0,033	14	(0,03;0,05)	18
Clean of business	0,035	13	(0,02;0,05)	19

Method of payment is most important criteria using both methods, quality is second most important criterion using fuzzy AHP, while second most important using rough AHP is delivery time. When it comes to local rank criteria, it is important to note that all criteria have equal ranked using both methods.

Ranking all criteria from first to twentieth places is also shown on Figure 5.

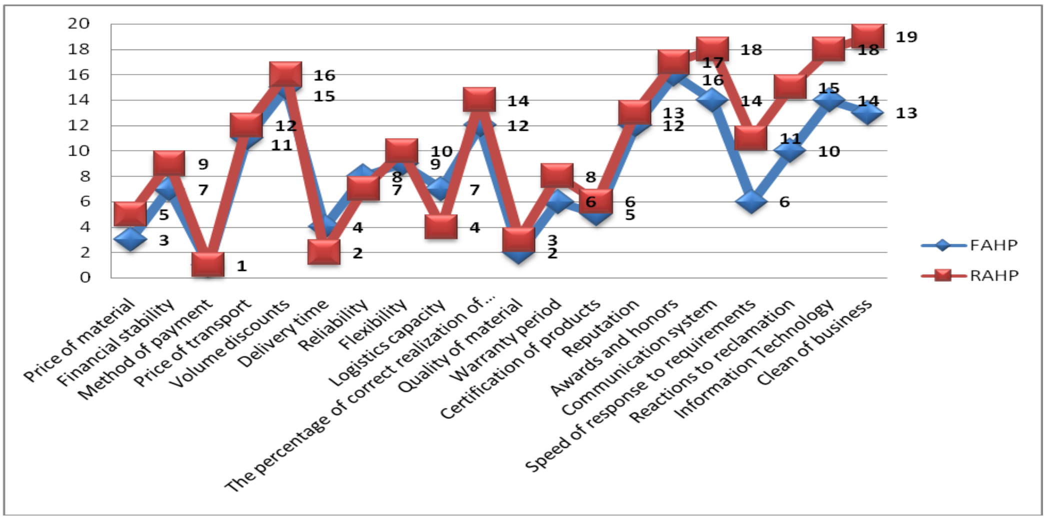

Figure 5. Ranking criteria using FAHP and RAHP method

5. CONCLUSION

This study proposed a rough group AHP approach to evaluation supplier criteria in company for production of wire. Rough AHP according [25] enables to measure consistency of preferences, manipulate multiple decision makers and calculate the relative importance for each criterion. The rough AHP according [26] combines the strength of rough sets in handling subjectivity and the advantage of AHP in hierarchy evaluation. According to the methodology applied in this paper conclusion is that decision making based on rough AHP can be very helpful in in productions companies. Compared to some research that have been done in the area of supplier evaluation, this paper shows that until now fewer criteria used can have a major impact on the supplier selection.

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