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New Integrated Approach for Solving a Supplier Selection Problem in a Competitive Environment

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The main objective of this paper is a presentation of new integrated approach for solving a supplier selection problem by the use of a defined technique, which derives from LPP (linear physical programming), and execution of F-PROMETHEE (fuzzy preference ranking method for enrichment evaluation) method as a ranking algorithm. The objective of supplier selection problem is an identification of suppliers that have the highest capability of responding desirably to firm's needs. Suppliers are ranked from the best to worst total performance regarding to use of a common set of criteria and measures. Defined method intends to take two considerable actions: to employ typically available information and lessen the burden of choosing of weights for DM (decision maker). Owing to the paucity of information, measuring of the exact value of the attributed weights of criteria and input data seem to be impossible. Therefore, the use of fuzzy techniques is justifiable. According to brought weights, F-PROMETHEE method is implemented to rank the suppliers. In previous works, weights of criteria were achieved in relation to DM's comments and there was less attention given to the fact that suppliers work in a competitive environment, furthermore, situations of rivals have not been considered as an important factor, precisely. In addressed approach, the information of the enterprise, which is working with DM and its rivals' information in different criteria, is regarded as input data and weighting of these criteria and ranking of those suppliers are conducted through a suggested algorithm.

Keywords: *supplier selection, linear physical programming, F-PROMETHEE, competitive environment, Fuzzy* sets.

Introduction. Multi Criteria Decision Making Techniques

Multi Criteria Decision Making problem (MCDM) is a branch of Operation Research (OR) ,which deals with procedures and techniques to assist a Decision Maker (DM) to have the best solution in his/her problem. MCDM methods have been implemented frequently in terms of solving different problems in both of certain and uncertain environments. One of the most important characteristics of solution method is brought preference information elicited from DM as well as their kind of these information asked from DM (Ignizio & Cavalier, 1994). Generally there are two sorts of techniques applied to solve decision making problems. Some of them are matched with problems with a number of limited alternatives; on the other hand, some applied methods are demonstrating continuous solution spaces. Methods such as AHP (Analytic Hierarchy Process) (Saaty, 1988) and outranking methods (Benayoun *et al.*, 1966; Roy, 1971) are categorized in the first group. Among the techniques with continuous solution spaces, goal programming (Lee, 1972; Ignizio, 1976) and fuzzy programming (Zimmermann, 1985) are regarded as the most prevalent methods. (Podvezko & Podviezko, 2010) suggested a model in terms of the relation of choice of the preference function and their parameters with multi-criteria appraisement results.

Let's consider we have some information about our scores in different criteria and projects as well as our rival's information. First of all, the importance of these criteria should be examined and after that by the use of one of the ranking techniques, we can make a deduction about our position among our rivals in a certain project. In this paper, a new approach has been presented in terms of ranking the alternatives in a competitive environment. In today world, we are facing with different uncertain aspects due to having incomplete information about them. Thus, a necessity of use of theory of fuzzy introduced by (Zadeh, 1965) is inevitable. Even though certain criteria are expressed in quantitative preferences, some of them are stated in a qualitative observation, which should be interpreted quantitatively. To be in a competitive environment, one of the applications of Linear Physical Programming (LPP) method has been utilized to elicit the weights of criteria. LPP intends to take two important actions: firstly, to employ typically available information and secondly, help DM to tackle the dubious task of choosing weights. Initially, weights of criteria are calculated by the use of this method. This method deals with several objectives in a way that only requires DM to specify meaningful targets. DM only needs to specify desirability ranges for each design metric, not those meaningless weights, which make this approach very user-friendly. The main contribution of the proposed approach is that weights of criteria are brought according to information related to rivals (information will be changed to scores for quantifying comparisons) and DM's opinions as well. Consequently, normalization process is carried out to extract the weights of defined criteria. In former works like AHP and so on, there was least attention given to the position of rivals and DM's opinions were considered the only gauge for calculating the weights of criteria. This deficiency is responded properly in the proposed approach. Finally, according to the weights of defined criteria and brought scores that belong to companies, one of the outranking methods is exerted to rank our situation among our rivals in a specific situation. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) is mentioned as one of the most efficient and suitable ranking methods (Geldermann *et al.,* 2000). Flexibility and simplicity of this outranking method makes it more desirable for its users (Geldermann *et al.,* 2000). PROMETHEE technique has been used repeatedly in various fields like portfolio selection problems (Rudolf & Vetschera, 2011) and etc. F (fuzzy)-PROMETHEE is an extension of PROMETHEE under dominance of fuzzy environment. By use of F-PROMETHEE, these alternatives are ranked from the best to worst, and decision making process will be facilitated for DM. In our approach, information of an enterprise, which is working with DM and its rivals' information in different criteria, is regarded as input data and weighting of these criteria and ranking of those suppliers are conducted through a suggested algorithm. It is clear that precise information is classified as secret profiles of companies and there is only the possibility of estimating of this information to elicit their status in defined criteria. Hence, lack of information as well as being in an uncertain environment leads us to the use of fuzzy techniques. To summarize the proposed procedure: a new integrated approach for solving a supplier selection problem was presented; LPP method was applied to calculate weights of defined criteria in mentioned problem and F-PROMETHEE technique, as an outranking method, was implemented to rank suppliers

The research objective: To present an integrated approach for solving a supplier selection problem.

The research problem: Ranking of suppliers in a competitive environment by the use of proposed approach.

The research method: Techniques are elicited from comparative analysis of literature, synthesis, and deductions. This paper embodies four notable sections: first of all, some reviews about related works and applied algorithms to solve supplier selection problems are stated. In section two some explanations about the applied methods are presented. The third section is devoted to a numerical example to become more familiar with a practical use of the stated approach. Conclusion is made in the fourth part of this article.

Literature review

Supplier (vendor) selection is a significant issue in supply chain management (SCM) field for many enterprises, therefore its objective is an identification of suppliers with the highest capability of responding desirably to firm's needs. Basically, there are two dimensions in the issue of the supplier selection problem: first dimension is a specification of criteria used for evaluation of suppliers, and the other one is an applied procedure or method to rank these suppliers. Evaluation of a supplier depends on several factors. Some criteria such as price, quality, delivery, reputation are frequently selected for comparison and appraisement (Swift, 1995). These criteria can influence the outcome of the decision-making process for vendor selection and they can also affect each other. An appropriate supplier may become and develop into a cooperative and long term partnership in SCM for DM's interests, which can help the growth of a corporation and can be crucial to the success of the DM's business. Hence, systematic and effective procedure or technique to select the most efficient supplier is compulsory. There is a great number of works in the domain of supplier selection problems and evaluations of companies. First of all, let's take a look at the former works in terms of criteria selection for solving a supplier selection problem. (Swift, 1995) summarized five factors for supplier selection from the view of preference for single sourcing or for multiple sourcing. These 5 factors are product, availability, dependability, experience, and price. (Choi & Hartley, 1996) selected National Association of Purchasing Managers (NAPM) membership list, Ohio Manufacturers List, and Japanese Automotive Supplier Directory as the objects of surveying to investigate the supplier selection-criteria. They summarized 26 criteria for supplier selection. After factor analysis, there were 26 criteria integrated into eight factors: finances, consistency, relationship, flexibility, technological capability, customer service, reliability, and price. In this article, six criteria have been determined to solve a supplier selection problem. They are namely called cost, design and development ability, performance history, flexibility of companies in preparation of demand, on time delivery percentage, quality and goodness of products. After choosing the criteria, we are supposed to pick out an algorithm to rank the suppliers. Ho *et al.,* (2010) analyzed multi criteria decision making (MCDM) approaches for supplier selection based on journal articles from 2000 to 2008. (Chen *et al.,* 2006) proposed a fuzzy multiple criteria decision-making method to cope with supplier selection problems, and to use TOPSIS (Hwang & Yoon, 1981) to determine the ranking order of all suppliers. Li, (Yamaguchi & Nagai, 2007) proposed a gray-based approach to deal with the supplier selection problem. (Araz & Ozkarahan, 2007) introduced PROMETHEE (Brans & Vincke, 1985; Brans *et al.,* 1986) methodology to evaluate suppliers for strategic sourcing, in which suppliers are evaluated regarding to supplier's co-design capabilities and categorized based on overall performances. (Ghodsypour & O'Brien, 2001) formulated a mixed integer non-linear programming model to solve the multi-criteria sourcing problem. The model was created to determine the optimal allocation of products to suppliers so that the total annual purchasing cost could be minimized. (Jain *et al.*, 2004) suggested a fuzzy based approach for supplier selection. The authors mentioned that it might be hard for an expert to define a complete rule set for assessment of the supplier performance. GA (genetic algorithm) was therefore implemented to generate a number of rules inside the rule set according to the essence and type of the priorities associated with the products and their supplier's attributes. (Rezaei & Davoodi, 2012) used a nonlinear physical programming algorithm to solve a problem according to determined criteria. (Liu & Zhang, 2011) addressed the extension of ELECTRE, called ELECTRE-III, with entropy weights. (Vahdani *et al.*, 2010) considered interval values as decision information in the application of ELECTRE. (Montazer *et al.*, 2009; Sevkli, 2010) extended ELECTRE for supplier selection when triangular fuzzy values provided the decision information. (Che *et al.*, 2011) integrated PROMETHEE with the extended fuzzy concept and studied a case of information system (IS) outsourcing under triangular fuzzy environments. (Buyukozkan & Cifci, 2012) proposed a new integrated approach for green supplier selection by the combination of TOPSIS and ANP techniques. (Zolfani *et al.*, 2012) proposed a hybrid MCDM model encompassing AHP and COPRAS-G methods for selecting company supplier. In the other work in supply chain management domain (Smeureanu *et al.*, 2012) presented Intelligent agents and risk based model for supply chain management.

Methodology: Calculations related to weights of criteria

Linear Physical Programming (LPP) technique is considered as one of the multi objective optimization techniques that have been implemented numerously in various fields (Maria *et al.*, 2003; Messac & Ismail-Yahaya, 2002; Messac, 1998, Melachrinoudis *et al.*, 2000). LPP divides the value of objective into some continuous regions to express preference for each criterion, and obtains preference function from piecewise spline segment interpolation. Detailed information about this method can be found in the references (Messac, 1996; Messac, Gupta & Akbulut, 1996). In this method, Decision Maker (DM) states his/her preferences according to each criterion by using 4 classes. Figure 1 illustrates these classes and qualitative and quantitative meaning of them.

Let's consider x is the decision vector and $g_p(x)$ is the p^{th} generic linear objective function. Horizontal axis reflects the value of objective function and vertical axis demonstrates the penalty function for specific criterion. A higher quantity of $Z_p$means that more urgent conducts should be done to improve the objective function and Z_p function should be minimized. One of the desirable characteristics of LPP is that it allows DM to express his/her preferences regarding to each criterion with more specificity and flexibility than by simply saying minimize, maximize, greater than, less than, or equal to (Maria *et al.*, 2003). For instance, let's examine the case of Class S1. Preference ranges are:

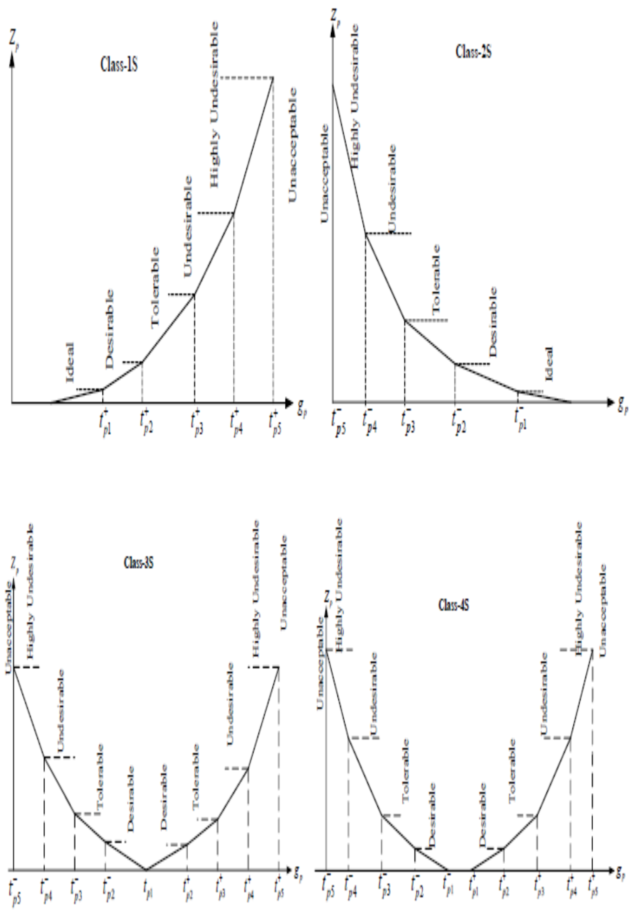

Figure 1. Class function regions for the generic p-th object

Ideal range $(g_p \leq t_{p1}^{+})$
Desirable Range $(t_{p1}^{+} \leq g_p \leq t_{p2}^{+})$
Tolerable range $(t_{p2}^{+} \leq g_p \leq t_{p3}^{+})$
Undesirable range $(t_{p3}^{+} \leq g_p \leq t_{p4}^{+})$
Highly Undesirable range $(t_{p4}^{+} \leq g_p \leq t_{p5}^{+})$
Unacceptable range $(g_p \geq t_{p5}^{+})$

The parameters t_{p1}^{+} through t_{p5}^{+} are physically meaningful constants that express DM's preference associated with the p^{th} generic design metric.

For class S2 the following preference ranges are considered:

Ideal range $(g_p \geq t_{p1}^{-})$
Desirable Range $(t_{p1}^{-} \geq g_p \geq t_{p2}^{-})$
Tolerable range $(t_{p2}^{-} \geq g_p \geq t_{p3}^{-})$
Undesirable range
Highly Undesirable range $(t_{p4}^{-} \geq g_p \geq t_{p5}^{-})$
Unacceptable range $(g_p \leq t_{p5}^{-})$

In this paper, LPP is used to determine the weights of our criteria in our numerical example. By the use of classes S1 and S2, the value of Z_p can be defined as follows. It has been supposed that Z_p has a constant quantity for each criterion in this article.

Be defined as follows. Set $a_0 = 1.1,\ \beta = 2$, then,

$$a_s = \beta^s a_0 \tag{1}$$

Then,

$$\tilde{Z}_s = (a_{s-1}/a_s/a_{s+1}) \quad s = 1,2,\ldots,5 \tag{2}$$

Values of a_0 and β depend on how bad a situation is if one criterion lags behind that of alternatives. Whenever the situation worsens, the higher a_0 and β are considered. Following stages are carried out to determine the weights of each criterion.

1. Defining of $\widetilde{w}_{ps}$, which represents the weight of range s in criterion p.

$$\widetilde{w}_{ps} = \tilde{Z}_s / t_{p,s} \quad (3)$$

2. Defining of $\widetilde{w}_p$, which demonstrates the weight of criterion.

$$\widetilde{w}_p = \widetilde{w}_{p,s} \quad when \quad t_{p,s-1} \geq g_p \geq t_{p,s}$$
$$s = 1,2,\dots,5 \quad (4)$$

Unacceptable ranges have no weight.

3. Calculation of the normalized weights for each criterion.

$$w_p^{norm} = \frac{w_p}{\sum_p w_p} \qquad for\ each\ \ p \quad (5)$$

4. Final weight of each criterion is deducted by calculation of weighting average, which comprises both DM's comments and rivals' situations.

$$W_p^{Final} = \alpha . W_p^{norm} + (1-\alpha). W_p^{DM} \qquad \forall\, p\,,$$
$$0 \leq \alpha \leq 1 \quad (6)$$
$$Final\ Weights = \alpha.(\text{Normalized Defuzzy Weights}) + (1-\alpha)(\text{Weight based on DM's opinions})$$

Ranking of suppliers

Next stage is the implementation of one of the ranking methods to elicit the situations of the suppliers. In this paper, one of the outranking methods called PROMETHHE has been executed to rank the suppliers according to their performances in defined criteria. PROMETHHE was introduced by (Brans & Vincke, 1985) and later extended by (Brans & Mareschal, 1994). It is considered as one of the outranking methods. This technique is regarded as a reaction to complete aggregation (MAUT) methods (Macharis *et al.*, 2004) and is one of the intuitive methods of MCDM, which is so much intelligible for DM (Ballis & Mavrotas, 2007).

For the use of this MADM technique, four following steps are carried out:

1. A table has to be formed that includes specific alternatives as well as certain criteria for assessment.
2. Preference function should be defined $P_j(a,b)$ that states deviation between two alternatives (a,b) on a particular criterion g_p into a preference degree ranging 0 to 1.
3. Choosing of one of the six possible shapes of preference functions put forward by Brans et al (1986) (usual shape, U-shape function, V-shape function, level function, linear function and Gaussian function)

$$P_j(a,b) = G_j\left(f_j(a) - f_j(b)\right) \quad 0 \leq P_j(a,b) \leq 1 \quad (7)$$

$f_j(a) - f_j(b)$ expresses the deviation score of two alternatives on a certain criterion.

4. By knowing the weights of criteria calculated in the previous part, we define the following formulas:

$$\pi(a,b) = \textstyle\sum_{j=1}^{k} w_j P_j(a,b) \quad (8)$$
$$\varphi^+(a) = 1/(n-1) \textstyle\sum_b \pi(a,b) \quad (9)$$
$$\varphi^-(a) = 1/(n-1) \textstyle\sum_b \pi(b,a) \quad (10)$$
$$\varphi(a)^{Net} = \varphi^+(a) - \varphi^-(a) \quad (11)$$

$\varphi^+(a)$ and $\varphi^-(a)$ represent positive and negative preference flow for each alternative, which measure how an alternative (a) is out ranking (formula 8) or out ranked (formula 9).

$\varphi(a)$ (formula 10) displays the value function and alternative (a) will be more attractive, if its value function has a higher amount.

In partial ranking, we face with three situations in terms of superiority of alternative (a) to alternative (b) (formula 12), being indifferent two alternatives (formula 13), being incomparable two alternatives (formula 14) (Brans, 1985).

$$\begin{cases} \emptyset^+(a) > \emptyset^+(b) \ \ and \ \ \emptyset^-(a) < \emptyset^-(b) \\ \emptyset^+(a) > \emptyset^+(b) \ \ and \ \ \emptyset^-(a) = \emptyset^-(b) \\ \emptyset^+(a) = \emptyset^+(b) \ \ and \ \ \emptyset^-(a) < \emptyset^-(b) \end{cases} \quad (12)$$
$$\{\emptyset^+(a) = \emptyset^+(b) \quad and \quad \emptyset^-(a) = \emptyset^-(b) \quad (13)$$
$$\begin{cases} \emptyset^+(a) > \emptyset^+(b) \ \ and \ \ \emptyset^-(a) > \emptyset^-(b) \\ \\ \emptyset^+(a) < \emptyset^+(b) \ \ and \ \ \emptyset^-(a) < \emptyset^-(b) \end{cases} \quad (14)$$

On the other hand by use of $PROMETHEE\ II$, we only measure the ϕ^{net} and it will be our main evaluation application for decision making. Every alternative, which has a higher ϕ^{net} has a better position in an ultimate ranking, and we have a complete ranking.

When DM states his/her experiences and considerations in linguistic terms as input data, the obscurity and fuzziness are taking place. In such circumstances, probability of making a mistake in our assessment arises incredibly. The solution is the use of F-PROMETHHE that is the combination of fuzziness and PROMETHEE.

In this paper, F-PROMETHE is implemented as it was suggested by (Goumas & Ligero 2000). The procedures of F-PROMETHEE are the same as of PROMETHEE, but fuzzy logic gets involved in this methodology as well. By using this technique, it will be easier for DM to interpret his/her qualitative attitudes and information to mathematical expressions.

$x = (a,m,b)$ is the presentation of a fuzzy number, which is shown in Figure 2.

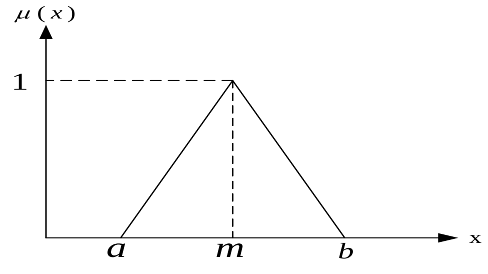

Figure 2. Presentation of fuzzy number x=(a, m, b)

x is a variable that belongs to the fuzzy set and its membership function $f(x)$ has the value between [0,1], inclusively.

For $x < a$ or $x > b$, x does not belong to the set.

For $[a \leq x \leq b]$ the membership degree is indicated by membership function that varies between 0 and 1, inclusively.

In our paper, Weights of criteria are brought by application of LPP method and preference thresholds (q *and* p) are crisp numbers.

According to the properties of our MCDM problem (in our case supplier selection problem), linear preference function (type 5) with indifferences and stringent preference thresholds (q *and* p) is our best choice to be employed.

$$\begin{cases} P(a,b)=0 & for \quad d\le q \\ P(a,b)=(d-q)/(p-q) & for \quad q\le d\le p \\ P(a,b)=1 & for \quad d\ge q \end{cases} \tag{15}$$

In F-PROMETHEE (d) exhibits the differences between two fuzzy numbers of (a,b) that result in a fuzzy number. Above equations are transformed to the following equations respectively;

$$\begin{cases} P(a,b)=0 & for \quad n-c\le q \\ P(a,b)=(d-q)/(p-q) & for \quad q\le n-c \;\; and \;\; n+d\le p \\ P(a,b)=1 & for \quad n+d\ge q \end{cases} \tag{16}$$

Essential formulas for basic computations with fuzzy number are characterized in Table 1.

Eventually, in application of F-PROMETHEE, we are given some fuzzy numbers. According to the mentioned computations, value of d will be calculated. Right now, this fuzzy numbers should be changed to the defuzzy forms according to following formula introduced by (Zadeh, 1965).

$$F(a,m,b)=(a+2m+b)/4 \tag{17}$$

One after that, remaining stages of F-PROMETHEE are performed and ϕ^{+},ϕ^{-} and ϕ^{net} will be measured regarding to stated formulas formerly.

Table 1

Basic fuzzy operations

Addition	$(m,a,b)_{LR} \oplus (n,c,d)_{LR} = (m+n,a+c,b+d)_{LR}$
Opposite	$-(m,a,b)_{LR} = (-m,a,b)_{LR}$
Subtraction	$(m,a,b)_{LR} - (n,c,d)_{LR} = (m-n,a+c,b+d)_{LR}$
Multiplication By Scalar	$(m,a,b)_{LR} \times (n,0,0) = (mn,an,bn)_{LR_{LR}}$
Multiplication By fuzzy	
for $m>0, n>0$	$(m,a,b)_{LR} \otimes (n,c,d)_{LR} \approx (mn,cm+an,dm+bn)_{LR}$
for $m<0, n>0$	$(m,a,b)_{LR} \otimes (n,c,d)_{LR} \approx (mn,an-dm,bn-cm)_{LR}$
for $m<0, n<0$	$(m,a,b)_{LR} \otimes (n,c,d)_{LR} \approx (mn,-bn-dm,-an-cm)_{LR}$
Inverse for $(m>0)$	$(m,a,b)_{LR}^{-1} \approx (m^{-1},bm^{2},am^{-2})_{LR}$

Numerical Example

In this section, a decision making problem is put forward in a competitive environment to discern practicality of the proposed approach more properly.

Let's consider we have a following information about our (a company, which is working with DM) scores in comparison with our five (A, B, C, D, E) rivals in various criteria. These criteria are (1, 2, 3, 4, 5, 6). LPP paradigm is introduced according to DM's wishes to: 1. Minimize Cost, 2. Maximize Design and development ability, 3. Maximize Performance History, 4.Maximize the Flexibility of companies in preparation of demands, 5. Maximize On time delivery percentage, 6. Maximize Quality and goodness of products. They have been stated in a style of fuzzy numbers, and they are transformed to form of crisp numbers.

Table 2 represents our fuzzy scores as well as our rivals in specific criteria in a defined supplier selection problem.

Table 2

Fuzzy scores of our rivals and our company

E	D	C	B	A	Own	Initial Data
(14,15.5,17)	(16,17,18.5)	(10,11,12)	(12,14,16)	(14.5,16,17.5)	(13,15,18)	Cost ()
(7,8,8)	(4,4,6)	(4,6,8)	(4,4,5)	(6,7,8)	(5,6,6)	Design and Development
(4,5,6)	(6,7,9)	(7,8,9)	(4,4,5)	(4,5,6)	(6,7,8)	Performance History
(7,8,9)	(3,4,5)	(2,3,4)	(4,5,7)	(6,6,8)	(5,6,7)	Flexibility of company in preparation of demand
(90,93,95)	(85,87,90)	(80,80,85)	(75,77,80)	(77,80,83)	(80,85,90)	On time delivery percentage ()
(85,87,90)	(82,83,85)	(87,90,90)	(90,90,93)	(78,80,82)	(85,85,87)	Quality and goodness of products()

Some of the criteria are quantitative that have been transformed to have an amount among [1, 10] inclusively in this numerical example. On the other hand, a number of criteria is qualitative and after being quantified, we will have a quantity among [1, 10], inclusively. There is a point that, when we are dealing with great quantities in a criterion, because of being t_{ps}^{+} and t_{ps}^{-} as denominator, attributed weight will have a low quantity. Contrarily, if there is low amount for a specific criterion, it results in a high quantity of the weight, which is wrongly interpreted as major importance of that criterion. Hence, the scale of a criterion has great significance. Table 3 demonstrates the normalized fuzzy scores of each company that have quantities among [1, 10] for defined criteria in our specific supply selection problem.

According to fuzzy rules, this information is transformed to crisp numbers as depicted in the Table 4.

As it was mentioned before, for obtaining of weights of criteria by LPP technique, essential ranges are described to achieve exact position of each input data in these brought intervals.

Table 3

Normalized fuzzy scores of companies in defined criteria

	D	C	B	A	Own	Normalized Data
(5.23,6.82,8.41)	(7.35,8.41,10)	(1,2.06,3.12)	(3.12,5.23,7.35)	(5.76,7.35,8.94)	(4.18,6.3,9.47)	Cost
(7,8,8)	(4,4,6)	(4,6,8)	(4,4,5)	(6,7,8)	(5,6,6)	Design and Development
(4.5,5.5,6.5)	(6,7,9)	(7,8,9)	(4,4,5)	(4,5,6)	(6,7,8)	Performance History
(7,8,9)	(3,4,5)	(2,3,4)	(4,5,7)	(6,6,8)	(5,6,7)	Flexibility of company in preparation of demand
(7.75,9.1,10)	(5.5,6.4,7.75)	(3.25,3.25,5.5)	(1,1.9,3.25)	(1.9,3.25,4.6)	(3.25,5.5,7.75)	On time delivery percentage
(5.2,6.4,8.2)	(3.4,4,5.2)	(6.4,8.2,8.2)	(8.2,8.2,10)	(1,2.2,3.4)	(5.2,5.2,6.4)	Quality and goodness of products

Table 4

Crisp number of each company in defined criteria

E	D	C	B	A	Own	Defuzzy Numbers
6.82	8.5425	2.06	5.2325	7.35	6.5625	Cost
7.75	4.5	6	4.25	7	5.75	Design and Development
5.5	7.25	8	4.25	5	7	Performance History
8	4	3	5.25	6.5	6	Flexibility of company in preparation of demand
8.99	6.51	3.81	2.01	3.25	5.5	On time delivery percentage
6.55	4.15	7.75	8.65	2.2	5.5	Quality and goodness of products

Table 5 illustrates these intervals and Figure 3 depicts the applied Class Function regions for the generic p-th objective in terms of two defined criteria (Cost, Design and Development) as an instance in our supply selection problem in a competitive environment. Initial data had been normalized before they changed into crisp numbers as it has been shown in Table 4. For Cost as a criterion, which should be minimized, Class S1 is applied and supplier *C* had the best situation in this criterion. Consequently, t_1^+ is considered as equal to cost of supplier *C* and t_2^+, t_3^+, t_4^+ , t_5^+ are equal to costs of suppliers *B*, *E* ,*A*, *D*, respectively. As it has been portrayed in Fig 3, the supplier, which is working with DM, has been situated in Tolerable zone and attributed weight to this criterion (Cost) is equal to the weight of Tolerable zone.

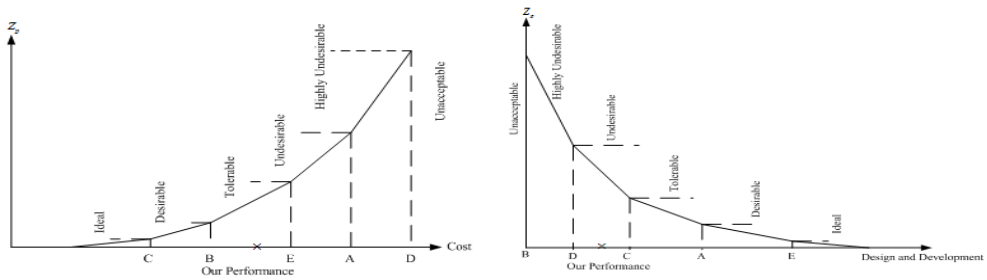

Figure 3. Class Function regions for the generic p-th objective for two defined criteria

Table 5

Calculated ranges related to defined criteria

	Ideal	Desirable	Tolerable	Undesirable	Highly Undesirable
1	(0.352,1.068,4.4)	(0.3,0.84,2.82)	(0.523,1.29,3.365)	(0.984,2.39,6.11)	(1.76,4.185,9.578)
2	(0.1375,0.275,0.628)	(0.275,0.628,1.467)	(0.55,1.467,4.4)	(1.467,4.4,8.8)	(3.52,8.8,17.6)
3	(0.122,0.275,0.628)	(0.244,0.628,1.467)	(0.677,1.6,3.91)	(1.467,3.52,8.8)	(3.52,8.8,17.6)
4	(0.122,0.275,0.628)	(0.275,0.733,1.467)	(0.628,1.76,4.4)	(1.76,4.4,11.73)	(4.4,1.73,35.2)
5	(0.11,0.242,0.568)	(0.284,0.687,1.6)	(0.8,2.71,5.41)	(1.91,5.41,18.53)	(5.41,18.53,70.4)
6	(0.11,0.268,0.536)	(0.268,0.536,1.375)	(0.536,1.375,3.385)	(1.692,4.4,10.353)	(5.176,16,70.4)

According to formula 4, weights of criteria are calculated and following fuzzy numbers are elicited that have been shown in Table 6. Then, they are altered to crisp numbers and eventually by the use of normalization, the attributed weights of criteria are attained. Table 7 represents the defuzzy weights of each criterion. Implementation of normalization process results in normalized deffuzy weights illustrated in Table 8.

Table 6

Calculated fuzzy quantities of weights for defined criteria

6	5	4	3	2	1	
(1.692,4.4,10.353)	(0.8,2.71,5.41)	(0.628,1.76,4.4)	(0.677,1.6,3.91)	(1.467,4.4,8.8)	(0.523,1.29,3.365)	Weight

Table 7

Defuzzied weights of each criterion

6	5	4	3	2	1	
5,211	2,907	2,137	1,947	4,767	1,617	Defuzzy Weights

Table 8

Normalized defuzzied weights of each criterion

6	5	4	3	2	1	
0,281	0,156	0,115	0,105	0,256	0,087	Normalized Defuzzy Weights

DM’s comments in terms of weights of criteria have been depicted in Table 9.

Table 9

Comments attributed to DM about each criterion

6	5	4	3	2	1	Criteria
0,236	0,121	0,057	0,207	0,136	0,243	Weights based on decision maker’s opinion

....

Final weight of each criterion is deducted by calculation of weighting average according to formula 6.

α represents the significance degree of situation of rivals and is specified by decision maker. In this paper it has been supposed to be 0,6. Table 10 shows the final weight of each criterion.

Table 10

Final weight of each criterion

6	5	4	3	2	1	Criteria
0.263	0.142	0.0918	0.1458	0.208	0.1494	Final Weights

In this stage, F-PROMMETHEE, as a ranking method, was executed according to its related formulas. φ^{-}, φ^{+} and φ^{Net} have been calculated according to the formulas 9, 10 and 11 respectively. Table 11 shows the brought results and greater quantity of φ^{Net} implies better situation of that alternative (supplier) in defined criteria. The calculations have been carried out regarding to the brought results associated with table 10.

Table 11

F-PROMETHEE flows

E	D	C	B	A	Own	
0,4067	0,167	0,36846	0,2424	0,1035	0,24574	φ^{+}
0,1092	0,3538	0,1443	0,3744	0,3972	0,1569	φ^{-}
0,2975	-0,1868	0,22416	-0,132	-0,2937	0,0888	φ^{Net}

....

Ultimate ranking has been portrayed in Figure 4.

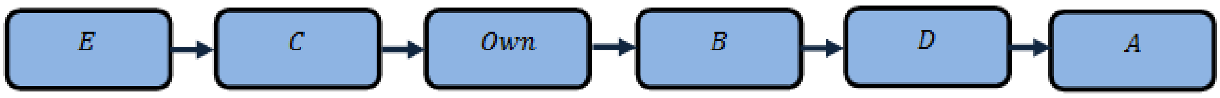

Figure 4. Depiction of final ranking

To be more familiar with the applied procedures of the mentioned approach, Figure 5 has been drawn to explain the summarized approach for solving a supplier selection problem.

Conclusion

In this paper, a new integrated approach for solving a supplier selection problem was presented; LPP method was applied to calculate weights of defined criteria in the mentioned problem and F-PROMETHEE technique, as an outranking method, was implemented to rank the suppliers regarding to the brought φ^{Net}s (which are related to the results of F-PROMETHEE method) of suppliers. Final ranking demonstrated that a supplier E had the best situation and performance among all the suppliers, and previous supplier, which cooperated with DM, has been ranked as a third place. Hence, it will be reasonable for DM to collaborate with a supplier E for tackling its needs. The stated approach has a great contribution in comparison with former approaches. In previous works, when a supply selection problem was put forward, determination of weights of criteria was assigned to DM. This dubious task was problematic for DM and his/her comments constitute the essence of attributed weights to defined criteria. Moreover, it could be resulted in ascribing an unrealistic degree of importance to criteria owing to negligence of other aspect in decision making process and lack of information in a competitive environment of today business. The neglected dimension, which has been accentuated in presented approach, was the role of rivals in decision making process to elicit the weights of criteria more realistically in a strict competitive environment.

The decision was made according to the information of suppliers as well as defined criteria. To summarize the great contribution of explained algorithm:

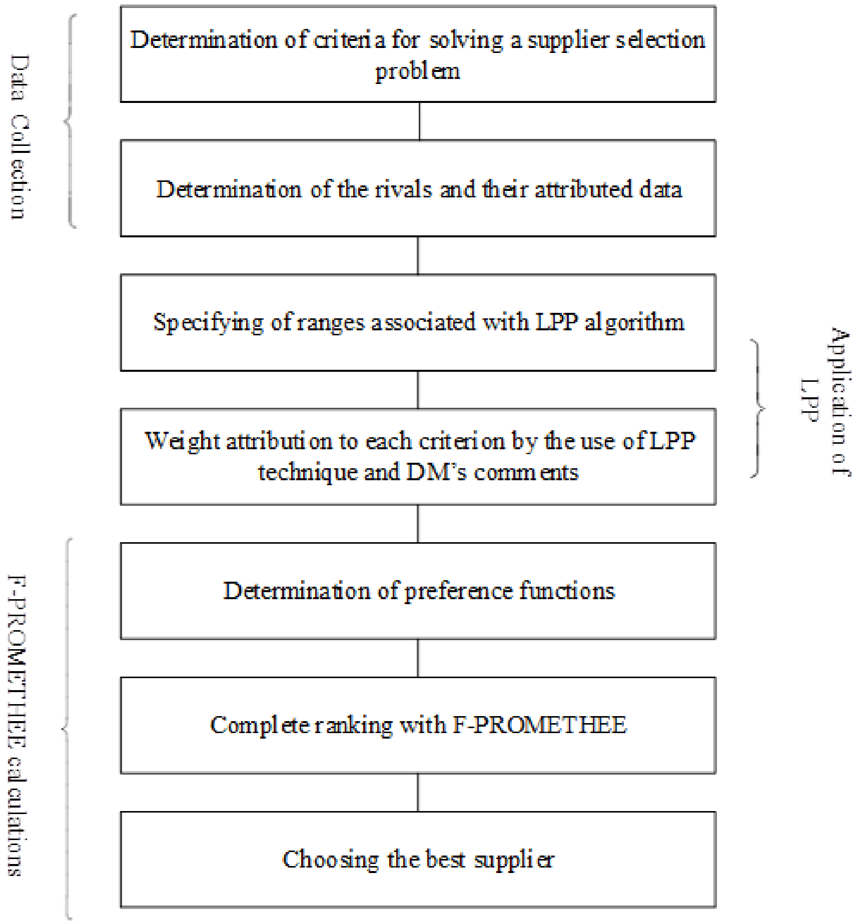

Figure 5. Schematic depiction of the new proposed approach for solving a supply selection problem

paying attention to the situations of rivals in defined criteria as well as DM's comments in calculation of weights of criteria in a supply selection problem and competitive environment related to that.

In future works, the other ranking techniques such as fuzzy-TOPSIS. SWARA, and etc can be applied to elicit the position of each alternative. The proposed approach can be implemented in other cases in different fields.

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Naujas integruotas požiūris sprendžiant tiekėjo pasirinkimo problemą konkurencinėje aplinkoje

Santrauka

Šio *darbo tikslas* – pateikti naują integruotą požiūrį, skirtą problemoms spręsti renkantis tiekėją, tam panaudojant *apibrėžtą metodą* (kilusį iš LPP (angl. *linear physical programming*) ir F-PROMETHEE (angl. *fuzzy preference ranking method for enrichment evaluation*)) kaip reitingavimo algoritmą. Svarbiausias tikslas yra nustatyti tiekėjus, kurie turi daugiausia/didžiausių galimybių, greičiausiai ir tinkamai reaguoti į įmonės poreikius. Tiekėjai yra reitinguojami vertinant veiklas nuo geriausios iki blogiausios, remiantis bendru kriterijumi. *Apibrėžtas metodas* atlieka du svarbius veiksmus: panaudoja lengvai prieinamą informaciją, ir sumažina reikšmių pasirinkimo naštą priimant sprendimus. Dėl nedidelio informacijos kiekio, tikslių, kriterijui priskirtų reikšmių bei įvesties duomenų, vertės nustatymas neįmanomas. Todėl, *neapibrėžtų metodų* naudojimas yra pateisinamas. Remiantis reikšmėmis, F-PROMETHEE metodas yra įdiegtas, norint sureitinguoti tiekėjus. Ankstesniuose darbuose buvo gautos kriterijų reikšmės, susijusios su sprendimų priėmimo komentarais ir buvo mažiau dėmesio skirta tokiam faktui, jog tiekėjai dirba konkurencinėje aplinkoje. Tuo metu konkurencija nebuvo laikoma svarbiu veiksniu. Nurodytame metode, informacija apie įmonę, kuri dirba su priimančiais sprendimus ir savo konkurentų informacija, laikoma įvesties duomenimis, o šių kriterijų reikšmės ir tiekėjų reitingavimas yra atliekamas panaudojant pasiūlytą algoritmą. Taigi tyrimo tikslas: pateikti integruotą požiūrį į tiekėjo pasirinkimą. Tyrimo problema: tiekėjų reitingavimas konkurencinėje aplinkoje. Tyrimo metodas: literatūros lyginamoji analizė, sintezė. Yra daugybė darbų, kuriuose analizuojamos problemas renkantis tiekėjus. Ho, Xu, ir Dey (2010) analizavo daugiakriterinio sprendimo priėmimo (DKSP) metodus, skirtus tiekėjams pasirinkti ir kurie buvo publikuoti straipsniuose nuo 2000 iki 2008 metų. Chen, Lin, ir Huang (2006) pasiūlė neapibrėžtą daugiakriterinį sprendimų priėmimo metodą renkantis tiekėją ir naudojant TOPSIS (Hwang ir Yoon, 1981), kad būtų nustatyta visų tiekėjų reitingavimo tvarka. Li, Yamaguchi, ir Nagai (2007) pasiūlė *pilka spalva* pagrįstą metodą renkantis tiekėją. Araz ir Ozkarahan (2007) pristatė PROMETHEE (Brans ir Vincke, 1985; Brans, Vincke, ir Mareschal,1986) metodiką, strateginei tiekėjų įvertinimo atrankai, kurioje tiekėjai yra įvertinami pagal tiekėjo bendro projektavimo galią ir suskirstomi į kategorijas, atsižvelgiant į jų bendrą veiklą. Chen, Wang, ir Wu (2011) įtraukė PROMETHEE su išplėsta, neapibrėžta koncepcija, ir nagrinėjo informacinės sistemos išornaudos atvejį, esant trišalei neapibrėžtai aplinkai. Buyukozkan ir Cifci (2012) pasiūlė naują jungtinį metodą, skirtą *žaliųjų prekių* tiekėjus pasirinkti suderinus TOPSIS ir ANP metodus. Zolfani ir kt. (2012) pasiūlė hibridinį DKSP modelį, apimantį AHP ir COPRAS-G metodus, renkantis kompanijos tiekėją. Kituose, tiekimo grandinės valdymo srities darbuose, Smeureanu ir kt. (2012) pateikė *protingais veiksniais* ir rizika pagrįstą modelį tiekimo grandinei valdyti.

LPP metodas yra laikomas vienu iš daugiatikslio optimizavimo metodų, kuris buvo įdiegtas įvairiose srityse (Maria ir kt., 2003; Messac ir Ismail-Yahaya, 2002; Messac, 1998, Melachrinoudis ir kt., 2000). LPP paskirsto tikslo vertę į tam tikrus ištisinius regionus, kad išreikštų kiekvieno kriterijaus pasirinkimą ir sudaro pasirinkimo funkciją iš *splain* funkcijos, sudarytos iš gabalų, segmento interpoliacijos. Smulkesnę informaciją apie šį metodą galima rasti nuorodose (Messac, 1996; Messac, Gupta ir Akbulut, 1996). Šiame metode *sprendimų priėmėja(s)* (SP) suformuluoja savo pasirinkimą kiekvieno kriterijaus atžvilgiu, panaudodama 4 klases. Šiame darbe LPP yra panaudojamas norint nustatyti kriterijų reikšmes mūsų pavyzdyje. Kitame etape įdiegiamas vienas iš reitingavimo metodų, siekiant išaiškinti tiekėjų situaciją. Šiame darbe buvo panaudotas vienas iš svarbesnių metodų, pavadintas PROMETHHE, kad būtų sureitinguoti tiekėjai pagal jų veiklą, remiantis nustatytais kriterijais. Sudarytoje lentelėje pateiktos konkrečios alternatyvos, taip pat tam tikri įvertinimo kriterijai. Reiktų apibrėžti pasirinkimo funkciją $P_j(a,b)$, kuri nurodo nukrypimą nuo dviejų alternatyvų (a,b) tam tikrame kriterijuje g_p į pasirinkimo laipsnio intervalą nuo 0 iki 1. Pasirinkta viena iš šešių galimų pasirinkimo funkcijos formų, kurias pasiūlė Brans ir kt. (1986) (įprasta forma, U-formos funkcija, V-formos funkcija, lygio funkcija, linijinė funkcija ir Gauso funkcija). Kai SP išreiškia savo patirtį ir pasvarstymus, įvesties duomenyse atsiranda neaiškumas ir neapibrėžtumas. Esant tokioms aplinkybėms, netikėtai atsiranda tikimybė padaryti klaidą mūsų įvertinime. Sprendimas: panaudoti F-PROMETHHE metodą, kuris yra neapibrėžtumo ir PROMETHEE derinys. Šiame darbe nustatyti kriterijai yra: 1) Minimizuoti kaštus; 2) Maksimizuoti projektavimo ir plėtros galimybes; 3) Maksimizuoti veiklos istoriją; 4) Maksimizuoti kompanijų lankstumą ruošiant reikalavimus; 5) Maksimizuoti pristatymo laiku procentinę išraišką; 6) Maksimizuoti gaminių kokybę ir tinkamumą.

Mes turime šiek tiek informacijos apie mūsų (kompanijos, kuri dirba su SP) taškus, lyginant su mūsų penkiais *(A, B, C, D, E)* konkurentais pagal įvairius kriterijus. Galutinis reitingavimas parodė, kad tiekėjo E situacija ir veikla buvo geriausia tarp visų tiekėjų, o ankstesnis tiekėjas, kuris bendradarbiavo su SP, buvo įvertintas kaip trečias. Taigi, SP būtų tikslinga bendradarbiauti su tiekėju *E,* norint patenkinti savo poreikius. Šio metodo reikšmė yra didelė, jei lyginsime su ankstesniais metodais. Ankstesniuose darbuose, kai buvo iškelta tiekėjo pasirinkimo problema, kriterijų reikšmių nustatymas buvo priskirtas SP. Tokia abejotina užduotis sudarė problemą SP, ir jo/jos komentarai nulėmė priskirtas reikšmes nustatytiems kriterijams. Dar daugiau, tai galėjo baigtis nerealistišku kriterijų svarbos laipsnio paaiškinimu dėl to, kad buvo nepaisyta kitų aspektų priimant sprendimą ir informacijos trūkumo apie šiandienos verslo konkurencinę aplinką. Nekreipiamas dėmesys į dydį, kuris buvo akcentuotas pateiktame metode, t. y. konkurentų vaidmenį priimant sprendimus, siekiant kuo objektyviau išaiškinti/ nustatyti kriterijų reikšmes negailestingoje konkurencinėje aplinkoje. Sprendimas buvo priimtas remiantis informacija apie tiekėjus, taip pat ir pagal nustatytus kriterijus. Taigi galima pateikti algoritmo naudą: dėmesio kreipimas į konkurentų situaciją nustatytais kriterijais, taip pat SP komentarai, apskaičiuojant kriterijų reikšmes ir sprendžiant tiekėjo pasirinkimo problemą esant konkurencinei aplinkai. Tolesniuose darbuose gali būti taikomi kiti reitingavimo metodai, tokie kaip neapibrėžtas TOPSIS, SWARA, ir t. t., norint išaiškinti kiekvienos alternatyvos situaciją. Pasiūlytas metodas gali būti įdiegtas ir kitais atvejais bei skirtingose srityse.

Raktažodžiai: *tiekėjo pasirinkimas, LPP, F-PROMETHEE, konkurencinė aplinka, neapibrėžtos sekos.*

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