Fuzzy AHP-Based Evaluation of Procurement Priorities at PT Krakatau Daya Listrik

Rizki Putra[*1] and Siti Maharani[2]

[1&2]Department of Electrical Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia

KEYWORDS: Performance Evaluation, Performance Indicators, Procurement Effeciency.

ABSTRACT

Supplier performance appraisal systems can be an important element for companies. The current evalution system can not to be used to select a potential supplier in a procurement system because it only provide uninvited supplier data but not provide vendor rating results in recommendations to participate in the bidding procurement. This research sets and gets 5 priority level criteria and 20 sub criteria in evaluation PT Krakatau Daya Listrik supplier performance. The Criteria, Sub Criteria and Alternative Supplier Priority analysis with fuzzy AHP method is known that Supplier A has the best achievement with the value of 1.008 compared to Supplier B with value of 0.602 and C pair with value of 0.660. it is recommended to select a pair because it has a good performance in the Daftar Rekanan Terundang (DRT). Evaluation of supplier performance the procurement of material in PT Krakatau Daya Listrik work effectively and efficiently.

INTRODUCTION

Supplieris one of necessary business partners in ensuring the availability of supply goods required by the company. There is no a prosperous and healthy company without having good suppliers who are excellent in delivering the best quality of goods in time. Hence, a company should assess supplier performance carefully and sustainably.

PT Krakatau Daya Listrik as one of PT Krakatau Steel subsidiaries put the effort in enhancing electrical production capacity, reduce production costs and intensifying equipment reliability. In order establishing that condusive operation, PT Krakatau Daya Listrik requires vendor who supply goods and services in time. PT Krakatau Daya Listrik has some criteria in selecting and finding vendors with excellent quality. They are punctuation in delivery, quality consistency, comprehensiveness of legal documents and others. In 1960, Dickson had made 23 criteria list which become reference for decades as a standard for evaluating suppliers.

Improvement in power plant supplier evaluation system in tight competition between industry insecutants in Cilegon become an important element for a company to work more efficient in raw material procurement and spare part and also selecting their strategic suppliers.

Some researchers have determined several criteria for supplier assessment such as quality, delivery, pricing, communication systems, service, flexibility, geographic location, etc. the main subject in this study is how to determine criteria and sub criteria in assessing the performance of suppliers on the procurement of goods in PT Krakatau Daya Listrik.

MATERIALS AND METHODS

Supplier performance evaluation become a difficult decision because various criteria shall be considered in the decision-making process. The analysis in selecting and measuring the supplier performance has been the focus of attentionmany scientists and procurement practitioners since the 1960s. Dickson (1960), for the first time conducting extensive studies in identifying, defining and analyzing the criteria are used in selecting a firm as a partner. There are more 23 criteria are determined in his study which each respondents should give assignment the importance to each criteria.

Additionally, Weber at al. (1991) presents the classification of all articles published since 1966 based on the criteria's attention. Build upon 74 papers, there are price criteria, delivery process, quality of goods, production capacity and geographical location which have became the most commonly referred to in the literature.

Table 1Criteria Used In Previous Research

Performace Criteria Used	Previous Researcher							
	Asamoah et al 2012	Pitchipoo et al (2013)	Roman et al (2014)	Kumar et al (2011)	Sarot et el (2011)	Prabjot et al (2014)	De felice et el (2015)	Garoma et al (2014)
Quality	x	X	X	X	x	X		X
Cost	x	X			x	X	X	
Price			X	X			X	X

Reliability	x							
Regulatory compliance	x							
Risk	x							
Financial Position	x		X					X
Financial Reputation		X						
Profil of Supplier	x							
Financial Status							X	
Delivery		X	X		x			X
Warranty		X						
Capacity		X						
Term of payment			X					
The Desire to Hold Stock			X					
Technology								
Service			X	X	x	X		
Reputation						X	X	X
After Purchase								X
Supplier Performance							X	

Table 1Criteria Used In Previous Research

Performace Criteria Used	Previous Researcher							
	Asamoah et al 2012	Pitchipoo et al (2013)	Roman et al (2014)	Kumar et al (2011)	Sarot et el (2011)	Prabjot et al (2014)	De felice et el (2015)	Garoma et al (2014)
Supplier Quality System							X	
Geographic Location							X	
Technical Capability							X	
Late Time				X				
Cycle Time						X		
Prospect Supplier Development			X					
Transportation			X					
Audit Supplier			X					
Production Capability			X					

RESULTS AND DISCUSSION

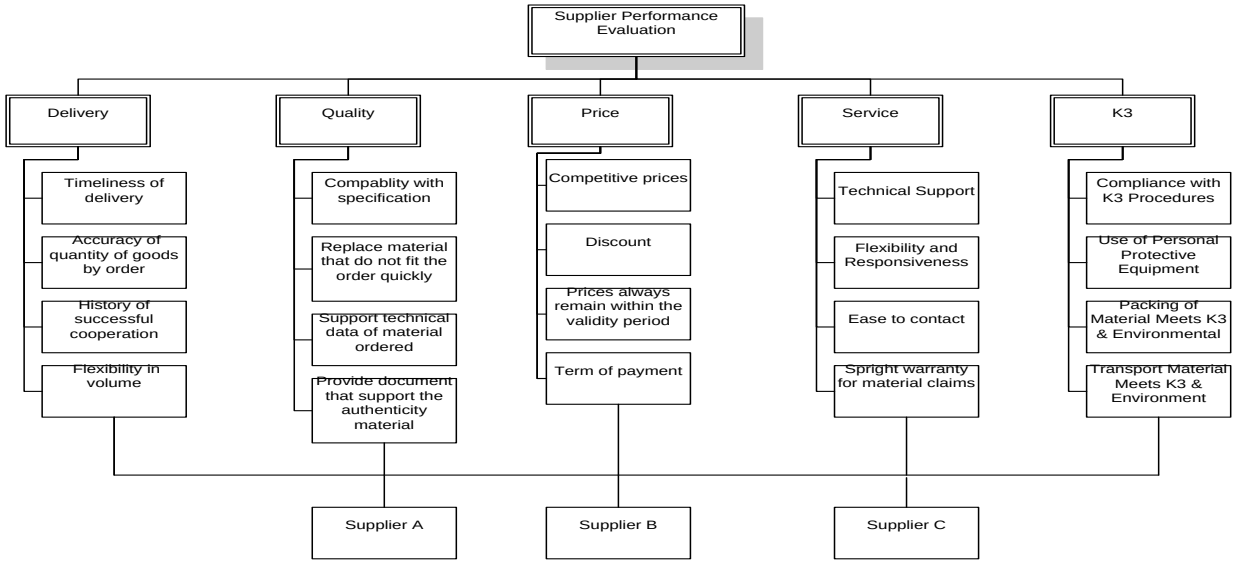

Figure 1 Hierarchical Decision Structure

Purpose

Criteria

Sub Criteria

In this study, define Criteria and Criteria Sub. Criteria and Sub Criteria Determination are obtained through literature review and benchmarking. Benchmarking type with functional method. Because PT Indonesia Power has the same process of power generation industry. The next step in the interview is to set up Criteria and Sub Criteria according to the needs of PT Krakatau Power based on the Court. Here are the selected Criteria and Sub Criteria :

Table 2 Selected Criteria and Sub Criteria

Criteria	Sub Criteria
Delivery	Timeliness of delivery
	Accuracy of quantity of goods by order
	History of successful cooperation
	Flexibility in volume
Quality	Compatibility with specifications
	Replace material that do not fit the order quickly
	Support technical data of material ordered
	Provide document that support the authenticity material
Price	Affordable price
	Discount
	Prices always remain within the validity period
	Term of payment
Service	Technical support
	Flexibility and responsiveness
	Ease to contacts
	Spright warranty for material claims
K3	Compliance with K3 Procedures
	Use of Personal Protective Equipment
	Packing of Material Meets K3 & Environmental Standards
	Transport Material Meets K3 & Environment standards

Alternative

Table 2 has shown that there are 5 selected Criteria and 20 Sub Criteria from PT Krakatau Daya Listrik Superintendent Procurement as Judgement Expert. The assessment Judgement Expert to Criteria & Sub Criteria is important in assessing supplier performance that later on would be arranged in Hierarchy Structure. This Hierarchy Structure would be used to evaluate supplier performance &questionnaire arrangement. In these questionnaires, the weight of the priorities for each criteria, sub criteria and alternative supplier will be assessed. The questionnaires would show which supplier who has the highest value as final result.

Criteria for Consistency Testing with Fuzzy AHP Methods

After obtaining the value $\lambda_{maksimum}$ of each matrix, each matrix is tested for its consistency. The respondents have set the values for pairs A, B and C before alternative calculations starts from filling out the matrix from each respondent. One respondent for one matrix table.

Table 3 Respondent Criteria Matrix 1

Criteria	Delivery	Quality	Price	Service	K3
Delivery	1.00	1.00	3.00	3.00	1.00
Quality	1.00	1.00	3.00	3.00	3.00
Price	0.33	0.33	1.00	1.00	1.00
Service	0.33	0.33	0.33	1.00	1.00
K3	1.00	0.33	1.00	1.00	1.00

The table shown above are using the Saaty Scale table. After data from each respondent matrix has been filled, the next step is to select respondent matrix 1 to normalize respondents assessment value.

Table 4 Respondent Normalization

Criteria	Delivery	Quality	Price	Service	HSE	Number	Priority Vector
Delivery	0.27	0.33	0.36	0.27	0.14	1.38	0.28
Quality	0.27	0.33	0.36	0.27	0.43	1.67	0.34
Price	0.09	0.11	0.12	0.27	0.14	0.74	0.11
Service	0.09	0.11	0.04	0.09	0.14	0.48	0.11
HSE	0.27	0.11	0.12	0.09	0.14	0.74	0.15

After normalizing the respondent assessment value, we get the priority vector values for suppliers A, B and C. Further steps, the consistency value (multiplication matrix) is shown as the table below:

Table 5 Consistency Value (Multiplicative Matrix)

Criteria	Delivery	Quality	Price	Service	HSE	Number	Priority Vector	Decision times	Time / Vector results
Delivery	0.27	0.33	0.36	0.27	0.14	1.38	0.28	1,45	5,13
Quality	0.27	0.33	0.36	0.27	0.43	1.67	0.34	1,75	5,15
Price	0.09	0.11	0.12	0.27	0.14	0.74	0.11	0,58	5,15
Service	0.09	0.11	0.04	0.09	0.14	0.48	0.11	0,58	5,15
HSE	0.27	0.11	0.12	0.09	0.14	0.74	0.15	0,77	5,16

The value $\lambda_{maksimum}$ is obtained by dividing the result value (a) with the priority Vector. The results are summed up and divided by many criteria (n)

$$\lambda_{maksimum} = \frac{5{,}13 + 5{,}15 + 5{,}15 + 5{,}15 + 5{,}16}{5} = 5{,}15$$

Furthermore, the value of the consistency index is calculated (CI)

$$CI = \frac{\lambda_{max} - n}{n - 1} = \frac{5{,}15 - 5}{5 - 1} = 0{,}038$$

Based on the table, for n = 5 , so RI = 1,120

$$CR = \frac{CI}{RI} = \frac{0{,}038}{1{,}120} = 0{,}034$$

For a matrix A is obtained CR <0.1000.This means that the assessmentvalue is obtained from consistent respondent. In the matrix of respondents 2, 3 and 4, the consistency value was tested with the same steps and processes. The results are listed in the table below:

Table 6 Respondent Matrix Test Result

Matriks	λ_{max}	CI	CR	Consistent
Respondents 2	5,44	0,109	1,120	Consistent
Respondents 3	5,18	0,045	1,120	Consistent
Respondents 4	5,24	0,060	1,120	Consistent

The consistency test results show a questionnaire consistently fulfilled by the respondents. This means that the questionnaire can go to the next step with criteria weightingby using AHP fuzzy method. Next step, the AHP scale matrix is converted to triangular fuzzy number (TFN).

In this method, the respondents' value results are converted into triangular fuzzy numbers in the form (l.m.u). The results of comparative data that are paired with AHP fuzzy method can be seen in the following table:

Table 7 Inter-Criteria Interval Assessed by 4 Respondents With Fuzzy AHP Method

		Delivery			Quality			Price			Service			K3		
		l	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*
Delivery	Respondent 1	1	1	1	1	1	1	2	3	4	2	3	4	1	1	1
	Respondent 2	1	1	1	1/9	1/9	1/8	1/8	1/7	1/6	1	1	1	1/6	1/5	¼
	Respondent 3	1	1	1	1/9	1/8	1/7	1/9	1/9	1/8	7	8	9	1/9	1/8	1/7
	Repondent 4	1	1	1	1/6	1/5	1/4	1/6	1/5	1/4	2	3	4	1/6	1/5	¼
Quality	Respondent 1	1	1	1	1	1	1	2	3	4	2	3	4	2	3	4
	Respondent 2	8	9	9	1	1	1	6	7	8	6	7	8	6	7	8
	Respondent 3	7	8	9	1	1	1	1/9	1/9	1/8	7	8	9	1/9	1/9	1/8
	Respondent 4	4	5	6	1	1	1	1	1	1	4	5	6	1	1	1
Price	Respondent 1	1/4	1/3	1/2	1/4	1/3	1/2	1	1	1	2	3	4	1	1	1
	Respondent 2	4	5	6	1/8	1/7	1/6	1	1	1	1/6	1/5	1/4	1/6	1/5	1/4
	Respondent 3	8	9	9	8	9	9	1	1	1	8	9	9	1/9	1/8	1/7
	Respondent 4	4	5	6	1	1	1	1	1	1	2	3	4	1	1	1
Service	Respondent 1	1/4	1/3	1/2	1/4	1/3	1/2	1/4	1/3	1/2	1	1	1	1	1	1
	Respondent 2	4	5	6	1/8	1/7	1/6	4	5	6	1	1	1	4	5	6
	Respondent 3	1/9	1/8	1/7	1/8	1/7	1/6	1/9	1/8	1/7	1	1	1	1/9	1/8	1/7
	Respondent 4	1/2/	1/3	1/4	1/4	1/5	1/6	1/2	1/3	1/4	1	1	1	1/7/	1/8	1/9
K3	Respondent 1	1	1	1	1/4	1/3	1/2	1	1	1	1	1	1	1	1	1
	Respondent 2	4	5	6	1	1	1	6	7	8	4	5	6	1	1	1
	Respondent 3	7	8	9	7	8	9	7	8	9	7	8	9	1	1	1
	Respondent 4	4	5	6	1	1	1	1	1	1	7	8	9	1	1	1

Then the average value of 4 respondents was obtained so that the pairing matrix for the main criteria

Table 8 Average Fuzzy Number

	Delivery			Quality			Price			Service			K3		
	l	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*
Delivery	1	1	1	0,59	0,61	0,65	0,67	0,97	1,31	1,29	1,80	2,31	0,79	0,80	0,81
Quality	2,25	2,75	3,25	1	1	1	1,79	2,30	2,81	2,06	2,83	3,63	1,25	1,50	1,75

Table 8 Average Fuzzy Number

	Delivery			Quality			Price			Service			K3		
	l	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*
Price	2,06	2,83	3,63	1,35	1,63	1,94	1	1	1	1,25	1,50	1,75	1,00	1,00	1,00
Service	0,88	1,17	1,50	0,67	0,97	1,30	0,81	1,08	1,38	1	1	1	0,78	0,78	0,79
K3	1,75	2	2,25	0,81	0,83	0,88	1	1	1	2,50	2,75	3	1	1	1

The table above already uses a blur scale that consists of l.m.u (lower value, middle / middle, top / bottom value

Main Weight Loss Criteria with Fuzzy AHP Methods

After the respondent's assessment data is converted to fuzzy triangular numbers, the next step is to use synthetic level analysis by determining the value of blur synthesis to obtain the weight vectors of each hierarchical element. The last stage is to normalize the weight gained instead of the blur number. This weight will be the basis for evaluating the performance of existing supplier

Weight rating is:

a. Calculation of the value of synthetic fuzzy area (Si). The first one will be calculated$\sum_{j=1}^{m} M_{gi}^{j}$, which is by adding each fuzzy number of matrix A
Then calculate the value $\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}$, by summing the sum of each blur number on the row row So the value obtained $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$

Table 9 Components of Fuzzy Components Calculation of Equations for Matrix Comparisons Comparing Major Criteria

	$\sum_{j=1}^{m} M_{gi}^{j}$			$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]$			$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$		
	l	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*
Delivery	4,34	5,18	6,08	30,55	36,10	41,93	0,023	0,027	0,032
Quality	8,35	10,38	12,44						
Price	6,67	7,95	9,31						
Service	4,13	4,99	5,98						
K3	7,06	7,58	8,13						

Table 10 Fuzzy Synthetic Wide Value Calculating Results for Main Criteria

$$S_i = \sum_{j=}^{m} M_{gi}^{j} \, x \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$$

	l	*m*	*u*
1	0,103	0,143	0,199
2	0,199	0,287	0,407
3	0,158	0,220	0,304
4	0,098	0,138	0,195
5	0,168	0,210	0,266

b. From the fuzzy synthetic values calculated in the previous step, the comparison of probability levels is obtained. After that, determine the probability level between 2 extents of synthetic fuzzy. In the appendix can be seen a more complete calculation.

c. Comparison of Synthetic and Minimum Blanket Value.

Table 11 Comparison of Synthetic and Minimum Blanket Value

	$S_1 \geq$	$S_2 \geq$	$S_3 \geq$	$S_4 \geq$	$S_5 \geq$
S_1		1,0	1,0	0,94	1,0
S_2	0,0004		0,61	0,24	1,0
S_3	0,34	1,0		0,31	0,46
S_4	1,0	1,0	1,0		1,0
S_5	0,31	1,21	1,08	0,27	
Min	0,0004	1,0	0,61	0,27	0,46

After the synthetic values are blurred, then the minimum value is taken. Minimum value to get a heavy vector

d. Then we calculate the weight vectors and normalize the weight vectors so we can know the weight of the main criteria as shown in the following table

Table 12 Vector weight

	$d'(A1)$	$d'(A2)$	$d'(A3)$	$d'(A4)$	$d'(A5)$
W'	0,0004	1,00	0,61	0,27	0,46

Table 13 Normal vector normalization

	A1	A2	A3	A4	A5

Priority weight (W)	0,0001	0,427	0,260	0,115	0,196

Based on the data processing result above, the main weight weight is considered for the following criteria:

1. Delivery criteria weighs 0.001
2. quality criteria weigh 0.427
3. Price criteria weighs 0.260
4. Service criteria weighs 0.115
5. K3 criteria weighs 0.196

Weighing the criteria using the AHP fuzzy is known to highest quality criterion 0,427. Therefore, suppliers are required to deliver material quality good. The price criteria rank second with value 0,260. This means that respondents want to get the best price in procurement at the company. Criteria K3 kept the third rank with a value of 0,196. This is in line with respondent knowledge of company policy in applying SMK3.the delivery criteria is ranked fourth with a value of 0,115. Suppliers are required to deliver material within the delivery time limit.

It is interesting to see the service criteria. The value of 0,001 has a smaller value than other criteria. This suggests that respondents rated the criterion as not top priority. However, of course, it is required that suppliers can carry out goods supply activities with good value on other criteria.

Table 14 Results of Priority Weight Calculation for Criteria, Sub Criteria and Alternative Supplier with AHP Fuzzy Method

No	Criteria	Weight Criteria	Sub Criteria	Weight Criteria Sub	Vendor	Priority Weight
1	Delivery		Timeliness of delivery	0,341	Vendor A	0,500
					Vendor B	0
					Vendor C	0,500
		0,117	Accuracy of quantity of goods by order	0,290	Vendor A	0,561
					Vendor B	0,179
					Vendor C	0,258
			History of successful cooperation	0,027	Vendor A	0,502
					Vendor B	0,366
					Vendor C	0,130
			Flexibility in volume	0,341	Vendor A	0,609
					Vendor B	0
					Vendor C	0,390
2	Quality	0,337	Compatibility with specifications	0,467	Vendor A	0,537
					Vendor B	0
					Vendor C	0,462

Table 14 Results of Priority Weight Calculation for Criteria, Sub Criteria and Alternative Supplier with AHP Fuzzy Method

No	Criteria	Weight Criteria	Sub Criteria	Weight Criteria Sub	Vendor	Priority Weight
			Can replace items not ordered quickly	0,341	Vendor A	0,221
					Vendor B	0,317
					Vendor C	0,460
			Can enter technical data of ordered items	0,130	Vendor A	0,328
					Vendor B	0,314
					Vendor C	0,357
			provide document that support the authenticity material	0,060	Vendor A	0,347
					Vendor B	0,305
					Vendor C	0,347

3	Price	0,230	Affordable price	0,495	Vendor A	0,745
					Vendor B	0,001
					Vendor C	0,253
			Discount	0,366	Vendor A	0,354
					Vendor B	0,290
					Vendor C	0,354
			Prices always remain within the validity period	0,054	Vendor A	0,084
					Vendor B	0,415
					Vendor C	0,499
			Term of payment	0,084	Vendor A	0,359
					Vendor B	0,460
					Vendor C	0,179
4	Service	0,101	Technical support	0,103	Vendor A	0,440
					Vendor B	0,118
					Vendor C	0,440

Table 14 Results of Priority Weight Calculation for Criteria, Sub Criteria and Alternative Supplier with AHP Fuzzy Method

No	Criteria	Weight Criteria	Sub Criteria	Weight Sub Criteria	Vendor	Priority Weight
			Flexibility and Responsiveness	0,172	Vendor A	0
					Vendor B	0,454
					Vendor C	0,545
			Ease to Contacts	0,149	Vendor A	0,139
					Vendor B	0,395
					Vendor C	0,465
			Spright Warranty For Item Claims	0,574	Vendor A	0,540
					Vendor B	0,459
					Vendor C	0
5	K3	0,173	Compliance with K3 Procedures	0,460	Vendor A	0,526
					Vendor B	0,100
					Vendor C	0,373
			Use of Personal Protective Equipment	0,364	Vendor A	0,492
					Vendor B	0,492
					Vendor C	0,014
			Packing of Material Meets K3 & Environmental Standards	0,170	Vendor A	0,291
					Vendor B	0,335
					Vendor C	0,373
			Transport Material Meets K3 & Environment standards	0,004	Vendor A	0,463
					Vendor B	0,453
					Vendor C	0,083

CONCLUSION

evaluating supplier performance based on selected criteria as well as each of its priorities. After analyzing priority weighting criteria, sub criteria and supplier alternative then supplier A has the best performance with value 1,008 compared supplier B with value 0,602 and supplier C with value 0,660. it is recommended to select Supplier A for having a good performance in the Daftar Rekanan Terundang (DRT). Supplier C can be a second option. supplier B became last option. the performance evaluation of the supplier, make the process of procurement in PT Krakatau Daya Listrik is effective and efficient.

REFERENCES

1. Asamoah, D., Annan, J., and Nyarko, S.(2012) AHP approach for supplier evaluation and selection in a pharmaceutical manufacturing firm in Ghana, *International Journal of Business and Management*, vol. 7, no. 10, pp. 49–62 May.
2. Chang, D. Y. (1996). Applications of the extent analysis method on Fuzzy AHP. *European Journal of Operation Research*, 95, 649-655.
3. De Felice, F., Deldoost, M. H., Faizollahi, M. and Petrillo, A., (2015). Performance measurement model for the supplier selection based on AHP. *International Journal of Engineering Business Management.* 7:17 | doi: 10.5772/61702
4. Dickson, G.W., (1966) "An Analysis of Vendor Selection Systems and Decision". *Journal ofPurchasing*Vol.2(1), 5-17.
5. Garoma, T and Diriba, S. (2014). Modeling and Analysis of Supplier Selection Method Using Analytical Hierarchy Process (AHP). *Science, Technology and Arts Research Journal Sci. Technol. Arts Res. J., Jan-March 2014, 3(1): 145 151*
6. Kaur, P . (2014) Selection of Vendor Based on Intuitionistic Fuzzy Analytical Hierarchy Process. *Hindawi Publishing Corporation Advances in Operations Research*, Article ID 987690, 10 pages
7. Pitchipoo, P., Venkumar, P., Rajakarunakaran, S.(2013) "Modeling and development of a decision support system for supplier selection in the process industry", *Journal of Industrial Engineering International*, vol. 9, no. 23.
8. Roman, H.,Petr, P., and Darko, B. (2014) The use of AHP method for selection of supplier, *Transport*, vol. 29, no. 2, pp. 195-203.
9. Saaty, T.L., (1980) *The Analytic Hierarchy Process*, McGraw-Hill, New York, USA.
10. Weber, C. A (1996), "A data envelopment analysis approach to measuring *supplier* performance", *Supply Chain Management*, Vol. 1 No. 1, pp. 28-30.

.