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Identification and Ranking Green Supplier Selection Criteria Using One-Sample T-Test and FANP Methods: A Case Study for Petrochemical Industry

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Abstract
Increasing global notices in environmental protection, green supply chain management (GSCM) has received much attention by researchers and managers more than the past. Commonly, firms have considered cost criteria to select their suppliers. Despite the fact that there are various papers considering the formal criteria in supplier selection, there is a few limited numbers considering the environmental issues. This study will use both traditional and environmental criteria and will offer a combined approach to identify and ranking of the criteria for green supplier selection in petrochemical industry. The One-Sample T-Test is to be used to identify the appropriate criteria, using the Pareto principle the relationships between the criteria are obtained and the Fuzzy Analytic Network Process (FANP) is to be used to calculate weights of green supplier selection's criteria considering the criteria interdependencies in petrochemical industry. Also, triangular fuzzy numbers are used to express linguistic values of experts' subjective preference in ANP stage.

Keywords
Green Supply Chain Management, Petrochemical Industry, One-Sample T-Test, Analytic Network Process

1. Introduction
Todays, most of the reputable companies and grand purchasers, besides claiming competitive price, excepted quality and delivery on time, want to make sure that the efficacies of the product and production process, supplying and consumption of the product on environment would be identified and under control. Although, the variety studies have been done in supply chain management and criteria of selecting suppliers [1-6], but the literature regarding green supplier evaluation or works that consider environmental criteria are rather limited [7-13]. Environmental challenges, such as global warming, air and water pollution, acid rains, etc., have demanded great concern by organizations regarding their environmental management [7]. Some of the major issues in environmental sustainability relate to a product's life cycle environmental burdens. For organizations to manage these burdens effectively they need to expand their vision of environmentally sound practices to go beyond their organizational boundaries. The one way they can fully accomplish this task from strategic and operational perspectives is through green supply chain management (GSCM) practices and programs. In order to reap the greatest benefits from environmental management, firms must integrate all members in the green supply chain. Among these expectations, increasing attention is devoted to suppliers' social responsibility with a particular focus on fair and legal use of natural resources. Hence, strategic partnership with environmentally, socially and Traditionally powerful suppliers should be integrated within the GSC

for improving the performance in many directions including reducing costs and lead time, eliminating wastages, improving quality and flexibility to meet the needs of the customers, etc [10]. This study attempt to, identify and rank the supplier selection criteria in petrochemical industry using of the linguistic preferences. The presented approach, inclusive eight ranking criteria in two traditional and environmental categories which are identified by expert opinions and One-Sample T-Test and their relative ranksare calculated by using Fuzzy Analytical Network Process (FANP) with considering the interdependency between them. Meanwhile, in order to remove the waste calculation in FANP method, the relationships of criteria are specified by expert opinions and Pareto principle. The rest of the paper is organized as follows: in Section 2 the literature review would be presented. The methodology of research would present in sections 3 and a numerical application of the proposed approach will present in section 4 and finally conclusion and future works would be presented in section 5.

2. Literature Review

Nowadays, the outsourcing, contracting out a business process to a third-party, is one of the most important strategies to avoid certain costs in a supply chain management such as production or labor costs [14]. In other view, with the changing environmental requirements, affecting the manufacturing operations, increasing attention is also required to be given to develop effective environmental management strategies for the supply chain [15].
Srivastava presented a definition for GSCM as: Integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers, as well as end-of-life management of the product after its useful life [16]. Some characteristic differences between traditional supply chain management (SCM) and green SCM presented by Deshmukh and Vasudevan are shown in Table 1.

Table 1. Traditional SCM vs Green SCM- Deshmukh and Vasudevan

Item	Characteristics	Convectional SCM	Green SCM
1	Objectives and values	Economic	Economic and Ecological
2	Ecologicaloptimization	Integrated Approach High	Ecological Impacts
3	Supplier Selection Criteria	Price Switching Supplier Short Term Relations	Ecological Aspects Logical Terms Relations
4	Cost Prices	Low	High
5	Speed and Flexibility	High	Low

Since 1960s, the supplier selection criteria and performance evaluation of suppliers have been a focal point of many researchers. While the traditional supplier evaluation methods primarily considered Traditional criteria in the decision-making process, more recent emphasis points to the incorporation of multiple suppliers' criteria into the evaluation process [17]. Location, additional value added capability, scope of resources, quality, cost, flexibility in contracts, on time delivery, reputation, culture and existing relationship are the top10 factors considered in supplier selection according to a survey [18]. Weber et al. (1991) presented a review of 74 articles that represented the supplier selection literature available since the year 1966. Capacity, quality, on time delivery and net price, were the criteria that appeared most often in articles [19]. Ho et al. (2009), suggested that flexibility, finance, risk, research & development, manufacturing capability, technology, management, service, relationship, reputation, price, delivery, safety and environment are followed after quality management, safety and environment [20].

Several decision-making approaches for supplier selection have been introduced in the past three to four decades, including AHP, ANP, the matrix method, artificial neural networks (ANN), case based reasoning (CBR), data envelopment analysis (DEA), fuzzy set theory, the genetic algorithm (GA), mathematical programming (MP), the simple multi-attribute rating technique (SMART), GRA, and their hybrids [21]. Extensive single model approaches have been proposed for supplier selection, such as the Analytical Hierarchical Process (AHP) by [22]. Bhutta and Huq analyzed as to how AHP provides a framework to cope up with multiple criteria situations, involving supplier selection, while total cost of ownership is a methodology and philosophy [23]. Analytic Network Process (ANP) is used as a decision tool to solve multi criteria decision making tool as also proposed by [24]. Lee et al. proposed a model for manufacturers to have a better understanding of the capabilities that a green supplier must possess that can evaluate and select the most suitable green supplier for cooperation and accordingly used Delphi and fuzzy extended AHP [9]. Hsu and Hu presented ANP as a new criterion of supplier selection to hazardous substance management including green purchasing, green materials coding & recording, capability of green design, inventory of hazardous substances, and management for hazardous substances, legal compliance competency and environmental management systems [25].

3.Material and methods

3.1 One-Sample T-Test

One-Sample T-Test is a statistical tools, which used to examine the mean difference between the sample (n<30) and the known value of the population mean. In One-Sample t-test, the population mean was known. We select a random sample from the population and then compare the sample mean with the population mean and make a statistical decision as to whether or not the sample mean is different from the population mean [26].

The statistical hypothesis for One-Sample T-Test is: $\begin{cases} H_.: \mu = a \\ H_1: \mu \neq a \end{cases}$ (1)

Where, "a" is a numerical value. The examination statistic equal to: $t = \frac{\bar{x}-\mu}{\frac{s}{\sqrt{n}}}$ (2)

Hypothesis testing: In hypothesis testing, statistical decisions are made to decide whether or not the population mean and the sample mean are different. Here, we will compare the calculated value with the table value. If the calculated value is greater than the table value, then we will reject the null hypothesis, and accept the alternative hypothesis [26].

3.2 Pareto Principle

A principle, named after economist Vilfredo Pareto that specifies an unequal relationships between inputs and outputs. The principle states that, for many phenomena, 20% of invested input is responsible for 80% of the results obtained. Put another way, 80% of consequences stem from 20% of the causes [27].

3.3 Fuzzy Analytic Network Process (FANP)

ANP is a general form of the Analytical Hierarchy Process (AHP) which was proposed by Saaty for extending the AHP to address restrictions of the hierarchical structure where criteria are independent from each other. In FANP, pair-wise comparison matrices are formed between various attributes of each level with the help of triangular fuzzy numbers. The FANP can easily accommodate the interrelationships existing among the functional activities [28].

Önüt et al. proposed the following four main steps of FANP as follows [28].

Step 1: Model problem structuring: The problem should be clearly defined and decomposed in to a logical system like a network.
Step 2: Pair wise comparison matrices and priority vectors: the geometric mean is used to aggregate the expert opinions and to obtain Eigenvectors of each pair wise tables, the logarithmic least squares method can be used as follows:

$$\widetilde{w}_k = \left(w_k^l, w_k^m, w_k^n\right) \;\; k = 1,2,3,\ldots,n \tag{3}$$

Where

$$w_k^s = \frac{\left(\prod_{j=1}^{n} a_{kj}^s\right)^{1/n}}{\sum_{j=1}^{n}\left(\prod_{j=1}^{n} a_{ij}^m\right)^{1/n}} \; s \in \{l, m, n\} \tag{4}$$

Step 3: Forming the super-matrix (w_{ij}): These matrixes include the eigenvectors which obtained from step 2.
Step 4: calculating final weighs of levels: final weights of elements for each level (w_i^*) are calculated using Eq. 4:

$$w_i^* = w_{ii} \times w_{i(i-1)} \times w_{i-1}^* \tag{5}$$

3.4 Methodology

Our proposed combined approach for identification and ranking of criteria for green supplier selection in petrochemical industry consists of four steps, as shown in Figure1. In the first step, traditional and environmental supplier selection criteria are specified by reviewing the literature. In the second step, a structured questionnaire which its validity confirmed by companies experts and its Reliability is equal to 0.822 according to Cronbach's Alpha method, is used to select the relevant supplier selection’s criteria based upon those suggested by the literature. The experts are asked to provide their opinions in linguistic terms on whether a criteria was relevant or not for supplier selection in petrochemical industry. Next, the relevant criteria are selected by One-Sample T-Test and using SPSS Software. In step third, the experts are asked in a structured questionnaire which its validity confirmed by companies experts and its Reliability is equal to 0.743 according to the Cronbach's Alpha method, to determine the relationship between the criteria. After receipt of the filled out questionnaire, number 1 will be inserted in case there is a relationship between two selected criteria and 0 if no relationship is assumed and the related Pareto chart is drawn. Relations between the pair of criteria that are covered by 80 percent of the expert opinions frequency are accepted and elected as the relationships among criteria. Finally, using pairwise comparisons in order to determine the relative importance of the criteria, ranks of the criteria using a super-matrix which is part of the FANP are calculated.

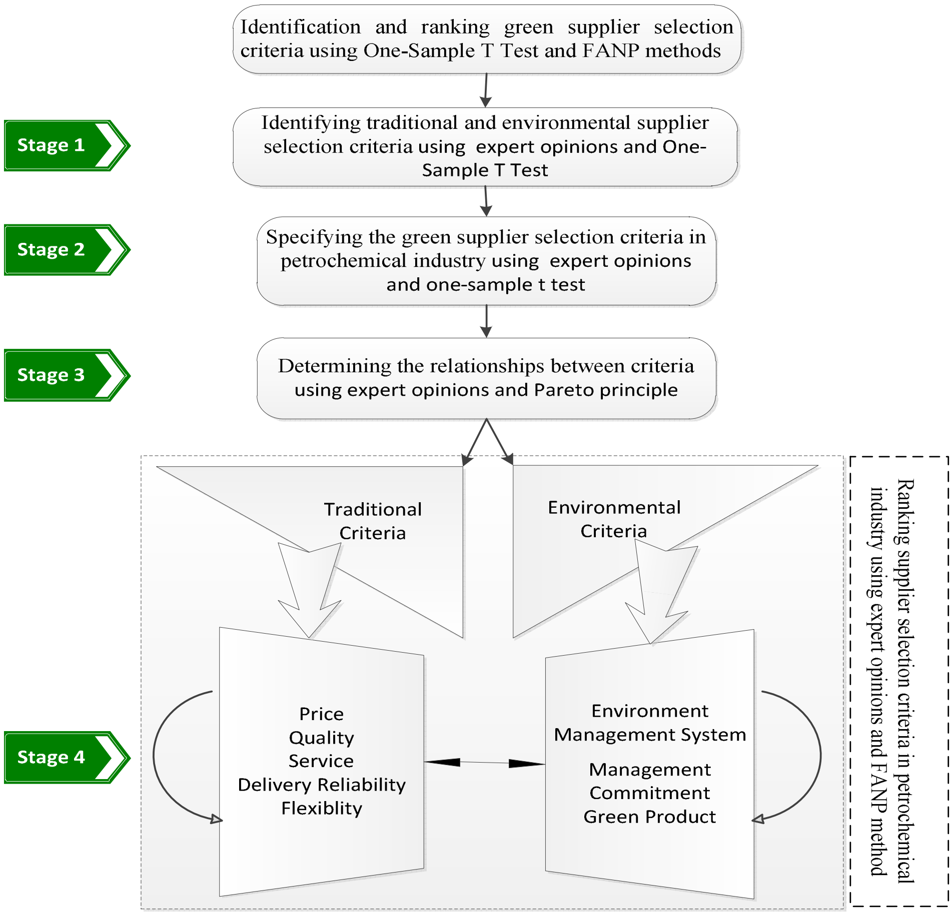

Figure 1. Diagram for proposed approach

Table 2. Suppliers Selection Criteria

Author / Authors	Criteria																					
	Traditional Criteria											Environment Criteria										
	Cost	Quality	Technology	Customer Satisfaction	Delivery Reliability	Service	Culture	Organization	Profitability	Flexibility	Location	Quality Management System	Management Commitment	Eco Technology	Eco Row Material	Environmental Training of Staff	Environment Management System	Pollution Control	Green Image	Green Design	Green Product	Resource Consumption
Shen et al. (2013)												✓	✓	✓	✓	✓		✓	✓	✓		✓
Bai and Sarkis(2010)	✓	✓						✓				✓	✓	✓		✓	✓					
Lee et al. (2009)	✓	✓	✓		✓	✓		✓				✓		✓			✓	✓	✓			
Awasthi et al. (2010)												✓	✓	✓	✓	✓	✓	✓		✓		
Büyüközkan and	✓	✓			✓	✓		✓				✓	✓	✓							✓	
Bali et al. (2013)		✓			✓	✓						✓			✓			✓	✓	✓	✓	
Shu and Wub(2009)	✓	✓			✓		✓			✓	✓											
Tuzkaya et al.(2013)	✓												✓	✓	✓		✓	✓	✓	✓	✓	
Yeh and Chuang(2013)	✓																		✓	✓	✓	
Ashraf Bakeshlu et	✓		✓		✓							✓	✓				✓				✓	
Hashemi et al.(2015)	✓	✓	✓										✓					✓				✓
Amin and Zhang(2012)	✓	✓	✓		✓									✓				✓			✓	
Tseng and Chiu(2013)	✓	✓		✓	✓			✓	✓	✓		✓						✓	✓	✓	✓	

3.5 Numerical example

The National Petrochemical Company (NPC), a subsidiary to the Iranian Petroleum Ministry, is owned by the government of the Islamic Republic of Iran. It is responsible for the development and operation of petrochemical facilities in the country. Founded in 1964, NPC began its activities by operating a small fertilizer plant. Over the years, it has not only expanded the range and volume of its products, but has also taken steps in the areas such as research and technology to achieve more self-sufficiency.

Simultaneous with issuing environment management system in collection of international management system and despite general imagine of the craftsmen in chemical industries that due to the nature of the activities of these industries, not assumed clean product. National Petrochemical Company's management trusting on experienced workers, followed implementation of ISO 140001 and in 1998 as the first petrochemical company in Iran, Esfahan Petrochemical Company obtained the certificate of implementation of the environmental management system. These days, the green supply chain is identified as a tool to gain a competitive advantage in the international level. Therefore, the NPC, like other organizations, need to move toward a GSCM.

In this study, in order to identification and ranking criteria of green supplier selection and with respect to distribution of petrochemical companies in Iran and lack of access to all companies, the expert opinions of top ten petrochemical companies with highest ranking in 100 premier companies of Iran in 2013 suggested by industrial management company (i.e.: Nouri, Jam, Bandar Emam, Maroon, Pars, BoualiSina, Shazand, Zagros, Amir Kabir and Esfahan Petrochemical Companies) are utilized.

3.5.1. Identifying traditional and environmental supplier selection criteria

As the first stage, by literature reviewing, 12 traditional criteria and 10 environmental criteria were gathered and assumed as the potential criteria for suppliers' selection in petrochemical industry (Table 2).

3.5.2. Specifying the green supplier selection criteria in petrochemical industry

In the second stage, by issuing a questionnaire, experts are asked to specify the importance of the criteria using linguistic preferences. In this phase, the linguistic terms of "very good", "good", "moderate", "weak" and "very weak" were used [29]. Then, to change the qualitative data to quantitative data, the values: 5~1 were allocated to the importance levels of "very high" to "very weak", respectively. The quantitative data were inserted to the SPSS software in order to perform One-Sample T-Test. The statistics for the test were shown in (Table 3).

According to Eq. 1, the statistic hypotheses aredefined as: $\begin{cases} H_\circ : \ \mu = 3 \\ H_1 : \ \mu \neq 3 \end{cases}$

For all the criteria significance level is less than 0.05 (the level of significance which usually used for the test), except the Technology. Weak significance forTechnology (0.051) and negative lower limit and positive upper limit of the 95% Confidence Interval of the Difference shows that the pollution mean is equal to test value (i.e., 3).

Table 3. One-SampleT-Test

Criteria	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Price	11.129	9	.000	1.70000	1.3544	2.0456
Technology	-2.250	9	.051	-.60000	-1.2032	.0032
Quality	19.000	9	.000	1.90000	1.6738	2.1262
Quality Management System	-4.000	9	.003	-.80000	-1.2524	-.3476
Customer Satisfaction	-6.000	9	.000	-1.20000	-1.6524	-.7476
Culture	-19.000	9	.000	-1.90000	-2.1262	-1.6738
Reliability Delivery	9.000	9	.000	1.50000	1.1230	1.8770
Organization	-3.498	9	.007	-1.10000	-1.8114	-.3886
Flexibility	11.129	9	.000	1.70000	1.3544	2.0456
Profitability	-3.873	9	.004	-1.00000	-1.5841	-.4159
Service	6.332	9	.000	1.40000	.8998	1.9002
Location	-8.573	9	.000	-1.40000	-1.7694	-1.0306
Green Product	4.743	9	.001	1.00000	.5231	1.4769
Green Design	-3.857	9	.004	-.90000	-1.4278	-.3722
Resource Consumption	-3.354	9	.008	-1.00000	-1.6744	-.3256
Green Image	-11.129	9	.000	-1.70000	-2.0456	-1.3544
Pollution Control	-6.128	9	.000	-1.10000	-1.5061	-.6939
Eco Technology	-6.000	9	.000	-.80000	-1.1016	-.4984
Eco Raw Material	-4.743	9	.001	-1.00000	-1.4769	-.5231
Management Commitment	6.000	9	.000	1.20000	.7476	1.6524
Environmental Training of Staff	-11.129	9	.000	-1.70000	-2.0456	-1.3544
Environment Management System	6.000	9	.000	1.20000	.7476	1.6524

Regarding others criteria, the significance level less than 0.05 Leads to rejection of the null hypothesis ($\mu = 3$). So, the pollution mean of these criteria are lower or upper than the test value (i.e., $\mu \neq 3$). However, the criteria with positive values for lower and upper limits of Confidence Interval of the Difference have population mean more than test value (i.e., $\mu > 3$). Therefore, the accepted criteria for green supplier selection in petrochemical industry, which are obtained from experts opinions and One-Sample T-Test are: Price (C1), Quality (C2), Service (C3), Delivery Reliability (C4), Flexibility (C5), Environment Management Systems (C6), Management Commitment (C7) and Green Product (C8) (Figure 2).

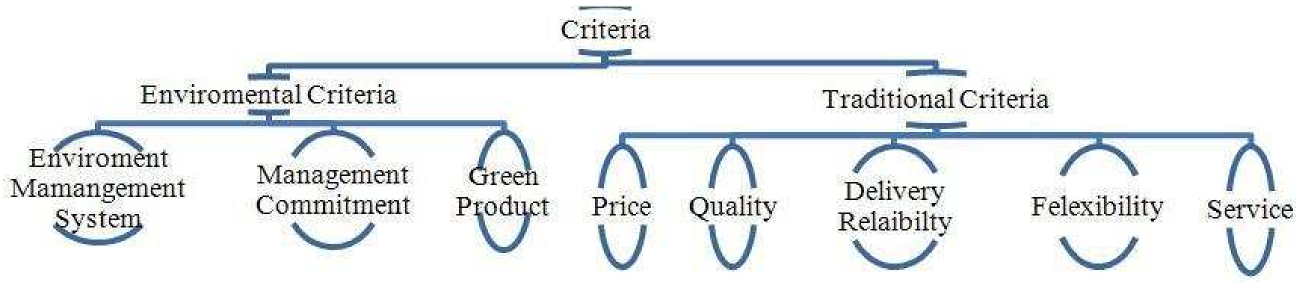

Figure 2. Green supplier selection criteria in petrochemical industry

3.5.3. Determining the relationships between criteria

To determination the relationships between the criteria, the experts were asked to assess the relationship or lack of relationship between the pair-criteria by a questionnaire. After receipt of the filled out questionnaires, the qualitative data were changed to quantitative data by inserting number 1 in case, there was a relationship between two selected criteria and 0 if no relationship was assumed. Then, the frequency percent of expert opinions were calculated and sorted in descending. In following, cumulative frequency of expert opinions were calculated and related Pareto chart was drawn (Fig.3). As it shown in Figure 3 and according to the Pareto principle, number of 15 relations between the pair-criteria that were covered by 81 percent of the expert opinions were accepted and selected as relationships among criteria. Figure4 shows relationships among all 8 criteria of this study.

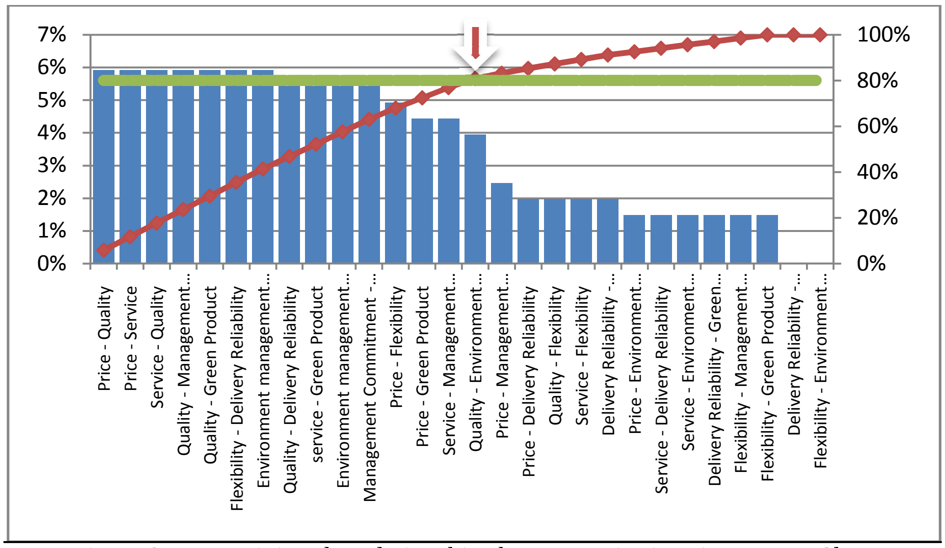

Figure 3. Determining the relationships between criteria using Pareto Chart

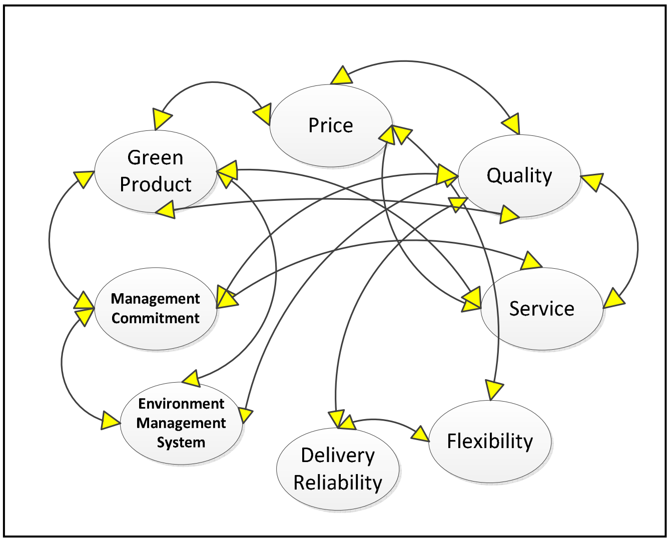

Figure 4. Relationships between the criteria

Table 4. Comparison Scale (Onut et. al, 2009)

1,1,1	Equal importance
2,3,4	Weak importance (of one over the other)
4,5,6	Strong importance
6,7,8	Demonstrated importance over the other
8,9,10	Absolute importance

3.5.4. Ranking supplier selection criteria in petrochemical industry using FANP method

First Step: In order to determine the weights of criteria by using FANP, network structure of problem was provided according to Figure 5.

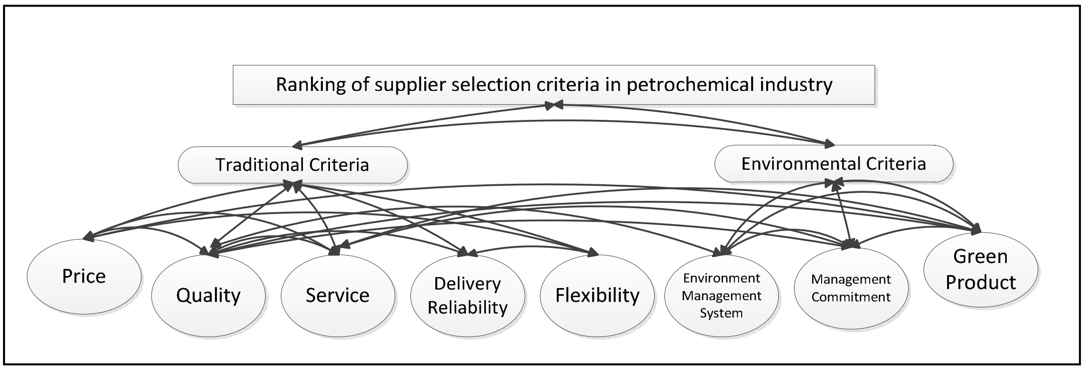

Figure 5. Problem network structure in FANP Stage

Second Step: According to the Figure 5, the experts were asked to specify the importance level of criteria by pairwise compression questionnaire and using linguistic terms. The linguistic terms used in this step are “equal importance”, “weak importance”, “string importance“, “demonstrated importance“ and “absolute importance“. Helping scale of Table 5 the expert opinions were changed to quantitative values and geometric mean was used to aggregating expert opinions. Tables 5-15 shows the results. In the last column of each matrix, eigenvectors which calculated by using the logarithmic least squares method (Eq. 3) were shown.

Table 5. Mean on pair wise comparison base on goal

Goal	Traditional Criteria	Environmental Criteria	Eigenvector
Traditional Criteria	(1,1,1)	(1.782,2.265,2.696)	(0.615,0.694,0.757)
Environmental	(0.371,0.442,0.561)	(1,1,1)	(0.281,0.306,0.345)

Table 6. Mean of pair wise comparison base on Traditional Criteria

	C1	C2	C3	C4	C5	Eigenvector
C1	(1,1,1)	(0.525,0.637,0.794)	(1.049,1.442,1.906)	(3.634,4.718,5.769)	(3.026,3.714,4.53)	(0.22,0.268,0.32)
C2	(1.26,1.57,1.906)	(1,1,1)	(2.828,3.873,4.899)	(5.769,6.804,7.83)	(5.14,6.169,7.191)	(0.39,0.465,0.538)
C3	(0.525,0.693,0.953)	(0.204,0.258,0.354)	(1,1,1)	(0.661,0.809,1)	(0.849,1.014,1.26)	(0.088,0.105,0.129)
C4	(0.173,0.212,0.275)	(0.128,0.147,0.173)	(1,1.236,1.513)	(1,1,1)	(1.049,1.442,1.906)	(0.072,0.086,0.103)
C5	(0.221,0.269,0.33)	(0.139,0.162,0.195)	(0.794,0.986,1.178)	(0.525,0.693,0.953)	(1,1,1)	(0.064,0.076,0.091)
CR^m =0.044CR^g =0.028						

Table 7. Mean of pairwise comparison based on Environmental Criteria

	C6	C7	C8	Eigenvector
C6	(1,1,1)	(0.354,0.417,0.525)	(0.437,0.53,0.674)	(0.167,0.188,0.22)
C7	(1.906,2.396,2.828)	(1,1,1)	(1.178,1.442,1.763)	(0.408,0.471,0.532)
C8	(1.484,1.886,2.289)	(0.567,0.693,0.849)	(1,1,1)	(0.294,0.341,0.389)
CR^m =0.002CR^g =0.006				

Table 8. Mean of pairwise comparison based on Price

	C2	C3	C5	C8	Eigenvector
C2	(1,1,1)	(3.026,4.096,5.14)	(2.57,3.004,3.525)	(1.906,2.365,2.884)	(0.425,0.503,0.582)
C3	(0.195,0.244,0.33)	(1,1,1)	(0.55,0.674,0.849)	(0.794,1.058,1.414)	(0.117,0.14,0.172)
C5	(0.284,0.333,0.389)	(1.178,1.485,1.817)	(1,1,1)	(1.26,1.661,2.14)	(0.174,0.206,0.24)
C8	(0.347,0.423,0.525)	(0.707,0.945,1.26)	(0.467,0.602,0.794)	(1,1,1)	(0.126,0.152,0.184)
CR^m =0.025CR^g =0.072					

Table 9. Mean of pairwise comparison based on Service

	C1	C2	C7	C8	Eigenvector
C1	(1,1,1)	(0.208,0.241,0.289)	(2.402,3.093,3.888)	(0.849,1.044,1.348)	(0.167,0.194,0.229)
C2	(3.464,4.155,4.804)	(1,1,1)	(4.579,5.666,6.721)	(1.587,1.886,2.14)	(0.462,0.533,0.595)
C7	(0.257,0.323,0.416)	(0.149,0.177,0.218)	(1,1,1)	(0.891,1.119,1.414)	(0.089,0.104,0.124)
C8	(0.742,0.958,1.178)	(0.467,0.53,0.63)	(0.707,0.894,1.122)	(1,1,1)	(0.145,0.169,0.197)
CR^m =0.018CR^g =0.054					

Table 10. Mean of pairwise comparison based on Quality

	C1	C3	C4	C6	C7	C8	Eigenvector
C1	(1,1,1)	(0.794,1,1.26)	(3.17,4.28,5.248)	(3.81,4.86,5.88)	(2.24,2.96,3.63)	(1.26,1.51,1.82)	(0.26,0.32,0.38)
C3	(0.79,1,1.26)	(1,1,1)	(1,1.29,1.73)	(3.24,3.93,4.58)	(1.20,1.51,1.91)	(0.53,0.66,0.89)	(0.16,0.2,0.24)
C4	(0.19,0.24,0.31)	(0.58,0.775,1)	(1,1,1)	(0.74,0.97,1.26)	(0.93,1.201,1.51)	(0.49,0.64,0.85)	(0.09,0.11,0.14)
C6	(0.17,0.21,0.26)	(0.22,0.25,0.31)	(0.79,1.029,1.35)	(1,1,1)	(0.33,0.38,0.47)	(1.48,1.89,2.29)	(0.07,0.09,0.11)
C7	(0.27,0.34,0.44)	(0.52,0.66,0.83)	(0.66,0.83,1.07)	(2.14,2.61,3.03)	(1,1,1)	(1.32,1.71,2.18)	(0.12,0.15,0.18)
C8	(0.55,0.66,0.79)	(1.12,1.50,1.87)	(1.18,1.57,2.04)	(0.4,0.53,0.67)	(0.46,0.58,0.76)	(1,1,1)	(0.11,0.13,0.16)
CR^m =0.031CR^g =0.025							

Table 11. Mean of pairwise comparison based on Delivery Reliability

	C2	C5	Eigenvector
C2	(1,1,1)	(2.884,3.608,4.28)	(0.7,0.783,0.853)
C5	(0.234,0.277,0.347)	(1,1,1)	(0.199,0.217,0.243)

Table 12. Mean of pairwise comparison based on Flexibility

	C1	C4	Eigenvector
C1	(1,1,1)	(6.172,7.197,8.214)	(0.813,0.878,0.938)
C4	(0.122,0.139,0.162)	(1,1,1)	(0.114,0.122,0.132)

Table 13. Mean of pairwise comparison based on Environment management system

	C2	C7	C8	Eigenvector
C2	(1,1,1)	(0.33,0.405,0.525)	(0.289,0.372,0.5)	(0.135,0.157,0.189)
C7	(1.906,2.466,3.026)	(1,1,1)	(2,2.466,2.994)	(0.461,0.539,0.616)
C8	(2,2.685,3.464)	(0.334,0.405,0.5)	(1,1,1)	(0.258,0.304,0.355)
CR^m =0.013CR^g =0.006				

Table 14. Mean of pairwise comparison based on Management commitment

	C2	C3	C6	C8	Eigenvector
C2	(1,1,1)	(2.14,2.84,3.634)	(0.257,0.323,0.416)	(0.294,0.368,0.5)	(0.135,0.162,0.199)
C3	(0.275,0.352,0.467)	(1,1,1)	(0.25,0.315,0.408)	(0.294,0.383,0.525)	(0.08,0.097,0.12)
C6	(2.402,3.093,3.888)	(2.449,3.177,4)	(1,1,1)	(1.698,1.969,2.289)	(0.379,0.447,0.521)
C8	(2,2.72,3.397)	(1.906,2.608,3.397)	(0.437,0.508,0.589)	(1,1,1)	(0.242,0.294,0.344)
CR^m =0.075CR^g =0.014					

Table 15. Mean of pairwise comparison based on Green product

	C1	C2	C3	C6	C7	Eigenvector
C1	(1,1,1)	(0.14,0.17,0.20)	(0.315,0.4,0.56)	(0.27,0.35,0.46)	(0.24,0.29,0.37)	(0.05,0.06,0.08)
C2	(4.9,5.916,6.93)	(1,1,1)	(2.14,2.87,3.56)	(1.12,1.442,1.78)	(0.39,0.49,0.63)	(0.23,0.28,0.33)
C3	(1.78,2.5,3.17)	(0.28,0.35,0.47)	(1,1,1)	(0.27,0.352,0.47)	(0.4,0.52,0.69)	(0.1,0.12,0.15)
C6	(2.14,2.84,3.63)	(0.56,0.69,0.89)	(2.14,2.84,3.63)	(1,1,1)	(0.89,1.04,1.18)	(0.20,0.25,0.29)
C7	(2.7,3.41,4.08)	(1.59,2.05,2.57)	(1.44,1.91,2.52)	(0.85,0.96,1.12)	(1,1,1)	(0.24,0.29,0.34)
CR^m =0.053CR^g =0.048						

Third Step: In this step, as it shown in Table 16~19, eigenvector matrixes were constructed including eigenvectors of the previous step.

Table 16. Eigenvector matrix of level 2 respect to level 1

	Research goal
Traditional criteria	(0.615,0.694,0.757)
Environmental criteria	(0.281,0.306,0.345)

Table 17. Eigenvector matrix of level 2 respect to level 2

	Traditional criteria	Environmental criteria
Traditional criteria	(1,1,1)	(0,0,0)
Environmental criteria	(0,0,0)	(1,1,1)

Table 18. Eigenvector matrix of level 3 respect to level 2

	Traditional criteria	Environmental criteria
C1	(0.22,0.268,0.32)	(0,0,0)
C2	(0.39,0.465,0.538)	(0,0,0)
C3	(0.088,0.105,0.129)	(0,0,0)
C4	(0.072,0.086,0.103)	(0,0,0)
C5	(0.064,0.076,0.091)	(0,0,0)
C6	(0,0,0)	(0.167,0.188,0.22)
C7	(0,0,0)	(0.408,0.471,0.532)
C8	(0,0,0)	(0.294,0.341,0.389)

Table 19. Eigenvector matrix of level 3 respect to level 3

	C1	C2	C3	C4	C5	C6	C7	C8
C1	(0.5,0.5,0.5)	(0.13,0.16,0.19)	(0.08,0.1,0.11)	(0,0,0)	(0.41,0.44,0.47)	(0,0,0)	(0,0,0)	(0.03,0.03,0.04)
C2	(0.21,0.25,0.29)	(0.5,0.5,0.5)	(0.23,0.27,0.3)	(0.35,0.39,0.42)	(0,0,0)	(0.07,0.08,0.1)	(0.07,0.087,0.1)	(0.12,0.142,0.17)
C3	(0.06,0.07,0.09)	(0.08,0.1,0.12)	(0.5,0.5,0.5)	(0,0,0)	(0,0,0)	(0,0,0)	(0.04,0.05,0.06)	(0.05,0.06,0.08)
C4	(0,0,0)	(0.04,0.05,0.07)	(0,0,0)	(0.5,0.5,0.5)	(0.06,0.06,0.07)	(0,0,0)	(0,0,0)	(0,0,0)
C5	(0.09,0.10,0.12)	(0,0,0)	(0,0,0)	(0.1,0.11,0.12)	(0.5,0.5,0.5)	(0,0,0)	(0,0,0)	(0,0,0)
C6	(0,0,0)	(0.04,0.04,0.05)	(0,0,0)	(0,0,0)	(0,0,0)	(0.5,0.5,0.5)	(0.19,0.22,0.3)	(0.1,0.12,0.15)
C7	(0,0,0)	(0.06,0.07,0.09)	(0.04,0.05,0.06)	(0,0,0)	(0,0,0)	(0.23,0.27,0.31)	(0.5,0.5,0.5)	(0.12,0.14,0.17)
C8	(0.06,0.07,0.09)	(0.05,0.07,0.08)	(0.07,0.08,0.1)	(0,0,0)	(0,0,0)	(0.13,0.15,0.18)	(0.12,0.14,0.17)	(0.5,0.5,0.5)

Fourth Step:In the last step, final weights of the criteria were calculated using Eq. 5. Therefore, the final relative weights of cost, quality, service, delivery reliability, flexibility, environment management system, management commitment and green product are 0.179, 0.283, 0.095, 0.049, 0.051, 0.087, 0.313 and 0.125, respectively (Table 20).

Table 20. Relative final weights of criteria

Criteria	Final fuzzy weight	Final weight
Price (C1)	(0.120,0.174,0.243)	0.179
Quality (C2)	(0.194,0.277,0.378)	0.283
Service (C3)	(0.060,0.091,0.134)	0.095
Delivery Reliability (C4)	(0.033,0.048,0.066)	0.049
Flexibility (C5)	(0.034,0.049,0.069)	0.051
Environment Management System (C6)	(0.059,0.083,0.119)	0.087
Management Commitment (C7)	(0.092,0.126,0.175)	0.131
Green Product (C8)	(0.084,0.120,0.171)	0.125

Figure 6 shows the final weights of criteria for green supplier selection in petrochemical industry as well:

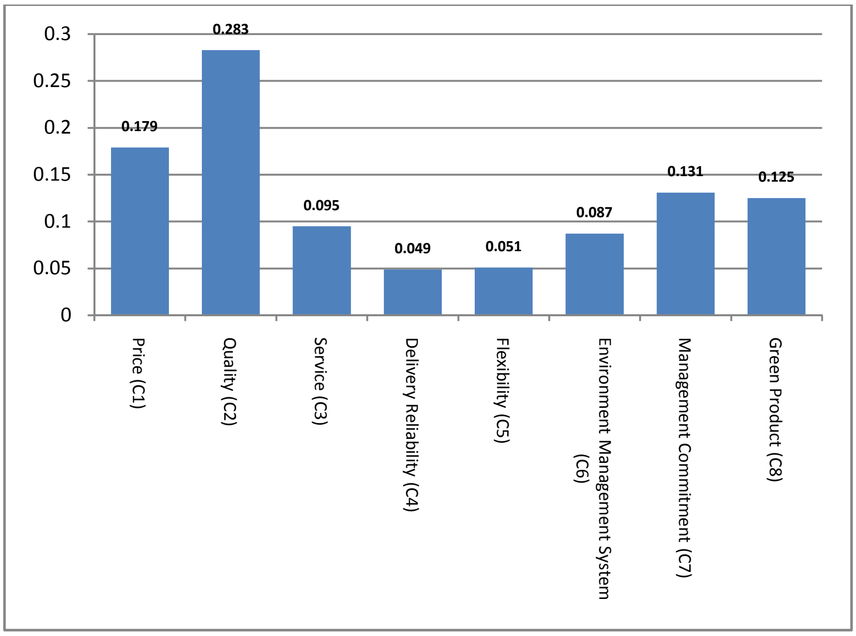

Figure 6. Final weights of criteria

5. Result and Conclusion

GSCM has appeared as a tools to decrees negative consequences of business operations on the environment. This paper, present a combined approach including One-Sample T-Test, Pareto principle and Fuzzy ANP methods, in order to identification and ranking criteria of green supplier in petrochemical industry. Appropriate criteria were determined by aggregating the expert opinions regarding the importance level of the submitted criteria and using One-Sample T-Test. One-Sample T-Test is a statistical procedure used to examine the mean difference between the sample ($n<30$) and the known value of the population mean. The Pareto principle was applied to determine the relationships between the criteria as well. At least, the Fuzzy ANP method was used to obtain relative weights of criteria considering the criteria interdependences.

The results shows that quality is the most important criteria and then the criteria of cost, management commitment, green product, service, environment management service, flexibility, and delivery reliability have higher relative weights, respectively in process of suppliers selection of petrochemical industry. One of the advantages of the presented approach is using of the One-Sample T-Test to determine the suitable criteria for green supplier selection in petrochemical industry, the others are: determination of relationships between criteria Led to the removal of waste calculations in Fuzzy ANP stages, considering the interdependences between criteria in determination of criteria relative weights using fuzzy ANP method.

In summary, this study contributes to literature by: (i) offering a GSCM combined approach that integrates environmental and traditional criteria in a framework; (ii) developing valid and reliable criteria for the GSCM based on expert's opinions and using linguistic terms. (iii) Developing a hybrid approach to solve the supplier's criteria ranking problem.

6. References

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