A Soft Hierarchical Process Approach for Decision Making in A Supply Chain

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ABSTRACT

Decision problems are usually complex and involve evaluation of several conflicting criteria (parameters). Multi Criteria Decision Making (MCDM) is a promising field that considers the parallel influence of all criteria and aims at helping decision makers in expressing their preferences, over a set of predefined alternatives, on the basis of criteria(parameters) that are contradictory in nature. The Analytic Hierarchy Process (AHP) is a useful and widespread MCDM tool for solving such type of problems, as it allows the incorporation of conflicting objectives and decision makers' preferences in the decision making. The AHP utilises the concept of pair wise comparison to find the order of criteria(parameters) and alternatives. The comparison in a pairwise manner becomes quite tedious and complex for problems having eight alternatives or more, thereby, limiting the application of AHP. This paper presents a soft hierarchical process approach based on soft set decision making which eliminates the least promising candidate alternatives and selects the optimum(potential) ones that results in the significant reduction in the number of pairwise comparisons necessary for the selection of the best alternative using AHP, giving the approach a more realistic view. A supplier selection problem is used to illustrate the proposed approach.

Keywords: Multi Criteria Decision Making(MCDM), Analytic Hierarchy Process(AHP), Soft Set, Supplier Selection

INTRODUCTION

To select an alternative based on multiple and often conflicting criteria (parameters) that necessitate the use of decision support system is challenging for a decision maker. Multi criteria decision making (MCDM) is a promising field for dealing with such type of problems, where the alternatives are predefined. The Analytic Hierarchy Process (AHP), proposed by Saaty (1998, 2008), is a powerful and widespread tool of MCDM used for solving choice and ranking problems. The fundamental part of AHP is based on the idea of structuring the problem in a hierarchy. The AHP procedure involves the pairwise comparisons of elements at a certain hierarchical level with reference to their effect on the elements of immediately higher hierarchical level on a 9-point scale. In AHP, the comparisons between criteria or alternatives are expressed in the form of comparison matrices. The number of pairwise comparisons needed to calculate priorities for a matrix of order k is $\frac{k(k-1)}{2}$ As the number of comparisons increases quadratically with the number of alternatives, it seems practically difficult to use AHP with higher number of alternatives. This limits the practical application of AHP to the problems with a low number of alternatives.

Several methods have been proposed to overcome this difficulty (Harker, 1987; Shen *et al.*, 1992; Zopounidis & Doumpos, 2002; Hotman, 2005; Islam & Abdullah, 2006; Ishizaka, 2012). But each method has its own difficulties and limitations. Moreover, even if the data is available, parameters often contain linguistic definition involving human judgment and subjectivity, which introduces uncertainties in decision making process. Keeping in view the above difficulties, this paper presents a decision making approach based on soft set theory. Molodstov (1999) introduced the concept of soft set theory as a mathematical tool for decision making, hereby, providing flexible information processing capacity in many areas and several directions. Maji *et al*. (2002) applied soft set theory in decision making problems that is based on the concept of knowledge reduction in rough set theory. Basu *et al*. (2012) gave the concept of choice matrix which represents the choice parameters of the decision makers and proposed an algorithm using these choice matrices to solve soft set based decision making problems. Xiao *et al*. (2013) developed a method based on interval valued fuzzy soft set for multi attribute group decision making problems which considers the Decision makers' risk attitude under uncertain environment. Agarwal *et al*. (2013) proposed the concept of intuitionistic fuzzy soft preference relations (IFSPR) to solve a multi criteria decision making problem.Omurca (2013) developed an effective hybrid system by fuzzy c-means (FCM) and rough set theory (RST) to solve supplier selection, evaluation, and development problems.

The proposed approach discusses a soft decision making method which selects a set of optimum (potential) alternatives from an exhaustive list of candidate alternatives, hereby, eliminating the least promising ones. A single best alternative is selected using AHP technique among the optimum (potential) alternatives. This results in the significant reduction of the number of pairwise comparisons necessary for the selection of the best alternative, giving the approach a more realistic practical view. The rest of the paper is organised as follows. The next section presents the preliminaries concerning soft set theory and Analytic Hierarchy Process (AHP) followed by a detailed discussion of the proposed approach in third section. A supplier selection problem is presented in fourth section to illustrate the applicability of the proposed approach and finally, some concluding remarks are presented in the fifth Section.

DEFINITIONS AND PRELIMINARIES

Soft Set Theory (Cagman & Enginoglu, 2010)

Definition 1 : Let U be an initial universal set and E be a set of parameters in relation to object U. Parameters are often attributes, characteristics or properties of object. Let $P(U)$ denotes the power set of U and $L \subseteq E$. A soft set F_L on the universe U is defined by the set of ordered pairs

$F_L = \{ (e, f_L(e)) : e \in E, f_L(e) \in P(U)\}$,where $f_L : E \rightarrow P(U)$ such that $f_L(e) = 0$ if $e \notin L$.

Here, f_L is called approximate function of the soft set F_L. The value of $f_L(e)$ is a set called e-element of the soft set for all $e \in E$.

Example: Let $U = \{u_1, u_2, u_3, u_4, u_5\}$ be an initial universal set and $E = \{e_1, e_2, e_3, e_4, e_5\}$ be a set of all parameters. If $L = \{e_2, e_3, e_4\} \subseteq E$ s.t., $f_L(e_2) = \{u_2, u_4\}$, $f_L(e_3) = \phi$, $f_L(e_4) = U$ then a soft set F_L is defined as collection of approximations:

$F_L = \{ (e_2, \{u_2, u_4\}), (e_3, \phi) \, (e_4, U)\}$.

(i) Product of soft sets

Definition 1 : If $F_A \wedge F_B \in S(U)$, then the $\wedge$ - product of two soft sets F_A and F_B ,denoted by $F_A \wedge F_B$, is a soft set defined by the approximate function,

$f_{A \wedge B} : E \, X \, E \rightarrow P(U), f_{A \wedge B}(x, y) = f_A(x) \cap f_B(y)$

Here, $S(U)$ is the set of all soft sets over U.

(ii) Uni-int decision making

Definition 1: Let $F_A \wedge F_B \in \wedge(U)$, then uni-int operators for the $\wedge$ - products, denoted by $uni_x int_y$ and $uni_y int_x$ are defined, respectively, as

$uni_x int_y : \wedge(U) \rightarrow : P(U), uni_x int_y (F_A \wedge F_B) = U_{x \in A} (\cap_{y \in B} (f_{A \wedge B}(x, y)))$

$uni_y int_x : \wedge(U) \rightarrow : P(U), uni_y int_x (F_A \wedge F_B) = U_{y \in B} (\cap_{x \in A} (f_{A \wedge B}(x, y)))$

Here, $\wedge(U)$ is a set of all $\wedge$ - products of the soft sets over U

The above operators transforms the $\wedge$-product $F_A \wedge F_B$ into a subset of the universe U.

Definition 2 : Let $F_A \wedge F_B \in \wedge(U)$, then uni-int decision function for the $\wedge$ - products is defined as,

$uni\text{-}int : \wedge(U) \rightarrow P(U)$.

$uni\text{-}int (F_A \wedge F_B) = uni_x \, int_y (F_A \wedge F_B) \, U \, uni_y \, int_x (F_A \wedge F_B)$

This reduces the size of the universe U. The values of *uni-int* $(F_A \wedge F_B)$ is a subset of U and is called *uni-int* decision set of $F_A \wedge F_B$.

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is an effective tool for dealing with complex decision making, and may aid the decision maker to set priorities and make the best decision. The AHP decomposes a complex multi-criteria decision making problem into a hierarchical tree of evaluation parameters and decision alternatives. The AHP methodology comprises three steps: (a) establishment of a hierarchical structure, (b) establishment of pairwise comparison judgments, and (c) synthesis of the priorities and Measurement of consistency.

(a) **Establishment of hierarchical structure:** A complex decision problem is structured into a hierarchy descending from an overall objective at the top level to the evaluation parameters that contributes to the decision at the intermediate level till the decision alternatives at the bottom level.

b) **Establishment of pairwise comparison judgments:** Once the hierarchy is constructed, the relative importance of the parameters within each level is determined. In each level, the parameters are compared pairwise according to their influence and effect on the elements at the immediately higher level. The pairwise comparisons are done on a nominal 9-point scale, called Fundamental scale, as shown in Table 1, indicates that how much one element is important than the other.

Table 1: Fundamental Scale

Comparative Importance	Definition
1	Equally important
3	Moderately more important
5	Strongly important
7	Very strongly more important
9	Extremely more important
2,4,6,8	Intermediate judgment values

The use of pairwise comparisons for deriving ratio scale priorities is a major strength of the AHP model as against traditional approaches of assigning weights.

c) **Synthesis of the priorities and measurement of consistency:** The results of the pairwise judgments are placed in a pairwise comparison matrix, where is the number of elements compared. Such matrices are constructed for each level of the hierarchy of the AHP model. For each pairwise comparison matrix, local priorities are obtained as the normalised principal eigenvector. Local priorities represent the relative importance among elements being compared. The redundancy of pairwise comparisons generates the problem of inconsistency and should be resolved at each stage. A consistency test requires the calculation of Consistency Ratio (CR) and it is appreciable that the value of CR should be less than or equal to 0.1

THEPROPOSED SOFT HIERARCHICAL PROCESS (SHP)APPROACH

Phases of the Proposed SHP Approach

Phase I: Screening Phase

This phase consists of following stages:

Stage 1: Problem definition and identification of criteria (parameters)

Step 1: Define the decision problem and clearly articulate its goal/objective.

Step2: Based on the objectives defined in step 1, identify the suitable screening criteria (parameters) affecting the decision problem by modified Delphi method. The screening criteria (parameters) will determine the threshold of progress to the selection phase.

Stage 2: Pairwise comparison judgments and calculation of priorities

A hierarchical model is developed for the decision problem consisting of goal at the first level subsequently followed by screening criteria (parameters) that are identified for their importance to the goal and the alternatives that are to be evaluated. Once the hierarchy is constructed, the screening criteria (parameters) are ranked on a 9-point scale by a number of decision makers. The judgements of the decision makers are expressed in the form of pairwise comparisons where two criteria (parameters) are compared at a time with respect to the goal. The relative importance/priorities of various screening criteria (parameters) are calculated using the pairwise comparison matrices so obtained.

Stage 3: Elimination of alternatives

This stage selects a set of optimum (potential) alternatives from a set of candidate alternatives on the basis of predefined screening criteria (parameters) and eliminates the least qualified. The uni-int decision making method (Cagman & Enginoglu, 2010) is used to determine the optimum (potential) alternatives from an exhaustive list of candidate alternatives. The method comprises of following steps:

Step 1: Define the feasible subset of the set of criteria (parameters) for each decision maker. The feasible subset contains those criteria (parameters) whose priority exceeds certain threshold value set by the decision makers’.

Step 2: Construct soft set for each set of criteria (parameters).

Step 3: Find the -product of the soft sets.

Step 4: Compute the *uni-int* decision set of the product.

Phase II: Selection Phase

This phase comprises of following stages:

Stage 1: Defining the evaluation criteria (parameters)

For an in-depth study of the potential alternatives progressed from the elimination phase, the screening criteria (parameters) are sub-classified further to define evaluation criteria (parameters).

Stage 2: Selection of best alternative

In this stage, the AHP is used to determine the relative importance weightings or priorities of potential alternatives with respect to the evaluation criteria (parameters). The relative importance weightings represent the ability of the alternatives in maximising the goal. The alternative with highest priority is selected as the best alternative.

ILLUSTRATION

Supply chains are value-adding chains of sub-suppliers, suppliers, manufacturers; distributors and end customers where the success of each participant is dependent on the supply chain as whole. The organisations integrate their supply chains to reduce costs and be able to better serve their customers. The management of supply chain is concerned with building the most optimised chains.

In this competitive environment, it is a challenge for manufacturers to produce low cost, high quality products without having a good base of reliable suppliers (Bag, 2012).The selection of suitable criteria as the input of decision making model has a direct impact on the model efficiency. Supplier selection is a multi-criteria decision making problem, often faced by ambiguity and vagueness, which makes decision process highly complicated. A number of methodologies used in supplier selection and evaluation studies include analytic network process (Bayazit, 2006), AHP, Hybrid artificial neural network (ANN)-AHP (Tang *et al.*, 2013), Total cost of ownership (TCO) (Degraeve *et al.*, 2005), fuzzy set theory (Zhang *et al.*, 2009; Wang, 2010), Hybrid Fuzzy-Analytic Hierarchy Process (Zeydan *et al.*, 2011), Data Envelopment Analysis (Behrooz *et al.*, 2012; Prasad *et al.*, 2012; Jahanshahloo & Piri, 2013), Fuzzy-TOPSIS (Haldar *et al.*, 2012; Liu *et al.*, 2013), Hybrid Fuzzy-Artificial Neural Network (Kuo *et al.*, 2010). Of these techniques, AHP has been seen as a very powerful and effective method, as it includes three basic functions, namely, structuring complexity into hierarchy, measurement on a ration scale and synthesis of priorities. The AHP technique has been used widely to solve supplier selection problems, but with small number of alternatives, preferably below nine (Barbarosoglu & Yazgac, 2000; Wang *et al.*, 2004; Bayazit *et al.*, 2006; Hemaida & Schmits, 2006; Percin, 2006; Chan & Kumar, 2007; Pearson *et al.*, 2007; Sevkli *et al.*, 2008; Lee, 2009; Kokangul & Susuz, 2009; Chen & Hung, 2010; Enyinda *et al.*, 2010; Chamodrakas *et al*, 2010; Labib, 2011; Pitchipoo *et al.*, 2013; Erdem & Göçen, 2012; Garoma & Diriba, 2014). As the number of alternatives becomes high, the AHP technique has a disadvantage of increased pairwise comparisons from the decision maker, thereby, limiting its practical application. The proposed approach overcome this difficulty by screening the exhaustive list of candidate suppliers to a manageable number of optimum (potential) suppliers, thereby, reducing the number of pairwise comparisons needed in the selection phase to a great extent. This approach proves to be quite useful in selecting best supplier in an e-tender process, where the number of candidate suppliers is quite high.

Application of the Proposed SHP Approach to Supplier Selection Problem

Phase I: Screening Phase

Stage 1: Problem definition and identification of parameters

Step 1: The organisation wants to select the best supplier from a list of candidate suppliers who fill in e-tender to have the contract.

Step 2: For this purpose, the screening parameters *pi* affecting the decision process were identified by using modified Delphi method. The basic information concerning the candidate suppliers on a defined set of screening parameters $E = \{p_1, p_2, p_3, p_4, p_5, p_6, p_7, p_8\}$ is recorded and tabulated. Here,the parameter $p_i ; i = 1, 2, ..., 8$ stand for "Operational Performance", "Clean", "Financial Health", "Risk factors", "Competency or Expertise", "Culture & Relationship", "Geographical Location", and "Cost" respectively. The problem is modeled as hierarchy (shown in Figure 1).

Stage 2: Pairwise comparison judgments and calculation of priorities

The Management has decided to scrutinize the candidate suppliers, on the basis of screening criteria (parameters), by the team of decision makers: one of them from purchase Department (X) and the other one from the marketing (Y). The screening criteria (parameters) are ranked using 9-point scale by the decision makers X and Y. The judgements of the decision makers X and Y are expressed in terms of pairwise comparisons. Using these pairwise comparison matrices, the relative importance/ priorities of various criteria (parameters) are calculated (as shown in Tables 2 and 3).

Figure 1:Supplier Evaluation Hierarchy Structure

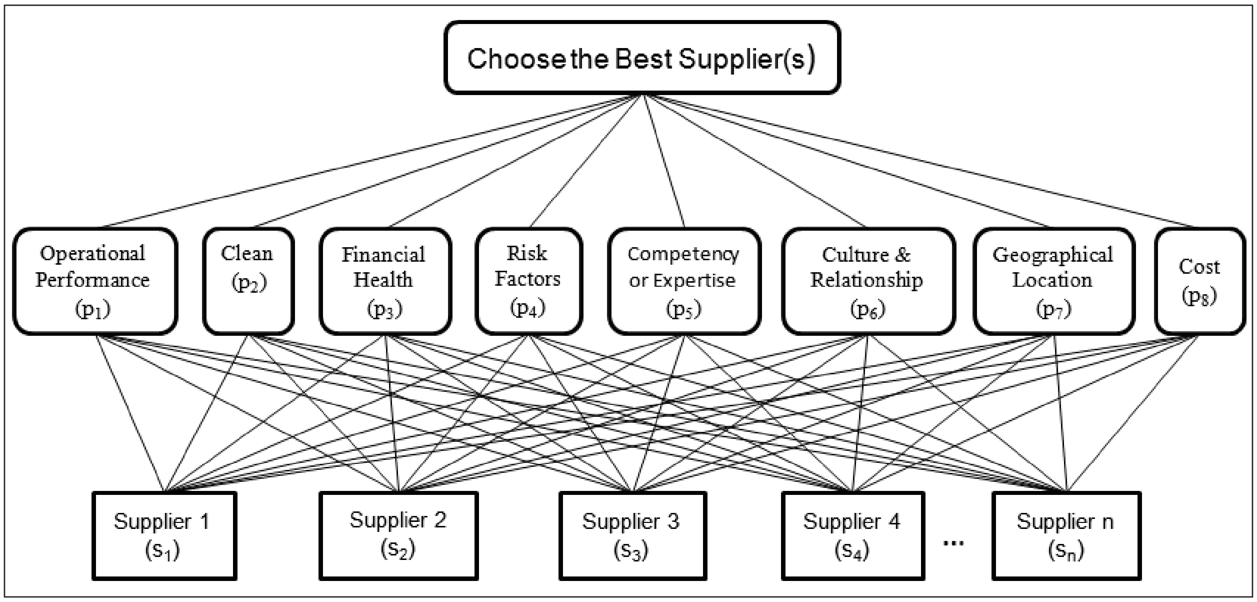

Table 2: Priorities of Screening Criteria (Parameters) with Respect to Goal for the Decision Maker X

	p_1	**p_2**	**p_3**	**p_4**	**p_5**	**p_6**	**p_7**	**p_8**	**Priorities**
p_1	x	1/5	1/3	1/3	1/2	1/4	1/5	1/5	0.035
p_2		x	2	2	3	2	1	1	0.201
p_3			X	3	3	3	1	1	0.186
p_4				x	1	2	2	2	0.138
p_5					x	2	1	1/2	0.092
p_6						x	1	1	0.089
p_7							x	1	0.124
p_8								x	0.135

Table 3:Priorities of Screening Criteria (Parameters) with Respect to Goal for the Decision Maker Y

	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	Priorities
p_1	x	3	3	2	2	1	2	1	**0.199**
p_2		x	3	4	2	2	2	1	**0.171**
p_3			X	1/3	1/2	1/4	1/5	1/4	**0.039**
p_4				X	1/4	1/4	1/4	1/3	**0.053**
p_5					x	2	1	1/2	**0.123**
p_6						x	1	1	**0.130**
p_7							x	1	**0.130**
p_8								x	**0.155**

Stage 3: Elimination of alternatives

Let $U = \{S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_9, S_{10}, S_{11}, S_{12}\}$ be the set of candidate suppliers who fill in e-tender.The *uni-int* decision making method, as explained above, is applied to obtain the optimum (potential) suppliers. The steps of the method are detailed as:

Step 1: The feasible subsets of the set of screening criteria (parameters), for the decision makers X and Y, is defined by considering the parameters having priority more than certain threshold value. For our analysis, this value has been taken as 0.1. Therefore, on the basis of priorities, as shown in Tables 2 and 3, the decision makers consider the set of screening criteria (parameters), $X = \{p_2, p_3, p_4, p_7, p_8\}$ and $Y = \{p_1, p_2, p_5, p_6, p_7, p_8\}$ respectively, to evaluate the candidate suppliers.

It is to be noted that as screening criteria (parameters) only determine the extent of admissibility of candidate suppliers to proceed to selection phase and are not used for final ranking, the threshold value is chosen arbitrarily to ensure a minimum adequacy of candidate supplier and may vary depending on severity of screening adopted by decision makers.

Step 2: The decision makers seriously investigate the profile of the suppliers in perspective of the goals and constraint of management according to a chosen subset $X, Y \subseteq E$. After rigorous scrutinyof the profiles of candidate suppliers, the decision makers construct the following two soft sets F_X and F_Y over U, according to their chosen parameters, defined in the previous step, respectively, as

$F_X = \{ (p_2,\{s_1, s_4, s_6, s_{11}, s_{12}\}), (p_3, \{s_2, s_3, s_5, s_{11}\}), (p_4,\{s_1, s_4, s_5, s_6, s_8, s_{10}, s_{11}\}), (p_7,\{s_2, s_3, s_6, s_7, s_9, s_{11}, s_{12}\}), (p_8,\{s_1, s_3, s_4, s_8, s_{11}, s_{12}\})\}$

$F_Y = \{ (p_1,\{s_2, s_3, s_4, s_7, s_{11}, s_{12}\}), (p_2, \{s_1, s_3, s_4, s_6, s_7, s_{12}\}), (p_5,\{s_1, s_2, s_3, s_9, s_{11}, s_{12}\}), (p_6,\{s_3, s_7, s_{12}\}), (p_7,\{s_2, s_3, s_4, s_8, s_{12}\}), (p_8,\{s_1, s_3, s_5, s_6, s_7, s_{12}\})\}$

Step 3: The $\wedge$ - product $F_X \wedge F_Y$ of soft sets F_X and F_Y is as follows:

$$\begin{aligned} F_x \wedge F_Y = \{ & ((p_2,p_1), \{s_4,s_{11},s_{12}\}),((p_2,p_2), \{s_1,s_4,s_6,s_{12}\}),\\ & ((p_2, p_5), \{s_1, s_{11}, s_{12}\}), ((p_2, p_6), \{s_{12}\}),\\ & ((p_2, p_7), \{s_4, s_{12}\}), ((p_2, p_8), \{s_1, s_6, s_{12}\}),\\ & ((p_3, p_1), \{s_2, s_3, s_{11}\}), ((p_3, p_2), \{s_3\}),\\ & ((p_3, p_5), \{s_2, s_3, s_{11}\}), ((p_3, p_6), \{s_3\}), ((p_3, p_7), \{s_2, s_3\}), ((p_3, p_8), \{s_3, s_5\}),\\ & ((p_4, p_1), \{s_4, s_{11}\}), ((p_4, p_2), \{s_1, s_4, s_6\}),\\ & ((p_4, p_5), \{s_1, s_{11}\}), ((p_4, p_6), \{\varphi\}),\\ & ((p_4, p_7), \{s_4, s_8\}), ((p_4, p_8), \{s_5, s_6\}), ((p_7, p_1), \{s_2, s_3, s_7, s_{11}, s_{12}\}), ((p_7, p_2), \{s_3, s_6, s_7, s_{12}\}),\\ & ((p_7, p_5), (s_2, s_3, s_9, s_{11}, s_{12}\}), ((p_7, p_6), \{s_3, s_7, s_{12}\}), ((p_7, p_7, \{s_2, s_3, s_{12}\}),\\ & ((p_7, p_8), \{s_3, s_6, s_7, s_{12}\}), ((p_8, p_1), \{s_3, s_4, s_{11}, s_{12}\}), ((p_8, p_2), \{s_1, s_3, s_4, s_{12}\}),\\ & ((p_7, p_8), \{s_1, s_3, s_{11}, s_{12}\}), ((p_8, p_1), \{s_3, s_4, s_{11}, s_{12}\}), ((p_8, p_2), \{s_1, s_3, s_4, s_{12}\}),\\ & ((p_8, p_5), \{s_1, s_3, s_{11}, s_{12}\}), ((p_8, p_6), \{s_3, s_{12}\}), ((p_8, p_7, \{s_3, s_4, s_8, s_{12}\}),\\ & ((p_8, p_8), \{s_1, s_3, s_{12}\})\} \end{aligned}$$

Step 4: The decision set *uni-int* can $(F_X \wedge F_Y)$ be defined as follows:

$$uni_a int_b = (F_X \wedge F_Y) = \cup_{a \in X} (\cap_{b \in Y} (f_{X \wedge Y} (a, b))) = U \left\{ \begin{array}{c} \cap \left\{ \begin{array}{c} \{s_4, s_{11}, s_{12}\}, \{s_1, s_4, s_6, s_{12}\}, \{s_1, s_{11}, s_{12}\}, \{s_{12}\} \\ \{s_4, s_{12}\}, \{s_1, s_6, s_{12}\} \end{array} \right\} \\ \cap \left\{ \begin{array}{c} \{s_2, s_3, s_{11}\}, \{s_3\}, \{s_2, s_3, s_{11}\}, \{s_3\} \\ \{s_2, s_3\}, \{s_3, s_5\} \end{array} \right\} \\ \cap \left\{ \begin{array}{c} \{s_4, s_{11}\}, \{s_1, s_4, s_6\}, \{s_1, s_{11}\}, \{\varphi\}, \\ \{s_4, s_8\}, \{s_5, s_6\} \end{array} \right\} \\ \cap \left\{ \begin{array}{c} \{s_2, s_3, s_7, s_{11}, s_{12}\}, \{s_3, s_6, s_7, s_{12}\}, \{s_2, s_3, s_9, s_{11}, s_{12}\}, \\ \{s_3, s_7, s_{12}\}, \{s_2, s_3, s_{12}\}, \\ \{s_3, s_6, s_7, s_{12}\} \end{array} \right\} \\ \cap \left\{ \begin{array}{c} \{s_3, s_4, s_{11}, s_{12}\}, \{s_1, s_3, s_4, s_{12}\}, \{s_1, s_3, s_{11}, s_{12}\}, \{s_3, s_{12}\}, \\ \{s_3, s_4, s_8, s_{12}\}, \{s_1, s_3, s_{12}\} \end{array} \right\} \end{array} \right\}$$

$$= U \{\{s_{12}\}, \{s_3\}, \{\varphi\}, \{s_3, s_{12}\}, \{s_3, s_{12}\}\} = \{s_3, s_{12}\}$$

$$uni_b int_a = (F_X \wedge F_Y) = \cup_{b \in Y} (\cap_{a \in X} (f_{X \wedge Y}(a, b))) = U \left\{ \begin{array}{c} \cap \left\{ \begin{array}{c} \{s_4, s_{11}, s_{12}\}, \{s_2, s_3, s_{11}\}, \{s_4, s_{11}\} \{s_2, s_3, s_7, s_{11}, s_{12}\}, \\ \{s_3, s_4, s_{11}, s_{12}\} \end{array} \right\} \\ \cap \left\{ \begin{array}{c} \{s_1, s_4, s_6, s_{12}\}, \{s_3\}, \{s_1, s_4, s_6\}, \{s_2, s_3, s_6, s_7, s_{12}\} \\ \{s_1, s_3, s_4, s_{12}\} \end{array} \right\} \\ \cap \left\{ \begin{array}{c} \{s_1, s_{11}, s_{12}\}, \{s_2, s_3, s_{11}\}, \{s_1, s_{11}\}, \{s_2, s_3, s_9, s_{11}, s_{12}\}, \\ \{s_1, s_3, s_{11}, s_{12}\} \end{array} \right\} \\ \cap \{\{s_{12}\}, \{s_3\}, \{\varphi\} \{s_3, s_7, s_{12}\}, \{s_3, s_{12}\}\} \\ \cap \{\{s_4, s_{12}\}, \{s_2, s_3\}, \{s_4, s_8\} \{s_2, s_3, s_{12}\}, \{s_3, s_4, s_8, s_{12}\}\} \\ \cap \{\{s_1, s_6, s_{12}\}, \{s_3, s_5\}, \{s_5, s_6\} \{s_3, s_6, s_7, s_{12}\}, \{s_1, s_3, s_{12}\}\} \end{array} \right\}$$

$$= U \{\{s_{11}\}, \{\varphi\}, \{s_{11}\}, \{\varphi\}, \{\varphi\}, = \{s_{11}\}$$

The elements of the following *uni-int* decision set give the list of potential suppliers.

$$uni\text{ - }int\ (F_X \wedge F_Y) = uni_a int_b\ (F_X \wedge F_Y)\ uni_b int_a\ (F_X \wedge F_Y) = \{s_3, s_{12}\}\ U\ \{s_{11}\} = \{s_3, s_{11}, s_{12}\}$$

Table 4: Priorities of Evaluation Criteria (Parameters) with Respect to Goal for the Decision Maker Z

	e_1	**e_2**	**e_3**	**e_4**	**e_5**	**e_6**	**e_7**	**e_8**	**Priorities**
e_1	x	4	4	3	1/2	2	1	1	**0.192**
e_2		x	1/3	1/2	1/2	1	1/2	1/3	**0.052**
e_3			X	3	2	2	1	1/2	**0.140**
e_4				x	1/3	1/2	1/2	1/4	**0.055**
e_5					x	3	2	1	**0.177**
e_6						x	1/3	1/5	**0.061**
e_7							x	1	**0.132**
e_8								x	**0.191**

Table 5: Priorities of alternatives with respect to Years in Business (e_1)

	s_3	**s_{11}**	**s_{12}**	**Priorities**
s_3	x	5	1	**0.498**
s_{11}		x	1/2	**0.367**
s_{12}			x	**0.135**

Table 6: Priorities of alternatives with respect to Transportation Infrastructure (e_2)

	s_3	**s_{11}**	**s_{12}**	**Priorities**
s_3	x	1/3	1/3	**0.123**
s_{11}		x	3	**0.592**
s_{12}			x	**0.285**

Table 7: Priorities of alternatives with respect to Customer Service (e_3)

	s_3	**s_{11}**	**s_{12}**	**Priorities**
s_3	x	7	1/2	**0.346**
s_{11}		x	1/9	**0.057**
s_{12}			x	0.597

Table 8: Priorities of alternatives with respect to Preventive Maintenance (e_4)

	s_3	**s_{11}**	**s_{12}**	**Priorities**
s_3	x	2	1/2	**0.286**
s_{11}		x	1/4	**0.143**
s_{12}			x	**0.571**

Table 9: Priorities of alternatives with respect to Pollution Reduction Capability (e5)

	s_3	**s_{11}**	**s_{12}**	**Priorities**
s_3	x	1/2	1/2	**0.196**
s_{11}		x	1/2	**0.311**
s_{12}			x	**0.493**

Table 10: Priorities of alternatives with respect to Contract Management (e6)

	s_3	**s_{11}**	**s_{12}**	**Priorities**
s_3	x	1/9	1/3	**0.064**
s_{11}		x	8	**0.798**
s_{12}			x	**0.138**

Table 11: Priorities of alternatives with respect to Innovation (e7)

	s_3	s_{11}	s_{12}	Priorities
s_3	x	3	2	**0.54**
s_{11}		x	1/2	**0.163**
s_{12}			x	**0.297**

Table 12: Priorities of alternatives with respect to Quality Standards e(8)

	s_3	s_{11}	s_{12}	Priorities
s_3	x	1/5	1/2	**0.135**
s_{11}		x	1	0.498
s_{12}			x	**0.367**

Table 13: Priority Scores and Ranking of Potential Suppliers

Evaluation Parameters	**Priorities**	**Potential Suppliers**		
		$\mathbf{s_3}$	$\mathbf{s_{11}}$	$\mathbf{s_{12}}$
e_1	0.192	0.498	0.367	0.135
$\mathbf{e_2}$	**0.052**	0.123	0.592	0.285
$\mathbf{e_3}$	**0.140**	0.346	0.057	0.597
$\mathbf{e_4}$	**0.055**	0.286	0.143	0.571
$\mathbf{e_5}$	**0.177**	0.196	0.311	0.493
$\mathbf{e_6}$	**0.061**	0.064	0.798	0.138
$\mathbf{e_7}$	**0.132**	0.540	0.163	0.297
$\mathbf{e_8}$	**0.191**	0.135	0.498	0.367
Overall Weightings		**0.038**	**0.042**	**0.045**
Ranking		***3***	***2***	***1***

Therefore, the potential suppliers s_3, s_{11}, s_{12} will progress to the selection phase (Phase II).

Phase II: Selection Phase

This phase aims to select the best supplier, from the three optimum (potential) suppliers who progressed from the previous stage using AHP.

Stage 1: Defining the Evaluation criteria (parameters)

The screening criteria (parameters), discussed in the last phase, determine the minimum adequacy of the candidate suppliers to proceed to the selection phase. For determining the suitability and to have a critical evaluation of optimum (potential) suppliers, the screening criteria (parameters) were further sub-classified into eight evaluation criteria (parameters), namely, Years in Business (e_1), (Transportation Infrastructure (e_2), Customer Service (e_3), Preventive Maintenance (e_4), Pollution Reduction Capability (e_5), Contract Management (e_6), Innovation (e_7), and Quality Standards (e_8).

Stage 2: Selection of best alternative

As a part of AHP, a series of pairwise judgements of importance, where two criteria (parameters) are simultaneously compared with respect to the goal and each potential alternative is compared against each other alternative with respect to the corresponding criteria (parameter) at a time, were carried out by a team of experts (Z) using the Saaty's discrete scale of preference from 1 to 9 (as shown in Tables 4 to 12).

After completion of all pairwise comparisons, the synthesis of relative priority of each evaluation parameter and each alternative is done. Consistency Index and Random Index were determined. As the calculated Consistency Ratio is less than 0.1, the weights are consistent and can be used in the selection process. The supplier is the best supplier as it has the best overall performance with highest weightings (as shown in Table 13).

CONCLUSION

To have sustainable decisions, the organisations consider several conflicting criteria in their decision process. The AHP method is a popular and widely used method in evaluating a multi criteria decision making problem, especially, when ranking and choice is to be done. However, the AHP method proves to be unrealistic to support decision making problems, in situations, where the number of actions/alternatives is large. This paper suggests an approach based on soft set theory that solves this problem to a great extent by selecting the optimum alternatives and, hence, reduces the number of pair wise comparisons. The present study aims to propose an integrated methodological framework for robust supplier selection, a one of most crucial subject in supply chain management, with the concept of using the threshold value at the screening phase. The concept of threshold value gives flexibility to the decision makers' in defining their choice parameters in a very systematic manner. Moreover, the study considers both the traditional supplier criteria as well as the issues that ensure environment friendly product quality for the selection of best supplier that have the highest contribution to the organisation's business objectives. The robustness of the proposed approach can be tested with several threshold values.

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