Research on Supplier Performance Evaluation Method under Environment Regulation

Based on Fuzzy Soft Set Theory Subtitle

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Abstract—**This paper constructs the evaluation index system of supplier's performance under environmental regulation. To avoid the loss of information in the process of evaluation, a group decision-making evaluation model based on AHP and the fuzzy soft set is proposed. Finally, an example is shown to illustrate the validity of the approach and rationality of the assessment result.**

Keywords—environment regulation; performance evaluation; fuzzy soft set

I. INTRODUCTION

With global warming, ecosystem degradation and lower energy crisis, more and more countries introduce energy-saving and emission reduction plans and programs. China as the world's factory, showing typical high carbon characteristics of economic development, energy and environmental issues are very prominent. Therefore, while maintaining stable economic growth, how to reduce carbon emissions will be a serious challenge facing China in the future.

At present, the carbon emissions of China are mainly concentrated in the manufacturing enterprises, so the government has adopted a series of environmental regulation policies, to carry out different levels of regulation for the manufacturing industry. With the continuous improvement of the environmental regulation policy system, the enterprises are facing high-intensity environmental regulation. Therefore, how to deal with the challenges of environmental regulation has become a key issue to be resolved. Supply of raw materials or parts as the core of the operation of the production process, its carbon emissions will directly affect the operation of the entire enterprise and carbon emissions. To make the carbon emissions minimize from the raw materials, parts and components to the production and finally realize the enterprise economic benefit, environment benefit, and social benefits coordination optimization, manufacturing enterprises need to consider the economic factors and environmental factors during the evaluation of supplier's performance. However, the study of supplier performance evaluation is often focused on the maximization of revenue or the cost minimization in the past and considers less about the environmental liability and related regulations. Therefore, it is urgent to study the performance evaluation of the suppliers under the environmental regulations.

There exist two main aspects in the research of supplier performance evaluation: one is the evaluation indexes of the supplier's performance, and the other is the evaluation method of the supplier's performance. In the study of index system, most of the previous study considered the cost, quality, on-time delivery rate, and service, etc., and comprehensive consideration of the traditional performance index and the index of environmental regulation is very scarce. On the method, the main method focuses on uncertain theory, which includes fuzzy set, rough set, probability theory and so on.

On the index system, the index can be divided into qualitative and quantitative indexes. Due to the complexity and uncertainty of the real world decision-making problems, researchers are paying more attention to the qualitative index, which can more precisely reflect the decision makers' language. For supplier performance evaluation problems, therefore, looking for more effective modeling method is still very necessary. Molodtsov [1] thought that due to the diversity of data, the traditional uncertain mathematical methods can't solve the problem of qualitative indexes, the reason for this is that these theories adopted improper parameters. So he proposed the soft set theory, which can deal with uncertainties. The soft set theory uses a more reasonable form to avoid these defects, through reasonable parameters, the Zadeh fuzzy set as a special soft set on the unit interval [1].

The problem of supplier performance evaluation under environmental regulation belongs to the problem of multiple attribute decision making. Due to the increasing complexity of the socio-economic environment and the lack of knowledge or data about the problem domain, a single expert or decision maker often can't comprehensively consider the whole aspect of the decision problem. Therefore, a general trend in the literature is to investigate group decision models. Given this, this paper proposes a group decision-making evaluation method using AHP and fuzzy soft set to study the problem of supplier performance evaluation under the environmental regulations, hoping to provide a new way of thinking for the relevant research.

The remainder of this paper is organized as follows: in section 2, we review some basic concepts fuzzy soft set, the similarity between fuzzy sets. Section 3 develops a novel

MAGDM approach to evaluating supplier performance under environment regulation. Section 4 gives an illustrative example. Finally, conclusions appear in Section 5.

II. THEORETICAL BACKGROUND

The soft set which was initiated by Molodtsov [18], as a new mathematical tool can deal with uncertainties. In recent years, research on soft set theory has become active, great progress has been achieved in the theoretical aspect. At the same time, there has been some progress concerning practical applications of soft set theory, especially the use of soft sets in decision making.

Definition 1(see [2]) Let $\mathcal{P}(U)$ be the set of all fuzzy subsets in an initial universe U. Let E be a set of parameters and $A \subset E$. A pair $(\tilde{F}, A)$ is called a fuzzy soft set over U, where $\tilde{F}$ is a mapping given by $\tilde{F}: A \to \mathcal{P}(U)$.

Definition 2 (see [3]): Let $f_{ij}(i=1,2,...n; j=1,2,...,m)$ be the element of resultant fuzzy soft set. Then we call $C=(c_{ij})_{n\times m}$ the score matrix of the resultant fuzzy soft set and c_i is choice value for each alternative h_i, such that

$$c_{ij} = \sum_{k=1}^{m} (f_{ik} - f_{jk}),$$

$$c_i = \sum_{j=1}^{m} c_{ij} \qquad (1)$$

Based on the choice value formula, we present the overall choice value of each alternative $h_i(i=1,2,...,n)$:

$$c_i(w) = \sum_{j=1}^{m} w_j c_{ij}, i=1,2,...,n \qquad (2)$$

Define 3(see [4]): Let $U=\{h_1,h_2,...,h_n\}$ be the initial universe, Let $E=\{e_1,e_2,...,e_m\}$ be a set of parameters and $A \subseteq E$, $B \subseteq E$, $(\tilde{F}, A)$ and $(\tilde{G}, B)$ are two fuzzy soft sets over the E, then the similarity $S(\tilde{F},\tilde{G})$ between two fuzzy soft sets $(\tilde{F}, A)$ and $(\tilde{G}, B)$ as follows:

$$S(\tilde{F},\tilde{G}) = \frac{1}{m}\sum_{i=1}^{m}\left(1-\frac{\sum_{j=1}^{n}\left|\tilde{F}_{ij}-\tilde{G}_{ij}\right|}{\sum_{j=1}^{n}\left|\tilde{F}_{ij}+\tilde{G}_{ij}\right|}\right) \qquad (3)$$

Where $\tilde{F}_{ij} = \mu_{\tilde{F}(e_i)}(x_j)$, $\tilde{G}_{ij} = \mu_{\tilde{G}(e_i)}(x_j)$ 。

III. SUPPLIER PERFORMANCE EVALUATION MODEL UNDER ENVIRONMENT REGULATION

A. Establishment of index system

In this study, the key factors for assessing the risk of supplier are derived from literature reviews [5] and [6].Detailed discussion on every criterion, the criteria of evaluation has been identified, which is shown in "Table I".

TABLE I. SUPPLIER SELECTION CRITERIA

Criteria	Subdivision
Contract and supply	Bank credit rating high e_1 On –time delivery rate e_2 Product qualification ratio e_3 Rejection rate of the product e_4 Strong comprehensive strength e_5
Service level	Smooth flow of information e_6 Short response time of after-sales service e_7 Service quality is good e_8
Environmental factors	High resource utilization e_9 Low carbon emissions of raw materials e_{10}

B. Determination method of experts' weights

Let $U=\{h_1,h_2,...,h_n\}$ be a discrete set of alternatives, consisting of n non-inferior alternatives, and $E=\{e_1,e_2,...,e_m\}$ be the set of attributes. Each alternative is assessed on the m attributes. Let $D=\{d_1,d_2,...,d_l\}$ be the set of l decision makers. The decision makers $d_k(k=1,2,...,l)$ provide their fuzzy preferences for each pair of alternatives and construct the fuzzy soft sets. The fuzzy soft set given by kth decision-maker is shown in "Table II".

TABLE II. THE FUZZY SOFT SET $(\tilde{F}_k, A)$

U	e_1	e_2	$\cdots$	e_m
h_1	a_{11}^k	a_{12}^k	$\cdots$	a_{1m}^k
$\vdots$	$\vdots$	$\vdots$	$\cdots$	$\vdots$
h_n	a_{n1}^k	a_{n2}^k	$\cdots$	a_{nm}^k

Considering the decision making experts have no prejudice against all the suppliers, under Yue [7] inspiration, we take a supplier average value of all the individual decision at a certain indicator as the ideal fuzzy soft set, which is expressed by $(\tilde{G}, B)$. Let a_{ij}^* be a fuzzy variable over the $(\tilde{G}, B)$, then the membership function can be defined as follows:

$$a_{ij}^* = \frac{1}{l}\sum_{k=1}^{l} a_{ij}^k (i \in n, j \in m) \qquad (4)$$

According to the formula (3), we can calculate the similarity S_k. The bigger the S_k, the higher the credibility of the kth is in the decision making. So we can get the objective weight of the decision maker, namely

$$w_k = \frac{S_k}{\sum_{k=1}^{l} S_k} \qquad (5)$$

However, since each DM has own expertise, recognition and familiarity, he may be familiar with some of the attributes, but not others. So the each DM should have different importance. This importance of as an expert in his area is called subjective weight[8], denoted it by c_k ($0 \le c_k \le 1$).

Both considerations can be combined as follows:

$$\chi_k = \alpha c_k + (1-\alpha) w_k, k = 1, 2, ..., l \quad (6)$$

Where $\alpha (0 \le \alpha \le 1)$ is the optimistic coefficient, whose value can be chosen according to group's optinion. χ_k is called a comprehensive weight coefficient.

Furthermore, the weight of *kth* ($k \in l$) DM can be obtained by

$$W_k = \frac{\chi_k}{\sum_{k=1}^{l} \chi_k} \quad (7)$$

C. Decision algorithm

Step 1: Construct the judgment matrix and compare the importance among criteria to derive the weight vector ω using the eigenvalue approach.

Step 2: Calculate expert weight vector W using the formula (5), (6), (7). By weight averaging, the fuzzy soft sets $(\tilde{F}_k, A)$ are integrated into a final decision fuzzy soft set $(\tilde{F}, A)$.

Step 3: Construct the resultant weighted fuzzy soft set $((\tilde{F}, \omega), A)$, according to fuzzy soft set $(\tilde{F}, A)$ and weight vector ω .

Step 4: According to the formula (2), we can get the relative score of h_i , $\forall i, s_i(\omega) = \sum_{j=1}^{m} s_{ij}(\omega)$. Then decision is h_k , if $s_k(w) = \min s_i(w)$.

IV. CASE STUDY

A manufacturer wants to select one supplier company as a long-term strategic partner for the purpose of achieving common emission reductions. After preliminary screening, three candidates (h_1, h_2, h_3) remain for further evaluation. For both economic and environmental benefits, the manufacturer considers it necessary to conduct a detailed, comprehensive performance evaluation of the enterprise. The evaluation group is composed of three experts, respectively from product managers (very high popularity in the country $c_1 = 0.8$), quality manager (very high popularity in the province $c_2 = 0.6$) and raw material procurement manager (very high popularity in the industry $c_3 = 0.4$).The sample given by the experts is shown in "Table III" ;

TABLE III.

DM	U	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}
DM#1	h_1	0.65	0.75	0.75	0.80	0.60	0.60	0.63	0.90	0.70	0.70
	h_2	0.70	0.80	0.55	0.75	0.65	0.65	0.65	0.83	0.50	0.55
	h_3	0.80	0.65	0.70	0.70	0.70	0.60	0.68	0.80	0.65	0.70
DM#2	h_1	0.70	0.85	0.75	0.85	0.60	0.80	0.65	0.88	0.70	0.70
	h_2	0.75	0.80	0.85	0.75	0.70	0.75	0.60	0.75	0.80	0.85
	h_3	0.60	0.75	0.80	0.75	0.85	0.70	0.80	0.80	0.75	0.80
DM#3	h_1	0.65	0.78	0.75	0.85	0.75	0.75	0.70	0.95	0.70	0.70
	h_2	0.75	0.85	0.70	0.83	0.78	0.80	0.65	0.75	0.65	0.65
	h_3	0.79	0.65	0.75	0.65	0.80	0.60	0.60	0.70	0.70	0.75

Compare the importance among criteria to obtain the judgment matrix and the attributes weights can be calculated by using the eigenvalue approach, as shown in "Table IV". Calculate the normalized weight vector and obtain the attributes weight vector: $\omega = (0.0588, 0.1902, 0.2349, 0.0792, 0.0396, 0.0436, 0.0505, 0.065, 0.1010, 0.1372)$

TABLE IV.

	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}	weight
e_1	1	2/7	1/3	5/7	10/7	9/7	8/7	6/7	4/7	3/7	0.1570
e_2	7/2	1	1/2	5/2	5	9/2	4	3	2	3/2	0.5078
e_3	3	2	1	3	6	5	4	3	2	2	0.6269
e_4	7/5	2/5	1/3	1	2	9/5	8/5	6/5	4/5	3/5	0.2115
e_5	7/10	1/5	1/6	1/2	1	9/10	4/5	3/5	2/5	3/10	0.1057
e_6	7/9	2/9	1/6	5/9	10/9	1	8/9	2/3	4/9	1/3	0.1163
e_7	7/8	1/4	1/4	5/8	5/4	9/8	1	3/4	1/2	3/8	0.1348
e_8	7/6	1/3	1/3	5/6	5/3	3/2	4/3	1	2/3	1/3	0.1736
e_9	7/4	1/2	1/2	5/4	5/2	9/4	2	3/2	1	3/4	0.2695
e_{10}	7/3	2/3	1/2	5/3	10/3	3	8/3	3	4/3	1	0.3662

Considering the decision making experts have no prejudice against all the suppliers, the ideal solution of each supplier can be calculated by the formula (4) and the objective weight vector of the expert is obtained according to the formula (3) and (5): $w = (0.3272, 0.3303, 0.3425)$. Through consultation, experts determine the subjective and objective preference $\alpha = 0.4$. According to the formula (6) and (7), the expert comprehensive weight vector is: $W = (0.3911, 0.3320, 0.2769)$.

According to the weight vector of decision expert, the fuzzy soft set $(\tilde{F}_k, A)$ is integrated into a final decision fuzzy soft set $(\tilde{F}, A)$ by weighted averaging. Construct the resultant weighted fuzzy soft set $((\tilde{F}, \omega), A)$ according to fuzzy soft set $(\tilde{F}, A)$ and weight vector ω, as shown in "Table V". According to formula (8), we can obtain

TABLE V. TABULAR REPRSENTATION OF THE RESULTANT WEIGHTED FUZZY SOFT SET $((\tilde{F}, \omega), A)$

U	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}
h_1	0.0394	0.1503	0.1762	0.0657	0.0253	0.0310	0.0328	0.0585	0.0707	0.0960
h_2	0.0429	0.1541	0.1621	0.0610	0.0277	0.0314	0.0318	0.0507	0.0646	0.0919
h_3	0.0429	0.1293	0.1738	0.0554	0.0305	0.0275	0.0348	0.0501	0.0697	0.1015

$s_1(\omega) = 0.0580, s_2(\omega) = -0.0250, s_3(\omega) = -0.0330$. Rank all the altervative $h_i (i = 1, 2, 3)$ in accordance with the scores $s_i(w)$: $h_1 \succ h_2 \succ h_3$. From the above analysis, the manufacturer should strengthen long-term cooperation with the supplier 1.

V. CONCLUSION

The evaluation of supplier's performance is an important job in the management of suppliers. Although many scholars from various perspectives use different methods to comprehensive evaluation, the traditional mathematical methods can't solve the problem of the qualitative index because of the diversity of data. The reason is that these theories are not suitable for the use of parameters. The innovation of this paper is to introduce the idea of fuzzy soft set and proposes a new method of supplier performance evaluation from the perspective of group decision making. The model integrates subjective and objective method to determine the weights of experts. Through expert weight, we can integrate fuzzy soft sets into the final fuzzy soft set. Finally, the results show that the proposed method is scientific and reasonable, simple and feasible.

Given the scientific nature of the evaluation model and the dynamic change of the performance of the supplier under the environment, it is very important to establish the dynamic performance evaluation method. At the same time, analysis of more types of uncertain data and explore the use of other membership functions (triangular, trapezoidal or L-R type) of the fuzzy soft set method applied to supplier performance evaluation.

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