A Two-Stage Multi-Criteria Decision Making Approach for Green Supplier Selection

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Objective

Awareness of environmental protection and sustainability in the manufacturing industry has grown making the green image a more critical factor in the supplier selection process. Supplier evaluation and selection are well studied in the literature. However, studies with a green focus are relatively limited. In order to fill this gap, this paper proposes a green supplier evaluation and selection (GSES) method that evaluates suppliers according to their green competencies and environmental performances. In this regard, a combined multi-criteria decision making (MCDM) approach capable of handling imprecise quantitative and qualitative data is proposed. To demonstrate the functionality of the approach, a case study is conducted on a U.S. based company that manufactures and distributes plastic closures and dispensing systems, internationally. The results of the approach along with the discussion for future research are also provided.

Methodology and Project Design

In this study Fuzzy Analytic Hierarchy Process (Fuzzy AHP) is used to do the pairwise comparison of the supplier selection criteria and following that Fuzzy Technique for Order Preference by Similarity (Fuzzy TOPSIS) is applied to rank the suppliers with respect to their performance in each criterion The study focused on evaluating and selecting supplier(s) of plastics used in the plastic injection molding of innovative dispensing pumps. In order to select the best alternative, thirteen potential suppliers were evaluated according to their performance using eight decision criteria. The following figure demonstrates the flow of the approach.

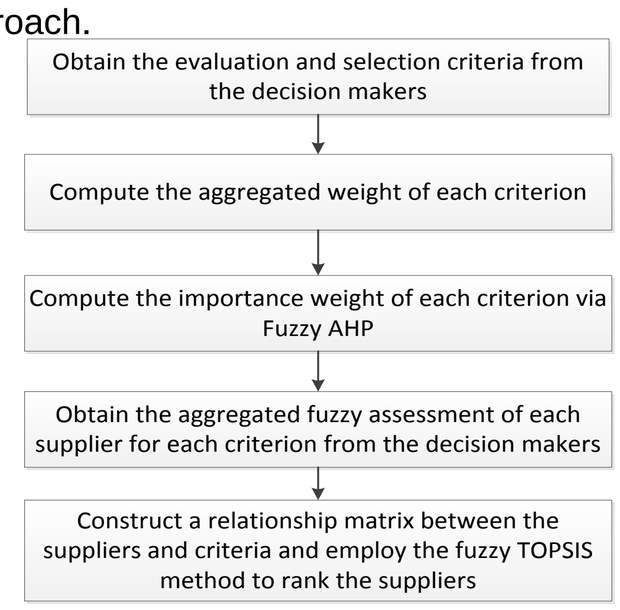

Figure 1: The steps of the proposed methodology

Case Study in Dispensing Systems Industry

The case study is conducted in a leading global manufacturer and distributor of dispensing systems for beauty and personal care in addition to home and consumer health care needs. The U.S. based manufacturing company uses plastics as one of its major raw materials.

Figure 2. Plastics Molding Process

As shown in Figure 1, defining the supplier evaluation and selection criteria is the initiation step of this approach. The obtained criteria are provided in the following:

COST	QUALITY	SERVICE LEVEL	LOGISTICS OPERATIONS
FINANCIAL POSITION	ORGANIZATION	CONTINUOUS IMPROVEMENT	GREEN IMAGE

Pairwise Comparison of Each Criterion via Fuzzy AHP

Given the set of above criteria, the decision makers are asked to rank their preference levels for each criterion. The evaluation was conducted based on the linguistic judgements of three different expert decision makers, who are responsible for the

- Operations,
- Purchasing,
- Quality control

Following this, in order to prioritize the green image in the supplier evaluation process, a Fuzzy AHP approach is employed. The evaluation scale used in Fuzzy AHP is provided in Table 1.

Table 1: Comparative linguistic scale for ratings of alternatives and weights of criteria

Linguistic Terms	Triangular Fuzzy Number (TFN)
Just equal (EQ)	(1,1,1)
Weak importance of one over another (WI)	(1,1,3)
Fairly Preferable (FP)	(1,3,5)
Essential importance of one over another (EI)	(3,5,7)
Strongly Preferable (SP)	(5,7,9)
Absolutely Preferable (AP)	(7,9,9)
If criteria i has one the values above assigned in pairwise comparison with criteria j, then criteria j has the reciprocal value when it compared with criteria i	

Data Collection

The data obtained from the decision makers for pairwise comparison is partially demonstrated in Table 2.

	Cost			Quality			Green Image		
	DM 1	DM 2	DM 3	DM 1	DM 2	DM 3	DM 1	DM 2	DM 3
Cost	EQ	EQ	EQ	WI	WI	1/WI	1/WI	1/WI	1/FP
Quality	1/WI	1/WI	WI	EQ	EQ	EQ	1/WI	1/FP	1/FP
Service Level	1/FP	1/FP	1/FP	1/FP	1/FP	1/EI	1/EI	1/EI	1/SP
Logistics Operations	1/FP	1/EI	1/EI	1/EI	1/EI	1/SP	1/EI	1/FP	1/SP
Financial Position	1/EI	1/EI	1/SP	1/EI	1/SP	1/SP	1/SP	1/EI	1/EI
Organization	1/AP	1/SP	1/EI	1/SP	1/EI	1/EI	1/SP	1/SP	1/AP
Continuous Improvement	1/SP	1/SP	1/EI	1/SP	1/SP	1/SP	1/SP	1/EI	1/SP
Green Image	WI	WI	FP	WI	FP	FP	EQ	EQ	EQ

Table 2: Comparative linguistic scale for ratings of alternatives and weights of criteria (Partial)

The results obtained via Fuzzy AHP is presented in Table3.

Table 3. The weight vectors of the criteria

Criteria	Weight
Cost	0.221894
Quality	0.23324
Service Level	0.100138
Logistics Operations	0.100387
Financial Position	0.016061
Organization	0.000416
Continuous Improvement	0.086838
Green Image	0.241026

Supplier Evaluation and Selection via Fuzzy TOPSIS

The weight vector represents the importance degree of each criterion which is used as an input in fuzzy TOPSIS method to evaluate the suppliers. Additional inputs are the fuzzy evaluations of the suppliers with respect to the criteria. These are obtained from the decision makers in the company using linguistic terms

Table 4: Linguistic scale to evaluate the ratings of the suppliers

Linguistic Terms	Triangular Fuzzy Number (TFN)
Very low (VL)	(0,1,2)
Low (L)	(2,3,4)
Medium (M)	(4,5,6)
High (H)	(6,7,8)
Very High (VH)	(8,9,10)

The data collected from the decision makers regarding the assessment of each supplier is partially provided in Table 5.

Table 5. Linguistic ratings of each supplier with respect to each criteria (Partial)

	Cost			Quality			Green Image		
	DM 1	DM 2	DM 3	DM 1	DM 2	DM 3	DM 1	DM 2	DM 3
Supplier 1	M	H	M	H	M	H	M	M	H
Supplier 2	VH	VH	VH	VH	VH	VH	H	H	H
Supplier 3	H	M	M	VH	H	VH	H	H	VH
Supplier 4	H	H	M	VH	H	H	H	VH	H
Supplier 5	VH	VH	VH	M	H	H	M	H	H
Supplier 6	VH	H	VH	H	M	M	M	L	VL
Supplier 7	M	VH	VH	H	H	H	M	L	M
Supplier 8	VH	H	H	M	H	H	H	M	M
Supplier 9	VH	VH	VH	H	VH	VH	VL	L	M
Supplier 10	VH	VH	H	M	H	H	M	H	H
Supplier 11	H	H	H	H	VH	VH	H	VH	H
Supplier 12	H	VH	VH	VH	VH	H	H	H	M
Supplier 13	M	H	H	M	H	H	H	M	M

The results obtained via Fuzzy TOPSIS is presented in Table6.

Table 6. Ranking of suppliers

Suppliers	d+	d-	CC	Rank
Supplier 1	7.16	0.841	0.1051	9
Supplier 2	7.051	0.949	0.1186	3
Supplier 3	7.027	0.973	0.1216	1
Supplier 4	7.031	0.969	0.1212	2
Supplier 5	7.13	0.871	0.1089	7
Supplier 6	7.337	0.665	0.0831	13
Supplier 7	7.195	0.807	0.1008	10
Supplier 8	7.145	0.856	0.107	8
Supplier 9	7.31	0.694	0.0867	12
Supplier 10	7.224	0.778	0.0972	11
Supplier 11	7.115	0.886	0.1107	6
Supplier 12	7.105	0.895	0.1119	5
Supplier 13	7.099	0.902	0.1127	4

As it can be seen in Table 6, Supplier 3 among 13 different suppliers has the best performance

Conclusions & Future Research

Fuzzy AHP and Fuzzy TOPSIS methods are both well studied for the supplier selection problem. However, these methods are rarely applied jointly in supplier evaluation and selection models with a green focus. Both models suffer from various limitations. Making advantage of both methods, this study proposed a real world case study for supplier evaluation and selection. The assessment measures and related ratings with respect to main criteria are directly obtained from the experts using linguistic terms. In the future, the data set can be expanded to include quantitative measures for additional technical sub-criteria.

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