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Green supplier selection for manufacturing organization using a hybrid MCDM approach

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Abstract

In today's competitive era business demands cost-effectiveness, logistic efficiency, quality products, after sale services, and environmentally responsible production activities. Sustainable development is need of the hour. Government as well as private agencies and business organisations are emphasising on its implementation in all business activities. Green production, green logistics and green waste management are the three major green business activities. A supplier, who has sensitivity towards the environment along with

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economic factors is the real asset of a green business chain and is termed as green supplier. In this study. we are concerned with "green supplier selection" by ranking the available green suppliers. The ranking of green supplier selection is considered to be a multi-criteria optimisation problem, which is more popularly known as a multi-criteria decision-making (MCDM) problem. We have applied five different MCDM techniques to rank the green suppliers for the manufacturing organisation in the Delhi-NCR region and proposed an integrated approach of MCDM for assessment and selection of the green supplier. The study is novel in nature as it suggests the ranking of green suppliers by identifying the preferential suppliers to carry forward a green business chain.

Subject Classification: *D2.*

Keywords: *Green supplier selection, MCDM, TOPSIS, PROMETHEE, SWARA and COPRAS, Green supply chain management.*

1. Introduction

Protection of the environment is the main issue and competitive factor in the manufacturing industry nowadays. Green supply chain strategies and actions are required for every facet of supply chain management (SCM), right from acquiring raw material from suppliers to delivering finished goods to the customer (Qureshi et. al., 2008). The GSCM methodology is nothing but a judicial blend of traditional SCM with green environmental protection practices for sustainable development (Madaan and Mangla, 2015). Tyagi et. al., 2019 explained GSCM as "integrating environmental thinking into the domain of SCM, including material sourcing, product design, and selection, practices of manufacturing, and to the customers (final product). It also includes product management after its intended life (end life management)." In the current global scenario, there is tremendous pressure from international environmental bodies, raising the flag when GSCM practises are not implemented. They are encouraging businesses to recognise the factors that will allow them to properly and effectively follow GSCM guidelines (Mathiyazhagan and Haq, 2013).

The Green Supplier Selection (GSS) system is critical to GSCM value chain. Green supplier firm, have a highly sensitive environmental image. That is why they have a competitive edge over non-environmentally performing suppliers. A green supplier focuses on using renewable and environment-friendly energy resources, recyclable and reusable raw materials and consumables, green designing, green packaging and packaging material, etc., in their supply chain operations (Wu et al., 2019). It is not easy to select a green supplier in comparison to selecting a conventional supplier (Mendoza and Ventura 2013; Aretoulis et al., 2010) as it has to consider both qualitative factors as well as opposing selection

standards (Cao et al., 2015). That is why GSS is acknowledged as a multi-criterion decision-making (MCDM) issue. This issue has drawn many researchers' attention in recent times (Chatterjee et. al., 2019; Wu et al., 2019; Mathiyazhagan et al., 2018). Additionally, a remarkable increase in research on GSS (Tseng et al., 2019; Malviya and Kant, 2015; Govindan et al., 2015) in recent years has highlighted the significance of the issue.

MCDM strategy is used in making decisions through setting up and fulfilling multiple and conflicting criteria. Its problems are common in daily routine; for instance, if anyone buys a mobile phone, it is qualified by cost, features, storage, looks, camera, etc. While in business, problems are much complicated. In recent years, this method is used for better business modelling. Purchase departments of many companies use this method to select their suppliers based on a vast range of criteria such as cost of material, quality, after-sales service, financial stability, etc. (Govindan, Khodaverdi, and Jafarian, 2013).

2. Objectives of the Study

1. The main objective of this paper is to find the best & appropriate green supplier through MCDM techniques in an organization.
2. The MCDM techniques like AHP, TOPSIS, PROMETHEE, SWARA and COPRAS are implemented based on their performance measurement & accuracy which stands best through the comparative analysis on literature survey.
3. The MCDM technique like AHP is to help managers in determining the weights of the green supplier selection criterion which are helpful in determining the ranking of the green suppliers.
4. Other techniques like TOPSIS, PROMETHEE, SWARA and COPRAS are implemented in determining the best and worst green suppliers and also determine the ranking of the green suppliers.
5. Spearman's rank correlation test is applied to determine the best optimal solution among the green suppliers.

3. Literature Review

Supplier selection is a crucial facet in the management of supplies and purchasing function (Banaeian et. al., 2018). Researchers have used a variety of MCDM methods for handling the problems of green supplier selection. Various criteria for supplier selection were explored in the first section of the literature review. These criteria, including quality, timely

delivery, and economic pricing, have been used by different companies to assess their suppliers (Hlioui et. al., 2017). The GSCM approach takes into consideration the environmental hazards, ecological balance, and climate change for all the phases of supply chain management, covering its entire cycle (Fahimnia et. al., 2015, Min and Kim, 2012, Mangla et. al., 2014). As far as green supplier selection criteria are concerned, many researchers have taken different criteria based on different experts and different industry inputs across different economies (Mathiyazhagan, Sudhakar, and Bhalotia, 2018). Lee et. al., 2009 considered the net cost of the product through its lifecycle, quality as well as technology capabilities, along with green criteria, such as pollution control, green image, green product, managing the environment, and green proficiencies. Grisi et. al., 2010, also took into consideration the green image and environmental management, along with ISO14001, environmental policies, ecological material, clean-technology, and environmental planning. Chen et. al., 2010 identified green design, ISO 14001, clean production, R&D on green products, green purchasing, quality, flexibility, and delivery. Kannan et. al., 2015 included environment protection, green image, green product, green innovation, corporate social responsibility, hazard management, and pollution control as criteria to implement GSS. A green supplier makes efforts primarily on using renewable energy sources and saving, reusing, and recycling the materials. Also, its focus remains on green designing as well as green packing while performing GSCM activities (Wu et. al., 2019). The process of selecting and verifying a green supplier is more complicated than that of a conventional supplier (Aretoulis et. al., 2010; Mendoza and Ventura 2013; Yousefi et. al., 2019). This is the reason why the problem of GSS is treated as a multiple-criteria decision-making (MCDM) issue (Cao, Wu, and Liang, 2015). This issue had drawn many researchers' attention in recent times (Chatterjee et al., 2019; Mathiyazhagan et al., 2018; Wu et al., 2019). Additionally, a remarkable increase in the research on GSS (Tseng et al., 2019; Malviya and Kant, 2015; Govindan et al., 2015) recently has highlighted the significance of the matter. Numerous economic and environmental facets have also been taken into consideration to verify and validate green suppliers (Yu et. al., 2018). On the basis of the literature review the attributes of the green supplier selection has been finalized in table 1.

4. Research Methodology

First of all the study identifies the criteria for selection of green suppliers on the basis of expert opinion andliterature review in this field. Total ten criteria have been identified which are shown in Table-1.

On the basis of these criteria major suppliers, dealing in supplying of raw material for plastic component manufacturing companies are assessed.To identify green suppliers we used Green Supplier Score (GSR score). The GSR score which is calculated on the basis of the analogy to measure corporate social responsibility score (Kapoor and Sandhu, 2010; Maqbool and Zameer, 2018). In the calculation of GSR scores, 1 has been assigned if a supplier engaged in a particular activity, disclosed in table 1 and 0 is assigned if the supplier is not engaged. The scores thus resulted are then equalised up for each individual supplier. After that, GSR percentage has been calculated by transforming scores with the help of following formulae:

GSR score of a Supplier = (No. of activities performed by a supplier out of the activities disclosed in Table-1. Total No. of activities in the table x 100).

On the basis of the GSR score top fifteen suppliers have been selected for evaluation or ranking by the manufacturing companies.

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a widely used MCDM method for ranking suppliers. This technique is based on the principles of determining the distance between an Ideal Negative Solution (INS) and an alternative from the ideal positive solution (IPS). Final decision is the alternative which is farthest to the negative ideal solution in a space of multi-dimensional computing. This technique considers the relative closeness of an alternative from IPS and INS simultaneously. (Ginting et. al., 2017,Poklepović, Babić, 2014, Velasquez, Hester, 2013).

The PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) in this method the finest option is obtained by outranking relationships using comparisons done pairwise. The ultimate decision is grounded on each alternative's negative and positive preference. The positive choice flow shows how one option outranks the remaining alternatives (Kou et. al., 2012).

The COPRAS (Complex Proportional Assessment Method) is useful in the situation where the decision making criteria are conflicting. In the case of conflicting criteria, the technique hypothesizes direct and proportionate dependency of the priority and alternatives the usefulness degree. It finds a solution grounded on the ratios of the 'ideal' and 'anti-ideal solutions'. Comparing the examined alternatives to the best one determines the degree of usefulness (Poklepović, Babić, 2014).

The SAW (Simple Additive Weighting) is another widely used technique of MCDM methods used for supplier selection. Usually SAW

goes along with TOPSIS. First of all, each criterion (attribute) has been given a weight. Then in the decision matrix, these allocated weights become the coefficients of the variables. Overall score for each and every alternative given is determined by multiplying and arranging the data for each criterion from the decision matrix. The ultimate rating of each option is determined by adding the goods across all criteria, with the highest-scoring alternative being recommended to the decision maker (Poklepović, Babić, 2014).

The linear assignment approach (Bernardo, Blin, 1977) is based on a collection of rank alternatives. The rank alternative is based on attribute of the criteria and weights allocated to it (refer table 2). It compares the components of decision matrix. Whereas, the actual data is utilize as input to the procedure. Each criterion is then used to rate the alternatives from best ranking to worst ranking.The rankings for each option are added together to arrive at the final rating.

Table 1

List of Green Supplier Selection criteria

S. No.	Criteria		References
1	MCC	Cost of Material	(Kannan et. al., 2015; Fallahpour et. al., 2017)
2	QIC	Quality Inspection Methods	(Humphreys et. al., 2006)
3	DTC	On-time Delivery	(Yang and Wu, 2008)
4	FOC	Flexibility in Ordering	(Kannan et. al., 2015)
5	ICC	ISO14001 Certification	(Humphreys et. al., 2006)
6	ELC	Eco-Labeling	(Yang and Wu, 2008)
7	GPC	Green Packaging	(Büyüközkan and Çifçi, 2012)
8	HWC	Hazardous Wastes Management	(Rostamzadeh et. al., 2015)
9	ETC	Using a modern eco-efficient transportation fleet	(Kannan et. al., 2015)
10	REC	Use of Renewable Energy	(Rostamzadeh et. al., 2015)

Table 2

Weights of the criteria using AHP

S. No.	Criteria		weights
1	MCC	Cost of Material	0.3
2	QIC	Quality Inspection Methods	0.01
3	DTC	On-time Delivery	0.2
4	FOC	Flexibility in Ordering	0.04
5	ICC	ISO14001 Certification	0.02
6	ELC	Eco-Labeling	0.03
7	GPC	Green Packaging	0.01
8	HWC	Hazardous Wastes Management	0.21
9	ETC	Using a modern eco-efficient transportation fleet	0.08
10	REC	Use of renewable energy	0.1

5. Result and Discussion

It is difficult to conclude about the best technique, as different MCDM technique makes the decision on the basis of different considerations and process. We, therefore propose a hybrid ranking method for green supplier selection first by ranking the above mentioned techniques.After this, Spearman's rank correlation coefficients is used between five different methods to obtain the final hybrid green supplier ranking. Table -3, shows the ranking of the supplier obtained by different MCDM methods. If we see the ranking carefully, ranking of a supplier is same of proximately same by most of the techniques. To check the correlation between the ranks of fifteen selected suppliers, Spearman's rank correlation coefficient has been used. That is shown in Table-4. Table-5 shows the calculation of normalized weight for all the methods. On the basis of the ranking by five applied MCDM techniques and weights which are normalised (Table-5). A hybrid and final ranking has been calculated, shown in Table 6.

Table 6, shows Sup-4 is the most preferred green supplier, with first ranking. Table 3, also shows that Sup-4 is the most preferred supplier by all the applied MCDM techniques except Liner Assignment method. Similarly Sup-5 and Sup-7 received second and third ranking by the hybrid ranking method.

Table 3

Ranking of the suppliers by different MCDM Techniques

	TOPSIS		PROMETH-EE		SWA		COPRAS		LIN-ASIGN
	Relative Closeness	Rank	Net Flow	Rank	Score	Rank	Quan-titative Utility	Rank	Rank
SUP-1	0.53	7	0.22	5	0.58	7	67.18	6	8
SUP-2	0.71	2	0.23	4	0.7	2	90.08	2	15
SUP-3	0.45	14	-0.13	13	0.48	15	47.25	15	11
SUP-4	0.84	1	0.42	1	0.75	1	100	1	4
SUP-5	0.67	3	0.27	3	0.64	3	74.09	4	3
SUP-6	0.42	15	0.35	2	0.56	8	52.55	13	12
SUP-7	0.47	12	-0.01	10	0.64	4	70.72	5	1
SUP-8	0.65	5	0.1	8	0.51	12	53.06	12	9
SUP-9	0.47	11	0.12	7	0.54	10	56.3	10	5
SUP-10	0.47	10	0.07	9	0.61	5	77.92	3	14
SUP-11	0.65	4	-0.07	12	0.56	9	66.04	7	13
SUP-12	0.55	6	-0.05	11	0.5	14	48.47	14	6
SUP-13	0.45	13	-0.15	14	0.54	11	59.97	9	7
SUP-14	0.47	9	0.2	6	0.51	13	53.4	11	2
SUP-15	0.5	8	-0.19	15	0.61	6	64.44	8	10

Table 4

Pearman's rank correlation coefficient between selected techniques

	TOPSIS	PROMETHEE	SAW	COPRAS	Linear Assignment
TOPSIS	1				
PROMETHEE	0.9356	1			
SAW	0.4891	0.30972	1		
COPRAS	0.8897	0.9298	0.6137	1	
Linear Assignment	0.9419	0.9517	0.3837	0.9082	1

Table 5
Weights and Normalize Weights

	Weights	Normalized Weights
TOPSIS	0.789	0.2146
PROMETHEE	0.8349	0.2271
SAW	0.8127	0.2210
COPRAS	0.8008	0.2178
Linear Assignment	0.4396	0.1195

Table 6
Final -Hybrid Ranking

	Score	Ranking
SUP-1	6.4477	7
SUP-2	4.0084	4
SUP-3	13.8531	15
SUP-4	1.3587	1
SUP-5	3.2178	2
SUP-6	12.2419	12
SUP-7	3.6196	3
SUP-8	10.9726	11
SUP-9	8.9481	9
SUP-10	5.88	6
SUP-11	8.399	8
SUP-12	12.3748	13
SUP-13	10.7331	10
SUP-14	12.7178	14
SUP-15	6.3865	5

Conclusion

It is difficult to conclude about the best technique, as different MCDM techniques make the decision on the basis of different considerations and processes. TOPSIS is built on the principal of measuring the distance between an alternative from the Ideal Positive Solution (IPS) and Ideal Negative Solution (INS). PROMETHEE is an outranking method, based on outranking relationships and pairwise comparisons and then selecting the best options. In SAW, the ultimate rating of each option is determined by adding the scores across all criteria, with the highest-scoring

alternative being recommended. The COPRAS technique hypothesis usefulness degree of the alternatives and their proportionate and direct dependences of the priorities. It finds a solution grounded on the ratios of the "ideal" and "anti-ideal solutions". The linear assignment approach is grounded on a collection alternatives of the rank organized by attribute and weighted by a set of criteria. After applying all five techniques, we got different ranking for the suppliers. Supplier-4 was rated the best supplier by all the techniques except liner assignment. Supplier-2 was ranked as the second best supplier by TOPSISS, SAW and COPRAS whereas Supplier-6 was ranked by PROMETHEE and Supplier-14 by Liner Assignment. In the same way, the worst supplier is supplier-15 as per SAW and COPRAS ranking whereas supplier-6, Supplier-15 and Supplier-2 by TOPSIS, PRMETHEE and liner assignment, respectively. To reduce this ambiguity, we used rank correlation coefficients of Spearman's among five diverse methods to obtain the final hybrid green supplier ranking. Suppliers 4, 5 and 7 are found to be the top three rankers, respectively. Suppliers 3, 12 and 14 are found to be the bottom rankers, respectively.

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