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A Literature Survey on Application of MCDM Mathematical Optimization Models for the Sustainable Supplier Selection in Manufacturing Industries

Abstract: - Organizations need to entertain and motivate their ability on sustainable supply chain activities based on environment protection regulation activities. GSCM needs multi-dimensional techniques and methods. Thus multi-criteria decision-making (MCDM) techniques adopted for performance assessment of suppliers in Green supply chain management (GSCM). Supplier selection is important and it is one of the important operational function for the development of GSCM. In order to select the most suitable suppliers, many economic and environmental criteria must be taken account in the decision process. Green supplier choice is a very hard work that needs to consider sustainable factors incorporated into the traditional supplier selection. This paper aims to survey the existing different MCDM approaches which are applied in GSCM for supplier selection and evaluation and identify most significant and effective MCDM approach in comparison with some other MCDM approaches.

Keywords: MCDM, Optimization, Mathematical models, Supplier selection, Sustainable supply chain

1. Introduction

Today Supply chain management (SCM) is most essential for businesses and are remain important vital tool to obtain the competitive advantage in the market. Organizations are started to integrate their supply chains operations to minimise the supply chain running and operating costs and maximise their customer service level. Businesses wants to have change in green deliver chain and have taken the opportunity to study all their enterprise tactics to perceive areas in which practicing a greener outlook , can increase their enterprise performance economically and environment friendly.

Supplier selection is an area of high importance and ought to be taken as a tactical element of an SCM and consequently, its miles significant and important to pick out quantifiable and vary clearly seen standards for vendor selection. Many authors have provided numerous criteria and ways for the selection of suppliers. According to the literature, choosing a sustainable supplier is a primary objective of the decision taking procedure in a firm's production and operation management functions. Sustainable supplier selection process the manufacturing operations can efficiently increase corresponding environmental performance assessment and end user happiness and satisfaction. In addition, a proper supplier selection can be helpful for organizations to collaborate the supply chain operations and can enhance the overall competitive advantages. Hence, companies must select the economically, socially and environmentally strong supportive supplier and build a long lasting relationship to ensure and gain competitive edge and advantages. This paper examines the existing essential MCDM methods in GSCM review .This review tries to identify the domains and important advantages of MCDM approaches in GSCM. To make out those articles that give the important information, a survey has been carried out for standard MCDM approaches in Green supplier selection.

This paper attempts to look at following troubles in a supply chain,

a) Which can be the contemporary MCDM strategies implemented in GSCM literature? b).what's the utility regions of MCDM techniques in industries which are followed sustainable practices? This study paper is arranged as follows; few fundamental concepts of MCDM strategies and their significance in GSCM are discussed in section 2. In section 3 MCDM strategies and applications are discussed. The research findings and dialogue, furthermore, the conclusion is given inside the final sections. The published papers on GSCM from period 2008 to 2021 and in total 106 journal papers are considered in this study

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2. MCDM Techniques in Sustainable Supply Chain

MCDM is an approach which integrates alternative performance evaluation across various contradicting, qualitative, and quantitative factors and results in a solution indicating a consensus. Knowledge harnessed from many fields, including decision-making theory, computer technology, optimization economics, information systems, and mathematics, is used. The objective of MCDM is not to recommend the best decision but to help decision-makers in choosing shortlisted alternatives or a single alternative that fulfils their requirements and meets their preferences mentioned that at beginning stages .Those techniques are precious gear for studying complex issues because of their capacity to assess distinct alternatives on diverse standards for feasible choice according to their character or group choices in which more than one conflicting standards exist. In general, more than forty MCDM strategies have been researched and applied. Some of the algorithms like ANP(Analytical Network Process), AHP(Analytical Hierarchy Technique), TOPSIS(Technique for Order
Preference by Similarity to Ideal Solution), VIKOR(VIekriterijumsko KOmpromisno Rangiranje) which are extensively used and, a few others are especially recently developed are limitedly used. MCDM approaches examine relationships amongst several criteria and environmental factors (Sarkis,1998) and resource agencies in balancing the alternative goals and the environmental worries.

2.1 Analytical Hierarchy Technique (AHP)

The AHP technique used in the early Seventies for finding the comparative significance of factors and the concern of a set of options (Saaty, 1980). The AHP technique mainly used because of its comparative easiness with which it takes in to considerations of many standards and plays with real world scenarios (Meade&Sarkis, 1998). Because of its user friendly and easily understandable, feature AHP is extensively used by many researchers in GSCM evaluation. In many applications, AHP is applied in GSCM practices without delay to provide opportunity solutions (Ireneusz Miciuła 2018: G. Karunakumar 2018). but, in a good wide variety of works of literature, it's far mixed with other strategies, inclusive of ELECTRE III(Ali Alazzawi, 2020), VIKOR (Ashwani Kumar, 2019), PROMETHEE (Tsui&Wen, 2015), TOPSIS (Rajnish Kumar,2018, Hsiu Mei 2016, Wang &Li, 2015 , Yazdani, 2014,) and ARAS (Yan Kai-Fu, 2019; Jolanta Tamošaitienė, 2017) to finally finish the decision-making approach. additionally, in a few instances, AHP is blended with Fuzzy approach range principle to deal with the un deterministic problems having probable nature of the problem (Yan-Kai Fu, 2019; Gülçin Büyüoközkan, 2017; Ashwani Kumar, 2019).AHP also integrated with Taguchi loss function (Ashwani Kumar, 2019), purpose Programming (Yan Kai-Fu, 2019).

2.2 Analytical Network Process (ANP)

ANP is a major MCDM approach which was used in GSCM (Saaty, 1980) and ANP is inherited from the popular AHP method and it is applied in MCDM issues to overcome the limitations of AHP approach (Wu & Barnes, 2016; Hsu et.al 2014) and also to signify a non-linear network system (Lin et al. 2015; Dou, Zhu &Sarkis, 2014). Unlike AHP's unidirectional hierarchical structure, ANP builds interlinks with the decision stages and features in a standard structure (Büyüközkan et.al 2012b). In many times, ANP approach is used to develop hybrid algorithms with other MCDM approaches such as ELECTRE II (Wan Shu-ping, 2017), VIKOR (Sahar Valipour, 2017; Akman et al., 2015), DEMATEL (Uygun et.al 2016), TOPSIS (Kuo et al. 2015). ANP approach is paired with Grey System method (Dou et al., 2014) to determine uncertainty in deciding and also to identify the relative importance (Uygun&Dede, 2016; Kuo et al., 2015; Lin et al., 2014; Büyüközkan et.al, 2012a, Büyüközkan et.al 2012b). Fuzzy based ANP combines three MCDM approaches such as Goal Programming, DEMATEL and TOPSIS for sustainable vendor monitoring and selection (Erfan Babaee et.al 2020).

2.3 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS technique was developed by Chen and Hwang (1992), and it is a multi-criteria method to determine required answers from a limited number of alternatives (Yazdani, 2014). TOPSIS is an approach to find out a choice based solution that is near to the best solution and far to the non-ideal solution in a multi-dimensional calculation space. It has many benefits. It has a simple and easy process. In calculation of Euclidean distance the correlation of attributes are not taken in to consideration, it is the one of the limitation of this process. The TOPSIS method is an extensively renowned method for ranking issues associated with vendor assessments and selection in the supply chain. In few cases, TOPSIS is generally combined with other MCDM methods such as AHP (Hsiu Mei et.al 2016, Yazdani, 2014, White, Wang & Li, 2015) or ANP (Uygun et.al 2016, Büyüközkan et.al 2012a, Kuo et al., 2015,). TOPSIS has been used extensively in GSCM problems in the fuzzy environment (Huseylin Selcuk et. al.2020, Ahmed Mohammed, 2019, Li &Wu, 2015, Kannan et al. 2014, Shen et al. 2013). Like AHP and ANP are the main concerned implementation domains of TOPSIS in GSCM policies in supplier selection.

2.4 Decision Making Trial and Evaluation Laboratory (DEMATEL)

DEMATEL method is suggested by the Battelle Memorial Institute of Geneva in Human Affairs program during 1976 and it's mainly regarded as a tool for analysing a structural and inter connection between complex factors

(Rukiye Kaya, 2019; Morteza Yazdani, 2017). It makes understanding of the problems and organisations communication and offers reliable answers by using a hierarchical network (Uygun&Dede, 2016). All-important main factors lessen into few categories in DEMATEL. This classification brings in a better knowledge of the elements and issues with systems (Falatoonitoosi et al., 2014Govindan et al., 2015).
In a few cases, DEMATEL's purpose-impact structure invites for combination of tender strategies together with fuzzy set theory (Mohd. Sufyan, 2019; Lin, 2013; Govindan et al., 2015; Mavi et al., 2013; Uygun et.al 2016) and complicated Proportional assessment (COPRAS) and first-class feature deployment (MortezaYazdani, 2017). Some inventors experimented that interconnected pairwise assessment approaches with AHP and ANP is advantageous for GSCM adoption process in industries (Büyüokayözkan et.al 2012a; Uygun&Dede, 2016). Even though supplier assessment is the primary utility area of DEMATEL, it is also used to assess, the effect, and examine the suppler development programs.

2.5 Data Envelopment Analysis (DEA)
DEA is a non-parametric computational tool, which takes many inputs and gives many outputs (Charnes, 1978). This is a mathematical approach that uses linear programming to evaluate the corresponding efficiencies of a group of logically similar decision making units (Kuo et.al, 2010, Imre Dobos, 2014).Performance may be analysed and quantified. An extensive downside is it does not address vague and clear records and assumes that all input data and output information are precisely considered. Additionally, DEA is used as a yard stick or standard approach to compare other algorithms (Fallahpour et al., 2015) and goal setting for green organizations (Shi &Yan. 2015; Kumar & Jain .2014).

2.6 The VIKOR Method
VIKOR approach developed by Opricovic (2004), makes a speciality of rating and choosing from many choices , determining compromise answers for a complex problems and helps the deciding manager to attain a final selection (Hsu et al., 2013). VIKOR is a pretty new approach in comparison with different popular MCDM strategies. VIKOR approach applied for supplier selection in affiliation with Fuzzy best worst method (Devika Kannan, 2020; Qun&Wu 2019). VIKOR is additionally incorporated with other MCDM strategies including Analytical network method (ANP) for dealer choice (Sahaj&Valipour, 2017; Akman,2015).VIKOR has a few blessings in comparison to different MCDM processes and it is compared with the techniques for ordering desire by similarity to best answer (TOPSIS) and VIKOR considers organization utility maximization and negative minimization and may absolutely display the decision makers' subjective choices.

2.7 Goal Programming (GP)
GP is a next version linear programming procedure, which includes several trade off goals, because of the method's capability to address numerous objectives, it is helpful for the development of GSCM practices and vendor choice and selection. GP approach is being applied to resolve issues in GSCM practices. Unlike other MCDM strategies, GP is majorly applied in SCN, optimization, and development of Green Supply Chains. These days, Fuzzy based Goal programming has been used usually for green supply chains (Arash Khalili Nasr 2021: Huseyin Selcukkilic, 2020). Also, the Goal programming method is integrated with Analytical Hierarchical process for supplier selection (Yan Kai-fu, 2019).

2.8 Elimination and Choice Expressing Reality (ELECTRE)
ELECTRE approaches were developed on the research of Benayoun, Roy, and Sussman in the early Sixties. ELECTRE approaches are ELECTRE 1 to 3. The approach is also branched by "outranking approach." ELECTRE is usually used to discard the beside the point opportunity and is included into the alternative MCDM techniques for choosing the high-quality opportunity. In GSCM literature, the ELECTRE III approach has been used in integration with AHP (Ali Alazzawi, 2020) .ELECTRE III used for almost all domains; vendor choices and assessment (Liu & Zhang, 2011; Tsui& Wen, 2014). ELECTRE II carried out for green supplier choice incorporated with ANP (Wan Shu-Ping, 2017).

2.9 Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)
PROMETHEE method was initially given by Brans and Vincke (1985). The first approach of PROMETHEE known as the PROMETHEE I which provides a partial ranking of choices. PROMETHEE II method is the complete ranking approach. PROMETHEE approaches are known as "Outranking approaches" similar to ELECTRE approach , and these approaches needs two types of data such as the factor weights and the efficiency of alternatives for each criterion (Tsui, Tzeng& Wen, 2015). Later, another types of the PROMETHEE approach have been developed, such as the PROMETHEE III which was used for ranking relative to the interval. The PROMETHEE IV approach is full or partial ranking of the substitutes when the set of viable solutions are uninterrupted and the PROMETHEE V for problems with partitions and groupings limitations, the PROMETHEE VI developed and used for the human's intellectual representation problems. Its advantage is that it is easy to use.

The major disadvantages are that it does not provide a straightforward method to assign weights. PROMETHEE has seen in environmental management, especially in sustainable supply chain.

2.10 Fuzzy Set Theory

The fuzzy set theory was added by Zadeh in 1965 has confirmed to be a powerful MCDM approach for the beyond several years, especially in the supply chain. Fuzzy approach is based on of original set theory which permits fixing many issues and problems related to dealing the vague and unsure statistics (Büyüközkan et.al 2012a). It has many benefits. Fuzzy logic considers inadequate information and the evolution of to be had know-how (Kannan, De Sousa, et al. 2014). In many of cases, they can need many runs of simulations before they applied to real situations. The various choice-making issues of the supply chain take advantage of the availability of vague input. The Fuzzy-based best and worst approach has been used commonly for supplier choice (Arash Khalili et. al., 2021; Devika Kannan et al. 2020; Ecer et al. 2020; Qun Wu et. al.2019). Fuzzy-based preference programming has used for dealer choice in fabric manufacturing (Alireza Fallahpour, 2017) and fuzzy-based totally goal programming for supplier selection (Huseylin Selcuk et. al.2020; Yan Kai-Fu, 2019).

2.11 Latest MCDM Techniques

Many MCDM strategies had been added and implemented to sustainable vendor selection. Apart from above widely known strategies, new and popular MCDM strategies used in GSCM are shown in table 1. A MULTI MOORA (Multi-objective Optimization by Ratio assessment) approach for choosing of sustainable battery supplier based on fuzzy entropy (triangular) is used. (Ruotong Wang et. al.2021, Amir Arabsheybani et al. 2018) Željko Stević introduced a brand new MCDM approach: dimension of options and ranking in keeping with Compromise solution (MARCOS) for supplier selection (Željko Stević et al., 2020). Weighted Aggregated Sum Product evaluation (WASPAS) has been applied for inexperienced dealer selection under fuzzy surroundings (Shubham Gupta et al., 2019; Arunodaya Raj Mishra et al., 2019). Grey Relational analysis (GRA) approach used in Pythagorean Fuzzy surroundings (ChunxiaYu, YifanShao, 2018) and fuzzy exceptional-worst technique (Seyed Amin SeyedHaeri, 2019). Additive Ratio assessment (ARAS) has been carried out in integration with intention programming (Yan Kai-fu, 2019; Liao, C.N., 2016) and AHP for green provider choice (Jolanta Tamošaitienė, 2017; Mavi R ok 2015). Complicated Proportional assessment (COPRAS), applied in integration with DEMATEL and satisfactory characteristic Deployment (Yazdani et al., 2017)

3. MCDM Techniques and its Applications in Sustainable Supply Chain

List of MCDM techniques applied in Green supply chain of various industries/sector for supplier evaluation and selection are provided in the Table 1 below.

Table 1: MCDM Methods applied in GSCM

Authors	MCDM Methods	Country	Industry/Area
Arash Khalili Nasr 2021	Fuzzy Goal programming, Fuzzy Best worst method	Iran	Garment industry
Ruotong Wang 2021	Fuzzy entropy -MULTIMOORA method	China	Battery supplier –Electronic vehicle
Hassan Mina, DevikaKannan, 2021	Fuzzy inference system (FIS) , AHP, TOPSIS	Iran	Petrochemical Industry
BehrouzAlavi, MadjidTavana, 2021	Fuzzy based Inference System, Fuzzy Best Worst method	Iran	Petrochemical company
ErfanBabaeeTirkolaee, 2020	Fuzzy ANP, TOPSIS, DEMATEL, Goal Programming	Iran	Electronic lamp supplier
ŽeljkoStević, 2020	MARCOS	Bosnia	Healthcare industry
Lizhong Tong,2020	PROMETHEE II	China	Petrochemical industry
ZhihuaChen, XinguoMing, 2020	Fuzzy TOPSIS, DEMATEL	China	New energy vehicle transmission supplier
R.Krishankumar,2020	VIKOR, q-rung fuzzy set based Orthopair (q-ROFS	India	Construction and Automotive company
Sepehr Hendiani, 2020	Fuzzy set Theory	Iran	Widget, Automobile, Transmission cable manufacturing companies
Ali Alazzawi, 2020	AHP, ELECTRE III	Iraq	Electrical cable –Transportation company
DevikaKannan 2020	Fuzzy Best-worst method, VIKOR	Iran	Wire and cable industry
Fatih Ecer 2020	Fuzzy Best-worst method, Fuzzy CoCoSo Method	Serbia	Home appliance
Huseyin SelcukKilic 2020	TOPSIS, Fuzzy Goal Programming	Turkey	Air filter industry
Mostafa Zandieha, 2019	AHP	Turkey	Plastic

Aijun Liu, Yaxuan Xiao, 2019	Fuzzy MADM, VIKOR, QFD	China	Battery supplier
Yan-Kai Fu, 2019	AHP, ARAS, Goal programming	Taiwan	Airline –food catering
RukiyeKaya, 2019	DEMATEL	Turkey	Automobile manufacturing
Hadi Moheb 2019	DEA, Multi-objective MILP model	Iran	Automotive industry
Shubham Gupta, 2019	Fuzzy AHP, TOPSIS, WASPAS, MABAC	India	Automotive industry
Jing Li,Hong Fang, 2019	TOPSIS	china	Photovoltaic module supplier
Ashkan Memaria, 2019	Fuzzy TOPSIS	Iran	Catalytic converter
Seyed Amin Seyed Haeri, 2019	Best-Worst method Grey Relational analysis, Fuzzy Grey Cognitive Maps	Iran	Automobile part manufacturing
Arunodaya Mishra, 2019	Fuzzy WASPAS	India	General
Liu Hu-Chen, 2019	Best-Worst method, Alternative Queuing Method	China	General
Qun Wu 2019	Fuzzy Best Worst Method, VIKOR	china	Electronics
JingLi,Hong Fang, 2019	TOPSIS	china	Photovoltaic module supplier
Ashwani Kumar, 2019	Fuzzy AHP, VIKOR	India	Recycling
Mona NajarVazifehdan,2019	Fuzzy QFD	Iran	Petrochemical industry
Xu Zhou 2019	AHP	china	General
M. Abdel-Baset, 2019	ANP, VIKOR	Egypt	Importing company
Ahmed Mohammed, 2019	Fuzzy Multi objective optimization, TOPSIS	Saudi Arabia	Metal factory
Atefeh Amindoust,2018	Fuzzy , DEA	Iran	Petrol container alloy manufacturing
IreneuszMiciuła 2018	AHP	Poland	Energy Sector
ChunxiaYu,YifanShao, 2018	TOPSIS,GRA, Pythagorean Fuzzy environment	China	Home appliances manufacturer
Amir Arabsheybani, 2018	Fuzzy MOORA	Iran	Home appliance
G. Karunakumar 2018	AHP	India	General
FuliZhou,Xu Wang, 2018	Fuzzy DEMATEL, VIKOR	China	Small and medium enterprise
Rajnish Kumar, 2018	AHP, TOPSIS, Taguchi Loss Function	India	Heavy locomotive manufacturer
Mohamed Abdel-Basset, 2018	AHP-QFD	Egypt	General
Armin Cheraghalipour, 2018	Fuzzy BWM, Multi-Choice Goal Programming	Iran	Plastic industry
Sanjay Kumar, 2018	TOPSIS	India	Steel manufacturing
Wei Song , Zhiya Chen, 2018	Third Generation Prospect Theory (PT3), Gray correlation method	China	Automobile manufacturing
Wan Shu-ping, 2017	ANP, ELECTRE II	China	Electrical bus
Jolanta Tamošaitienė, 2017	AHP,ARAS	Lithuania	Construction
Sadeque Hamdan Cheaitou, 2017a	Fuzzy TOPSIS, AHP	UAE	Aluminum manufacturing & Facilities management company
Sadeque Hamdan AliCheaitou, 2017b	Fuzzy TOPSIS, AHP	United Arab Emirates	General
Gülçin Büyüközkan, 2017	AHP and Fuzzy Axiomatic Design	Turkey	RFID
Alireza Fallahpour, 2017	Fuzzy preference programming, TOPSIS	Iran	Textile manufacturing
SaharValipour Parkouhi, 2017	ANP, VIKOR	Iran	Wood and paper
MortezaYazdani 2017	DEMATEL, QFD, COPRAS	Spain	General
Yunna Wu 2016	Fuzzy, VIKOR	China	Nuclear power
Rezaei et al., 2016	Best Worst Method	Netherlands	Edile oil industry
Arroyo et al., 2016	Choosing by advantage (CBA)	USA	Global information technology company
Ghorabaee, et al., 2016	WASPAS, Fuzzy set	Iran	General
Hsiu Mei Wang Chen 2016	AHP, TOPSIS	Taiwan	Luminance enhancement film industry
Liao, C.N., 2016	Fuzzy ARAS, Fuzzy AHP, Multiple segment Goal Programming	Taiwan	Watch manufacturing

Yu &Hou, 2016	AHP	Hong Kong	Automobile manufacturing
Chung et.al, 2016	ANP	Taiwan	Bicycle manufacturing
Wu & Barnes, 2016	ANP	China	Electrical appliance and equipment
Uygun&Dede, 2016	DEMATEL, ANP, TOPSIS	Turkey	General
Awasthi&Kannan, 2016	VIKOR	India	Automobile manufacturing
Fallahpour, Olugu, 2015	DEA , Genetic programming	Malaysia	Garment manufacturing
Akman, 2015	ANP VIKOR	Turkey	Automobile manufacturing
Li, D.F. &. Wan, S.P, 2015	Fuzzy LINMAP	China	Semi conductor manufacturing
Tsui, Tzeng&Wen, 2015	PROMETHEE	Taiwan	TFT-LCD Opto- electronics
Wang, Kuei Lin, Tsai, & Madu, , ,2015	ANP	Taiwan	Electronics
Kuo, Hsu & Chen, 2015	ANP, TOPSIS	Taiwan	Electronics
Govindan, Khodaverdi ,2015	DEMATEL	Iran	Automobile
Mavi R K 2015	Fuzzy AHP, ARAS	Iran	Manufacturing
Hu, Rao, Zheng & Huang,2015	TOPSIS	China	General
Li &Wu, 2015	Fuzzy TOPSIS	China	General
Guo&Tsai, 2015	DEMATEL	China	Printed circuit board
DevikaKannan, 2015	Fuzzy Axiomatic Design (FAD)	Singapore	Plastic material
Shi, Yan, Shi &Ke, 2015	DEA	China	Home appliance manufacturing
Yazdani, 2014	AHP, TOPSIS	Spain	Automobile parts manufacturing
Dou, Zhu & Sarkis, 2014	ANP	China	Irrigation equipment manufacturing
Theiben & Spinler, 2014	ANP	Germany	FMCG
ImreDobos, 2014	DEA	Hungary	General
Kannan, et.al 2014	Fuzzy TOPSIS	Brazil	Electronics
Falatoonitoosi, Ahmed, 2014	DEMATEL	Malaysia	Automotive
Kumar, Jain et.al 2014	DEA	India	Automobile
Hsueh&Yan, 2013	AHP	Taiwan	Construction
Hsu, Kuo&Chiou, 2013	ANP,VIKOR	Taiwan	Electronics manufacturing
Kannan, Khodaverdi, 2013 ,	Fuzzy TOPSIS	Denmark	General
Devika Kannan, 2013	Fuzzy AHP, TOPSIS	Iran	Automobile manufacturing
Shen, Olfa, 2013	Fuzzy TOPSIS	Iran	Automobile
LixinShen, 2013	Fuzzy TOPSIS	Iran	Automobile
Mavi, Kazemi, Najafabadi & Mousaabadi, 2013	Fuzzy DEMATEL	Iran	Manufacturing
Peng et.al 2012	AHP, GRA	China	General
Shaw, Shankar, et.al 2012	Fuzzy AHP	India	Garment manufacturing
Tsui&Wen, 2012	AHP, PROMETHEE	Taiwan	Optoelectronics
Büyüközkan&Çifçi, 2012a	Fuzzy, ANP, DEMATEL, TOPSIS	Turkey	Ford Otosan automobile company
Chen, Lin &Ting, 2012	ANP	Taiwan	General
Zhou, Ma, Li & Li, 2012	ANP	China	General
Datta, Samantra, Mahapatra, ,2012	VIKOR	India	Automobile
Liu & Zhang, 2011	ELECTRE III	China	Manufacturing
Shaik, M.et.al 2011	MAUT	Canada	General
Büyüközkan&Çifçi, 2011	Fuzzy ANP	Turkey	White goods manufacturing
Kuo, Wang et.al 2010	DEA, ANP	Taiwan	Electronics
Che, 2010	AHP	Taiwan	Waste Electrical and Electronics equipment processing
Lee, Kang, Hsu & Hung,2009	Fuzzy AHP	Taiwan	TFT-LCD electronics industry
Hsu & Hu, 2009	AHP	Taiwan	Electronics
Tuzkaya et.al 2009	Fuzzy ANP, PROMETHEE	Turkey	White Goods
Kannan & Muresan, 2009	Fuzzy TOPSIS	India	Tyre manufacturing
Kannan, 2008	AHP	India	Automobile

4. Research Outcome and Discussion

The survey reveals that a significant application domain area of MCDM methods in GSCM area is in sustainable supplier choice and assessment (Table 1). The goal of "Vendor identification, choice & assessment" is to examine the Green accomplishment of different vendors and identify the top vendor who meets sustainable criteria efficiently. Indeed, 106 research articles were referred and analysed in this issue.

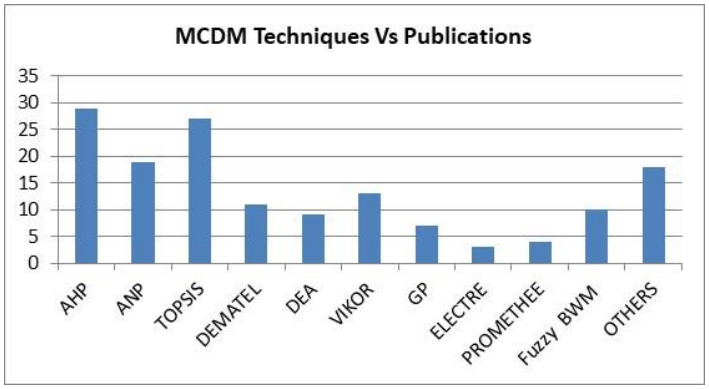

Figure 1: Frequencies of MCDM Techniques

Fuzzy set theories were widely used in integration with other prominent MCDM strategies. Greater than 60% MCDM associated journal papers have been applied in the fuzzy environment to cope with vagueness and unsure information problems in supplier selection. The survey of research papers indicates AHP approach is most the extensively implemented MCDM approach in GSCM implementations. It is observed that 29 research papers use AHP in dealer choice issues in GSCM. Nearly 19 to 27 papers uses TOPSIS and ANP methods used in GSCM strategies. The VIKOR technique (thirteen Papers) has lately been used frequently for supplier selection inside the green supply chain. Additionally, these days, ELECTRE, GP and PROMETHEE techniques have extensively used in many domains as compared to other ANP and DEA methods.

Table 2: Year wise Publications in MCDM-Green supplier selection

SLNO	Years	Publications
1	2021	4
2	2020	10
3	2019	18
4	2018	11
5	2017	8
6	2016	11
7	2015	13
8	2014	7
9	2013	7
10	2012	7
11	2011	3
12	2010	2
13	2009	4
14	2008	1

It is important to note that publications in MCDM techniques applied in sustainable supplier selection are gaining popularity over the years (Table 2). In the year 2019, there were 18 papers published for Green supplier selection with respective to various MCDM techniques. In the years 2019 and 2018, there were 10 and 11 journals published, respectively. From the period 2008 to early 2021, there is steady increase in the quantity of publications related to green supplier selection using MCDM (Table 2).

Table 3- MCDM –Green Supplier Selection methods applied in countries

SL:No	Country	Publications
1	Taiwan	14
2	Iran	21
3	India	14
4	China	23
5	Turkey	9
6	Malaysia	2

7	UAE	2
8	Egypt	2
9	Spain	2
10	Egypt	2

While examining country-wise publications, it is observed that researchers from countries such as China (23 papers) and Iran (21 papers) have significantly applied MCDM techniques for sustainable supplier selection across various industries shown in Table 1 and Table 3. For example, Fuzzy set theories have been used for supplier selection in four different companies such as widget, automobile, transmission, cable manufacturing companies (Sepehr Hendiani, 2020). Combined TOPSIS and DEMATEL methods have been used at new energy vehicle transmission firms for supplier selection in China (Zhihua Chen, 2020). Researchers from India (14 papers) applied MCDM techniques mainly in automotive industries (R.Krishankumar,2020; Shubham Gupta,2019; Rajnish Kumar,2018), steel manufacturing industry (Sanjay Kumar, 2018), and Tyre manufacturing company (Kannan&Muresan, 2009).

Table 4-Journal's list in MCDM Green Supplier selection

SL:NO	Journal Name	Publications
1	Journal of Cleaner Production	19
2	Computers & Industrial Engineering	10
3	Applied Soft Computing	3
4	Expert Systems with Applications	7
5	Information Sciences	6
6	International Journal of Production Research	3
7	European Journal of Operational Research	3
8	International Journal of Environmental Science and Technology	3
9	Procedia Computer Science	2
10	Computers in Industry	2
11	Resources, Conservation and Recycling	2

During the literature assessment, it's recognized that forty six journals, which includes international and country wide degree, are posted articles in supplier choice by the usage of MCDM techniques and important journal list are given in the Table 4. Journal of cleaner production and Computers & Industrial Engineering have published 19 and 10 articles related to vendor selection in the SCN. It is exciting to know that in thirty-five papers (32%), two or more MCDM strategies have been combined to take gain of each MCDM approach. In seven literature papers, the AHP method is included with the TOPSIS approach. Additionally, three MCDM strategies, TOPSIS, ANP and DEMATEL, had been combined in several papers (Uygun et.al, 2016; Büyüközkan et.al 2012a). Four MCDM strategies, which includes ANP, TOPSIS, DEMATEL, and goal Programming, were collaborated for sustainable, reliable vendor choice and evaluation in a supply chain network design (Erfan Babaee et al., 2020). Dealer choice in the automotive enterprise, 4 MCDM strategies AHP, TOPSIS, WASPAS, and MABAC, are blended (Shubham Gupta, 2019). Quality function deployment (QFD) utilized in mixture with MADM, VIKOR (Aijun Liu, 2019) and DEMATEL, COPRAS (Yazdani, 2017) in choosing green providers. There are many new and extensively used MCDM techniques- AIRM ,COMET, DRSA, GRIP, MVT, SAW, SIR, SMART , SMAA , SWARA & WSM in the research papers; many of them have not been applied to GSCM for vendor choices and evaluation.

5. Conclusion

This survey on research paper is identifying the applications MCDM approaches and techniques for GSCM vendor selection. It was identified that 18 MCDM approaches were applied research studies for GSCM supplier selection. This literature Survey identifies that frequently used methods are ANP, AHP, Fuzzy Set Theory, TOPSIS, DEMATEL, VIKOR, ELECTRE, PROMETHEE and these are observed in detail in terms of application domains, benefits and limitations. Many research articles in the Green supply chain centred on supplier choice and assessment using MCDM methods. Thus, it is obvious that the introduction of environmental and sustainable issues in the vendor identification, choice and assessment process are popular implementation field for MCDM system. In addition, in course of survey of research papers, the many MCDM journals in GSCM, uses the hybridization of fuzzy theories with different system to cope with the probability, vague, distinct interval application, and semantic kind of input data. One of the major finding is that hybrid methods are extensively applied in GSCM. Few of the MCDM approaches identify the comparative importance of various factors (example ANP and AHP), others can rank the alternatives (example TOPSIS, VIKOR ELECTRE, and PROMETHEE). MCDM approaches used to establish the relationships between cause and effect (DEMATEL), standard process for comparison (example DEA), and optimization tool (example GP). Thus, joining these approaches derives benefit of each individual approach. In spite of above said advantageous this study also has some demerits: (a) in

this work only, the research publications are surveyed. (b) Google based Scholar Scopus, Sci-Hub and IEEE xplore based journals are mainly considered (c) This survey considers the articles published in between 2008 to 2021only.However, with these constraints, this research would provide some important insights for researchers about utilizing MCDM techniques in the various GSCM domain.

6. Future scope

Future scope of research, further exploring MCDM techniques in GSCM literature the usage of statistics-oriented systematic techniques like web or text mining, is usually recommended. GSCM practices will gain from integration with artificial intelligence and machine learning for the reason that MCDM techniques can benefit optimization and more complicated trouble-fixing competencies. The future work scope consists of reviewing and examining distinct MCDM techniques utilized for dealing with the numerous issues in GSCM practices, such as achievement appraisal of green supply chain management and accomplishment of corresponding green suppliers.

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