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MCDM Techniques for Supply Chain Sustainability: A Review

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ABSTRACT

Among the present-day research community, different multi-criteria decision making (MCDM) techniques have become quite popular as effective multi-objective optimization tools to logically determine the weights between multiple metrics. MCDM has been an active area of research since the 1970s. The use of MCDM methods for supply chain sustainability in manufacturing, agriculture, automobile industries by decision makers to finalize the decision among different criterion forced researchers to review these techniques on their pros and cons basis. The study delves into the importance of multi-criterion decision-making methods for supply chain sustainability in this competitive era. The systematic review of the identified articles has been studied and the outputs of the review will help the decision makers to choose the best method according to their need for future. The study provides that the use of MCDM methods with sustainable practices can contribute to more sustainable supply chain future.

INTRODUCTION

MCDM is concerned with structuring and solving decision and planning problems involving multiple criteria. The main aim of the use of MCDM is to support decision-makers facing problems in decision making where does not exist a unique solution for complex problems and it is necessary to use decision-makers' preferences to differentiate between solutions. It is basically a branch of operational research has been applied in many academic fields of research studies.

MCDM problems are broadly classified into two main categories of multi-objective decision-making (MODM), and multi-attribute decision-making (MADM). MCDM is a method targeted at enabling decision-makers to integrate information to ease the process of decision making and the outcome is usually a set of weights connected to different objectives. MCDM techniques involving e-constraints, weighted sum, goal programming and SAW methods. MADM involving AHP. TOPSIS, PROMETHEE, and Best Worst Method. MADM is categorized into outranking methods (e.g. ELECTRE, PROMETHEE), distance-based methods (e.g. TOPSIS), value or utility function (e.g. AHP, SAW) and pair-wise comparison methods (e.g. AHP/ANP) (Brans & Vincke, 1985; Hwang et, al, 1993; Saaty, 1980).

MCDM has been an active area of research since the 1970s. The objective of multi-criteria decision-making (MCDM) is to logically determine the weights between multiple metrics. It provides a ranking order of available alternatives according to the preferences of a decision-maker by logically defining the relationship between multiple metrics. Its advantage is that it is easy to use. It does not require the assumption that the criteria are proportionate. The disadvantages are that it does not provide a clear method by which to assign weights and it requires the assignment of values but does not provide a clear method by which to assign those values. A life example of this is supplier selection which evaluates and select suppliers based on criteria such as cost, quality, reliability, and environmental sustainability. MCDM draws upon knowledge in many areas like mathematics, economics, computer technology, data science, and decision analysis. The most commonly MCDM methods are AHP, ANP, ELECTRE, GRA, PROMETHEE, DEMATEL, TOPSIS, VIKOR, WSM and WPM.

LITERATURE REVIEW

In this competitive era, every business is part of a supply chain which involves efficient and effective movement of products or services from suppliers through to customers via manufacturers, distributors, and retailers. A typical supply chain involves multiple businesses, resources, people, technologies, and information for buying, manufacturing, distributing, storing, and selling products. When a supply chain is environmentally sustainable, Examples of an environmentally sustainable supply chain include the treatment of waste, recycling, environmental education and training, green purchasing, green manufacturing, and green design (Kazancoglu et al., 2018; dos Santos et al., 2019). In recent studies in this area, MCDM methods were widely applied (see Table 1). Different characteristics, including recycling,

remanufacturing, greenhouse gas emissions, waste management, environmental education and training, green design, green/cleaner production, green purchasing, green logistics/distribution, and energy consumption are considered (Govindan et al., 2015; Gebre et al., 2021; Wu and Chang, 2015; Kazancoglu et al., 2018).

MCDM Techniques

AHP (Analytical Hierarchy Process) is one of the most widely applied MCDM methods in Sustainable development. A detailed methodological explanation of the process of the AHP can be seen in (Malczewski, 1999; Malczewski and Rinner, 2015) which both gave a comprehensive methodological description of various MCDM methods and examples. Application of the technique is reviewed by literature review of ten research articles found in this area out of them five articles have been found on the challenges in production SC and manufacturing practices for sustainability and their performance indicator identification with ranking of the factors. (Luthra et al., 2016; Shen et al., 2015; Gupta et al., 2015; Shankar et al., 2016; Saroha et al., 2020).

DEMATEL (Decision making trial and evaluation laboratory) is considered as an effective method for the identification of cause-effect chain components of a complex system. It deals with evaluating interdependent relationships among factors and finding the critical ones through a visual structural model. It was developed to comprehensively analyze complex interconnected decision problems. DEMATEL are the frequently used methods in sustainability. 12 research articles have been published on this technique in last ten years. DEMATEL technique used for identification and analysis of success factors for sustainability in supply chain either food chain of manufacturing sector also used in remanufacturing area for identification of challenges in the sector. The study of the technique and its advantages also help in other area like ICT for sustainability, performance indicator identification of implementation of sustainability, (Saroha et al., 2022; Sharma et al., 2018; Bhagawati et al., 2018; Gandhi et al., 2015; Li and Mathiyazhagan, 2018). It has been also used to find the cause and effect factors for implementation of sustainable practices (Saroha et al., 2022).

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is next most applied technique. It was introduced in 1981 by Hwang and yoon. This technique based on the idea is to select alternatives that are the farthest from the negative ideal solution and the closet to the positive ideal solution. The applications encompass the suppliers' evaluation and selection in sustainable supply chains based on multiple criteria. These criteria include applications of TOPSIS in selecting sustainable suppliers (Li et al., 2019; Bai and Sarkis, 2018) and applications of fuzzy TOPSIS in evaluating green supplier performance (Rouyendegh et al., 2020), evaluating sustainable and green suppliers (Memari et al., 2019), and assessing areas for improvement in implementing green supply chain initiatives. This method follows the concept that the favourable alternative is the one that is differentiated by the most immediate positive and farthest negative ideal solution (Lee et al., 2014). The procedure for the TOPSIS involves eight important steps and details can be found in (Amiri et al., 2019).

PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) evaluates and ranks renewable energy investment opportunities based on criteria such as cost-effectiveness, financial viability, and social impact. Different versions of PROMETHEE have been developed, each with its own specific characteristics and requirements. This method is widely used to ranking renewable and non renewable fuel based vehicles (Troldborg et al., 2014) and assessing the performance of energy sources for sustainable perspective (Tsoutsos et al., 2009). Some other areas that explains PROMETHEE for use are (Greco et al., 2016; Brans and Smet, 2016; Velasquez and Hester, 2013, Verma, 2020).

BWM (Best Worst Method) technique gives an assessment of sustainability in an emerging economy, assessment of social sustainability (Badri et al., 2017), evaluation of external forces for sustainability in the context of the oil and gas industries (Wan et al., 2017), analysis of enablers for social sustainability in an emerging economy (Munny et al., 2019), evaluation and prioritization of criteria for sustainable innovation (Kusi-Sarpong et al., 2018), analysis of product-package alternatives in food supply chains, ranking sustainable suppliers, and analyzing barriers for sustainable supply chain innovation (Razaei et al., 2019; Jafarzadeh et al., 2019).

ELECTRE (Elimination and Choice Expressing Reality) was first proposed by Bernard Roy and his colleagues at SEMA consultancy company. It was first applied in 1965, the ELECTRE method was to choose the best action(s) from a given set of actions, but it was soon applied to three main problems: choosing, ranking and sorting. But the first journal article did not appear until 1968, when Roy (1968) described the method in detail. ELECTRE have been applied in SSCM to classify suppliers in the manufacturing industry using the ELETCRE method (Costa et al., 2018; Kumar et al., 2016, Govindan et al., 2016).

DEA (Data Envelopment Analysis) is a linear programming technique that is used to empirically measure productive efficiency of decision-making units. It assesses the sustainability of renewable energy supply chains by evaluating their efficiency, environmental impact, and social responsibility (Gebre et al., 2021). DEA has been applied in a large range of

fields including international banking, economic sustainability and police department operations (Charnes et al., 1978, Rane et al., 2013).

WSM (Weighted Sum Model) assigns weights to each criterion based on its relative importance, and then sums the weighted scores for each alternative to determine the overall performance. WSM is similar to SAW, but allows for the use of non-linear or non-additive functions to combine the scores for each criterion. WSM is useful when the decision maker has a clear idea of the relative importance of each criterion, and when the decision problem is relatively simple like in selecting sustainable transport plans based on the sustainability index (Mitropoulos and Prevedouros, 2016), and comparing the various electricity generation technology (Klein et al., 2015).

ANP in a generalized form was created to enhance and put into consideration multiple dependencies and interdependencies in the clustered group referred to as networks (Saaty, 1996; Sarkis, 2003). Two studies applied the ANP (Analytic Network Process) method in SSCM. The applications include selecting suppliers for managing sustainability [94] and selecting suppliers integrating the triple bottom-line aspect (Kumar et al., 2016). Wang et al. (2019b) reported 98% accuracy when the authors applied a hybrid model consisting of ANP and DEMATEL.

Table: 1MCDM Techniques for Supply Chain Sustainability

METHOD	DESCRIPTION	REFERENCES
AHP (Analytic Hierarchy Process)	A decision-making technique that helps structure complex problems into a hierarchy of criteria and alternatives, and then evaluates them based on pair-wise comparisons using numerical scores. AHP is useful when there are multiple criteria to consider, and when the decision maker wants to incorporate subjective judgments into the decision-making process	Luthra et al., 2016; Shen et al., 2015; Gupta et al., 2015; Shankar et al., 2016; Saroha et al., 2020
TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)	A method that ranks alternatives based on their similarity to the ideal solution and dissimilarity to the worst solution, using distance measures such as Euclidean or Manhattan distance. TOPSIS is useful when there are multiple criteria to consider, and when the decision maker has a clear idea of what constitutes the best and worst solutions.	Li et al., 2019; Bai and Sarkis, 2018; Rouyendegh et al., 2020; Memari et al., 2019; Amiri et al., 2019
ELECTRE (Elimination and Choice Expressing Reality)	A family of methods that use outranking relations to compare alternatives based on a set of criteria, and then select the best alternatives using a preference threshold. ELECTRE is useful when there are multiple criteria to consider, and when the decision maker wants to incorporate noncompensatory rules, such as minimum or maximum thresholds for each criterion.	Costa et al., 2018; Kumar et al., 2016; Gebre et al., 2021
DEMATEL (Decision making trial and evaluation laboratory)	It is considered as an effective method for the identification of cause-effect chain components of a complex system. It deals with evaluating interdependent relationships among factors and finding the critical ones through a visual structural model.	Saroha et al., 2022; Sharma et al., 2018; Bhagawati et al., 2018; Gandhi et al., 2015; Li and Mathiyazhagan, 2018
PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations)	Evaluates and ranks renewable energy investment opportunities based on criteria such as cost-effectiveness, financial viability, and social impact.	Troldborg et al., 2014; Greco et al., 2016; Brans and Smet, 2016; Velasquez and Hester, 2013
DEA (Data Envelopment Analysis)	Assesses the sustainability of renewable energy supply chains by evaluating their efficiency, environmental impact, and social responsibility	Charnes et al., 1978, Rane et al., 2013
WSM (Weighted Sum Model)	A method that assigns weights to each criterion based on its relative importance, and then sums the weighted scores for each alternative to determine the overall performance. WSM is similar to SAW, but	Mitropoulos and Prevedouros, 2016; Klein et al.,

	allows for the use of non-linear or non-additive functions to combine the scores for each criterion. WSM is useful when the decision maker has a clear idea of the relative importance of each criterion, and when the decision problem is relatively simple.	2015
ANP (Analytic Network Process)	ANP is an extended version of the analytic hierarchy process that enables feedback and interactions between and within clusters, making it a more comprehensive decision-making tool.	Saaty, 1996; Sarkis, 2003; Kumar et al., 2016
BWM (Best Worst Method)	It is a multi-criteria decision-making (MCDM) method that is used to evaluate a set of alternatives with respect to a set of decision criteria. The BWM is based on pair-wise comparisons of the decision criteria	Badri et al., 2017; Munny et al., 2019; Kusi-Sarpong et al., 2018; Razaei et al., 2019; Jafarzadeh et al., 2019

CONCLUSION

This paper presented a literature review on MCDM methods applied in different dimensions of Sustainability. A systematic literature analysis and review to identify different domains of supply chain sustainability and applications of different MCDM methods was lacking. It can be concluded that there has been a significant increase in the application of MCDM models in all engineering areas in the last decade. The complexity of synchronous problems forces researchers to search for more flexible and simpler methods. Therefore, it is expected that there will be a further increase in works that consider the application of existing MCDM models and the development of new models for multi-criteria decision-making. The consideration of uncertainty will encourage researchers in the field of sustainable engineering to expand further research towards the creation of hybrid models, upgrading the existing MCDM models. There is no uniform distribution of publications across the world. There is a limited publication report from developing countries. With regards to criteria dimension analysis, more than 40 percent of the publications have considered only the environmental aspect. Less than fifteen percent of the publications have considered the three combinations of economic, environmental, and social aspects.

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