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Framework for selecting sustainable supply chain processes and industries using an integrated approach

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ABSTRACT

This study introduces a process view of sustainable supply chain management and identifies 17 sustainable supply chain processes (SSCPs) from literature. Further, a framework is proposed to identify the significance of various SSCPs on firm performance using the theoretical lenses of stakeholder theory and resource based view. Through a semi-structured interview of stakeholders, critical SSCPs across eight industries were identified in the Indian context. The study identifies five important SSCPs, such as sustainable design and development, strategic sourcing and efficient technology and sustainable product returns and recycling. Among the selected industries, pharmaceutical, agricultural and chemical industries were identified to be the front-runners in SSCPs practice. Subsequently, these five processes and three industries were evaluated using strategic decision making approach by integrating group decision making and fuzzy multi-criteria decision making methods. To handle the uncertainties of strategic decision making, six Fuzzy Multi-Criteria Decision Making methods have been applied and compared to understand their relevance while evaluating the above industries, based on the above identified SSCPs. This study introduces an approach to enhance sustainability of supply chain that can be extended across industries through a process view of supply chain, in emerging economies like India.

1. Introduction

Over the years, firms have been operating globally in a competitive market with a growing need for integrating economical, ecological and social aspects of the T*riple Bottom Line (3BL) approach* across a supply chain (Ahi and Searcy, 2015). Some of the issues of ecological and social aspects have been raised in several international forums, such as the Kyoto protocol and Paris summit. These initiatives have led to the evolution of the concept of the *Sustainable Supply Chain*. A vision of achieving a sustainable supply chain can only be realized by designing robust, system-wide processes meeting the desired deliverables and preferences of various stakeholders (Kleindorfer et al., 2005; Linton et al., 2007; Wu et al., 2016). In a similar vein, one cannot overlook the role of *Supply Chain Processes (SCP)* in achieving the sustainable development objective of industries.

Research over the past decades at the firm and supply chain levels (Kleindorfer et al., 2005; Li et al., 2016) has addressed various issues pertaining to SCPs from the perspective of sustainability. Linton et al. (2007) also indicated that supply chain excellence could be achieved through efficient and effective movement of firm resources such as products, services, finances, and/or information between sources and consumers. The design of an integrated *Sustainable Supply Chain Process* (SSCP) using this perspective has evolved over time and has drawn attention from practitioners and researchers (Krikke et al., 2003; Jayaraman, 2006; Ahi and Searcy, 2013; Li et al., 2016; Wolf, 2011). The present study defines SSCPs as *The key sustainable business processes across supply chain entities, which improve its performance along the three dimensions of the 3BL approach*. The literature presents numerous theoretical analyses of sustainable supply chain practices. Touboulic and Walker (2015) have made a review of literature on the application of different management theories to sustainable supply chain. They have observed that the stakeholder theory used by Wolf (2014), Hörisch et al. (2014), and Mariadoss et al. (2016) and the resource-based view used by Newbert (2007) and Guide and Wassenhove (2009) are the ones that have been predominantly used for conceptualizing various aspects of sustainable supply chains. The present study attempts to identify the most significant SSCPs in the Indian manufacturing industries, from the perspectives of the stakeholder theory and the resource-based view.

The emerging socio-ecological concerns across various stakeholders have made the selection of the best-fit SSCPs a crucial but complicated task. Several studies (Zhu and Sarkis, 2007; Zhu et al., 2007; Dey and Cheffi, 2013; Wu et al., 2016) have also indicated the difficulty faced in pinpointing the sustainable business process that best fits a firm and its supply chain to improve its sustainability performance from the*3BL* perspective. According to the RBV, the nature of the infrastructure/resource and skill set required to implement each (or a combination) of these SSCPs vary from one to another (Fahy,

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2002). The differences seen in various industrial contexts (based on processes used, regulation, competition, etc.) across the supply chain make it increasingly difficult to select the most appropriate SSCP in an industry. Touboulic and Walker (2015) have also advocated the need for advanced methodologies to investigate aspects of SSC such as the selection of efficient SSCP(s) for an industry/firm. In contrast, Wu et al. (2016, 2017) have warned that an error in the selection of an appropriate SSCP might lead to sub-optimal *3BL* performance and could be an expensive proposition for the decision makers. Furthermore, Su et al. (2016) and Wu et al. (2017) have indicated that when group decision making procedure is used to identify sustainable supply chain processes, a difference in opinion and the lack of a mechanism to select efficient SSCPs increase the level of decision making uncertainty.

Given the importance of SSCPs and the gap between ideal and actual practices indicated above, it is important to investigate the extent to which these processes are recognized and planned for in the industries, the objectives which the SSCPs aim to achieve, and the degree to which resources are actually deployed in these processes. The overreaching aim of the study is to present a framework to address the above SSCP issues. Therefore, the present study attempts to answer the following research questions:

1. What are the sustainable supply chain processes and what are their objectives? An associated question is: What method should one use to select a sustainable supply chain process?
2. How should the SSCPs be evaluated for stakeholder preferences and firm resource deployment?
3. Which methods should be used for ranking the SSCPs and the industries?

The first objective of this study is to identify the list of SSCPs from supply chain management literature. Content analysis is used in this paper to extract relevant material from the literature that uses supply chain process for improving the sustainability performance along the supply chain. Although notable SSCPs can be identified from the literature, the fact remains that different stakeholders (or firms) may have different preferences about SSCPs uses concerning importance of resource deployment to improve the 3BL performance of their supply chain. Hence, the second objective of this study is to prepare a shortlist of important SSCPs based on stakeholder preferences, resource deployment, and their *3BL* performance and to identify the industries that operate through these SSCPs. The methods used are a semi-structured interview and the analysis of stakeholders' responses by means of a regression analysis where the SSCP performance is used as the dependent variable, stakeholder preference is used as the independent variable, and firm resource deployment is used as a moderator. Industries are identified based on significant resource deployment. Considering, the use of a SSCP may have different impact on different industries and consequently hold a specific importance for an industry (Luthra et al., 2016). Thus, a set of feasible SSCPs need to be ranked to manage their uses in different industries. Similarly, ranking of industries based on the uses of SSCPs could be worthwhile for practitioners to understand the best performing industry. Additionally, the use of a ranking method may not be applicable for all kinds of problem involving conflicting selection criteria, incomparable units of measurements (Padhi and Mohapatra, 2009), and decision-making uncertainties and therefore, there is a need to analyze the decision making methods (Bazerman and Moore, 2008). Thus, the present study uses the strategic decision-making methods by assessing group of experts' opinion for ranking SSCPs and industries and also compares the ranking methods to understand the differences in each ranking method, while solving such problems.

The scope of the study is limited to manufacturing industries in India. India is an emerging economy that has significantly been investing in the manufacturing sector (Luthra et al., 2016). "The manufacturing sector grew at a compound annual growth rate of 7.32% between financial year 2012 and 2017" (IBEF, 2018). Government support and policies like *Make in India* aims to make India a global manufacturing hub. Given that there is an enormous scope for implementation of SSCPs in the manufacturing sector, collective but not exhaustive to sustainable waste management, green warehousing, environment friendly technologies etc., it becomes apparent that there is huge scope for improvement of SSCPs in such industries in the context of a developing economy.

The remainder of this paper is organized as follows: Section 2 presents a comprehensive literature review to identify the major SSCPs along with their objectives. In addition, this section also identifies various Multi-Criteria Decision Making (MCDM) tools for use in subsequent sections. Section 3 illustrates the development of the research framework for evaluating the identified SSCPs and process to be followed for sustainability ranking of the selected industries. In section 4, data collection and analysis based on a semi-structured interview-based survey is presented to identify the most important SSCPs in the manufacturing industry. Subsequently, the GDM approach is applied through Fuzzy-MCDM techniques to compare the sustainability performance of selected industries using a selected set of SSCPs. In section 5, discussions and managerial insights of this study is presented. Finally, section 6 provides the conclusion of the study, highlighting important observations followed by the future scope of work.

2. Literature review

To understand the development of the literature on SSCPs, section 2.1 attempts to identify 17 major SSCPs and define their objectives from the existing SSC literature using content analysis. Initial list of articles for the content analysis were collected using keyword based search in popular databases such as EBSCO, Scopus, and PROQUEST, using keywords (((("sustainable" OR "green" OR "ecological" OR "social" OR "closed loop") AND "supply chain") OR "reverse logistics") AND "Process"). Out of more than 1500 papers that appeared for the period 2000 to 2017, only articles published in peer reviewed journals using English language were selected. Articles required for the content analysis from journals were selected based on the criteria followed in Rajeev et al. (2017), to ensure quality and rigor. In the final stage, papers which specifically focused on issues of sustainability from the business process perspective along the supply chain were selected for the study. Two researchers independently checked the final list of papers to ensure exhaustive coverage of studies done in sustainable supply chain process. Subsequently, section 2.2highlights the literature development on the use of various MCDM techniques for understanding the identified SSCPs. Based on this section, the MCDM tools used to fill the gaps in the literature have been identified.

2.1. Identification of sustainable supply chain processes

Traditionally, most of the supply chain processes were driven by economic objectives only (Linton et al., 2007), but over the past two decades, the scarcity of firm resources and stakeholder preferences have forced businesses to include ecological and social dimensions of the *3BL* approach as well. Hence, the adoption of SSCPs has been considered to improve the SSCM performance (Kleindorfer et al., 2005; Rajeev et al., 2017).

Zailani et al. (2012) conducted a survey of 400 Malaysian manufacturing firms and reported the positive impact environmental-friendly purchase and sustainable packaging SSCM. Similar observations have also been observed by Hasan (2013) for manufacturing firms such as Coca Cola Enterprises and Eastman Chemical Company. The study of manufacturing firms in emerging economies by Hsu et al. (2016) reported that reverse logistics could apprehend positive outcomes to firms' SSCM. However, firms such as the Standish Group suffered the failure of 24% of its Management Information System projects on SSCM performance due to incorrect selection of SSCPs (Saban et al., 2017). Similarly, Forrester (2005) reported a few of the US firms (only 9% of 48%) have gone for the prospect of up-gradation of SSCPs (e.g., sustainable technologies) to meet SSCM performance. Saban et al. (2017) observed that these SSCPs are susceptible to process interruptions, technology up-gradation issues, inadequate collaboration, etc., leading to dissatisfied stakeholders and higher uncertainties during its implementation. These observations emphasize judicious identification of SSCPs are paramount for enhancing firms' SSCM performance, which have also been reported in various other studies (e.g., Hong et al., 2018).

With the growing importance of stakeholder preferences and resource utilization, several studies have supported the RBV (e.g., Newbert, 2007; Touboulic and Walker, 2015) and/or the Stakeholder theory (e.g., Wolf, 2014; Hörisch et al., 2014; Mariadoss et al., 2016) approaches for the identification and improvement of sustainability aspects. Moreover, Rajeev et al. (2017) have identified various managerial themes as well as broad firms/industries on SSC aspects witnessed from 2000 to 2015. They have reported that studies focusing on all three dimensions of sustainability are reasonably rare and significant attention on firm/industry-specific studies is required in emerging economies. Thus, Table 1 presents 17 types of identified SSCPs and their process objectives using the perspective of conventional supply chain processes and the above-mentioned theoretical lenses. It may be noted that some of the studies also consider more than one process. Therefore, they have been represented under multiple SSCPs.

2.2. MCDM methods for selection of sustainable industries

Section 2.1 has identified 17 SSCPs from two theoretical lenses, hence clearly indicating the need for use of Multi Criteria Decision Making (MCDM) methods to evaluate the success of the SSCPs as well as their successful implementation in industries. This conclusion was also supported by Ishizaka and Nemery (2013). A variety of MCDM methods such as priority-based, outranking, distance-based and mixed methods have been applied to solve priority-based selection (or ranking) of alternatives (Opricovic and Tzeng, 2007). Each of these prominent decision-making methods has its own characteristics and can be classified based on the degree of certainty of the system to be modeled (deterministic, stochastic, fuzzy methods or hybrid method); the number of decision makers (single or group decision); decision making under subjectivity (or linguistic) and the interdependence of criteria (Saaty, 1992), etc. Moreover, these methodologies share common characteristics such as complications in the selection of criteria and alternatives, conflicts among criteria, and incomparable units of measurements, i.e., qualitative or quantitative scale (Padhi and Mohapatra, 2009). The seminal works of Weber et al. (1991), De Boer et al. (2001), and Ho et al. (2010) provide a comprehensive review of the articles on MCDM in consecutive time frames. In the conventional supply chain management literature, MCDM has widely been used in supplier selection problems (e.g., Chai et al., 2013; Sawik, 2014) and logistics network design (Pati et al., 2008;

Table 1
Objective and theoretical perspective of SSCPs.

SSCP #	Sustainable Supply Chain Processes	Process Objective	Theoretical Views	Source(s)
1	Sustainable Design and Development of Green Products (SSCP 1)	Design and development of green products primarily from ecological and economic benefits perspective	RBV	Si et al. (2016), Diego-Mas et al. (2016); Krikke et al. (2003); Guide and Wassenhove (2009)
2	Sustainable Product Development and Commercialization (SSCP 2)	Conceptualizing the product design from user utility with *3BL* performance measure criteria.	RBV and Stakeholder theory	Luthra et al. (2016); Ren et al. (2015); Sabaghi et al. (2016); Chappin et al. (2015)
3	Sustainable Product Returns and Recycling (SSCP 3)	Design of Effective end of life product utility through reuse, remanufacturing, recycling etc. and developing effective return methods to enhance the availability of virgin raw material for longer time.	RBV and Stakeholder theory	Prakash and Barua (2016); Ilgin et al. (2015); Pati et al. (2008); Guide and Wassenhove (2009); Ruan and Xu (2016); Ilgin and Gupta (2010)
4	Sustainable Demand Management (SSCP 4)	Demand management using appropriate marketing tools to synchronize with supply (issues like inventory, supplier selection etc.) in SC to improve *3BL* performance.	Stakeholder theory	Luthra et al. (2016); Sheu et al. (2005); Jayaraman (2006)
5	Sustainable Customer Relationship Management(SSCP 5)	Understanding customer needs including social issues of products/ services and communicating to groups responsible for design in the SC.	Stakeholder theory	Ilgin et al. (2015); Chen and Hung (2016)
6	Sustainable Sourcing and Procurement (SSCP 6)	Framing appropriate guidelines for identifying appropriate suppliers and corresponding procurement policies/principles to improve the sustainability measures in SSC.	RBV	Govindan et al. (2013); Shen et al. (2013); Barla (2003); Kumar et al. (2014); Winter and Lasch (2016);
7	Sustainable Supplier Collaboration and Ethical practice (SSCP 7)	Collaborating with suppliers to improve their *3BL* performance measures leading to SSC improvements	RBV and Stakeholder theory	Prakash and Barua (2016); Blome et al. (2014); Kumar and Rahman (2016); Akhavan and Beckmann (2017); Tidy et al. (2016)

Table 1 (*Continued*)

SSCP #	Sustainable Supply Chain Processes	Process Objective	Theoretical Views	Source(s)
8	Sustainable Manufacturing Flow Management (SSCP 8)	Indicating manufacturing operations using tools/techniques to reduce wastage and enhancing sustainability at various value adding activities in SSC.	RBV	Thanki et al. (2016); Luthra et al. (2016); Ilgin and Gupta (2010); Jayaraman (2006)
9	Sustainable Use of Environment Friendly Technologies (SSCP 9)	Identifies ecological friendly/sustainable technologies in various operational processes to improve *3BL* performance measures	RBV and Stakeholder theory	Talaei et al. (2014); Si et al. (2016); Ren et al. (2015); Ruan and Xu (2016)
10	Sustainable Logistics (SSCP 10)	Providing Design-For-Logistics product and appropriate logistics network and distribution strategies to improve sustainability practices in SSC	RBV	Żak and Węgliński (2014); Sheu et al. (2005); Pati et al. (2008); Krikke et al. (2003); Guide and Wassenhove (2009); Elhedhli and Merrick (2012); Ellram and Golicic (2016); Yu et al. (2016)
11	Sustainable Order Fulfillment(SSCP 11)	Development of strategies and processes to reduce customers' lead time and improve customers' order fill rate.	Stakeholder theory	Ramanathan et al. (2010); Brabazon et al. (2010)
12	Sustainable Green Warehousing (SSCP 12)	Enhancing warehousing practice, e.g., eco-packaging, reduced inventory, facilitate use of renewable energy, helps in efficient utilization of space with green and sustainable warehousing practices.	RBV and Stakeholder theory	Żak and Węgliński (2014)
13	Sustainable Customer Service Management (SSCP 13)	Development of strategies with sustainability aspects leading to improved customer sales/after sales service experience	Stakeholder theory	Chen and Hung (2016)
14	Periodic Evaluation of Supply Chains' Environmental Performance(SSCP 14)	Evaluating the ecological performance and risk associated across various processes such as quality, audit of operational processes, emission issues, waste management practices etc.	RBV and Stakeholder theory	Rostamzadeh et al. (2015); Tseng et al. (2018); Haghighi et al. (2016); Ilgin et al. (2015); Kusi-Sarpong et al. (2015); Olugu et al. (2010)
15	Sustainable Waste Management (SSCP 15)	Planning effective waste management strategies of converting waste to valuable resources thought Public private partnership model, waste recycling etc.	RBV and Stakeholder theory	Chauhan and Singh (2016); Pires et al. (2011); Prakash and Barua (2016); Gangolells et al. (2014); Ruan and Xu (2016)
16	Carbon Trading and Anti-pollution Policy (SSCP 16)	Proposing steps/ policies to reduce emissions through technological innovation in lieu of economic incentives through carbon credits and its trading in markets.	RBV	Yang et al. (2016); Kumar et al. (2014); Tidy et al. (2016)
17	Less Impactful Emission(SSCP 17)	Designing mitigation plans for socio-ecological catastrophes, regulatory action. Additionally, understands link between materials and land management and green gas emissions etc.	RBV and Stakeholder theory	Karakosta et al. (2009); Ren et al. (2015); Kumar et al. (2014); Elhedhli and Merrick (2012); Ellram and Golicic (2016); Yu et al. (2016); Tidy et al. (2016)

Paksoy et al., 2012; Liu and Papageorgiou, 2013) under different competitive market scenarios.

Table 2 highlights various MCDM methods that have been utilized in the sustainability literature on identified SSCPs. These methods help in better understanding the intrinsic features of decision-making scenarios in the presence of a complex and uncertain business environment. The changes in the external environment increase the significance of inputs from participants in decision-making processes. Pohekar and Ramachandran (2004) noted the significance of compromise and collective decisions for understanding the perception of models in a realistic scenario. Thus, the need for the Group Decision making (GDM) approach is timely, and the present study uses this approach in combination with various fuzzy MCDM methods (capturing uncertainty) in developing the research framework and conducting the subsequent analysis.

Lin (2009) indicated that the grouping of sustainable processes could enable more efficient and effective management of supply chain transactions. Hence, the identified SSCPs are further clubbed into six groups (Refer Table 2) to understand the broad domain of

Table 2
Classification of SSCPs and application of MCDM methods.

Broad SSCP	SSCP #	Sub SSCP	Literature	MCDM methods used	Industry/case	Issue Discussed
Sustainable Design and Development	1	Sustainable Design and Development of Green Products (SSCP 1)	Si et al. (2016)	AHP	Construction industry	Integrate green building technology assessment and selection framework
			Diego-Mas et al. (2016)	SUAR models based on ANN and Genetic Algorithm	Furniture manufacturer	Optimize product design to transmit ecological friendliness to users.
	2	Sustainable Product Development and Commercialization (SSCP 2)	Luthra et al. (2016)	AHP	Indian Plastics manufacturer	Identify and evaluate adoption barriers of Sustainable Consumption and Production initiatives in SC design
			Ren et al. (2015)	AHP with TOPSIS	Hydrogen production	Prioritize the roles of different hydrogen production technologies to reduce pollution
			Sabaghi et al. (2016)	SAFT with Fuzzy AHP and Shammon's entropy formula	Aircraft End-of-Life recycling	Introduce interface platform SAFT to facilitate the sustainability assessment of products/processes in different manufacturing industries
			Chappin et al. (2015)	fsQCA	Wood/timber in the Netherlands	Internalize sustainable practices
	3	Sustainable Product Returns and Recycling (SSCP 3)	Prakash and Barua (2016)	Fuzzy AHP with VIKOR	Electronics company in India	Evaluate and select third party reverse logistics partners while achieving efficiency and effectiveness
			Ilgin et al. (2015)	Mix of MCDM tools	Hypothetical example	Evaluate Environmentally Conscious Manufacturing and Product Recovery (ECMPRO) indicators
			Pati et al. (2008)	Mixed Integer Goal Programming	Paper recycling. in India	Sustainable supply chain network design with paper recycling option.
Sustainable Marketing and Customer Management	4	Sustainable Demand Management (SSCP 4)	Luthra et al. (2016)	AHP	Indian Plastics manufacturer	Identify and evaluate adoption barriers of Sustainable Consumption and Production initiatives in SC design
			Sheu et al. (2005)	Linear weighted multi-objective programming	Computer manufacturer in Taiwan	Optimize supply chains with forward and reverse logistics
	5	Sustainable Customer Relationship Management(SSCP 5)	Ilgin et al. (2015)	Mix of MCDM tools	Hypothetical example	Evaluate Environmentally conscious manufacturing and product recovery (ECMPRO) indicators
Sustainable Supply Chains' Upstream Management	6	Sustainable Sourcing and Procurement (SSCP 6)	Govindan et al. (2013)	FST (capturing linguistic preference), Fuzzy TOPSIS	Hypothetical example	Evaluate sustainability performance of supplier (during selection)
			Shen et al. (2013)	FST (capturing linguistic preference), Fuzzy TOPSIS	Hypothetical example	Select green supplier based on ecological criteria also
			Barla (2003)	MSM (Multi-attribute Selection Model)	Glass	Select supplier based on lean principle
			Kumar et al. (2014)	Green DEA (GDEA)	Automobile spare parts in India	Select supplier selection is based with carbon footprint monitoring
	7	Sustainable Supplier Collaboration and Ethical practice (SSCP 7)	Prakash and Barua (2016)	Fuzzy AHP with VIKOR	Electronics company in India	Evaluate and select third party reverse logistics partners while achieving efficiency and effectiveness
Sustainable Manufacturing Management	8	Sustainable Manufacturing Flow Management (SSCP 8)	Thanki et al. (2016)	AHP	Manufacturing SMEs	Investigate the impact of select lean and green practices on performance benefits and evaluate its influence on overall performance of SMEs. TPM, KAIZEN, 5S are identified as the most important lean practice, while ISO 14001is the most significant green practice.
			Luthra et al. (2016)	AHP	Indian Plastic manufacturer	Identify and evaluate adoption barriers of Sustainable Consumption and Production initiatives in SC design
	9	Sustainable Use of Environment Friendly Technologies (SSCP 9)	Talaei et al. (2014)	AHP	Energy sector in Iran	Policy package aiming at facilitating the transfer of low carbon technologies to the country was developed

Table 2 (*Continued*)

Broad SSCP	SSCP #	Sub SSCP	Literature	MCDM methods used	Industry/case	Issue Discussed
			Si et al. (2016)	AHP	Construction industry	Integrated green building technology assessment and selection framework
			Ren et al. (2015)	AHP with TOPSIS	Hydrogen production	Prioritize the roles of different hydrogen production technologies to reduce pollution
Sustainable Supply Chains' Downstream Management	10	Sustainable Logistics (SSCP 10)	Żak and Węgliński (2014)	ELECTRA III/IV	Logistics industry in Poland	Select most desirable location of the logistics center
			Sheu et al. (2005)	Linear weighted multi-objective programming	Computer manufacturer in Taiwan	Optimize supply chains with forward and reverse logistics
			Pati et al. (2008)	Mixed Integer Goal Programming	Paper recycling in India	Develop a sustainable supply chain network design with paper recycling option.
	11	Sustainable Order Fulfillment (SSCP 11)	Rachuba and Werners (2014)	Fuzzy multi objective optimization	Scheduling in German hospitals	Fuzzy MILP based surgery scheduling in the presence of multiple stakeholders and uncertain demand
	12	Sustainable Green Warehousing (SSCP 12)	Żak and Węgliński (2014)	ELECTRA III/IV	Logistics industry in Poland	Select most desirable location for sustainable warehousing in logistics network
	13	Sustainable Customer Service Management (SSCP 13)	Raut et al. (2017)	Fuzzy AHP and fuzzy TOPSIS	Sustainability practices in Indian banking services	Integrated MCDM model for evaluation of sustainable banking services
Sustainability Evaluation and Regulatory Issues	14	Periodic Evaluation of Supply Chains' Environmental Performance(SSCP 14)	Rostamzadeh et al. (2015)	FST, VIKOR,Fuzzy VIKOR	Laptop manufacturer in Malaysia	Evaluate green supply chain management (GSCM) indicators
			Tseng et al. (2018)	FST, ANP and DEMATEL	Health care services provider	Evaluate firm ecological knowledge management capabilities in uncertainty
			Haghighi et al. (2016)	Hybrid balanced Scorecard (BSC)- DEA framework	Plastics recycling company in Iran	Integrated approach for performance evaluation in sustainable supply chain networks
			Ilgin et al. (2015)	Mix of MCDM tools	Hypothetical example	Evaluate Environmentally conscious manufacturing and product recovery (ECMPRO) indicators
			Kusi-Sarpong et al. (2015)	RST and Fuzzy TOPSIS	Mining industry in Ghana	Introduce a set of tools to help evaluate green supply chain in mining industry
	15	Sustainable Waste Management (SSCP 15)	Chauhan and Singh (2016)	Interpretive Structural Modeling (ISM), fuzzy AHP, fuzzy TOPSIS	Healthcare in India	Healthcare waste disposal facility location problem of an Indian city
			Pires et al. (2011)	AHP and TOPSIS	Waste management system in Portugal	Select best waste management practices under an uncertain environment with implication of Life Cycle Assessment (LCA)
			Prakash and Barua (2016),	Fuzzy AHP and VIKOR	Indian Electronics company	Evaluation and selection of third party reverse logistics partners while achieving efficiency and effectiveness
	16	Carbon Trading and Anti-pollution Policy (SSCP 16)	Yang et al. (2016)	Zero One Goal Programming (ZOGP)	Public transport infrastructure in Taiwan	Facilitate an optimal portfolio of sustainable public transport infrastructure projects based on pollution policy
			Kumar et al. (2014)	Green DEA (GDEA)	Automobile spare parts in India	Select Supplier based with carbon footprint monitoring
	17	Less impactful Emission (SSCP 17)	Karakosta et al. (2009)	ELECTRA	Energy sector in Chile, China, Israel, Kenya and Thailand	Direct Clean Development Mechanism (CDM) toward national sustainable development priorities, through the identification of sustainable energy technology priorities for electricity generation
			Ren et al. (2015)	AHP with TOPSIS	Hydrogen production	Prioritize the roles of different hydrogen production technologies to reduce pollution
			Kumar et al. (2014)	Green DEA (GDEA)	Automobile spare parts in India	Supplier selection is based with carbon footprint monitoring

SSC evolution under the MCDM environment. This framework is expected to help researchers understand the extent of growth of the literature in respective groups. The six groups are (i) Sustainable Design and Development (*SSCP 1 to SSCP 3*); (ii) Sustainable Marketing and Customer Management (*SSCP4 and SSCP 5*); (iii) Sustainable Supply Chains' Upstream Management (*SSCP 6 and SSCP 7*); (iv) Sustainable Manufacturing Management (*SSCP 8 and SSCP 9*); (v) Sustainable Supply Chains' Downstream Management (*SSCP 10to SSCP 13*), and (vi) Sustainability Evaluation and Regulatory Issues (*SSCP 14 to SSCP 17*).

Table 2 clearly indicates that in the past five years, many studies have emphasized sustainable design and development, the sustainable supply chain's upstream management (in particular, sourcing and procurement issues) and downstream management (in particular, sustainable logistics). In the past three years, most of these studies have been directed to understanding sustainability evaluation and regulatory issues. The majority of these studies focus on Asian countries (India, Taiwan, Malaysia, China, etc.) due to the anticipated growth in these emerging economies. In the Indian scenario, the previous research has attempted to understand three of the identified SSCPs. These scant studies were from the electronics, automobile, healthcare, and plastics industries. The present study attempts to understand the SSC issues in some of the most polluting and socially relevant industries in the Indian context, viz., the pharmaceutical, agriculture, and chemical industries. A recent review by Rajeev et al. (2017) indicates the potential opportunity for more studies on the unaddressed research issues related to sustainability in these industries. Hence, the present study targets these industries.

Most of the studies presented in Table 2 address only a few identified SSCPs. Hence, the present study makes a novel attempt to conduct a survey across respondents (stakeholders) from different industries, enquiring about various aspects of all the identified SSCPs in their respective industry. Hence, the study provides much needed inputs from practitioners' and assists in identifying industries having a homogeneous practice of SSCP, which further helped to rank those industries. Ranking of the identified industries can help to gain deeper insights for GDM with various Fuzzy-MCDM methods. The popularly used fuzzy-based methods, i.e., Fuzzy-TOPSIS, Fuzzy-ELECTRE, Fuzzy-AHP, Fuzzy-MAHP, Fuzzy-SMART, and Fuzzy-VIKOR, are considered for this study. Subsequently, the results are compared to evaluate their performance across the identified industries (detailed calculation steps of these tools are presented in Supplementary Appendix B). Since the dynamic external environment and working scenarios of decision makers can create uncertainties, Fuzzy-MCDM methodologies are only used in this study. Subsequently, comparison of Fuzzy-MCDM tools is conducted to handle decision-making uncertainties. This study presents a unique attempt to fill the gap of determining the applicability of various GDM tools under the Fuzzy-MCDM methodology, and at the same time, it considers all seventeen SSCPs together across different industries. Hence, the study is expected to help managers and academicians by providing insightful observations under strategic decision making using an integrated approach of the GDM and MCDM tools.

3. Research framework

Sustainable supply chain processes are adopted by firms primarily due to stakeholder pressure (Zhu and Sarkis, 2007; Sarkis, 2010; Meixell and Luoma, 2015). The adopted SSCPs have different impacts on *3BL* performance of the supply chains based on the type of resources possessed by the firms involved (Gold et al., 2010; Surroca et al., 2010). Firm resources such as innovation (Cho and Pucik, 2005), reputation (Roberts and Dowling, 2002), and culture (Marcoulides and Heck, 1993) moderate the relationship between firm performance and sustainability processes in firms (Surroca et al., 2010). These firm resources vary largely across industries, and it is necessary to study SSCP adoption along with the impact on *3BL* performance across industries to identify the optimal mix of SSCPs required for each industry. Hence, this section discusses the development of a proposed research framework to evaluate SSCPs and the subsequent ranking of the identified industries on sustainability performance.

3.1. Stakeholder preferences lead to SSCP adoption

Many researchers (e.g., Carter and Easton, 2011; Sarkis, 2010) have studied the adoption of sustainability practices in supply chains from the lenses of Stakeholder theory. From the environmental perspective, González-Benito and González-Benito (2006) studied the consumer pressure induced sustainability measures at the supply chain level. Major stakeholders in a business context involve customers, suppliers, government bodies, employees and society at large. Along a similar line, the adoption of sustainable processes in any supply chain is influenced by the preference of various stakeholders of the supply chain. Primary stakeholders such as customers, employees and regulators will have a direct impact on the strategic decision making of SSCP adoption, and secondary stakeholders, such as NGOs, influence primary stakeholders and influence SSCP adoption (Clarkson, 1995; Van Der Lann et al., 2008).

3.2. Influence of firm resources on stakeholder preferences and SSCP adoption

Based on RBV, Barney (1991) suggests that the competitive advantage of firms is achieved through resources that are valuable, rare and inimitable. Resources can be knowledge, assets or capabilities that the firms possess, which leads to better firm performance. Hart (1995) argued that sustainable practices could lead to a competitive advantage through the Natural Resource-Based View (NRBV) of firms. Golicic and Smith (2013) indicated that these resources vary across firms/ industries and hence results in a variation in firm performance for similarly adapted sustainable supply chain practices. Thus, firms' resources play a major role in deciding the effectiveness of SSCP adoption even if the stakeholder preferences are similar in a business context. Thus, we expect that the relationship between stakeholder preferences and SSCP adoption is influenced by the stakeholder's perceived impact of each SSCP on the *3BL* performance of the supply chain.

3.3. Strategic decision making

Strategic decisions are usually made under uncertainty and by a group of experts. Desanctis and Gallupe (1987) and Maymand and Samaeizadeh (2017) have used GDM techniques in such a situation and observed that the successful outcome of any process depends not only on the process itself but also on how the process is perceived by the decision makers (or stakeholders), along with the firm resources (following RBV). Thus, the use of the proper identification of methodologies (accommodating consensus decision-making approach) for the selection of appropriate SSCPs is essential to provide desirable supply chain performance.

Several authors (e.g., Govindan et al., 2013; Ilgin et al., 2015; Wu et al., 2016) have argued in favor of Fuzzy-Multi Criteria Decision Making (Fuzzy-MCDM) techniques in the presence of multiple selection criteria and uncertainties in the decision-making scenario. Furthermore, no study in the literature has compared the frequently used Fuzzy-MCDM techniques such as Fuzzy-TOPSIS and Fuzzy-VIKOR in handling the uncertainties of decision makers. Thus, a framework with a two-step approach for the identification of SSCPs and the evaluation of sustainable industries, as given in Fig. 1, is proposed through this study. In the first step, various SSCPs were identified from the literature using the lenses of stakeholder theory and RBV. Based on the identified SSCPs, a questionnaire was developed to conduct a survey among stakeholders to understand the impact of various SSCPs on the *3BL* performance of supply chains in different Indian manufacturing firms/industries (Part I, Fig. 1). The relative impact of various SSCPs in improving the *3BL* performance across Indian industries has been identified and ranked using this step.

In the second step, a group of decision makers (from the stakeholders) ranked the selected major Indian industries based on identified SSCPs practices using an integrated approach of GDM and Fuzzy-MCDM tools (Fig. 1, Part II) for obtaining the relative performance of these industries. This will help in identifying the best performing industry (among the compared) from the SSCP perspective being considered in the study.

4. Application of the proposed framework

Using content analysis 17 SSCPs are identified from the literature (section 2.1), important SSCPs are shortlisted in section 4.2 from the perspective of Indian manufacturing industries practitioners. Hence, for this analysis, data has been collected from stakeholders belonging to eight major industries in India. In section 4.3, the shortlisted SSCPs are ranked based on industry practices, and subsequently the industries are ranked using six popular fuzzy MCDM methods. Further, the ranking methods are compared considering their level of SSCP practices (adoption). Thus, data has been collected from an expert panel based on expert judgment to conduct this analysis. The detailed data collection procedure is mentioned in next section.

4.1. Data collection

The following steps were taken to collate the present practices of SSCPs by the Indian manufacturing industries:

- To answer the second research question, data collection was done using a semi-structured interview process, where the questions (*reported in* Supplementary Appendix A) were framed based on the inputs from the literature, predominantly following SSCP objectives as discussed in Table 2. The questions were based on the sustainability concepts of the*3BL* approach practiced by respective firms and their working executives (Stakeholders). To evaluate the status of the SSCPs of a firm, the respondents were asked to use a ten-point *Likert* scale (where 10 represents completely agree). The target respondents of the firms were managers or above designated executives in the supply chain department of Indian manufacturing firms. Questions for semi-structured interviews were pre-tested for clarity and feasibility by circulating the questionnaire among management students and industry experts. Based on the feedback received from the respondents, interview questions were reframed and rephrased. The data collection interviews were conducted between May 2015 and June 2016 in several cities of India, viz., Mumbai, Vadodara, Surat, Indore, Nagpur, Vishakhapatnam, Hyderabad, and Ahmedabad. A total of 136 respondents (with managerial experience of 8–25 years) were interviewed from 73 firms (with sales volume ranging between less than 1.5 million USD to more than 20 million USD). See Table 3 for details on firms and respondents.
- To answer the third research question, data collection was done by a group of experts and was based on expert judgement (Padhi and Mohapatra, 2009). A group of three DMs was selected as experts to provide their judgment, each of them representing either of pharmaceutical, chemical, and agricultural industries, having adequate knowledge about all three industries. These industries are heavily polluting industries as reported by central pollution control board of

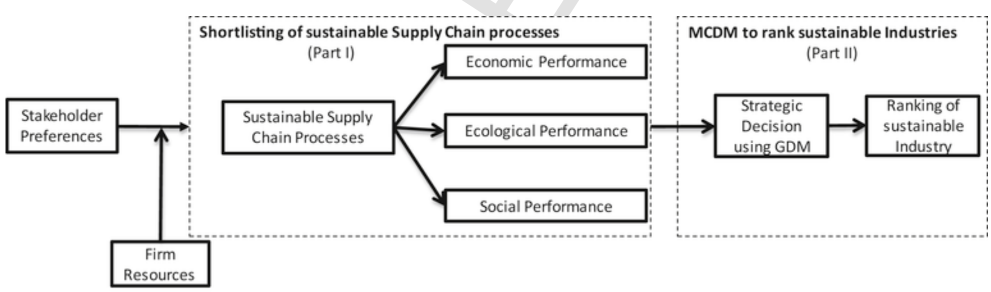

Fig. 1. Framework to evaluate SSCPs and ranking of sustainable industries.

Table 3
Industry affiliation of survey respondents.

Sales volume vs. No. of firms		Industry - Respondent Representation			Profile of respondents		
Sales Volume in USD	No. of Firms	Industry	No. of Firms	No. of Respondents	Designation	No. of Respondents	Experience
<2 to 4 million	5	Automobile	7	15	Manager	35	8
4.1–8 million	18	Pharmaceutical	16	18	Sr. Manager	22	10
8.1–12 million	27	Textile	6	12	CEO	12	25
12.1–16 million	15	Electronics parts (OEM)	7	25	Managing Director	21	20
>16 million	8	Electrical	9	15	Vice president	17	15
–	–	Agricultural	11	17	Scientist	12	10
–	–	Chemical	10	19	COO	8	20
–	–	Power plant	7	15	Director	9	20

India (2017) and also deploys high resource to meet stakeholders' preferences to improve sustainability (Rajeev et al., 2017). Senior managers with minimum work experience of 12 years in handling supply chain activities in their respective industry were considered as DMs for the study. Each DM has provided his importance scores independently about adoption of SSCPs for each industry and also for the industries based on adoption of each SSCP using a 10-point TFN scale (Table 6).

4.2. Shortlisting SSCPs

The inputs received from the sample of 73 firms under eight industrial categories are further analyzed, Table 4 reports the summary of inputs used to analyze the practice of each SSCP at the firm level. Columns 1 and 2 of Table 4 report the SSCP serial number and number of firms (or industries) practicing the respective SSCP. Column 3 reports the mean and standard deviation of stakeholders' preferences for each SSCP (Question 1, Supplementary Appendix A) in different firms. Similarly, Column 4 reports the mean and standard deviation of the *3BL* performance of each SSCP, which is converted into a 10-point scale by taking the average performance (in percentage) of all the *3BL* approach dimensions (Question 2, Supplementary Appendix A), and then, the percentage performance score on a 10-point scale is mapped (CGPA Calculator, 2017). Column 5 reports the number of firms (industries) with access to high firm resources for practicing each SSCP, and finally, Column 6 reports the impact of each SSCP on the *3BL* performance observed from the data. It is also interesting to note that most of the SSCPs are widely used in the pharmaceutical, chemical and agricultural industries. These industries are among the most polluting industries and face severe environmental and quality regulations across the globe (Rajeev et al., 2017), which might lead to higher stakeholder pressure and thus more SSCP adoption.

Table 4
Summery of input data.

SSCP #	# Firms/(# Industries) practicing (N)	Stakeholder Preferences (SP) of SSCP (Mean, StdDev)	*3BL* Performance of SSCP (Mean, StdDev)	# Firms (Industry) Access to High Firm Resources (HFR)	Observation
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
SSCP 1	66 (7)	5.1±0.7	4.9±0.5	37 (Phar, Chem, Agri)	Average impact
SSCP 2	*66 (7)*	*7.7±1.2*	*8.7±1.2*	37 (Phar, Chem, Agri)	*High impact*
SSCP 3	*66 (7)*	*8.4*±0.9	*8.2*±1.3	37 (Phar, Chem, Agri)	*High impact*
SSCP 4	67 (7)	4.6±1.1	5.2±0.8	33 (Phar, Chem, Auto)	Average impact
SSCP 5	*73 (8)*	*7.9*±2.1	*8.2*±1.6	37 (Phar, Chem, Agri)	*High impact*
SSCP 6	*67 (7)*	*7.1*±1.4	*7.6*±1.2	37 (Phar, Chem, Agri)	*High impact*
SSCP 7	66 (7)	5.2±1.1	7.1±0.7	21 (Chem, Agri)	Average impact
SSCP 8	27 (4)	7.4±0.7	7.0±0.7	16 (Phar)	Average impact
SSCP 9	*73 (8)*	*7.2*±1.5	*6.9*±1.4	37 (Phar, Chem, Agri)	*High impact*
SSCP 10	27 (3)	4.2±0.8	2.3±0.8	16 (Phar)	Low impact
SSCP 11	28 (3)	5.5±1.2	3.5±0.8	16 (Phar)	Low impact
SSCP 12	27 (2)	3.1±2.0	2.9±0.4	16 (Phar)	Low impact
SSCP 13	25 (2)	2.7±1.7	3.5±0.9	11 (Agri)	Low impact
SSCP 14	23 (3)	3.6±1.5	3.2±0.6	10 (Chem)	Low impact
SSCP 15	26 (2)	4.2±2.1	3.2±0.7	11 (Agri)	Low impact
SSCP 16	24 (3)	4.4±1.2	2.1±1.0	10 (Chem)	Low impact
SSCP 17	7 (1)	3.9±1.6	1.9±0.8	7 (PP)	Low impact

Categorical Moderator: FR (High, 1 and Low,0).

Based on the observations from Table 4, it can be inferred that stakeholder preferences are positively associated with the perceived *3BL* performance of the firm. For further understanding of the SSCP adoption and firm performance relationship, we have analyzed the moderating effect of firm resources on this relationship.

The impact of firm resources on supply chain performance using variables such as innovation, culture, and technology has already been studied in the literature. This study focuses more on achieving sustainability of the supply chain using *access to clean technology* as the variable to study the moderating effect of firm resources. Access to clean technology can come from innovation and knowledge creation within the firm or through technology or knowledge transfer because of strong ties with various internal and external stakeholders (such as suppliers), which can be considered as firm resources (López-Gamero et al., 2009; Meyskens and Carsrud, 2013).

We analyzed the stakeholders' responses by means of regression analysis where the SSCP performance is used as the dependent variable (Column 4, Table 4), stakeholder preference (Column 3, Table 4) is used as the independent variable, and firm resource (Column 5, Table 4) deployment is used as the moderator. Industries are identified based on significant resource deployment. The results of the moderator analysis is given in Table 5. Because sufficient data are not available to make statistically significant inferences for some SSCPs (namely, SSCP 8, Sustainable Supply Chains' Downstream Management (SSCP 10 to 13) and Sustainability Evaluation & Regulatory Issues (SSCP 14 to 17)), further analysis to study the moderating effect of firm resources (i.e., *clean technology adoption*) on these SSCPs has not been done.

From Table 5, it can be inferred that firm resources (i.e., clean technology adoption) moderate the relationship between stakeholder preferences for the SSCP and *3BL* performance of firms in the following SSCPs: SSCP 2, SSCP 3, SSCP 5, SSCP 6 and SSCP 9. As expected, SSCPs with a high impact on *3BL* performance are observed to be moderated by the firm resources in the respective firms. Firm resources were not observed to moderate the relationship between SSCPs (SSCP 1, SSCP 4, and SSCP 7) and *3BL* performance. Based on these above result, further analysis for identifying the best performing industry (from the SSCP adoption perspective) is done using the five popular SSCPs (SSCP 2, SSCP 3, SCP 5, SSCP 6, and SSCP 9), which were selected based on the proposed framework.

4.3. Ranking of identified SSCPs and industries

In a Group Decision-Making (GDM) process, the linguistic criteria is commonly used (e.g., Chai et al., 2013) by Decision Makers (DMs) to assess the weights assigned to each criteria for selection based on rankings (or ratings) of the SSCPs. The GDM under multiple choices of scale and ambiguity of judging criteria leads to evaluation difficulties. In such situations, Padhi and Mohapatra (2009) suggested using10-point TFN scale (Table 6) to access the priorities of evaluation criteria. Hence, in this study, the same scale has been used for the evaluation of various SSCPs individually and to study their combined effect on the respective industry using the judgement of three DMs (data collection procedure is mentioned in section 4.1). In

Table 5
Output of the moderator analysis.

SSCP #	Firms (df)	Constant	SP	FR	Moderator (SP) × (FR)	Simple Slope		Observation
						HFR	LFR	
SSCP 1	66 (62)	10.899	0.507	3.127	0.281[a]	0.538[a]	0.507[a]	Not Significant
(t-, p-value)		2.512, 0.013	5.151, 0.000	2.611, 0.009	0.539, 0.600	1.239, 0.220	1.816, 0.075	
SSCP 2	*66 (62)*	*8.121*	*0.322*	*7.517*	*0.897*	*1.219*	*0.322*[a]	*Significant*
(t-, p-value)		3.474, 0.000	3.001, 0.000	2.611, 0.005	2.344, 0.006	*8.038, 0.000*	*1.830, 0.072*	
SSCP 3	*66 (62)*	*6.717*	*0.401*	*5.988*	*0.773*	*1.174*	*0.401*	*Significant*
(t-, p-value)		5.454, 0.000	3.577, 0.001	4.157, 0.000	3.854, 0.000	*7.741, 0.000*	*2.278, 0.026*	
SSCP4	67 (63)	15.011	0.481[a]	3.515	0.199[a]	0.680[a]	0.481[a]	Not Significant
(t-, p-value)		8.915, 0.000	1.982, 0.081	2.620, 0.015	1.166, 0.210	1.540, 0.130	1.920, 0.061	
SSCP 5	*73 (69)*	*6.07*	*0.175*	*6.786*	*0.581*	*0.756*	*0.175*[a]	*Significant*
(t-, p-value)		7.568, 0.000	3.457, 0.000	5.244, 0.000	3.778, 0.000	*4.985, 0.000*	*0.994, 0.324*	
SSCP 6	*67 (7)*	*8.79*	*0.309*	*5.904*	*0.911*	*1.22*	*0.309*[a]	*Significant*
(t-, p-value)		7.241, 0.000	3.896, 0.000	3.410, 0.000	2.854, 0.008	*8.045, 0.000*	*1.755, 0.084*	
SSCP 7	66 (62)	12.799	0.456	3.194	0.091[a]	0.547[a]	0.456[a]	Not Significant
(t-, p-value)		8.611, 0.000	1.890, 0.084	3.579, 0.001	0.639, 0.801	1.239, 0.547	1.816, 0.080	
SSCP 9	*73 (69)*	*7.044*	*0.213*	*8.477*	*0.978*	*1.191*	*0.213*[a]	*Significant*
(t-, p-value)		3.854, 0.000	3.355, 0.001	2.871, 0.003	2.394, 0.005	*7.850, 0.000*	*1.209, 0.230*	

Moderator: FR: Firm resources (Access to Clean Technology).

[a] Not Significant at 5% level of significance; SP: Stakeholder Preferences.

Table 6
The linguistic scale and their fuzzy numbers.

Fuzzy number	Linguistic scale	Triangular fuzzy number
$\tilde{1}$	Very poor	(1, 1, 2)
$\tilde{2}$	Poor	(1, 2, 3)
$\tilde{3}$	Average	(2, 3, 4)
$\tilde{4}$	Above average	(3, 4, 5)
$\tilde{5}$	Medium	(4, 5, 6)
$\tilde{6}$	Good	(5, 6, 7)
$\tilde{7}$	Very good	(6, 7, 8)
$\tilde{8}$	Prime	(7, 8, 9)
$\tilde{9}$	Excellent	(8, 9, 10)
$\widetilde{10}$	Outstanding	(9, 10, 10)

addition, to maintain uniformity across the six Fuzzy-MCDM methods, the same fuzzy-scale and the five linguistic selection criteria have been used for priority weight calculation and the ranking of industries.

In the process of evaluating all six Fuzzy-MCDM methods in ranking the considered industries, a few logical steps were taken to standardize the evaluation methods and make them comparable to one another (*Refer* Supplementary Appendix –B and -C). Furthermore, this study has applied and compared six Fuzzy-MCDM methods and their standardization process to understand the differences in each ranking method.

4.3.1. Ranking of selected SSCPs

Selected SSCPs were ranked in order to evaluate the importance of practicing selected SSCPs (SSCP 2, SSCP 3, SSCP 5, SSCP 6, and SSCP 9) in the selected industries. These selections of SSCPs and industries are based on Table 5 output. Moreover, we observed that for SSCP 2 and SSCP 6, several authors (e.g., Shen et al., 2013; Ren et al., 2015) have used the TOPSIS method (Table 2) for ranking. Hence, for the case under consideration, we have applied the Fuzzy-TOPSIS method (following Patil and Kant, 2014) using GDM approach to rank the selected SSCPs in these industries.

To evaluate these five SSCPs, a group of three senior-managers acting as DMs is interviewed and data is collected through DMs judgment of importance if SSCPs for their industries on a 10-point TFN scale. Thereafter, following a seven steps approach Fuzzy-TOPSIS $_{\text{ranking}}$ analysis is undertaken to find the importance scores of five SSCPs across three selected industries. The importance scores and ranking are as follows:

$$A_1^* = 0.5254,\ A_2^* = 0.057,\ A_3^* = 1\ A_4^* = 0,\ \text{and}\ A_5^* = 0.479$$

$$A_3^*\,(SSCP\ 2)\ > A_1^*\,(SSCP\ 5)\ > A_5^*\,(SSCP\ 9)\ > A_2^*\,(SSCP\ 6)$$

The detailed procedures followed to obtain the Fuzzy-TOPSIS outcomes are included in Appendix A.

4.3.2. Ranking of industries and comparison of selected Fuzzy-MCDM methods

To answer the third research question, the case under consideration was solved using six identified Fuzzy-MCDM methods to evaluate three selected industries (i.e., chemical, pharmaceutical, and agricultural), and the results of each ranking method are presented in Table 7. These Indian industries were selected based on their adop-

Table 7
Comparison of ranking methods to select sustainable industries.

Ranking Method	Rank 1 (Score)	Rank 2 (Score)	Rank 3 (Score)
Fuzzy TOPSIS	*Phar (1.000)*	*Chem (0.523)*	*Agri (0.000)*
Fuzzy ELECTRE	*Phar (Graphical analysis*	*Chem (Graphical analysis)*	*Agri (Graphical analysis)*
Fuzzy AHP	*Phar(0.548)*	*Chem (0.525)*	*Agri (0.512)*
Fuzzy MAHP	*Phar (0.382)*	*Chem (0.347)*	*Agri (0.343)*
Fuzzy SMART	*Phar (0.344)*	*Chem (0.337)*	*Agri (0.318)*
Fuzzy VIKOR	*Agri (0.040)*	*Chem (0.090)*	*Phar (0.240)*

Note: Phar, Chem, and Agri represent the Pharmaceutical, Chemical, and Agriculture industries, respectively.

tion of SSCPs as discussed in previous sections. The detailed procedures followed to obtain these outcomes are included in Supplementary Appendix-B and C. Based on the study conducted, a comparison of the Fuzzy MCDM methods is presented in Table 7. The detailed strengths, weaknesses and operational procedure of the Fuzzy MCDM methods are presented in Appendix B.

In either of the methods, i.e., Additive (Fuzzy-AHP and Fuzzy-SMART) or multiplicative (Fuzzy-MAHP), the Fuzzy MCDM methods produce the same rank-order, although the multiplicative approach can make high priorities (with integer values) more readily identifiable than the additive model. Thus, the scores obtained through the Fuzzy-AHP (*Phar, 0.548; Chem, 0.525; and Agri, 0.512*), Fuzzy-SMART (*Phar, 0.344; Chem, 0.337; and Agri, 0.318*) and Fuzzy-MAHP (*Phar, 0.382; Chem, 0.347; and Agri, 0.343*) methods are very close to one another for respective industries. Thus, it is difficult to clearly identify the best sustainable industry with higher impact on achieving sustainability, considering the given set of five selected SSCPs (as indicated in section 4.2). However, Fuzzy-TOPSIS (*Phar, 1.000; Chem, 0.523; and Agri, 0.000*), Fuzzy-ELECTRE (*Graphical analysis*), and Fuzzy-VIKOR (*Agri, 0.040; Chem, 0.090; and Phar, 0.240*) provide clear ranking order in the same context.

5. Discussions and managerial implications

5.1. Discussions

Based on the shortlisted SSCPs, it is evident that stakeholders across industries prefer and practice the following five SSCPs namely SSCP 2, SSCP 3, SSCP 5, SSCP 6, and SSCP 9. Thus, the SSCPs scoring high on *3BL* performance and high stakeholders' preferences are observed to be moderated by the firm resources. It is in line with the argument of Ray et al. (2004) that the impact of firm resources can be better understood when studied with their impact on the performance of the business process and not with the performance of the entire firm. Although, SSCP 1 and SSCP 4 are practiced by most firms, they are less preferred by stakeholders and are expected to yield less performance. It suggests that sustainable innovation and forecasting have not yet been considered as important sustainability practice by Indian industries. It may be because of higher research and development cost for developing technology compared to that of technology transfer options available from developed countries. SSCP 7 is less preferred by stakeholders but is expected to have a high *3BL* performance. It may be because the firms prefer to select a supplier with a better *3BL* performance than to collaborate and develop sustainability practices with existing suppliers. Although SSCP 8 has high stakeholder preference and impact on *3BL*, it is mostly practiced in the pharmaceutical industry only. The pharmaceutical industry has high value addition through the manufacturing process and has a great social and environmental impact, which might be the reason why they focus more on improving the sustainability of the manufacturing process. Other SSCPs are not practiced much in the selected industries and are perceived to have very little impact on the *3BL* performance of the firm. Some of these SSCPs have a significantly overlapping in their activities hence considered insignificant by stakeholders (e.g., SSCP 13 can be considered as a sub-process of SSCP 5).

From the ranking of the SSCPs, it is evident that the three selected industries would prefer to practice SSCP 2 as the first SSCP to yield superior *3BL* performance (followed by SSCP 5 and SSCP 9), almost having proximity in terms of priority scores and the least priority to SSCP 6 and SSCP 3. The importance provided to SSCP 2, SSCP5 and SSCP 9 is due to the nature of these industries where the products produced account for one-time utility. In such a scenario, regulatory authorities would be more stringent at product development (SSCP 2) and the adoption of environmental friendly technology (SSCP 9) along with continuous interaction with the customers (SSCP 5). It would be very difficult and costly to invest in the product return and recycling (SSCP 3) process, as most of the time, it may be only for disposal (regulatory compliance).

By comparing six Fuzzy MCDM methods (see Appendix B and Table 7), it is observed that in addition to the Fuzzy-TOPSIS method, all of the other methods yielded the same outcome, i.e., *Phar(Rank 1) > Chem(Rank 2) > Agri(Rank 3)*, for a given set of inputs. This indicates that the sustainability performance of the pharmaceutical industry is better than that of the chemical and agricultural industries, whereas the agricultural industry is the worst performing. However, Fuzzy-VIKOR gave *Agri(Rank 1) > Chem(Rank 2) > Phar(Rank 3)* as the ranking order. This is due to the procedure of obtaining the solution using the Fuzzy-VIKOR method. The Fuzzy-VIKOR method provides the solution that is closest to the ideal solution and evaluates alternatives according to the established criteria, where the criteria are conflicting and non-commensurable. However, for the case under consideration, we have used similar criteria (not conflicting) and common standards of measurement (i.e., commensurable), using a 10-point TFN scale. Moreover, Fuzzy-VIKOR works better under the assumption that compromising any alternatives is permissible for the resolution of conflicting criteria (Opricovic and Tzeng, 2007; Liu et al., 2013). In this case, the absence of conflicting criteria, hence compromising alternatives, limits the effectiveness of the Fuzzy-VIKOR method.

Let us elucidate using the following example. A group of decision makers is looking for a solution that is closest to the ideal scenario and attempting to evaluate alternatives according to the established yet conflicting and non-commensurable criteria. In this scenario, rank order provided by Fuzzy-VIKOR performs the best as given in Fig. 2, which is in line with Pires et al. (2011), though capturing the linguistic criteria using fuzzy methods performs better under conflicting and non-commensurable scenarios. Even though, the role of GDM is vital in all six methods, individual DM's judgment can be used separately to perform the Fuzzy -TOPSIS and –MAHP analysis.

Apart from additive (Fuzzy –AHP and –SMART) or multiplicative (Fuzzy-MAHP) methods the Fuzzy-VIKOR method uses an aggregation of linear functions to represent 'closeness to the ideal';

Measurement scale

Criteria		
	Conflicting, Commensurable (Fuzzy-AHP, -MAHP)	**Conflicting, Non-Commensurable** (Fuzzy-VIKOR)
	Non-conflicting, Commensurable (Fuzzy-TOPSIS, -ELECTRE, -AHP, -MAHP, -SMART)	**Non-conflicting, Non-Commensurable** (Fuzzy -TOPSIS, -AHP, -MAHP)

Fig. 2. Combination of scenarios and choice of Fuzzy-MCDM methods.

whereas the Fuzzy-TOPSIS method finds a solution described by the shortest and the farthest distance from the ideal and negative-ideal solution, respectively. The Fuzzy-ELECTRE method introduces a net preference flow as an aggregating function (similar to observations by Opricovic and Tzeng, 2007).

As mentioned in Appendix B, the Fuzzy-SMART approach can handle a large number of attributes having commensurable scale compared to that of the Fuzzy-AHP and -MAHP methods (aligned with observations in Padhi and Mohapatra, 2009). This approach also facilitates the decision makers to form multiple clusters to represent different sub-attributes in the hierarchical order like the Fuzzy-AHP and -MAHP methods. In addition, these methods involve less calculation compared to that in other methods. Furthermore, a consistency check using AHP is done while assigning priority weights to the attributes in contrast to the ELECTRE and VIKOR methods. It may be noted that the methodologies as well the industries selected are different from the existing results. Hence, the results cannot be compared with the single observation based studies in the previous literature. Hence, in the future, managers as well as academicians can refer to the present study to select the most appropriate process in a given industry, keeping the stated properties/differences of each fuzzy approach in mind.

5.2. Managerial implications

This study puts forward several inferences of SSCPs for development of sustainable business policies to improve ecological performance and social acceptability of products and processes, which can further increase the business opportunities of firms to trade in the global carbon market. Understanding different types of SSCPs and their respective objectives can help decision makers to adopt and implement best fit SSCPs for their firms. For instance, to capture customer needs and behavioral changes two SSCPs like sustainable customer relationship management (SSCP 5) and sustainable product development and the commercialization process (SSCP 2) can be used by firms. Hence, the decision makers can use this methodological framework to identify and evaluate such SSCPs to strengthen their *3BL* performance either sequentially by prioritizing SSCPs or simultaneously based on availability of resources.

Classification of SSCPs into groups, such as upstream and downstream processes, regulatory processes is expected to help decision makers to pinpoint the areas of improvement using these groups, where the resources must be deployed to enhance sustainability in a given industrial context.

The methodology proposed is expected to help decision makers to rank alternative industries (as well as SSCPs within them) through GDM methods using all the possible processes associated with sustainability in any geographical region of the world. Decision makers may also refer this study to understand the risks and benefits associated with each strategic decision making method. The results obtained through the analysis (*w.r.t.* Indian manufacturing industries) help DMs to enhance supply chain sustainability under process selection uncertainties. DMs can accordingly decide where to make necessary investment in order to maximize the desired performance benefits.

6. Conclusions, limitations, and future directions

6.1. Conclusions

Ever-rising stakeholders' preferences towards improving supply chain performance has triggered the adoption of SSCPs across firm's supply chain by effective deployment of firm resources. However, role of firms' resources towards practice of each SSCP under stakeholders' preferences is yet to be substantiated. Additionally, identification and evaluation of SSCPs (and industries) with a high impact on *3BL* performance and high stakeholders' preferences is not reported either. This paper proposes a framework to address the above concern. Initially, this study identifies 17 discernible SSCPs from the previous literature using stakeholder theory and the RBV, which have an impact on the sustainability performance of the entire supply chain. The 17 identified SSCPs are further classified into six groups, such as sustainable design and development, sustainability evaluation and regulatory issues, based on similarity in the process outcomes.

As mentioned earlier, it is important for firms to prioritize the adoption of SSCPs based on their impact on supply chain performance. In this context, we have identified five key SSCPs namely sustainable product development and commercialization (SSCP 2), sustainable customer relationship management (SSCP 5), use of environment friendly technologies (SSCP 9), sustainable sourcing (SSCP 6), and sustainable product returns and recycling (SSCP 3). We find that these SSCPs are increasingly being emphasized by Indian practitioners, which corroborates Forrester (2005), Chen and Hung (2016), and Zailani et al. (2012).

Furthermore, this study attempts to select the most sustainable industry in the given condition using six selected Fuzzy-MCDM methods. Hence, we use various commonly used Fuzzy-MCDM methods using GDM approach to handle the uncertainties involved in strategic decision making. Finally, it is compared and proposed a methodological framework to prioritize the identified processes for a given industry/cross-industry with an objective to enhance the performance of sustainable supply chain. The prioritization of the SSCPs could assist managers to arrive at an appropriate decision by considering several sustainability business processes sequentially based on available resources. This is perhaps the first time that such an approach under GDM has been employed in sustainable supply chain within the context of an uncertain and complex decision making process. This is considered one of the major contributions of the present study.

6.2. Limitations and future directions

Apart from stakeholder theory and RBV, other theories can also be used to understand the perspective of SSCPs. Additionally, unavailability of large panel data of SSCP performance and other factors limits this study from the empirical research (hypotheses development) perspective, it would be desirable to collect data from other geographic regions to investigate country-specific effects related to the practice of new (or upgraded) SSCPs. Although we have used GDM to remove opinion based uncertainties, unavailability of objective data limits the evaluation and validation of SSCPs progression.

Before commencing the process of adopting appropriate SSCPs, manufacturing firms are expected to also (i) study the return on investment and risk of implementation before investing and (ii) always consider requirement-based and firm-specific processes rather than falling into industry-based trappings. Lifecycle assessment is an important tool for assessing the sustainability of supply chains, and it will be an outcome of the combination of various processes identified in this study. The methodology used in this study to finalize the most suited fuzzy MCDM tool can also be applied among product life cycle assessments for better understanding of the sustainability performance in supply chains. This may be applied for sustainability assessment among industries and is expected to help future researchers select the best MCDM technique for making appropriate policy decisions under uncertainty. Also, more integrated MCDM methods can be applied. In particular, fuzzy methods, which integrate individual DM's preferences as well as those of the group, can be applied to SSCP selection. Last but not the least, development of number of propositions could also be an interesting extension using the proposed research framework.

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Appendix A. Ranking of selected SSCPs using Fuzzy-TOPSIS

The selected five SSCPs are ranked using the following steps similar to approach of Patil and Kant (2014):

Step 1: Performance rating and weights are evaluated with linguistic terms using TFN (Table 6). These linguistic ratings, employed by decision makers (DM) to represent the performances under certain criteria, let a TFN, $W_{jk} = (w_{1jk},\ w_{2jk},\ w_{3jk})$, represent the weight evaluated by decision maker DM_k under criterion C_j, where $j=1,2,\ \dots,\ n; k=1,\ 2,\ \dots,\ p$.

Then, $W_j = (w_{1j},\ w_{2j},\ w_{3j}) = (1/p) \otimes (W_{j1} \oplus W_{j2} \oplus W_{j3} \oplus\ \dots\ ,\ W_{jp})$ represents the average weight on criterion C_j, where $w_{1j} = \sum_{k=1}^{p} w_{1jk}/p$, $w_{2j} = \sum_{k=1}^{p} w_{2jk}/p$and $w_{3j} = \sum_{k=1}^{p} w_{3jk}/p$. For the case under consideration, three decision makers, each from the chemical, agriculture, and pharmaceutical industries, provide their importance scores for practicing SSCPs in each industry using a 10-point TFN scale, as reported in Table A1.

Table A1 Importance Weightage of industries towards SSCPs practice

Industry	Importance scores				
	DM-I	DM-II	DM-III	Total weight	Average weight
Chem	(4,5,6)	(5,6,7)	(5,6,7)	(14,17,20)	(4.8,5.8,6.8)
Agri	(5,6,7)	(4,5,6)	(4,5,6)	(13,16,19)	(4.3,5.3,6.3)
Phar	(5,6,7)	(6,7,8)	(5,6,7)	(16,19,22)	(5.4,6.4,7.4)

Table A2 Importance scores of SSCP in each industry

Industries	SSCP	Decision Makers Score				
		DM-I	DM-II	DM-III	Total	Average (G_{ij})
Chem	*SCRM*	(6,7,8)	(7,8,9)	(5,6,7)	(18,21,24)	(6,7,8)
	SSP	(2,3,4)	(1,1,2)	(4,5,6)	(7,9,2)	(2.4,3,4)
	SPDC	(9,10,10)	(5,6,7)	(7,8,9)	(21,24,26)	(7,8,8.7)
	SPRR	(2,3,4)	(3,4,5)	(1,1,2)	(6,8,11)	(2,2.7,3.7)
	SUEFT	(5,6,7)	(6,7,8)	(4,5,6)	(15,18,21)	(5,6,7)
Agri	*SCRM*	(1,2,3)	(3,4,5)	(1,1,2)	(5,7,10)	(1.7,2.4,3.4)
	SSP	(6,7,8)	(4,5,6)	(2,3,4)	(12,15,18)	(4,5,6)
	SPDC	(4,5,6)	(8,9,10)	(6,7,8)	(18,21,24)	(6,7,8)
	SPRR	(5,6,7)	(4,5,6)	(3,4,5)	(12,15,18)	(4,5,6)
	SUEFT	(4,5,6)	(4,5,6)	(6,7,8)	(14,17,20)	(4.7,5.7,6.7)
Phar	*SCRM*	(6,7,8)	(9,10,10)	(4,5,6)	(19,22,24)	(6.4,7.4,8)
	SSSP	(2,3,4)	(2,3,4)	(5,6,7)	(9,12,15)	(3,4,5)
	SPDC	(6,7,8)	(5,6,7)	(8,9,10)	(19,22,25)	(6.4,7.4,8.4)
	SPRR	(5,6,7)	(2,3,4)	(1,2,3)	(8,11,14)	(2.7,3.7,4.7)
	SUEFT	(4,5,6)	(5,6,7)	(3,4,5)	(12,15,18)	(4,5,6)

Step 2: Let a TFN $G_{ijk} = (g_{1ijk},\ g_{2ijk},\ g_{3ijk})$, represent the performance rating given by decision maker DM_k to alternative A_i against criterion C_j, where alternative $i=1,2,\ \dots,\ m$; *criterion* $j=1,2,\ \dots,\ n$; *Decision Maker* $k=1,\ 2,\ \dots,\ p$. Then, G_{ij} is the average performance rating of alternative A_i against criterion C_j and is represented as $G_{ij} = (g_{1ij},\ g_{2ij},\ g_{3ij}) = (1/p) \otimes (G_{ij1} \oplus G_{ij2} \oplus G_{ij3} \oplus\ \dots\ \oplus G_{ijp})$, where $i=1,2,\ \dots,\ m; j=1,2,\ \dots,\ n;$ and $g_{1ij} = \sum_{k=1}^{p} (g_{1ijk})/p$, $g_{2ij} = \sum_{k=1}^{p} (g_{2ijk})/p$, and $g_{3ij} = \sum_{k=1}^{p} (g_{3ijk})/p$. For the case under consideration, Table A2 reports the importance scores provided by the above decision makers for the present practice of SSCPs in the respective industry.

Step 3: Then, the decision-making matrix $G = [G_{ij}]_{m\times n}$, which is the performance rating of alternative $A_1,\ A_2,\ \dots,\ A_m$; and $G = [G_{i1},\ G_{i2},\ \dots\ ,G_{in}]$, denotes the performance ratings of alternative $A_i$on all criteria. Let $A^+ = [G_1^+,\ G_2^+,\ \dots\ ,\ G_n^+]$ be the ideal solution and $A^- = [G_1^-, G_2^-, \cdots, G_n^-]$ be the negative ideal solution, respectively, where $G = Lo\ [G_{1j},\ G_{2j},\ \dots\ ,\ G_{mj}]$ represents the lower value and $G = Up\ [G_{1j},\ G_{2j},\ \dots\ ,\ G_{mj}]$ is the upper value of the performance rating by the alternatives against a criterion j. By the partial ordering relationship, we know $G_j^+ \succ G_{ij} \succ G_j$. For the case under consideration, the average performance score of the ideal and negative ideal solutions of SSCPs is reported below:

$$G_1^+ = (7,\ 8,\ 8.7) \quad G_1^- = (2,\ 2.7,\ 3.7)$$

$$G_2^+ = (6,\ 7,\ 8) \quad G_2^- = (1.7,\ 2.4,\ 3.4)$$

$$G_3^+ = (6.4,\ 7.4,\ 8.4) \quad G_3^- = (2.7,\ 3.7,\ 4.7)$$

Step 4: Then, we compute the Euclidian distance $d_{ij}^- = d(G_{ij},\ G_j^-)$, and $d_{ij}^+ = d(G_{ij},\ G_j^+)$, using $d(M, N) = \sqrt{\frac{1}{3}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2\right]}$, where $\widetilde{M}$ and $\widetilde{N}$ are two TFNs and are represented by $\widetilde{M} = [a_1,\ b_1,\ c_1]$, $\widetilde{N} = [a_2, b_2,\ c_2]$, respectively. For the case under consideration, the Euclidian distance of the ideal to negative ideal solution of five SSCPs of each industry is reported in Table A3.

Table A3 Ideal and negative ideal solution

Industry	*SCRM*		*SSSP*		*SPDC*
	$d(G_{1j},\ G_j^+)$	$d(G_{1j},\ G_j^-)$	$d(G_{2j},\ G_j^+)$	$d(G_{2j},\ G_j^-)$	$d(G_{3j},$
Chem	0.911	4.202	4.769	0.271	0
Agri	4.502	0	2.0	2.501	0
Phar	0.231	3.572	3.4	0.3	0

Step 5: Then, calculate $D_i^- = \sum_{j=1}^{n} W_j \otimes d_{ij}^-$ and $D_i^+ = \sum_{j=1}^{n} W_j \otimes d_{ij}^+$, which are the weighted distance of alternative A_i to the negative ideal solution A^- and ideal solution A^+, respectively. For the case under consideration, the weighted distances are:

$D_1^+ = (24.98, 30.62, 36.27) \quad D_1^- = (39.45, 47.23, 55.01)$

$D_2^+ = (49.85, 60.02, 70.19) \quad D_2^- = (13.67, 16.75, 19.82)$

$D_3^+ = (0, 0, 0) \quad D_3^- = (63.82, 77.13, 90.44)$

$D_4^+ = (53.07, 63.87, 74.67) \quad D_4^- = (10.77, 13.27, 15.77)$

$D_5^+ = (27.69, 33.3, 38.9) \quad D_5^- = (36.17, 43.87, 51.58)$

Step 6: Let A_i^- denote the distance from $\left[D_i^-, D_i^+\right]$ to $[LD^-, UD^+]$, and A_i^+ denotes the distance from $\left[D_i^-, D_i^+\right]$to $[UD^-, LD^+]$, where $LD^- = Lo\ \left(\{D_1^-, D_2^-, ..., D_m^-\}\right)$, $UD^- = Up\ \left(\{D_1^-, D_2^-, ..., D_m^-\}\right)$, $LD^+ = Lo\ \left(\{D_1^+, D_2^+, ..., D_m^+\}\right)$, and $UD^+ = Up\left(\{D_1^+, D_2^+, ..., D_m^+\}\right)$.Then, A_i^- and $A_i^+$are represented as $A_i^- = d\left(D_i^+, UD^+\right) + d\left(D_i^-, LD^-\right)$and $A_i^+ = d\left(D_i^+, LD^+\right) + d\left(D_i^-, UD^-\right)$, respectively. For the case under consideration, the upper- and lower-ideal and negative ideal are:

$UD^+ = (53.07, 63.87, 74.67)\ LD^+ = (0, 0, 0)$

$UD^- = (63.82, 77.13, 90.44)\ LD^- = (10.77, 13.27, 15.77)$

The distance between the positive weighted point of each SSCP to the upper-ideal point and lower-ideal are:

$d\left(D_1^+, UD^+\right) = 33.51 \quad d\left(D_1^+, LD^+\right) = 30.96$

$d\left(D_2^+, UD^+\right) = 3.88 \quad d\left(D_2^+, LD^+\right) = 60.59$

$d\left(D_3^+, UD^+\right) = 64.47 \quad d\left(D_3^+, LD^+\right) = 0$

$d\left(D_4^+, UD^+\right) = 0 \quad d\left(D_4^+, LD^+\right) = 64.47$

$d\left(D_5^+, UD^+\right) = 30.87 \quad d\left(D_5^+, LD^+\right) = 33.61$

The distance between the negative weighted point of each SSCP to the upper negative-ideal and lower negative-ideal are:

$d\left(D_1^-, UD^-\right) = 30.23 \quad d\left(D_1^-, LD^-\right) = 34.24$

$d\left(D_2^-, UD^-\right) = 60.96 \quad d\left(D_2^-, LD^-\right) = 3.51$

$d\left(D_3^-, UD^-\right) = 0 \quad d\left(D_3^-, LD^-\right) = 64.47$

$d\left(D_4^-, UD^-\right) = 64.47 \quad d\left(D_4^-, LD^-\right) = 0$

$d\left(D_5^-, UD^-\right) = 33.57 \quad d\left(D_5^-, LD^-\right) = 30.9$

The negative ideal solution A^- and ideal solution A^+ scores of SS-CPs are:

$A_1^+ = 61.19 \quad A_1^- = 67.74$

$A_2^+ = 121.55 \quad A_2^- = 7.39$

$A_3^+ = 0 \quad A_3^- = 128.94$

$A_4^+ = 128.94 \quad A_4^- = 0$

$A_5^+ = 67.18 \quad A_5^- = 61.77$

Step 7: Finally, the closeness coefficient $A_i^*$of alternative $A_i$is defined as $A_i^* = \frac{A_i^-}{A_i^- + A_i^+}$.

$A_1^* = 0.5254,\ A_2^* = 0.057,\ A_3^* = 1,\ A_4^* = 0,\ \text{and}\ A_5^* = 0.479$

The Fuzzy-TOPSIS $_{\text{ranking}}$ of five SSCPs across the three selected industries:

$A_3^*\,(SSCP\ 2) > A_1^*\,(SSCP\ 5) > A_5^*\,(SSCP\ 9) > A_2^*\,(SSCP\ 6)$:

Appendix B. Comparison of GDM based Fuzzy-MCDM methods for strategic decision making under uncertainty

Fuzzy TOPSIS	Fuzzy ELECTRE	Fuzzy AHP	Fuzzy MAHP	Fuzzy SMART	Fuzzy VIKOR
Provides score that lies between 0 and 1	Does not provide score of the alternatives	Provides score that lies between 0 and 1	Provides score that lies between 0 and 1	Provides rank that lies between 0 and 1	Provides score that lies between - ∞ to + ∞
Lowest score of the alternative is zero always	Does not provide score of the alternatives	It gives some score to the lowest ranked alternative.	It gives some score to the lowest ranked alternative.	It gives some score to the lowest ranked alternative.	It gives some score to the lowest ranked alternative.
Not sensitive to the data set	Sensitive to the data set	Sensitive to the data set	Not Sensitive to the data set	Sensitive to the data set	Sensitive to the data set
Normalization is not needed.	Normalization is not needed.	Normalization is needed.	Normalization is needed.	Normalization is needed.	Normalization is needed.
Consistency check is not done.	Consistency check is not done.	Consistency check is done.	Consistency check is done.	Consistency check is done.	Consistency check is not done.
Single cluster is used.	Single cluster is used.	Single and multiple clusters including hierarchy can be used.	Single and multiple clusters including hierarchy can be used.	Single and multiple clusters can be used.	Single and multiple clusters can be used.
Higher calculation is needed.	Higher calculation is needed.	Less calculation is needed.	Less calculation is needed.	Less calculation is needed.	Higher calculation is needed.
Large number of attributes and alternatives can be handled.	Large number of attributes and alternatives can be handled.	Large number of attributes and alternatives cannot be handled	Large number of attributes and alternatives cannot be handled.	Large number of attributes and alternatives can be handled.	Large number of attributes and alternatives can be handled.
It can handle conflicting criteria	It cannot handle conflicting criteria	It cannot handle conflicting criteria	It cannot handle conflicting criteria	It cannot handle conflicting criteria	It can handle conflicting criteria
Error percentage is lower.	Error percentage is higher.	Error percentage is lower.	Error percentage is lower.	Error percentage is lower.	Error percentage is higher.
Cannot be used as index for other calculation	Cannot be used as index for other calculation	Can be used as index for other calculation	Can be used as index for other calculation	Can be used as index for other calculation	Cannot be used as index for other calculation
It gives clear ranking.	Does not give clear ranking	Does not give clear ranking	It gives clear ranking.	It gives clear ranking.	It gives compromise solution and clear ranking of alternatives.
Defuzzyfication of weights not needed	Defuzzyfication of weights needed	Defuzzyfication of weights not needed	Defuzzyfication of weights needed	Defuzzyfication of weights not needed	Defuzzyfication of weights not needed
Comparison is done through Euclidian distance between the pair of alternatives.	Ratio is used for pairwise comparison between the alternatives.	Done through pairwise comparison between the alternatives	Ratio is used for pair-wise comparison between the alternatives.	Absolutes scores are used to compare the alternatives.	Comparison is done through determining ideal and nadir values of alternatives.
Same procedure is not followed for attributes weights calculation (average of the DM's performance rating is used).	Same procedure is not followed for attributes weights calculation (average of the DM's performance rating is used.)	Same procedure is used for attributes weights are calculation as that is used for alternatives.	Same procedure is used for attributes weights are calculation as that is used for alternatives.	Same procedure is not followed for attributes weights calculation (average of the DM's performance rating is used).	Same procedure is not followed for attributes weights calculation (average of the DM's performance rating is used).
Individually treats all DM preference ratings for alternatives	Average of the DM weights is used.	Average of the DM weights is used.	Treats all DM weights individually	Average of the DM weights is used.	Average of the DM weights is used
Both ordinal and linguistic scale data can be used simultaneously.	Both ordinal and linguistic scale data can be used simultaneously.	Conversion to linguistic scale is needed.	Both ordinal and linguistic scale data can be used simultaneously.	Both ordinal and linguistic scale data can be used simultaneously.	Both ordinal and linguistic scale data can be used simultaneously.
Ratio, interval, and ordinal scales are used.	Ratio, interval, and ordinal scales are used.	Ratio and Ordinal scale is used.	Ratio and ordinal scale is used.	Ratio, interval, and ordinal scales are used.	Ratio, interval, and ordinal scales are used.
Ranking of alternatives is done through Euclidian Distance measure.	Ranking of alternatives is done through comparison of concordance and discordance matrix.	Arithmetic mean is used for ranking of alternatives.	Geometric mean is used for ranking of alternatives.	Arithmetic mean is used for ranking of alternatives.	Ranking of alternatives is done through acceptable advantage and stability conditions.

Appendix C. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jclepro.2018.02.306.

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