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A framework to overcome barriers to green innovation in SMEs using BWM and Fuzzy TOPSIS

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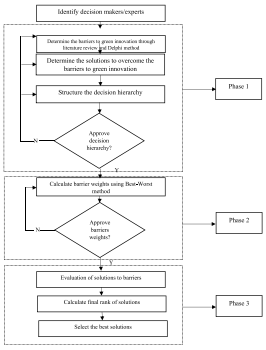
HIGHLIGHTS

- Barriers to green innovation for SMEs are identified.
- Solutions to overcome these barriers are identified.
- Barriers and solutions to green innovation are prioritized.
- A novel hybrid methodology of BWM and Fuzzy TOPSIS is used.

GRAPHICAL ABSTRACT



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ABSTRACT

Recent years have witnessed a significant rise in exploring the barriers which obstruct adoption of green practices by SMEs. There is a constant need to innovate in terms of products, processes, and management so that we can overcome these barriers to green practices adoption and implementation. This study employs a three-phase methodology to identify barriers and solutions to overcome these barriers to green innovation in SMEs. Through extensive literature review and the opinion of selective manager's, seven main category barriers, thirty-six sub-category barriers, and twenty solutions to overcome these barriers were identified. BWM is used to rank these barriers and Fuzzy TOPSIS is used to rank solutions to overcome these barriers. Four Indian SMEs are taken to exemplify the proposed three paged model. To check the robustness of the model, a sensitivity analysis was also performed. The results of the analysis can act as a stepping stone for SME managers to eliminate and overcome barriers to green innovation in their firm and compete healthily in the market. The paper sets a framework for future studies in this area of research-work.

1. Introduction

Today, customers are more conscious about their environment than ever before (Mumtaz et al., 2018). Also, the government is making stricter regulations to control the environmental pollution caused by these organizations than ever before (Mathiyazhagan et al., 2014). Organizations irrespective of their size or structure are essential for growth of a country and also contribute substantially towards the degradation of the environment. Similarly, SMEs are the driving force behind the dynamic growth of any economy. But, being smaller in size their impact on environment goes unnoticed both at regional and national levels. It is often quoted that they accord to around 70% of the total industrial waste and pollution (Hillary, 1995; 2004). Consequently, due to surmounting customer awareness, calls by various stakeholders

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and pressure from the government, eventually has increased the responsibility of these organizations especially SMEs; towards minimizing the impact of industrial activities on the environment (Walker et al., 2008). Various conventions at international level have highlighted the need to protect environmental resources and also eliminate the challenges of climate change through reductions in environment pollution by industries. Most of the countries of the world; at the 2015 Paris convention took a collective pledge in order to reduce environmental pollution and save the mother earth. As mentioned above SMEs are one of the largest producers of industrial pollution, so the government and stakeholders focus is shifting towards this cluster of SMEs in order to help them reduce pollution and maintain ecological balance. But SMEs being resource constrained are not able to act responsively as per growing market needs. Thus, the need of innovation arises; so as to survive this cut-throat competition and sustain competitiveness (Cordeiro and Vieira, 2012). Green innovation involves the usage of new products, methods, materials etc. that reduce the use of natural resources and also limit the discharge of toxic substances in the environment (Ghisetti et al., 2017); it can act as a probable solution to address the growing problem of SMEs. SMEs are trying tirelessly to implement green practices since effective implementation will lead to gaining a competitive advantage over other and sustain in long run (Zhu and Sarkis, 2004; Mathiyazhagan et al., 2014). But, SMEs face a lot of barriers in implementing and adopting green innovation practices at their end. Thus, there is growing need for SMEs to address and overcome these barriers. Keeping in view of the above, this study has following objectives:

i. To identify the barriers to green innovation for SMEs.
ii. To rank and prioritize these barriers.
iii. To identify the optimal solutions to overcome these barriers.
iv. To rank the solutions with respect to these barriers.

To achieve these objectives a three-phase methodology is used in this research. In the first phase, Delphi method along with literature review is used to identify and finalize the barriers of green innovation and solutions to overcome these barriers in SMEs. In second phase Best Worst methodology developed by Rezaei (2015, 2016) is used to rank the barriers to green innovation. In the third phase, Fuzzy TOPSIS methodology is used to rank the solutions with respect to these barriers.

The unique contribution of this study is that it is the first study to identify and rank a detailed list of barriers to green innovation. Also, this study is a first in providing the solutions to overcome barriers to green innovation. The research work has also employed an innovative and new methodology called BWM to rank the barriers to green innovation. Green innovation being a topic of great importance is still less researched and moreover, studies related to the barriers to green innovation are still evolving, so this study provides a basic framework for further research to be carried out in this context.

The rest of the paper is structured as follows. The second section is dedicated to the identification of barriers to green innovation and also the solutions to overcome these barriers. The third section explains in detail about the three-phase methodology used in this paper. Section fourth illustrates the example of proposed methodology using case study. The fifth section presents result analysis and discussion. The sixth section gives managerial and practical implications. The seventh section performs sensitivity analysis. Next section presents feedback, validation of results and the last section deals with conclusions and future scope.

2. Literature review

Green innovation leads to a reduction in pollution, environmental risks and another negative impact of product use on the environment throughout its life cycle. It can be categorized as green product innovation, green process innovation, and green system or managerial innovation (Chen et al., 2006; Chen, 2008). There are many definitions of green innovation given by researchers over the period of time. In this study terms, green innovation and environmental innovation are used interchangeably. Kemp (2010) defines green innovation as the "production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives". Similarly, green innovation is regarded as a new or modified process, products, or services that reduce environmental harms (Beise and Rennings, 2005; De Marchi, 2012). It is also defined as "the introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle of the product" (Ghisetti et al., 2017).

However, adopting a green innovation is often marred with many obstacles. SMEs especially are at the back foot when it comes to implementation of green practices. An extensive literature review is conducted to identify the barriers to green innovation for SMEs. Few studies have been conducted in past regarding barriers to green innovation and green practices. These studies are summarized in Table 1.

After studying the available papers on barriers to green innovation, Delphi method approach as applied by Bouzon et al. (2016) was used to finalize the barriers and solutions. After several rounds of discussion with managers seven main categories of barriers and thirty-six sub-barriers were finalized. Also, solutions to overcome these barriers were identified and finally twenty solutions were finalized. These are presented in Tables 2 and 3 respectively.

The various barriers finalized after literature review and discussion with managers are discussed below:

2.1. Managerial, organizational and human resource related barriers

Lack of commitment from top management is a major impediment to adopt green practices in organizations (Fai Pun, 2006). Management needs to ensure superior human resources for implementation of green innovation practices (Lee, 2008; Wu et al., 2012). SMEs are often marred in this aspect due to lack of commitment from top management, their top management consists of entrepreneurs which often tend to work in traditional ways in order to avoid risk and lack commitment towards green innovation practices. The major barriers under this category involves, lack of commitment from SME entrepreneur (Ashford, 1993; Ravi and Shankar, 2005; Zhu et al., 2012a, 2012b; Mathiyazhagan et al., 2013; Dubey et al., 2015; Mangla et al., 2017); reluctance to switch to green practices (Ashford, 1993; Zhu et al., 2012a, 2012b; Lin and Ho, 2008; Jones et al., 2011); lack of training and consultancy programs related to green innovation practices (Ashford, 1993; Carter and Dresner, 2001; Urban and Naidoo, 2012; Longoni et al., 2014; Mangla et al., 2017); lack of human resources for green innovation (Collins et al., 2007; Lin and Ho, 2008); high costs for certifications related to green practices for SMEs (Hillary, 2004); lack of interaction with government agencies and participation in programs organized by government related to green initiatives (Our contribution); lack of reward systems for green innovations (Our contribution).

2.2. Technological and green resource-related barriers

Technology is defined as "the practical knowledge, know-how, skill and artifacts that can be used to develop a new product or service and/or a new production/delivery system" (Moriarty and Kosnik, 1989). Resources can be defined as "stocks of available factors that are owned or controlled by the firm (Amit and Schoemaker, 1993, p. 35). Technology and resources are essential for green innovations and

Table 1
Past studies on barriers to green innovation/green practices.

Author(s) and year	Key findings/issues	Methodology/method	Region/context
Hillary (2004)	The author conducted a study on SMEs where the objective was to study the environmental management systems in SMEs. A detailed review of 33 studies was done to identify barriers, opportunities, and drivers for EMS implementation. The major barriers identified include, "resources, understanding & perception, implementation, attitudes & company culture, certifiers, economics, institutional weaknesses and support & guidance".	Literature review	European Union
Runhaar et al. (2008)	They conducted a research to study environmental leaders from different backgrounds regarding their recommendations for going green. The study came out with around 26 barriers and prominent among these based on their frequency are modest demand for green and sustainable products, increased costs, availability of resources for green production and customer not willing to pay for sustainability.	Exploratory study/interviews	Netherlands
Walker et al. (2008)	They conducted a study to explore the barriers and drivers to green innovation in SMEs. Few important barriers identified are characteristics of SMEs, resource availability and lack of environmental knowledge apart from strict legislation and policies.	Literature review	Australia
Arundel and Kemp (2009)	They conducted a study to primarily discuss and measure green innovation. In the course of their study, they also identified the barriers of green innovation, which includes: economic barriers, regulations, lack of research efforts, lack of market demand, technological barriers, labor-related barriers, managerial and supplier related barriers.	Survey-based research	Japan
Del Río et al. (2010)	They conducted a study to formulate policy strategies for promoting green innovation. The studied barriers to green innovation and found the absence of pressure from stakeholders, weak legislation, lack of financial resources, low technological competencies as key barriers. They concluded that a combination of environmental and technological policies needs to be adapted for different barriers in order to overcome them.	Conceptual Study	Generalized
Matus et al. (2012)	They conducted a study to identify drivers, policies, and barriers to green innovation in China. The major barriers identified include: "competition between economic growth and environmental agenda", "regulatory and bureaucratic barriers", "availability of research funding", "technical barriers", "workforce training", "industrial engineering capacity", and "economic and financial barriers".	Semi-structured interviews	China
Marin et al. (2015)	In their study of barriers to green innovation in European SMEs, the author have identified certain barriers namely funds, uncertain returns, technical capabilities, knowledge barriers, market barriers etc. They divided the SMEs into 6 clusters based on these barriers.	Cluster analysis, Principal Component Analysis (PCA)	European Union
Pinget et al. (2015)	They conducted a study to identify the barriers to green innovation in SMEs. A sample of 435 SMEs was taken to analyze the extent to which SMEs perceive these to be barriers to green innovation. Important barriers that were identified include: knowledge barriers, financial barriers, and market-related barriers. They also found that these barriers are faced more by SMEs that engage in green innovations.	Multinominal logit estimation and regression	France
Abdullah et al. (2016)	They conducted a study to identify internal and external barriers to green innovation. They found that barriers are different for product, process and service innovations. Environmental resources, attitude and perception, customer demand and government support are specific to green product innovation whereas poor external partnerships, lack of information and environmental benefits are few barriers related to green process innovations.	Partial Least Square (PLS)	Malaysia
Cecere et al. (2016)	In their study on European SMEs, the authors have analyzed the effect of financial barriers and public funding on green innovations. They tried to distinguish between internal, external and public funding. The study found that lack of internal funding is a major challenge for green innovation and also public funding effectively improve green innovations.	Logit regression	Europe
Hojnik and Ruzzier (2016)	The conducted case studies to enumerate drivers and barriers to green innovation. They categorized the barriers to internal and external and found that cost is the most important internal barrier and legislations are a most important external barrier.	Case study	Slovenia
Ghisetti et al. (2017)	They conducted a study to analyze the effect of financial barriers in the adoption of green innovation in SMEs. They found that financial barriers often impede the adoption of green innovation and they are mostly neglected by SMEs. Certain policies are also suggested by authors for green innovation adoption.	Simultaneous Equation Modelling	European Union

SMEs are often found to be resource constrained (Gupta and Barua, 2017). The major barriers under this category involves, lack of capabilities in R&D and green innovation (Lai et al., 2003; Perron, 2005; Silva et al., 2008; Pawanchik and Sulaiman, 2010); technological and market uncertainty and fear of failure related to green innovations (Rao and Holt, 2005; Jinzhou, 2011); incompetent technologies to absorb green innovations developed by others (Del Río et al., 2010); complex designing process in order to reuse/recycle products and reduce resource usage (Russel, 1998; Beamon, 1999; Perron, 2005); lack of new technology, materials, processes and skills to innovate (Perron, 2005; Collins et al., 2007); lack of investments in R&D for green innovation (Hall and Lerner, 2010; Mina et al., 2013; Nanda and Kerr, 2015; Hall et al., 2016).

2.3. Financial and economic barriers

High cost often acts as a deterrent to finance an innovation project. Organizations often face cash crunch due to lack of internal and external financial resources (Pinget et al., 2015). These financial barriers hamper environmental plans of the organizations especially SMEs and thus preclude them from adopting and practicing green innovations (AlKhidir and Zailani, 2009; Ghisetti et al., 2017). The major financial barriers to green innovation for SMEs include, less payoff as compared to investment in green innovations (Matus et al., 2012; Govindan et al., 2014); lack of access to government subsidies and financial incentives (EIO, 2011; Cecere et al., 2016; Hojnik and Ruzzier, 2016); unavailability of bank loans to promote green practices (Mathiyazhagan et al., 2013; Cecere et al., 2016); high costs of disposing hazardous wastes (Mathiyazhagan et al., 2013; Govindan et al., 2014); high change over costs from traditional to green system (Konar and Cohen, 2001; Mudgal et al., 2010); no economies of scale for green products for SMEs due to lesser demand (Our contribution).

2.4. Poor external partnership and stakeholders' engagement

External linkages are essential for SMEs to carry on green innovation initiatives. However, finding partners having common interests in green innovation programs is difficult for SMEs (Ylinenpää, 1998;

Table 2
Barriers to green innovation in SMEs.

Barriers	Sub-barriers	Reference
Managerial, organizational and human resource related barriers (MO)	Lack of commitment from SME entrepreneur (MO1)	Ashford (1993), Ravi and Shankar (2005), Zhu et al. (2012a, b), Mathiyazhagan et al. (2013), Dubey et al. (2015), and Mangla et al. (2017)
	Reluctance to switch to green practices (MO2)	Ashford (1993), Zhu et al. (2012a, b), Lin and Ho (2008), and Jones et al. (2011)
	Lack of training and consultancy programs related to green innovation practices (MO3)	Ashford (1993), Carter and Dresner (2001), Urban and Naidoo (2012), Longoni et al. (2014), and Mangla et al. (2017)
	Lack of human resources for green innovation (MO4)	Collins et al. (2007) and Lin and Ho (2008)
	High costs for certifications related to green practices for SMEs (MO5)	Hillary (2004)
	Lack of interaction with government agencies and participation in programs organized by government related to green initiatives (MO6)	AlKhidir and Zailani (2009) and Zhu et al. (2012a, b)
	Lack of reward systems for green innovations (MO7)	Hadjimanolis (1999) and Madrid-Guijarro et al. (2009)
Technological and green resource-related barriers (TG)	Lack of capabilities in R&D and green innovation (TG1)	Lai et al. (2003), Perron (2005), Silva et al. (2008), and Pawanchik and Sulaiman (2010)
	Technological and market uncertainty and fear of failure related to green innovations (TG2)	Rao and Holt (2005) and Jinzhou (2011)
	Incompetent technologies to absorb green innovations developed by others (TG3)	Del Río et al. (2010)
	Complex designing process in order to reuse/recycle products and reduce resource usage (TG4)	Russel (1998) Beamon (1999), and Perron (2005)
	Lack of new technology, materials, processes, and skills to innovate (TG5)	Perron (2005) and Collins et al. (2007)
	Lack of investments in R&D for green innovation (TG6)	Hall and Lerner (2010), Mina et al. (2013), Nanda and Kerr (2015), and Hall et al. (2016)
Financial and economic barriers (FE)	Less payoff as compared to investment in green innovations (FE1)	Matus et al. (2012) and Govindan et al. (2014)
	Lack of access to government subsidies and financial incentives (FE2)	EIO (2011), Cecere et al. (2016), and Hojnik and Ruzzier (2016)
	Unavailability of bank loans to promote green practices (FE3)	Mathiyazhagan et al. (2013) amd Cecere et al. (2016)
	High costs of disposing of hazardous wastes (FE4)	Mathiyazhagan et al. (2013) and Govindan et al. (2014)
	High change over costs from traditional to the green system (FE5)	Konar and Cohen (2001) Mudgal et al. (2010)
	No economies of scale for green products for SMEs due to lesser demand (FE6)	Our contribution
Poor external partnership and stakeholders engagement (PP)	The unwillingness of supply chain partners to exchange information on green practices (PP1)	Walker et al. (2008), Hong et al. (2009), Mudgal et al. (2010), Ninlawan et al. (2010), and Dhull and Narwal (2016)
	Lack of understanding regarding green practices by other SMEs (PP2)	Sarkar and Mohapatra (2006), Wolf and Seuring (2010), and Dhull and Narwal (2016)
	Poor communication with external partners and lack of role clarity (PP3)	Lettenmeier et al. (2012), Dubey et al. (2015), and Mangla et al. (2017)
	Lack of platforms or forums for SMEs to discuss problems related to green innovation (PP4)	Madrid-Guijarro et al. (2009); Gupta and Barua (2017)
	Lack of pressure from large organizations to switch to green practices (PP5)	Gupta and Barua (2017)
Lack of government support for green initiatives (GS)	Complex and rigid rules for green practices (GS1)	Runhaar et al. (2008), Brammer et al. (2012), and Zhu et al. (2012a, b)
	Enforcement of environmental policies thus giving trespassing advantage to few (GS2)	Runhaar et al. (2008), AlKhidir and Zailani (2009), Zhu et al. (2012a, b), and Blok et al. (2015)
	Lack of training programs by the government for SMEs to incorporate green practices (GS3)	Runhaar et al. (2008), and Zhu et al. (2012a, b)
	Lack of help by the government for technology upgradation by SMEs (GS4)	Blok et al., 2015
Market and customer related barriers (MC)	Lack of customers' responsiveness towards green products (MC1)	Ashford, 1993; Silva et al., 2008; Dhull and Narwal, 2016
	Lack of awareness and knowledge regarding green products (MC2)	Min and Galle, 2001; Chen et al., 2006; Mudgal et al., 2010; Dhull and Narwal, 2016
	Unable to access resources from market to produce green products (MC3)	Our Contribution
Insufficient knowledge and information regarding green practices (IK)	Lack of knowledge regarding green practices and legislations among employees and entrepreneurs (IK1)	Shen and Tam, 2002; Simpson et al., 2004; Runhaar et al., 2008; Mudgal et al., 2010; Horbach et al., 2012; Mathiyazhagan et al., 2013; Longoni et al., 2014; Mangla et al., 2017
	Lack of ability of employees to identify environmental opportunities (IK2)	Theyel, 2000; Runhaar et al., 2008; Govindan et al., 2014
	Lack of belief in environmental benefits of green products (IK3)	Revell and Rutherfoord, 2003; Walker et al., 2008; Mathiyazhagan et al., 2013; Govindan et al., 2014
	Lack of technological information regarding green technologies (IK4)	Woolman and Veshagh, 2006; Madrid-Guijarro et al., 2009; Pinget et al., 2015; Mangla et al., 2017
	Lack of awareness about recycling and reverse logistics facilities (IK5)	Ravi and Shankar, 2005; Marsillac, 2008; Meade et al., 2007; Mathiyazhagan et al., 2013

Hadjimanolis, 1999). External organizations often shy away from connecting with SMEs for green initiatives for variety of reasons, the major barriers under this category involves, unwillingness of supply chain partners to exchange information on green practices (Walker et al., 2008; Hong et al., 2009; Mudgal et al., 2010; Ninlawan et al., 2010; Dhull and Narwal, 2016); lack of understanding regarding green practices by other SMEs (Sarkar and Mohapatra, 2006; Wolf and Seuring, 2010; Dhull and Narwal, 2016); poor communication with external partners and lack of role clarity (Lettenmeier et al., 2012; Dubey et al., 2015; Mangla et al., 2017); lack of platforms or forums for SMEs to discuss problems related to green innovation (Our contribution);

Table 3
Solutions to overcome barriers to green innovation in SMEs.

S·no.	Solutions/Strategies	Reference
S1	The transition from the end of pipe technology towards cleaner production initiatives	Arundel and Kemp, 2009
S2	Using electronic media for collaborating with supply chain partners for the effective and timely return of products to avoid wastage	Johnson and Whang, 2002; Prakash and Barua, 2015
S3	Organizing awareness programs at regional and district level by various NGOs and state agencies to increase awareness among all the stakeholders regarding benefits of green products	Mathiyazhagan et al., 2014; Solazzo et al., 2016
S4	Setting up of environmental management systems (EMS and ISO 14001) in SMEs for monitoring, auditing and measuring the systems and practices being followed to deal with issues of material, waste and energy use.	Zhu et al., 2012a, 2012b; Johnstone and Hascic, 2008; Lee et al., 2014; Somsuk and Laosirihongthong, 2016
S5	Developing alternate and more environmentally friendly solutions for production and consumption for SMEs	Johnstone and Hascic, 2008; Nikbakhsh, 2009; Blok et al., 2015; Maruthi and Rashmi, 2015
S6	Role of public institutes and universities should be enhanced in providing low-cost consultancy to SMEs regarding green and innovative technologies and products	Mathiyazhagan et al., 2014; Gupta and Barua, 2017
S7	Developing green logistics facilities like green storage and green transportation of products for SMEs	Zhu et al., 2012b; Kannan et al., 2014; Jabbour et al., 2015; Somsuk and Laosirihongthong, 2016
S8	Developing internal research practices at SMEs to carry out green innovation-related activities and acquiring scientific expertise	Green et al., 1994; Horbach et al., 2012; Dangelico, 2016
S9	Developing green clusters for SMEs where they can share their latest innovations, technologies and also problems related to green manufacturing on a common platform	Vanhaverbeke, 2006; MesseniPetruzzelli et al., 2011
S10	Adopting simplified and standardized procedures for green practices at SMEs	Prakash and Barua, 2015
S11	Designing of effective policies and framework by government and policy makers to reduce environmental degradation	Arundel and Kemp, 2009; Kiss et al., 2013; Govindan et al., 2016
S12	Investing in green R&D practices to design green products that can be easily recycled or disposed of after their useful life is over	Horbach et al., 2012; Zailani et al., 2012; Govindan et al., 2014, 2016
S13	Designing green products to reduce their hazardous impact and improve energy efficiency	Tseng, 2011; Tseng and Chiu, 2012; Gupta and Barua, 2017
S14	Training SME entrepreneur and managers regarding green processes and green purchasing	Gupta and Barua, 2017
S15	Involving all the stakeholders in environmental management initiatives and purchasing environmentally friendly raw material	Zhu et al., 2012b; Awasthi et al., 2010; Eltayeb et al., 2011; Lee et al., 2014; Somsuk and Laosirihongthong, 2016
S16	Stringent actions by regulatory authorities to enforce green design and environmental policies	Rehfeld et al., 2007; Horbach, 2008; Govindan et al., 2016
S17	The government should provide tax cuts, incentives and technical assistance to SMEs for producing green products	Johnstone et al., 2010; Qi et al., 2010; Kiss et al., 2013; Govindan et al., 2016
S18	Large organizations must pressurize their SME suppliers to adopt green practices and carry out innovations to reduce the impact of products on the environment	Friedman and Miles, 2002; Vachon and Klassen, 2006; Lee, 2008; Gupta and Barua, 2017
S19	Focusing on investment recovery strategies like recovery, redeployment and reselling to reduce wastage of material	Sarkis, 2001; Zhu et al., 2008; Kapetanopoulou and Tagaras, 2011; Lee et al., 2014; Wang and Song, 2017
S20	Investing in qualified and trained human resources, who can actively participate in green innovation activities	Montalvo, 2003; Zailani et al., 2012; Bliesner et al., 2014; De Medeiros et al., 2014; Gupta and Barua, 2018

lack of pressure from large organizations to switch to green practices (Our contribution).

2.5. Lack of government support for green initiatives

Often government regulations and policies act as impediment for green innovation practices due to their stringent nature and unclear procedures. Organizations are often demotivated due to lack of government support to carry out green innovation activities (Runhaar et al., 2008). The major barriers under this category are discussed below, complex and rigid rules for green practices (Runhaar et al., 2008; Brammer et al., 2012; Zhu et al., 2012a, 2012b); poor enforcement of environmental policies thus giving trespassing advantage to few (Runhaar et al., 2008; AlKhidir and Zailani, 2009; Zhu et al., 2012a, 2012b; Blok et al., 2015);lack of training programs by government for SMEs to incorporate green practices (Our contribution); lack of help by government for technology upgradation by SMEs (Our contribution).

2.6. Market and customer related barriers

Customers are determinant in deciding the demand of green products in the market and hence are the basis for implementation and adoption of green practices in the organization (Dhull and Narwal, 2016). Generally high costs associated with producing green products often forces industries not to adopt green practices and this problem is more prominent in SMEs (Ghisetti et al., 2017). However, high market demand can spur even small industries to adopt green practices in their operations. The various barriers under this category involves, lack of customers' responsiveness towards green products (Ashford, 1993; Silva et al., 2008; Dhull and Narwal, 2016); lack of awareness and knowledge regarding green products (Min and Galle, 2001; Chen et al., 2006; Mudgal et al., 2010; Dhull and Narwal, 2016); unable to access resources from market to produce green products (Our contribution).

2.7. Insufficient knowledge and information regarding green practices

Green innovations require certain information and employees that have required skills and knowledge regarding environmental practices and technologies (Pinget et al., 2015). The level of knowledge required to perform green innovation in SMEs is quite high and complex as compared to technological innovations (MesseniPetruzzelli et al., 2011; De Marchi, 2012). However, SMEs lack necessary skills, managerial expertise and knowledge to carry out green innovations. The various barriers under this category involves, lack of knowledge regarding green practices and legislations by employees and entrepreneurs (Shen and Tam, 2002; Simpson et al., 2004; Runhaar et al., 2008; Mudgal et al., 2010; Horbach et al., 2012; Mathiyazhagan et al., 2013; Longoni et al., 2014; Mangla et al., 2017); lack of ability of employees to identify environmental opportunities (Theyel, 2000; Runhaar et al., 2008; Govindan et al., 2014); lack of belief in environmental benefits of green products (Revell and Rutherfoord, 2003; Walker et al., 2008; Mathiyazhagan et al., 2013; Govindan et al., 2014); lack of technological information

regarding green technologies (Woolman and Veshagh, 2006; Madrid-Guijarro et al., 2009; Pinget et al., 2015; Mangla et al., 2017); lack of awareness about recycling and reverse logistics facilities (Ravi and Shankar, 2005; Meade et al., 2007; Marsillac, 2008; Mathiyazhagan et al., 2013).

2.8. Solutions/strategies to overcome barriers to green innovation

In response to growing climate change needs, manufacturers need to actively incorporate and develop green innovations. SMEs, which have relatively lesser resources often, face a lot of obstacles in developing green innovations and solutions. Literature suggests many strategies/solutions for SMEs to overcome these barriers and adopt green innovations, these include: transition from end of pipe technology towards cleaner production initiatives where focus is not only to reduce pollution at the end but also during its production phase; by changing either production technology or materials used (Arundel and Kemp, 2009). Designing of effective policies by government to reduce environment degradation can also be helpful in easy adoption of green innovation (Kiss et al., 2013; Govindan et al., 2016). Setting up EMS like ISO 14001 for monitoring and auditing the environmental practices is also an important step towards green innovation (Lee et al., 2014; Somsuk and Laosirihongthong, 2016). Developing internal research practices at SMEs to carry out green innovation-related activities and acquiring scientific expertise is also essential (Horbach et al., 2012; Dangelico, 2016). Similarly, many other solutions are identified both through literature review and discussion with managers and are presented in Table 3 below.

2.9. Research gaps and highlights

Increased production has led to surge in consumption of resources like raw materials and also has caused increased discharge of pollutants and industrial waste (Mudgal et al., 2010). SMEs being large in number are equal contributor to the same. Wong (2013) suggested that green innovations can help decrease the harmful environmental impact of these firms. But, SMEs face number of barriers in developing and incorporating green innovations into their system. Therefore, the need is to identify these barriers in context of SMEs. But, literature suggests that there are very limited number of studies related to barriers to green innovation (See Table 1) and that too only few are in context of SMEs (Runhaar et al., 2008; Walker et al., 2008; Marin et al., 2015; Cecere et al., 2016; Ghisetti et al., 2017). Also, there is almost negligible study in context of developing countries like India and almost all of the studies are being conducted in developed economies especially European Union. There is also no study conducted to rank the barriers to green innovation so that their importance can be known. Lastly, there is no study available that proposes solutions to overcome these barriers. So, in the backdrop of this, the current research aims to first identify the barriers to green innovation in Indian SMEs and simultaneously list the solutions to overcome these barriers. The study also aims to rank these barriers and also the solutions with respect to these barriers.

3. Methodology

To rank barriers and solutions to overcome these barriers, a three-phase methodology is proposed (Fig. 1). Phase 1 involves identification of managers, literature review and discussion with managers through Delphi method to finalize barriers and solutions to green innovation. Delphi method involves several rounds of discussion with managers until a final consensus is reached between managers. Through a detailed literature survey, a total of thirty barriers were identified and put for discussion with managers (see the profile of managers in Section 4). After several rounds of discussion with managers, two barriers were deleted and eight new barriers were added in the context of Indian SMEs and a total of thirty-six barriers were identified which were categorized into seven main categories. Similarly, twenty solutions were finalized for the study. Through literature review 28 solutions were identified. The managers were asked to finalize these solutions using several rounds of discussions. Some solutions seem redundant to managers and were deleted as they were overlapping and finally 20 solutions were adopted for this study.

The second phase involved ranking of the barriers, BWM given by Rezaei (2015, 2016) is used to rank the barriers. There are several MCDM techniques available like AHP, ANP, MAUT, SMART etc. to rank the barriers by calculating weights of the barriers (Subramoniam et al., 2013; Bhattacharya et al., 2014; Wang et al., 2016; Scholz et al., 2017; Tudzarov and Stefanov, 2017), but BWM has advantage over these MCMD techniques because it requires lesser number of pairwise comparisons as compared to other MCDM techniques like AHP (Rezaei, 2015). BWM compares the alternatives with best alternatives and worst alternative with all other alternatives only, so relatively lesser data is required than AHP which requires pairwise comparison among all the alternatives. In the third phase, solutions to overcome barriers are ranked using Fuzzy TOPSIS methodology. Fuzzy TOPSIS is the most widely used methodology for conditions like the ranking of alternatives/solutions (Kannan et al., 2014; Patil and Kant, 2014; Kabra and Ramesh, 2015; Prakash and Barua, 2015; Gupta and Barua, 2017; Kumar and Dash, 2017). The details of each phase are discussed in further subsections:

3.1. Finalization of the barriers to study

A total of thirty-six barriers categorized into seven main categories along with twenty solutions to overcome these barriers are finalized using literature review and Delphi method.

3.2. Obtaining weights of barriers using BWM

BWM is used to rank the barriers to green innovation. BWM is a very strong MCDM technique and is widely used by researchers all over the world like Gupta and Barua, 2016 (technological innovation enablers ranking); Rezaei et al., 2016 (green supplier selection); Gupta and Barua, 2017 (green supplier selection); Gupta, 2017 (airport evaluation based on service quality); Salimi and Rezaei, 2017 (evaluating firms R&D performance); van de Kaa et al., 2017a (selection of biomass technology); van de Kaa et al., 2017b (selecting electric vehicle); Abadi et al., 2018 (evaluation of medical tourism strategy). The steps as given by Rezaei (2015, 2016) are explained below:

Step 1: Selection of attributes (barriers) for analysis.

Through literature review and manager opinion, the attributes (barriers) are finalized for analysis.

Step 2: Among finalized attributes best and the worst attribute is finalized by each manager for both main category and subcategory attributes.

Step 3: Next each manager is asked to give preference rating for the best attribute selected over all other attributes using a scale of 1 to 9.

Step 4: After this, preference rating of all attributes with the worst attribute is taken by managers.

Step 5: Optimized weights ($w_1^*, w_2^*, \ldots\ldots, w_n^*$) for all the attributes is calculated next.

The objective is to obtain the weights of attributes so that the maximum absolute differences for all j can be minimized for $\{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$. This minimax model will be obtained:

$$\min \max \{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$$

$$\sum_j w_j = 1 \quad \text{(s.t)}$$

$$w_j \geq 0, \text{ for all j} \quad (1)$$

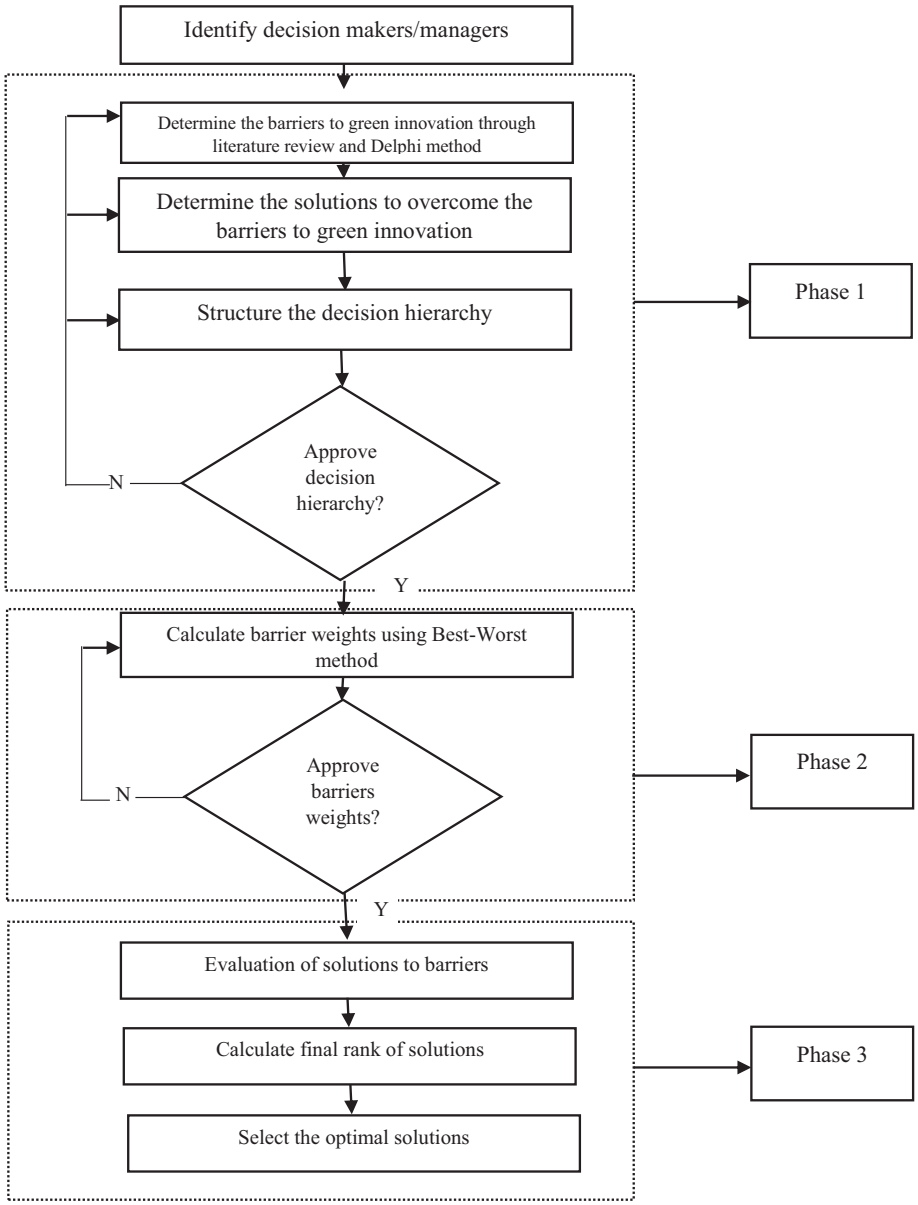

Fig. 1. Schematic diagram for phases of methodology.

Model (1) when transformed into a linear model gives better results, the model is shown below:

$$\xi^L \quad (\min)$$

s.t.
$|w_B - a_{Bj}w_j| \le \xi^L$, for all j.
$|w_j - a_{jW}w_W| \le \xi^L$, for all j

$$\sum_j w_j = 1$$

$$w_j \ge 0, \text{ for all j} \quad (2)$$

Model (2) can be solved to obtain optimal weights ($w^*_1, w^*_2, \ldots\ldots, w^*_n$) and optimal value ξ^L.

Consistency (ξ^L) of attribute comparisons close to 0 is desired (Rezaei, 2016).

3.3. Ranking the solutions through Fuzzy TOPSIS

The TOPSIS methodology is well known MCDM technique that was first presented by Hwang and Yoon (1981); Lai et al. (1994). The major advantage of using TOPSIS is the requirement of very fewer data points from managers like criteria weights and linguistic preference of alternatives. TOPSIS methodology works on the principle that

Table 4
Linguistic scale for alternatives selection.

Linguistic variables	Corresponding fuzzy numbers
VL	(0, 0, 0.2)
L	(0, 0.2, 0.4)
M	(0.2, 0.4, 0.6)
H	(0.4, 0.6, 0.8)
VH	(0.6, 0.8, 1)
E	(0.8, 1, 1)

VL – "Very Low", L – "Low", M – "Medium", H – "High", VH – "Very High" and E – "Excellent".

Table 5
Best and Worst barriers identified by managers.

Green innovation barriers	Determined as Best by managers	Determined as Worst by managers
Managerial, organizational and human resource related barriers (MO)		3
MO1		
MO2	3, 4	
MO3	1, 2	
MO4		
MO5		
MO6		1, 2, 3, 4
MO7		
Technological and green resource-related barriers (TG)	1, 2, 3, 4	
TG1		
TG2		
TG3		
TG4		1, 4
TG5	1, 2, 3, 4	
TG6		2, 3
Financial and economic barriers (FE)		
FE1		1, 2, 3, 4
FE2		
FE3		
FE4		
FE5	1, 2, 3, 4	
FE6		
Poor external partnership and stakeholders engagement (PP)		1, 2, 4
PP1		
PP2	1, 2, 3	
PP3	4	
PP4		1, 3, 4
PP5		2
Lack of government support for green initiatives (GS)		
GS1	3, 4	
GS2		
GS3		1, 2, 3, 4
GS4	1, 2	
Market and customer related barriers (MC)		
MC1		1, 2, 3, 4
MC2	3	
MC3	1, 2, 4	
Insufficient knowledge and information regarding green practices (IK)		
IK1	1, 4	
IK2		2, 4
IK3		
IK4	2, 3	
IK5		1, 3

we consider we have n criteria and m alternatives and selected alternative is having a minimum distance from positive ideal solution and maximum distance from negative ideal solution. Since TOPSIS requires giving preference ratings to alternatives through managers, but it is often difficult for managers to give precise ratings for alternatives. To overcome this limitation, Fuzzy TOPSIS is suggested where fuzzy numbers are used to give preference rating by managers (Chang et al., 2008; Sun, 2010).

The steps of Fuzzy TOPSIS methodology are presented below:

Step 1: Scale mentioned in Table 4 is used to formulate an evaluation matrix ($k_{ij}^{\sim}$)which consists of comparison of alternatives (solutions) with respect to criteria of study.This study uses linguistic scale and follow the rule that triangular fuzzy numbers lie in the range [0,1] thus doing away with the requirement of normalization (Dağdeviren et al., 2009).

Step 2: After obtaining evaluation matrix this matrix is converted into the weighted normalized matrix as shown below:

$V^{\sim} = [v_{ij}^{\sim}]_{m\times n}$ where $i = 1, 2, 3, \ldots.m$ and $j = 1, 2, 3, \ldots.n$ and

$$v_{ij}^{\sim} = k_{ij}^{\sim} \otimes w_j \tag{3}$$

Step 3: Next FPIS and FNIS are obtained, where FPIS and FNIS is 'fuzzy positive ideal' and the 'fuzzy negative ideal solution' respectively:

$$A^{+} = \left\{ v_1^{+\sim}, \ldots\ldots\ldots, v_n^{+\sim} \right\}, \quad where\ v_j^{+\sim} = \left\{ \max\left(v_{ij}^{+\sim} \right) if\ j\varepsilon J;\ \min\left(v_{ij}^{\sim} \right) if\ j\varepsilon J' \right\}, \quad j = 1\ldots.n \tag{4}$$

$$A^{-} = \left\{ v_1^{\sim -}, \ldots\ldots\ldots, v_n^{\sim -} \right\}, \quad where\ v_j^{\sim -} = \left\{ \min\left(v_{ij}^{\sim} \right) if\ j\varepsilon J;\ \max\left(v_{ij}^{\sim} \right) if\ j\varepsilon J' \right\}, \quad j = 1\ldots.n \tag{5}$$

Step 4: Using equation mentioned below, a distance of each solution is obtained from FPIS and FNIS:

$$d_i^{+} = \left\{ \sum_{j=1}^{n} \left(v_{ij}^{\sim} - v_{ij}^{\sim +} \right)^2 \right\}^{1/2}, \quad i = 1\ldots\ldots\ldots m \tag{6}$$

$$d_i^{-} = \left\{ \sum_{j=1}^{n} \left(v_{ij}^{\sim} - v_{ij}^{\sim -} \right)^2 \right\}^{1/2}, \quad i = 1\ldots\ldots\ldots m$$

Table 6
Main criteria barriers comparison.

BO	Managerial, organizational and human resource related barriers (MO)	Technological and green resource-related barriers (TG)	Financial and economic barriers (FE)	Poor external partnership and stakeholders engagement (PP)	Lack of government support for green initiatives (GS)	Market and customer related barriers (MC)	Insufficient knowledge and information regarding green practices (IK)
Best criteria: *technological and green resource related barriers (TG)*	7	1	2	9	6	3	4

OW	Worst criteria: Poor external partnership and stakeholders engagement (PP)
Managerial, organizational and human resource related barriers (MO)	2
Technological and green resource-related barriers (TG)	9
Financial and economic barriers (FE)	5
Poor external partnership and stakeholders engagement (PP)	1
Lack of government support for green initiatives (GS)	2
Market and customer related barriers (MC)	3
Insufficient knowledge and information regarding green practices (IK)	3

Table 7
Pairwise comparison for Managerial, organizational and human resource related barriers for case company 1.

BO	MO_1	MO_2	MO_3	MO_4	MO_5	MO_6	MO_7
Best criterion: MO_3	2	3	1	4	7	9	5
OW						Worst criterion: MO_6	
MO_1					5		
MO_2					3		
MO_3					9		
MO_4					3		
MO_5					2		
MO_6					1		
MO_7					2		

Step 5: Closeness coefficient (CC_i) for each solution is obtained by using the equation below:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+} \; i = 1.....m \quad CC_i \varepsilon (0,1) \tag{7}$$

Step 6: Finally solutions are ranked on the basis of CCi values obtained.

4. An illustrative application of the proposed methodology

This section is dedicated to explaining the proposed methodology in companies selected for the case study. The proposed three-phase methodology is applied to the SMEs selected for a case study. The real world example of the proposed methodology signifies the robustness and validity of the model proposed for analysis.

4.1. Case companies and managers background

Four SMEs have been chosen for the case study. The SMEs were chosen considering their willingness to incorporate green practices into their operations and their experience in the field. All the SMEs are operating for at least ten years and are a supplier to at least one multinational corporation. One manager from each of the SMEs is selected for the study. The manager 1 is a post graduate in management and is the owner of the first SME which is producing products for a leading automobile company. Manager 1 is managing the unit for past twelve years and has collaborated with many MNCs and is continually trying to adopt green practices at their firm. The manager 2 is also a post graduate in engineering and is the joint owner of the SME 2. Manager 2 is at the helm of affairs for past nine years and is a manager in managing manufacturing operations. SME 2 is a component supplier for a major electrical company. The manager 3 is a graduate in engineering and is the owner of SME 3, manager 3 has started the unit twelve years back and before that manager worked with a leading automobile company as a senior manager of operations and environment management. SME 3 is also a component supplier for a major automobile company.

Table 8
Pairwise comparison of Technological and green resource-related barriers for case company 1.

BO	TG_1	TG_2	TG_3	TG_4	TG_5	TG_6
Best criterion: TG_5	2	3	6	8	1	5
OW					Worst criterion: TG_4	
TG_1				4		
TG_2				3		
TG_3				2		
TG_4				1		
TG_5				8		
TG_6				2		

Table 9
Pairwise comparison of Financial and economic barriers for case company 1.

BO	FE_1	FE_2	FE_3	FE_4	FE_5	FE_6
Best criterion: FE_5	9	3	7	2	1	3
OW					Worst criterion: FE_1	
FE_1				1		
FE_2				3		
FE_3				2		
FE_4				4		
FE_5				9		
FE_6				3		

Table 10
Pairwise comparison for Poor external partnership and stakeholders engagement barriers for case company 1.

BO	PP_1	PP_2	PP_3	PP_4	PP_5
Best criterion: PP_2	3	1	2	8	4
OW				Worst criterion: PP_4	
PP_1				3	
PP_2				8	
PP_3				4	
PP_4				1	
PP_5				2	

The manager 4 is a doctorate in management and is the owner of the SME 4. Manager 4 has a wide experience with many MNCs working at managerial positions and also acted as a consultant to many companies before starting their enterprise. SME 4 is in inception for almost fifteen years and deals with making plastic and rubber products. The SME 4 is one of the best in the region following environmental standards. The three-phase methodology applied to these case companies is illustrated below:

4.2. Finalization of selection criteria/barriers

A combined method of extensive literature review and Delphi method developed by Dalkey and Helmer (1963) is used to finalize the criteria (barriers to green innovation). This approach involves first identifying barriers through review of past studies and then putting these barriers before managers for their deliberations to add or delete any barriers. A panel of all the four managers selected for study was formed and they were made to hold several rounds of discussions in order to finalize the barriers among the thirty barriers that were identified through literature review. After three rounds of discussions among managers and various additions and deletions in barriers, thirty-six barriers were finalized which were categorized into seven categories as shown in Table 2 above. A similar technique was adopted for finding the solutions to these barriers and a total of twenty solutions were finalized for the study as mentioned in Table 3 above.

Table 11
Pairwise comparison of Lack of government support for green initiatives barriers for case company 1.

BO	GS_1	GS_2	GS_3	GS_4
Best criterion: GS_4	2	5	8	1
OW			Worst criterion: GS_3	
GS_1			4	
GS_2			2	
GS_3			1	
GS_4			8	

Table 12
Pairwise comparison for Market and customer related barriers for case company 1.

BO	MC_1	MC_2	MC_3
Best criterion: MC_3	8	3	1
OW			Worst criterion: MC_1
MC_1			1
MC_2			4
MC_3			8

Table 13
Pairwise comparison of insufficient knowledge and information regarding green practices barriers for case company 1.

BO	IK_1	IK_2	IK_3	IK_4	IK_5
Best criterion: IK_1	1	7	4	3	9
OW					Worst criterion: IK_5
IK_1					9
IK_2					2
IK_3					3
IK_4					4
IK_5					1

4.3. Calculation of weights of barriers using Best–Worst Methodology

After barriers are finalized by the managers the next step is to evaluate the weights of these barriers. All the managers were asked to rate the barriers in main criteria as well as sub-criteria. The comprehensive list of best and worst barriers identified by all the managers is shown in Table 5. Here the best barrier in BWM methodology is the one that is most severe and needs to be addressed first and the worst barrier is the one that is least severe and hence least important from the point of view of study and can be addressed last.

First weights of main criteria barriers are calculated using the methodology shown in Section 3 above. The ratings of main criteria barriers by manager 1 are shown in Table 6.

The managers from each SME were asked to rate the main criteria barriers as well as sub-criteria barriers using the steps shown in Section 3 above. The ratings of manager 1 for subcriteria barriers are shown in Tables 7 to 13 below.

After the pairwise comparison of each of the main criteria barrier and sub-criteria barrier by the managers, the next step is determining main criteria and sub-criteria weights. Using formulation (2), the main criteria and sub-criteria weights for all the barriers are calculated and an average of weights obtained through ratings of four managers are presented in Table 14. Weights of main category barriers and sub-category barriers are calculated individually through ratings obtained by each expert and they were then aggregated using average of weights obtained by each manager. A similar method was adopted for calculating aggregated consistency ratio.

4.4. Ranking the solutions to overcome barriers using Fuzzy TOPSIS

After calculating weights of all the main criteria and sub-criteria barriers, the next step is to obtain the ranking of solutions to overcome these barriers. Fuzzy TOPSIS methodology as discussed in Section 3 is used to rank the solutions. A panel of the four managers from each

Table 14
Aggregate weights of Main and sub-criteria barriers for all case companies.

Main criteria	Weights of main criteria	Aggregated consistency ratio of main criteria	Sub-criteria	Weights of sub-criteria	Aggregated consistency ratio of sub-criteria	Global weights	Ranking
Managerial, organizational and human resource related barriers (MO)	0.059	0.033	MO1	0.166	0.035	0.010	24
			MO2	0.250		0.015	20
			MO3	0.256		0.015	19
			MO4	0.121		0.007	30
			MO5	0.054		0.003	34
			MO6	0.036		0.002	36
			MO7	0.083		0.005	33
Technological and green resource-related barriers (TG)	0.376		TG1	0.220	0.031	0.083	3
			TG2	0.126		0.047	5
			TG3	0.113		0.043	7
			TG4	0.056		0.021	16
			TG5	0.421		0.158	1
			TG6	0.064		0.024	15
Financial and economic barriers (FE)	0.200		FE1	0.045	0.025	0.009	27
			FE2	0.149		0.030	11
			FE3	0.071		0.014	21
			FE4	0.165		0.033	10
			FE5	0.430		0.086	2
			FE6	0.140		0.028	14
Poor external partnership and stakeholders engagement (PP)	0.046		PP1	0.174	0.038	0.008	29
			PP2	0.376		0.017	17
			PP3	0.256		0.012	23
			PP4	0.063		0.003	35
			PP5	0.130		0.006	31
Lack of government support for green initiatives (GS)	0.072		GS1	0.407	0.025	0.029	12
			GS2	0.130		0.009	26
			GS3	0.071		0.005	32
			GS4	0.392		0.028	13
Market and customer related barriers (MC)	0.136		MC1	0.098	0.034	0.013	22
			MC2	0.336		0.046	6
			MC3	0.567		0.077	4
Insufficient knowledge and information regarding green practices (IK)	0.110		IK1	0.322	0.041	0.036	9
			IK2	0.073		0.008	28
			IK3	0.139		0.015	18
			IK4	0.378		0.042	8
			IK5	0.088		0.010	25

SME was formed and they were asked to rate the solutions using the linguistic scale as shown in Table 4.The resultant matrix showing corresponding fuzzy values of linguistic variables for comparison is shown in Table 15.

Next step is to calculate weighted normalized fuzzy matrix as per Eq. (3) and is presented in Table 16. Also FPIS, A^+ and FNIS, A^-, are determined using Eqs. (4) and (5). FPIS and FNIS in this case can be defined as $v\sim_1^+ = (1,1,1)$ and $v\sim_1^- = (0,0,0)$ respectively, for benefit criteria and as $v\sim_1^+ = (0,0,0)$ and $v\sim_1^- = (1,1,1)$ for cost criteria, but in this case all the criteria are considered cost because the aim is to minimize the barriers to green innovation, so the values of FPIS and FNIS are taken as per this situation.

After obtaining weighted fuzzy matrix, the final step is to obtain a ranking of the solutions through closeness coefficient value CCi and using Eqs. (6) and (7). The corresponding CCi values and ranks of the solutions are presented in Table 17.

The three-phase methodology applied for shows that S11 is the optimal solution among all the solutions to overcome barriers to green innovation in SMEs. The ranking of the solutions obtained is as follows S11 > S8 > S4 > S19 > S10 > S1 > S12 > S13 > S20 > S18 > S5 > S3 > S6 > S16

Table 15
Fuzzy comparison matrix for solutions.

	MO1	MO2	MO3	MO4	MO5	MO6	MO7	TG1	TG2	.....	.....	GS4	MC1	MC2	MC3	IK1	IK2	IK3	IK4	IK5
S1	0, 0, 0.2	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0, 0.2, 0.4	0, 0, 0.2	0.2, 0.4, 0.6	0.2, 0.4, 0.6	.....	.....	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0, 0.2, 0.4	0, 0, 0.2
S2	0, 0.2, 0.4	0.4, 0.6, 0.8	0.6, 0.8, 1	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.8, 1, 1	0, 0.2, 0.4	0.4, 0.6, 0.8	0.4, 0.6, 0.8	.....	.....	0.8, 1, 1	0.4, 0.6, 0.8	0.6, 0.8, 1	0.6, 0.8, 1	0.6, 0.8, 1	0.2, 0.4, 0.6	0.6, 0.8, 1	0.6, 0.8, 1	0.4, 0.6, 0.8
S3	0.6, 0.8, 1	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0, 0.2, 0.4	0, 0.2, 0.4	0.2, 0.4, 0.6	0, 0.2, 0.4	0, 0.2, 0.4	0.4, 0.6, 0.8	.....	.....	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.6, 0.8, 1	0.4, 0.6, 0.8	0.6, 0.8, 1	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.4, 0.6, 0.8
S4	0, 0, 0.2	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	0.6, 0.8, 1	0, 0, 0.2	0, 0, 0.2	0, 0.2, 0.4	0, 0.2, 0.4	.....	.....	0, 0, 0.2	0, 0.2, 0.4	0.2, 0.4, 0.6	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0.2, 0.4	0, 0.2, 0.4	0.2, 0.4, 0.6
S5	0, 0.2, 0.4	0.4, 0.6, 0.8	0, 0.2, 0.4	0.2, 0.4, 0.6	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0.4, 0.6, 0.8	0.4, 0.6, 0.8	.....	.....	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0, 0.2, 0.4	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0.2, 0.4, 0.6	0, 0.2, 0.4
S6	0, 0, 0.2	0, 0, 0.2	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0, 0.2, 0.4	0, 0, 0.2	0, 0, 0.2	0.4, 0.6, 0.8	0, 0.2, 0.4	.....	.....	0.6, 0.8, 1	0, 0, 0.2	0, 0.2, 0.4	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.6, 0.8, 1	0.2, 0.4, 0.6	0.6, 0.8, 1	0.6, 0.8, 1
S7	0, 0.2, 0.4	0, 0.2, 0.4	0.6, 0.8, 1	0.4, 0.6, 0.8	0, 0.2, 0.4	0, 0, 0.2	0, 0, 0.2	0.6, 0.8, 1	0.2, 0.4, 0.6	.....	.....	0, 0, 0.2	0, 0, 0.2	0, 0.2, 0.4	0.6, 0.8, 1	0.4, 0.6, 0.8	0.8, 1, 1	0.2, 0.4, 0.6	0.8, 1, 1	0.6, 0.8, 1
S8	0, 0, 0.2	0, 0.2, 0.4	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0.2, 0.4	.....	.....	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2
S9	0, 0.2, 0.4	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0, 0.2, 0.4	0, 0.2, 0.4	0.4, 0.6, 0.8	0.4, 0.6, 0.8	.....	.....	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.6, 0.8, 1	0.6, 0.8, 1
S10	0.2, 0.4, 0.6	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	0.2, 0.4, 0.6	0, 0, 0.2	0, 0, 0.2	0.2, 0.4, 0.6	0, 0.2, 0.4	.....	.....	0, 0.2, 0.4	0, 0.2, 0.4	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0, 0.2, 0.4	0.2, 0.4, 0.6	0, 0, 0.2	0.2, 0.4, 0.6	0, 0.2, 0.4
S11	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0.2, 0.4	0.2, 0.4, 0.6	.....	.....	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0.4, 0.6, 0.8
S12	0, 0, 0.2	0.2, 0.4, 0.6	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	0.2, 0.4, 0.6	0.2, 0.4, 0.6	.....	.....	0.4, 0.6, 0.8	0, 0.2, 0.4	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0, 0, 0.2	0, 0.2, 0.4	0, 0, 0.2	0, 0.2, 0.4	0.6, 0.8, 1
S13	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	0.2, 0.4, 0.6	0.2, 0.4, 0.6	.....	.....	0, 0, 0.2	0, 0.2, 0.4	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0.2, 0.4, 0.6
S14	0.6, 0.8, 1	0.6, 0.8, 1	0.8, 1, 1	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.2, 0.4, 0.6	.....	.....	0, 0.2, 0.4	0, 0.2, 0.4	0.8, 1, 1	0.8, 1, 1	0.8, 1, 1	0.8, 1, 1	0.6, 0.8, 1	0.6, 0.8, 1	0.8, 1, 1
S15	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	0, 0, 0.2	0, 0, 0.2	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	.....	.....	0.4, 0.6, 0.8	0.6, 0.8, 1	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0, 0.2, 0.4	0, 0.2, 0.4
S16	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0, 0, 0.2	0, 0.2, 0.4	0.4, 0.6, 0.8	0, 0.2, 0.4	0, 0.2, 0.4	0, 0.2, 0.4	.....	.....	0.6, 0.8, 1	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.6, 0.8, 1	0, 0.2, 0.4	0, 0.2, 0.4	0.4, 0.6, 0.8	0.2, 0.4, 0.6
S17	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0, 0.2, 0.4	0.6, 0.8, 1	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0, 0.2, 0.4	.....	.....	0.6, 0.8, 1	0.2, 0.4, 0.6	0, 0.2, 0.4	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.4, 0.6, 0.8
S18	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0, 0.2, 0.4	0, 0, 0.2	0, 0, 0.2	0.2, 0.4, 0.6	0, 0.2, 0.4	0, 0.2, 0.4	.....	.....	0, 0, 0.2	0, 0.2, 0.4	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0, 0.2, 0.4	0, 0.2, 0.4	0.4, 0.6, 0.8	0.4, 0.6, 0.8
S19	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0.2, 0.4	0, 0.2, 0.4	.....	.....	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0.2, 0.4	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0, 0, 0.2	0.4, 0.6, 0.8
S20	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0, 0.2, 0.4	0.8, 1, 1	0, 0.2, 0.4	0, 0.2, 0.4	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.2, 0.4, 0.6	.....	.....	0, 0, 0.2	0, 0.2, 0.4	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.6, 0.8, 1	0.6, 0.8, 1	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.6, 0.8, 1
Criterion weights	0.010	0.015	0.015	0.007	0.003	0.002	0.005	0.083	0.047	.....	.....	0.0028	0.013	0.046	0.077	0.036	0.008	0.015	0.042	0.010

Table 16
Weighted fuzzy evaluation matrix for solutions.

	MO1	MO2	MO3	MO4	MO5	MO6	MO7	TG1
S1	0.000,0.000,0.002	0.006,0.009,0.012	0.003,0.006,0.009	0.001,0.003,0.004	0.001,0.001,0.002	0.000,0.000,0.001	0.000,0.000,0.001	0.017,0.033,0.050
S2	0.000,0.002,0.004	0.006,0.009,0.012	0.009,0.012,0.015	0.001,0.003,0.004	0.001,0.001,0.002	0.002,0.002,0.002	0.000,0.001,0.002	0.033,0.050,0.066
S3	0.006,0.008,0.010	0.006,0.009,0.012	0.003,0.006,0.009	0.000,0.001,0.003	0.000,0.001,0.001	0.000,0.001,0.001	0.000,0.001,0.002	0.000,0.017,0.033
S4	0.000,0.000,0.002	0.000,0.003,0.006	0.000,0.003,0.006	0.000,0.001,0.003	0.002,0.003,0.003	0.000,0.000,0.000	0.000,0.000,0.001	0.000,0.017,0.033
S5	0.000,0.002,0.004	0.006,0.009,0.012	0.000,0.003,0.006	0.001,0.003,0.004	0.000,0.000,0.001	0.000,0.000,0.000	0.000,0.000,0.001	0.033,0.050,0.066
S6	0.000,0.000,0.002	0.000,0.000,0.003	0.006,0.009,0.012	0.003,0.004,0.006	0.000,0.001,0.001	0.000,0.000,0.000	0.000,0.000,0.001	0.033,0.050,0.066
S7	0.000,0.002,0.004	0.000,0.003,0.006	0.009,0.012,0.015	0.003,0.004,0.006	0.000,0.001,0.001	0.000,0.000,0.000	0.000,0.000,0.001	0.050,0.066,0.083
S8	0.000,0.000,0.002	0.000,0.003,0.006	0.000,0.000,0.003	0.000,0.000,0.001	0.000,0.000,0.001	0.000,0.000,0.000	0.000,0.000,0.001	0.000,0.000,0.017
S9	0.000,0.002,0.004	0.006,0.009,0.012	0.006,0.009,0.012	0.003,0.004,0.006	0.001,0.001,0.002	0.000,0.000,0.001	0.000,0.001,0.002	0.033,0.050,0.066
S10	0.002,0.004,0.006	0.000,0.003,0.006	0.000,0.003,0.006	0.000,0.001,0.003	0.001,0.001,0.002	0.000,0.000,0.000	0.000,0.000,0.001	0.017,0.033,0.050
S11	0.000,0.000,0.002	0.000,0.000,0.003	0.000,0.000,0.003	0.000,0.000,0.001	0.000,0.000,0.001	0.000,0.000,0.000	0.000,0.000,0.001	0.000,0.017,0.033
S12	0.000,0.000,0.002	0.003,0.006,0.009	0.000,0.003,0.006	0.000,0.001,0.003	0.000,0.001,0.001	0.000,0.000,0.001	0.000,0.001,0.002	0.017,0.033,0.050
S13	0.000,0.000,0.002	0.000,0.000,0.003	0.000,0.000,0.003	0.000,0.000,0.001	0.000,0.001,0.001	0.000,0.000,0.001	0.000,0.001,0.002	0.017,0.033,0.050
S14	0.006,0.008,0.010	0.009,0.012,0.015	0.012,0.015,0.015	0.001,0.003,0.004	0.001,0.001,0.002	0.001,0.001,0.002	0.001,0.002,0.003	0.033,0.050,0.066
S15	0.000,0.002,0.004	0.000,0.003,0.006	0.000,0.003,0.006	0.000,0.000,0.001	0.000,0.000,0.001	0.000,0.000,0.001	0.000,0.001,0.002	0.000,0.017,0.033
S16	0.002,0.004,0.006	0.003,0.006,0.009	0.003,0.006,0.009	0.000,0.000,0.001	0.000,0.001,0.001	0.001,0.001,0.002	0.000,0.001,0.002	0.000,0.017,0.033
S17	0.002,0.004,0.006	0.006,0.009,0.012	0.006,0.009,0.012	0.000,0.001,0.003	0.002,0.003,0.003	0.000,0.001,0.001	0.001,0.002,0.003	0.033,0.050,0.066
S18	0.002,0.004,0.006	0.003,0.006,0.009	0.003,0.006,0.009	0.000,0.001,0.003	0.000,0.000,0.001	0.000,0.000,0.000	0.001,0.002,0.003	0.000,0.017,0.033
S19	0.000,0.000,0.002	0.000,0.000,0.003	0.000,0.000,0.003	0.000,0.000,0.001	0.000,0.000,0.001	0.000,0.000,0.000	0.000,0.000,0.001	0.000,0.017,0.033
S20	0.002,0.004,0.006	0.003,0.006,0.009	0.000,0.003,0.006	0.006,0.007,0.007	0.000,0.001,0.001	0.000,0.000,0.001	0.001,0.002,0.003	0.017,0.033,0.050
A^+	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$
A^-	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$

> S15 > S17 > S14 > S7 > S9 > S2. The ranking of solutions can help decision makers to implement strategies for overcoming barriers to green innovation in SMEs.

5. Result analysis and discussion

Best–Worst analysis is used to rank the barriers to green innovation. Table 14 shows the weights of main criteria barriers as well as sub-criteria barriers, the rankings are obtained on their respective weights. Total seven main barriers were finalized and among them, Technological and green resources related barriers (TG) is ranked first through manager opinion and analysis. The results are in conformance with the past studies (Perron, 2005; Silva et al., 2008) wherein they also found lack of technical expertise as one of the major barriers to green innovation. Lack of technical expertise negatively effects green innovation abilities of the organization (Revell and Rutherfoord, 2003), and sufficient R&D capabilities, resources, and green innovation abilities provides an edge to the organization over their competitors and help them further venture into green product categories through innovations (Lai et al., 2003). For any organization to sustain in long run, environmental resources are a necessity. The general deficiency of resources and the reluctance of management in order to allocate resources for green initiatives act as a major barrier for SMEs (Hillary, 2004; Silva et al., 2008). Physical as well as science-technology infrastructure is an important part of innovation system but this infrastructure requires monetary support and private agencies are often unable to support much, thus assistance from public agencies is required to build infrastructure for innovation (Foxon and Pearson, 2008). Second among a ranking of barriers is Financial and economic barriers (FE), financial support is necessary for innovations but despite the need to develop a proper financial system, the financial support system for green innovations is still not developed (Cainelli and Mazzanti, 2013). Companies often invest >20% of their revenues towards buying resources for green innovation (Nikolaou and Evangelinos, 2010). But small organizations lack the capital investments for these resources and thus financial constraints act as a major barrier for green innovations (Del Río et al., 2010). High cost for green innovations is also a major concern for SMEs, green innovation activities like environmental packing of materials, environmentally friendly waste disposal, and management, maintaining hazardous material inventory all involve substantial investments. The amount of financial budget available with these SMEs are too less to handle these activities, thus costs along with limited financial support from both internal and external sources act as a major impediment to green innovation (Pinget et al., 2015). Third among main category barriers is Market and customer related barriers (MC), The demand for any product depends upon willingness of the customers to pay for that product, with green products customers are often reluctant to shed extra money, this, in turn, hampers green innovation efforts of the firms which often loose motivation to carry on innovations due to lack of customer demand (Silva et al., 2008). It is generally found that customers are not aware of the benefits of green products and this lack of awareness about benefits of eco-friendliness influences their buying decisions and thus leads to the low demand of green products (Chen et al., 2006; Mudgal et al., 2010; Dhull and Narwal, 2016). Green innovations involve complex technologies and different demand pattern, thus there is a need to effectively manage the technology push and demand pull for green products that often act as a barrier to green innovations (Pinget et al., 2015).

Among sub-criteria barriers, lack of new technology, materials, processes, and skills to innovate (TG5) is ranked first. Innovation requires access to latest technologies, raw materials, and novel methodologies. SMEs lack on all these fronts and thus are unable to innovate to that extent. Lack of technology to design efficient products, inadequate facility to switchover to the new system (Revell and Rutherfoord, 2003; Perron, 2005) are few barriers under this category. Second among sub-criteria barriers is high change over costs from traditional to the green system (FE5), Mudgal et al. (2010) also found that adoption of the new system is often costly and switching over to the green system is considered unnecessary burden by the organizations and act as a major barrier. Third among sub-criteria barrier, is lack of capabilities in R&D and green innovation (TG1), organizations involved in innovations get first mover advantage, increase their market share significantly and gain over their competitors and this is possible only when organizations have more capabilities in R&D and green innovation as compared to its competitors (Lai et al., 2003).

Similar to ranking of barriers, solutions to overcome these barriers are ranked with respect to barriers using Fuzzy TOPSIS methodology. First among solution is designing of effective policies or framework by government and policy makers so as to reduce environmental degradation (S11), green innovations in case of SMEs are driven to a great extent by regulations and policies, but due to complex nature of these regulatory policies SMEs are unable to meet regulatory requirements (Brammer et al., 2012). Government need to develop a clear and simple framework to adopt green practices by SMEs through policies like

TG2			MC3	IK1	IK2	IK3	IK4	IK5
0.009,0.019,0.028			0.031,0.046,0.062	0.007,0.014,0.021	0.002,0.003,0.005	0.003,0.006,0.009	0.000,0.008,0.017	0.000,0.000,0.002
0.019,0.028,0.038			0.046,0.062,0.077	0.021,0.028,0.036	0.002,0.003,0.005	0.009,0.012,0.015	0.025,0.033,0.042	0.004,0.006,0.008
0.019,0.028,0.038			0.031,0.046,0.062	0.021,0.028,0.036	0.003,0.005,0.006	0.006,0.009,0.012	0.017,0.025,0.033	0.004,0.006,0.008
0.000,0.009,0.019			0.000,0.000,0.015	0.000,0.000,0.007	0.000,0.000,0.002	0.000,0.003,0.006	0.000,0.008,0.017	0.002,0.004,0.006
0.019,0.028,0.038			0.000,0.015,0.031	0.000,0.000,0.007	0.000,0.000,0.002	0.000,0.000,0.003	0.008,0.017,0.025	0.000,0.002,0.004
0.000,0.009,0.019			0.015,0.031,0.046	0.014,0.021,0.028	0.005,0.006,0.008	0.003,0.006,0.009	0.025,0.033,0.042	0.006,0.008,0.010
0.009,0.019,0.028			0.046,0.062,0.077	0.014,0.021,0.028	0.006,0.008,0.008	0.003,0.006,0.009	0.033,0.042,0.042	0.006,0.008,0.010
0.000,0.009,0.019			0.000,0.000,0.015	0.000,0.000,0.007	0.000,0.000,0.002	0.000,0.000,0.003	0.000,0.000,0.008	0.000,0.000,0.002
0.019,0.028,0.038			0.031,0.046,0.062	0.014,0.021,0.028	0.002,0.003,0.005	0.003,0.006,0.009	0.025,0.033,0.042	0.006,0.008,0.010
0.000,0.009,0.019			0.031,0.046,0.062	0.000,0.007,0.014	0.002,0.003,0.005	0.000,0.000,0.003	0.008,0.017,0.025	0.000,0.002,0.004
0.009,0.019,0.028			0.000,0.000,0.015	0.000,0.000,0.007	0.000,0.000,0.002	0.000,0.000,0.003	0.000,0.000,0.008	0.004,0.006,0.008
0.009,0.019,0.028			0.015,0.031,0.046	0.000,0.000,0.007	0.000,0.002,0.003	0.000,0.000,0.003	0.000,0.008,0.017	0.006,0.008,0.010
0.009,0.019,0.028			0.015,0.031,0.046	0.000,0.000,0.007	0.000,0.000,0.002	0.000,0.000,0.003	0.000,0.000,0.008	0.002,0.004,0.006
0.009,0.019,0.028			0.062,0.077,0.077	0.028,0.036,0.036	0.006,0.008,0.008	0.009,0.012,0.015	0.025,0.033,0.042	0.008,0.010,0.010
0.000,0.009,0.019			0.015,0.031,0.046	0.014,0.021,0.028	0.003,0.005,0.006	0.006,0.009,0.012	0.000,0.008,0.017	0.000,0.002,0.004
0.000,0.009,0.019			0.015,0.031,0.046	0.021,0.028,0.036	0.000,0.002,0.003	0.000,0.003,0.006	0.017,0.025,0.033	0.002,0.004,0.006
0.000,0.009,0.019			0.031,0.046,0.062	0.014,0.021,0.028	0.002,0.003,0.005	0.003,0.006,0.009	0.017,0.025,0.033	0.004,0.006,0.008
0.000,0.009,0.019			0.031,0.046,0.062	0.014,0.021,0.028	0.000,0.002,0.003	0.000,0.003,0.006	0.017,0.025,0.033	0.004,0.006,0.008
0.000,0.009,0.019			0.000,0.015,0.031	0.000,0.000,0.007	0.000,0.000,0.002	0.000,0.000,0.003	0.000,0.000,0.008	0.004,0.006,0.008
0.009,0.019,0.028			0.031,0.046,0.062	0.021,0.028,0.036	0.005,0.006,0.008	0.003,0.006,0.009	0.017,0.025,0.033	0.006,0.008,0.010
$v_1^+ = (0,0,0)$	$v_1^+ = (0,0,0)$	$v_1^+ = (0,0,0)$	$v_1^+ = (0,0,0)$	$v_1^+ = (0,0,0)$	$v_1^+ = (0,0,0)$	$v_1^+ = (0,0,0)$	$v_1^+ = (0,0,0)$	$v_1^+ = (0,0,0)$
$v_1^- = (1,1,1)$	$v_1^- = (1,1,1)$	$v_1^- = (1,1,1)$	$v_1^- = (1,1,1)$	$v_1^- = (1,1,1)$	$v_1^- = (1,1,1)$	$v_1^- = (1,1,1)$	$v_1^- = (1,1,1)$	$v_1^- = (1,1,1)$

environmental tax benefits, subsidized loans, technological support etc. Second solution is developing internal research practices at SMEs to carry out green innovation-related activities and acquiring scientific expertise (S8), SMEs lack in formal research wing and are thought of doing zero or minimal significant research. However, SMEs also have intangible assets in terms of their workforce who are directly involved in all the operational activity of the unit. Certain green innovations can be result of research at ground level, so SMEs need to set up a formal research wing for its employees to help them motivate and train for green innovations. Third among the solutions is setting up of environmental management systems (EMAS and ISO 14001) in SMEs for monitoring, auditing and measuring the systems and practices being followed to deal with issues of material, waste and energy use (S4), these practices includes participation of top management towards implementing environmental practices in the firm. SMEs need to implement practices like continuous monitoring and audit, environmental trainings, pollution control and prevention plans (Hajmohammad et al., 2013). Implementing these practices help SMEs grow economically, gain competitive advantage and become legitimate, thus avoiding any legal penalties by the government (Rennings et al., 2006). The fourth solution is focusing on investment recovery strategies like recovery, redeployment and reselling to reduce wastage of material (S19), investment recovery strategies are environmental management initiatives of the internal management which aims to reduce resource consumption and waste generation (Shrivastava and Hart, 1995; Bergmiller and McCright, 2009). SMEs which are always short on resources needed to implement these strategies effectively so as to reuse and recycle few resources. This will greatly reduce their burden both economically and environmentally. Next to solution is adopting simplified and standardized procedures for green practices at SMEs (S10), adopting standardized procedures can help SMEs to easily incorporate green practices. The green practices that are followed at other benchmark organizations can be directly adapted and thus can be beneficial for SMEs. SMEs being resource constraint and novice are not experts in developing new technologies and thus adopting standard procedures can help SMEs to easily turn green (Prakash and Barua, 2015).

Table 17
Final ranking of the solutions.

Solutions	D+	D−	CCj	Ranks
S1	0.360	35.684	0.990	6
S2	0.685	35.337	0.981	20
S3	0.447	35.589	0.988	12
S4	0.247	35.803	0.993	3
S5	0.442	35.592	0.988	11
S6	0.454	35.582	0.987	13
S7	0.574	35.457	0.984	18
S8	0.245	35.802	0.993	2
S9	0.616	35.410	0.983	19
S10	0.315	35.728	0.991	5
S11	0.177	35.871	0.995	1
S12	0.391	35.649	0.989	7
S13	0.409	35.629	0.989	8
S14	0.568	35.460	0.984	17
S15	0.474	35.563	0.987	15
S16	0.457	35.581	0.987	14
S17	0.556	35.477	0.985	16
S18	0.441	35.598	0.988	10
S19	0.249	35.802	0.993	4
S20	0.434	35.600	0.988	9

6. Managerial and practical implications of the research

The results obtained through this research has several managerial and practical implications, these are discussed as follows.

6.1. Identifying various barriers to green innovation in SMEs

Integrating green practices is the need of the hour for every organization to sustain and SMEs are also not left out. But, as compared to large enterprises, SMEs face a lot of constraints in adopting green practices in their regular working. To become environmentally and economically sustainable, SMEs need to carry out green innovations at their end. This study can act as a cornerstone for SMEs to identify hindering forces to green innovation and work towards overcoming them. Through extensive literature review and discussion with managers, seven main category barriers and thirty-six subcategory barriers were identified. Managers of case company, as well as other SMEs, can benefit from these barriers as they can work towards improving these barriers in their firm. Technological and resource-related barriers are ranked first among all barriers and managers can work towards improving their technologies and also look for avenues to acquire green resources from the market. Financial barriers are ranked up in the analysis and before opting for green practices, managers need to build strong financial capabilities in order to carry on green innovations and compete in the market.

Table 18
Variation in weights value for all barriers after varying TG weight value.

Barriers	Normalized Weight	Run 1 (0.1)	Run 2 (0.2)	Run 3 (0.3)	Run 4 (0.4)	Run 5 (0.5)	Run 6 (0.6)	Run 7 (0.7)	Run 8 (0.8)	Run 9 (0.9)
Technological	0.376	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Financial	0.200	0.288	0.256	0.224	0.192	0.160	0.128	0.096	0.064	0.032
Market	0.136	0.197	0.175	0.153	0.131	0.109	0.087	0.066	0.044	0.022
Knowledge	0.110	0.159	0.142	0.124	0.106	0.089	0.071	0.053	0.035	0.018
Government	0.072	0.105	0.093	0.081	0.070	0.058	0.046	0.035	0.023	0.012
Managerial	0.059	0.085	0.076	0.066	0.057	0.047	0.038	0.028	0.019	0.009
External partnership	0.046	0.066	0.059	0.051	0.044	0.037	0.029	0.022	0.015	0.007
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

6.2. Developing a framework for providing solutions to overcome green innovation related barriers

Apart from identifying and ranking barriers to green innovation, this study takes a step further to identify solutions/strategies which can help overcome these barriers. A total of twenty solutions are identified through literature and manager opinion. Fuzzy TOPSIS is applied to rank these solutions so that managers have a clear idea about important barriers. Designing of effective policies and framework by government and policy makers to reduce environmental degradation is ranked as one of the most important solutions. Although the government has a number of policies for SMEs to adopt green practices and carry out innovations, most of the times either policies are not stringent or SME managers are not aware of actual benefits of these policies. So managers can exploit these policies and also suggest some changes during their annual review to the government. Similarly, a score of other solutions are suggested and managers can practically try to implement these solutions like green designing, internal research, recycling to name a few; in order to effectively develop green innovations at their end.

7. Sensitivity analysis

Sensitivity analysis is a powerful tool to check the robustness of the model and eliminate biasness during data collection and analysis (Prakash and Barua, 2015; Gupta and Barua, 2017). In order to execute sensitivity analysis, the weight of barrier in the main category that got highest weight (TG in this case) is varied from 0.1 to 0.9 and subsequently, weights of all the main category barriers are varied. A total of ten different runs were performed in sensitivity analysis. Table 18 shows weights of all main criteria barriers when the weight of TG is varied.

Next step is to use these main criteria barrier weights to calculate global weights of sub-criteria barriers and these global weights are used in Fuzzy TOPSIS methodology again for ten different runs to calculate new ranking of solutions in these ten different conditions. The results are presented in Table 19.

Table 19 and Fig. 2 shows that ranking of the solutions doesn't vary much even after varying the weights of main criteria barrier. Hence the results are free from biasness and proposed model is robust.

8. Feedback and validation of the results

To further validate the results and obtain feedback from managers a further step was undertaken. Three managers, different from those who participated in this study were approached. Manager 1 is an environmental manager of a large enterprise and is involved in auditing and monitoring SMEs associated with the organization he is working with. Manager 2 and 3 are owners of two different SMEs. All the managers are having minimum of ten years of experience. Managers were presented with Tables 2 and 3 where all the barriers and solution to green innovation are listed. Also they were presented with results as shown in Tables 14 and 17. Managers were mostly in conformance with our results and pointed out few observations. Manager 1 is of the opinion that managerial and human resource related barriers must have got higher ranking as compared to financial and insufficient knowledge related barriers. According to Manager 1, often managers and workforce of SMEs are reluctant to change and adopt green practices even when executing small changes require very little economic support and knowledge, but they do not want to disturb the status quo and tend to carry on the regular practices. Lack of rewards for green innovation is also an important barrier cited by the manager and he was of the view that SMEs should come up with better reward systems for its employees in order to motivate them to innovate.

Table 19
Ranking of solutions during sensitivity analysis when weight of criteria TG varies from 0.1 to 0.9.

Solutions	Run 1 (0.1)	Run 2 (0.2)	Run 3 (0.3)	Run 4 (0.4)	Run 5 (0.5)	Run 6 (0.6)	Run 7 (0.7)	Run 8 (0.8)	Run 9 (0.9)	Normalized
S1	9	8	6	6	6	6	5	5	4	8
S2	20	20	20	20	20	20	19	19	18	20
S3	16	15	13	11	9	7	7	7	7	13
S4	4	4	4	2	2	2	2	2	2	4
S5	8	9	9	12	13	15	16	16	15	9
S6	10	10	11	14	14	13	14	14	14	10
S7	15	16	17	18	18	19	20	20	20	16
S8	2	2	2	3	4	4	4	4	5	2
S9	18	18	19	19	19	18	18	18	19	18
S10	5	5	5	5	5	5	6	6	6	6
S11	1	1	1	1	1	1	1	1	1	1
S12	7	7	7	7	7	9	11	11	12	7
S13	6	6	8	8	12	12	15	15	16	5
S14	19	19	18	17	16	16	13	12	11	19
S15	13	13	15	15	15	14	12	13	13	14
S16	14	14	14	13	11	11	10	9	9	15
S17	17	17	16	16	17	17	17	17	17	17
S18	12	12	12	10	10	10	9	10	10	12
S19	3	3	3	4	3	3	3	3	3	3
S20	11	11	10	9	8	8	8	8	8	11

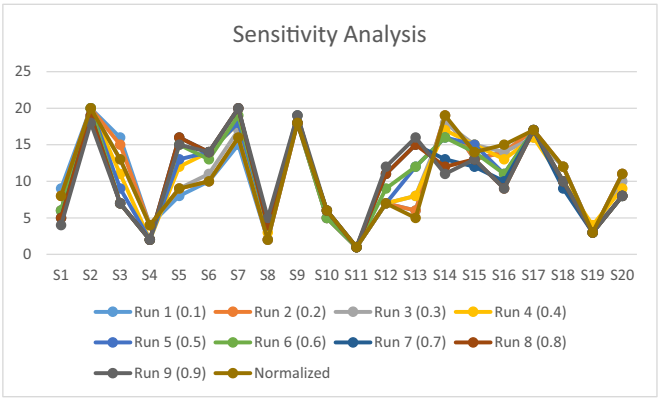

Fig. 2. Results of sensitivity analysis for solutions.

Manager 2 believed that technological, resource and economic barriers are most important as SMEs are having less economic backing, hence they are unable to acquire green resources and modern technologies so as to upgrade their infrastructure. Manager 3 was of the opinion that lack of awareness among SME managers and also customers is a major barrier for green innovation. However, resources is the most crucial barrier according to Manager 3, as SMEs are unable to do design modification, material modification on its own, because of the absence of resources and technological support. Overall managers were satisfied with the results of both barriers and solutions.

9. Conclusions and scope of future work

Adoption of green practices, the production of green products and recycling activities are still at nascent stage in developing economies like India. Small and medium sector is especially lagging behind because of their limited size and small resource base. Green innovations can be a solution to their problem of implementing green practices, but they are also marred by many barriers. Neither studies related to barriers of green innovation in SMEs are present in context of developing countries, nor a framework to overcome these barriers is given anywhere in the literature. A deeper understanding of these barriers from academic managers and practitioners of green practices is required in the context of SMEs in developing countries.

To address this gap, the present study has developed a comprehensive framework to identify barriers of green innovation and also solutions to overcome these barriers. The framework was developed with the help of literature review and help from four managers of Indian SMEs. A total of seven main category barriers and thirty six subcategory barriers were identified, along with twenty solutions to overcome these barriers. These barriers were than subjected to Best-Worst analysis to rank them. The results of the analysis showed that managers of case companies found "technological and resource related barriers" as most important barriers followed with "financial and economic barriers" and "market and customer related barriers". Further, Fuzzy TOPSIS analysis was used to rank solutions to overcome these barriers. "Designing of effective policies and framework by government and policy makers to reduce environmental degradation" is ranked first among solutions followed by "developing internal research practices at SMEs to carry out green innovation related activities and acquiring scientific managerise" and "focusing on investment recovery strategies like recovery, redeployment and reselling to reduce wastage of material". Working on these solutions can greatly benefit managers of SMEs for their green initiatives.

Although the study was carried out in a detailed way, but like other studies, it has some limitations. Given that this study involves case study of four Indian SMEs, so we need to compare the results of the current study with similar industries of other countries. This study uses BWM and Fuzzy TOPSIS for ranking barriers and solutions respectively; however other MCDM techniques like VIKOR, MAUT, AHP, ELECTRE, SMART etc. can also be explored to compare the results for any changes. Also, this study can be further explored by taking a larger sample of SMEs and statistically validating the findings. Lastly, we believe that this is an initial attempt to explore barriers to green innovation in SMEs and a further research can shed much more light on this topic.

Annexure 1

Abbreviations

AHP	Analytical Hierarchal Process
ANP	Analytical Network Process
BWM	Best Worst Method
EMS	Environment Management System
	ELECTRE ELimination Et ChoixTraduisant la REalité (Elimination and Choice Expressing Reality)
FPIS	Fuzzy positive ideal solution
FNIS	Fuzzy negative ideal solution
ISO	International Organization for Standardization
MAUT	Multi Attribute Utility Theory
MCDM	Multi Criteria Decision Making
	PROMTHEE Preference ranking organization method for enrichment evaluation
R&D	Research and Development
SMART	Simple Multiple Attribute Rating Technique
SME	Small and Medium Enterprises
TOPSIS	Technique for order preference by Similarity to Ideal Solution
VIKOR	VlseKriterijuskaOptimizacija I KomoromisnoResenje

Annexure 2

Definition 1. A fuzzy set $A^{\sim}$ in a universe of discourse X is characterized by a membership function $\mu_{a}{\sim}(x)$ which associates with each element x in X a real number in the interval [0,1]. The function value $\mu_{a}{\sim}(x)$ is termed the grade of membership of x in A.

Definition 2. A triangular fuzzy number $a^{\sim}$ can be defined by a triplet (a_1, a_2, a_3). The membership function $\mu_{a}{\sim}(x)$ is defined.

$$\mu_{a^{\sim}}(x) = \begin{cases} 0, & x<a_1 \\ \dfrac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ \dfrac{x-a_3}{a_2-a_3}, & a_2 \le x \le a_3 \\ 0, & x>a_3 \end{cases}$$

Let $a^{\sim}$ and $b^{\sim}$ be two triangular fuzzy numbers parameterized by the triplet (a_1, a_2, a_3) and (b_1, b_2, b_3), respectively, then the operational laws of these two triangular fuzzy numbers are as follows:

$$a^{\sim}(+)b^{\sim} = (a_1, a_2, a_3)(+)(b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3),$$
$$a^{\sim}(-)b^{\sim} = (a_1, a_2, a_3)(-)(b_1, b_2, b_3) = (a_1 - b_3, a_2 - b_2, a_3 - b_1),$$
$$a^{\sim}(\times)b^{\sim} = (a+1, a_2, a_3)(\times)(b_1, b_2, b_3) = (a_1.b_1, a_2.b_2, a_3.b_3),$$
$$a^{\sim}(\div)b^{\sim} = (a_1, a_2, a_3)(\div)(b_1, b_2, b_3) = (a_1 \div b_3, a_2 \div b_2, a_3 \div b_1),$$
$$a^{\sim} = (ka_1, ka_2, ka_3).$$

Definition 3. Let $a^{\sim} = (a_1, a_2, a_3)$ and $b^{\sim} = (b_1, b_2, b_3)$ be two triangular fuzzy numbers, then the vertex method is defined to calculate the distance between them.

$$d(a^{\sim}, b^{\sim}) = \sqrt{\frac{1}{3}\left[(a_1-b_1)^2 + (a_2-b_2)^2 + (a_3-b_3)^2\right]}$$

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