ANALYSIS AND DESIGN OF A FRAMEWORK FOR GREEN INNOVATION IMPLEMENTATION IN SMEs

Ph.D. THESIS

by

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ROORKEE

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"ANALSYIS AND DESIGN OF A FRAMEWORK FOR GREEN INNOVATION IMPLEMENTATION IN SMEs"** in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of Management Studies of the Indian Institute of Technology Roorkee is an authentic record of my own work carried out during a period from July, 2015 to February, 2019 under the supervision of Dr. Mukesh Kumar Barua, Associate Professor, Department of Management Studies, Indian Institute of Technology Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institution.

(HIMANSHU GUPTA)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

(Mukesh Kumar Barua)
Supervisor

The Ph.D. Viva-Voce Examination of Himanshu Gupta, Research Scholar, has been held on ………………….

Chairperson, SRC **Signature of External Examiner**

This is to certify that the student has made all the corrections in the thesis.

(Mukesh Kumar Barua) **Head of the Department**

Supervisor

Date:

ABSTRACT

Globalization has produced remarkable changes in business structures and organizations across the world. The businesses are expanding at a rapid pace due to globalization and industrialization. With exponential expansion in business, the waste and pollution generated due to this expansion have also increased rapidly causing deterioration of the environment. Compelled by deteriorating environmental condition due to rapid industrialization and market pressures, environmentalists, industrialists as well as academicians are concerned about incorporating green practices into the manufacturing processes. Further, SMEs being the backbone of any economy is the major contributor in terms of manufacturing output and also contribute significantly towards the environmental degradation. But SMEs being resource constrained are unable to mitigate the harmful impact of their production processes on the environment. Consequently, to address the rising environmental concern, government and other stakeholders need to come up with innovative ways to reduce environmental degradation. Thus keeping this in mind this study aims to analyze and develop a model for green innovation adoption and implementation in SMEs so that SMEs can effectively manage environmental concerns.

This research work has five objectives and the whole thesis is divided into eight chapters. The first chapter is an introduction and presents the basic background and the need for the study. It highlights the importance of SMEs in economic growth of the country and also in the innovation process. The second chapter deals with literature review and it provides an in-depth and exhaustive review of the literature on green innovation. Detailed definitions of green innovation and types of green innovation are also discussed. An extensive review of the literature on enablers and barriers to green innovation in SMEs is also presented in this chapter. Third chapter presents the research approach followed. It discusses about various methodologies adopted and their brief description. Fourth chapter is aimed to assess the current situation of green innovation SMEs in selected SMEs. PPS and TPS approach is used to assess the current situation of green innovation in SMEs and results indicate that the level of green adoption is poor in Indian SMEs. Fifth chapter deals with the development of a framework to identify barriers of green innovation and also solutions to overcome these barriers. A total of seven main category barriers and thirty six sub category barriers are identified, along with twenty solutions to overcome these barriers.

Technological and resource related barriers emerged as the most important barriers followed with financial and economic barriers and market and customer related barriers. Sixth chapter deals with identifying enablers of green innovation in SMEs and supplier selection among SMEs on the basis of these enablers. Forty two enablers are identified and supplier selection using case of seven SMEs is done on the basis of these enablers. Seventh chapter deals with the development of a conceptual framework for green innovation adoption and implementation in SMEs. Mixed method research is adopted for this purpose. The results have indicated that a 'green competency building based approach' is the key strategy to solve the present research problem. 'Green technology and research based approach' and 'green networking based approach' have occupied the second and third positions respectively. This framework can act as a benchmark for other SMEs to adopt green innovation for better environmental management.

Keywords: Green innovation, SMEs, Green competencies, Best Worst method, Fuzzy TOPSIS, Options Profile Methodology, Options Field Methodology, DEMATEL.

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(Himanshu Gupta)

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INTRODUCTION

1.1 Background

Earth's resources are finite and are continuously depleting due to large scale industrialization and globalization, thus forcing governments and environmental activist all over the world to critically think about the alternate as well as the judicious use of these resources, their other major concern is the waste and effluents being disposed off in the environment due to rapid industrialization, thus causing negative impact on the environment (Roscoe et al., 2016). Today, organizations are under tremendous pressure to incorporate environmental friendly processes and products, due to increased awareness and surmounting concern of various agencies and governments globally (Arimura et al., 2011; Choudhary et al., 2016).

Intergovernmental Panel on Climate Change (IPCC, 2013) in their meeting pointed out that manufacturing organizations are responsible for major environmental problems like environmental pollution, resources depletion and global warming. This has led the NGO's and various government agencies all over the world to emphasize the need to switch from traditional practices to new innovative and green technologies for manufacturing and production. Further UNEP (2016) in their agenda for sustainable development identified resource efficiency and sustainable production and consumption as a standalone goal for 2030, it also identified three key areas that need to be focused to achieve this goal viz. creating an enabling environment, adopting sustainable production and consumption practices across sectors and global supply chains and following sustainable consumption and lifestyles, among these adopting sustainable production and consumption practices across sectors and global supply chains has been signified as most important and further key areas to achieve this goal are highlighted that includes sustainable development in tourism, building and construction and most importantly adopting green innovations across supply chains.

Consequently organizations around the world have recognized the need to change their business operations and respond effectively and efficiently so as to achieve the objective of sustainable development (Pujari, 2006). This sudden focus on sustainability issues threatens the existing manufacturers to either change the 'rules of game' or cease to exist and make way for new players (Tidd et al., 2005). To overcome these challenges organizations must ascertain new solutions of manufacturing like improved manufacturing practices and product design and new ways to dispose of waste into environment without causing damage to the environment (Belin et al., 2009). Innovation is essential to respond to growing pressures from customers, regulators and other stakeholders (Porter & van der Linde, 1995). Since most of the concerns from customers and regulators are related to environment, therefore green innovation is a vital solution to overcome these concerns (Olugu et al., 2011). However, green innovation which comprises of both product and process innovation is not as simple as technological innovations. It encompasses of changing the status quo, changing the norms of society, various structures, mindset of people and has to face resistance from people and thus involves a large amount of risk (Tidd et al., 2005, Arundel and Kemp, 2009). Also it is under-stood that downstream partners in supply chain are one of the largest source of waste for organizations (Dath et al., 2009; Arimura et al., 2011). According to Chiou et al. (2011) suggested that in order to relieve pressure of buyer's requirement, companies should work closely by integrating their business processes with their suppliers and also provide technical assistance, guidance to implement environmental management systems and arrange to organize training programs to improve the environmental performance of their suppliers.

1.2 SMEs as driver of Economic Growth and Innovation

SMEs all over the world are the source for driving innovations and economic growth of the country. Figure 1.1 represents the dynamics of both innovation and economic growth. The rate at which SMEs are created and the rate at which SMEs are dying (or SME destruction) decides the total number of SMEs in an economy. SMEs come into existence due to available market opportunities for their products. As more and more markets open up, the number of SMEs in the country also increases. As SMEs are one of the largest job providers of any economy, so with increase in number of SMEs, the number of jobs also increases, which in turn leads to rise in per capita income (Okonta and Pandya, 2007; Hassan and Olaniran, 2011). Due to increase in purchasing power of the people of the country, they tend to buy more products and this leads to increase in overall consumption of the products. Now, due to increase in consumption, more and more SMEs needs to be setup and hence the rate of SME creation increases. As most of the SMEs have their localized roots with owners belonging to the same country, so revenue generated from SMEs will stay in country and benefit country, which increases economic growth of the country. Economic growth is also driven by reinforcing loop of innovation. With the rise in number of products and consequently number of SMEs, the knowledge of SMEs about their products and industry also increases. With greater knowledge about their products and business processes, SMEs are placed in a better situation to innovate both in terms of product and process innovations, the result of innovation is that it gives competitive advantage to SME over other SMEs and helps their business to flourish. As their business grows, the profits also increases. This loop continues and with increasing profits, the new markets also open ups and people tend to capture this opportunity to grow in new market by establishing more SMEs, thus the rate of SME creation keeps on increasing. Apart from economic growth and innovation, SMEs play a substantial role in fulfilling other development goals of a country. They are a source of income to underprivileged, who did not had enough opportunities and SMEs also help critical sectors like health and education to grow (Kotelnikov and Kim, 2007; Pandya and Anand, 2008).

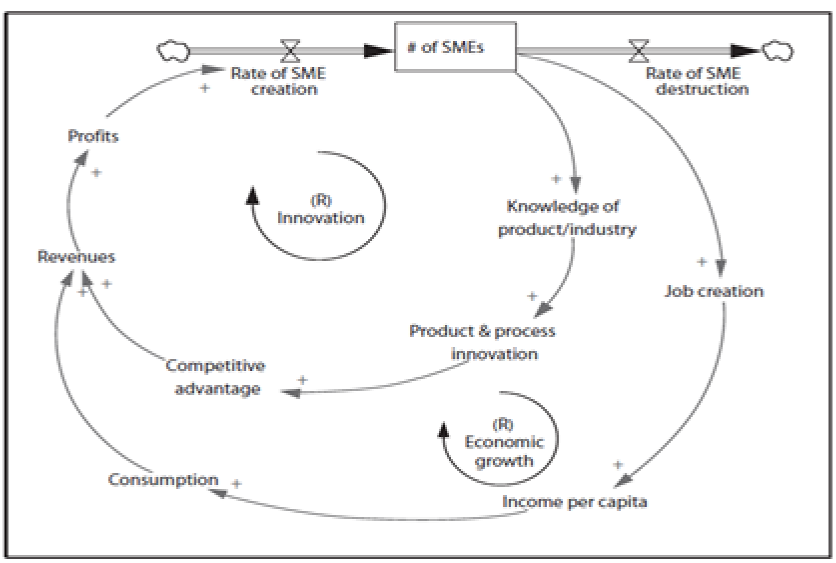

Fig.1.1 SMEs as a Driver of Economic Growth and Innovation (Kotelnikov and Kim, 2007)

1.3 Global Competitive Index Report (2017-2018) and Global Innovation Index (2018)

Table 1.1 Comparison of Global Competitive Index Parameters of few Asian Countries

S.No.	Parameter	India's Rank	Hong Kong's Rank	Singapore's Rank	Korea's Rank	China's Rank	Taiwan, China
1	Burden of government regulation	20	4	1	95	18	30
2	Transparency of government policymaking	50	6	2	98	45	22
3	Quality of overall infrastructure	46	3	2	14	47	19
4	Quality of railroad infrastructure	28	3	4	10	17	12
5	Quality of the educational system	26	21	2	81	29	31
6	Local availability of specialized training services	49	12	4	52	55	33
7	Extent of staff training	34	19	5	41	36	25
8	No. procedures to start a business	131	2	7	2	104	7
9	Effect of taxation on incentives to work	32	4	1	60	45	24
10	Availability of financial services	34	6	4	81	54	13
11	Easy access to loans	35	13	3	90	34	6
12	Availability of latest technology	72	29	15	23	81	30
13	Firm-level technology absorption	73	27	14	23	58	29
14	Local supplier quantity	53	7	73	11	52	6
15	Local supplier quality	69	14	29	30	56	21
16	Production process sophistication	41	19	16	24	39	21
17	Capacity for innovation	42	28	20	35	44	22
18	Quality of scientific research institutions	35	28	12	32	36	26
19	Company spending on R&D	23	27	17	28	21	10
20	University-industry collaboration in R&D	26	15	8	27	28	16
21	Availability of scientists and engineers	32	23	9	38	29	30
22	Utility patents/million population	63	n/a	12	5	30	n/a
23	Government procurement of advanced technology products	8	16	5	32	10	34
	Overall Global Competitive Index Ranking Out of 137	**40**	**6**	**3**	**26**	**27**	**15**

Source: Global Competitive Index Report (2017-2018)

The Table 1.1 presents a comparison on various parameters of Global Competitiveness Index among four Asian Tigers, China and India. As can be seen that India is lacking behind its major competitors of Asia in overall Global Competitive Ranking where it has obtained 40th rank as compared to others where China has obtained 27th rank, Korea obtained 26th rank, Taiwan obtained 15th rank, Hong Kong obtained 6th rank and Singapore obtained 3rd rank overall among 137 nations. India's poor ranking as compared to its Asian competitors is mainly attributed due to its poor performance on many fronts like lack of procedures to start a new business, lack of availability of latest technologies, lack of firm level technology absorption, lack of capacity for innovation and lesser numbers of patents being filed. To improve global ranking India needs to build a climate of innovation for its organizations, especially SMEs as they are the major contributor of GDP. Technology absorption and technology development through technology innovation can be a key solution to overcome this challenge to compete with Asian neighbors. Thus the need for technological development of SMEs through innovation plays a vital role.

Similar to Global Competitiveness Report, another agency namely INSEAD, prepares Global Innovation Index every year for participating countries. Table 1.2 presents the comparative Global Innovation Index for India and Asian Tigers. The comparison shows that India is lagging behind on almost all the parameters of Global Innovation Index as compared to its Asian neighbors. Special emphasis needs to be made for environmental performance on which India is ranked at 123 out of 126 participating nations. This shows the need for environmental and green innovation adoption in India. India's strength lies in graduates in science & engineering, ICT services exports, trade, competition & market scale, domestic market and creative goods exports. Whereas the major weaknesses of India include political stability & safety, ease of starting new business, Overall education, ICT use; environmental performance and new business.

Table 1.2 Comparison of Global Innovation Index Parameters of few Asian Countries

S.No.	Parameter	India's Rank	Hong Kong's Rank	Singapore's Rank	Korea's Rank	China's Rank
1	Political stability and safety	110	24	1	56	91
2	Government effectiveness	65	5	1	30	48
3	Regulatory environment	72	3	1	45	100
4	Ease of starting a business	114	3	6	9	73
5	Ease of resolving insolvency	91	40	25	5	52
6	Education	112	52	42	28	13
7	Graduates in science and engineering	6	n/a	n/a	12	n/a
8	Research and development	32	31	10	1	17
9	Information and communication technologies (ICTs)	83	9	8	2	45
10	Logistics performance	34	9	5	24	26
11	Environmental performance	123	n/a	45	53	96
12	ISO 14001 environmental certificates/bn PPP$ GDP	68	54	40	41	15
13	Ease of getting credit	26	26	26	49	61
14	Investment	35	7	2	43	84
15	Trade, competition and market scale	16	14	17	29	2
16	Knowledge intensive employment	91	28	2	70	n/a
17	Firms offering formal training, % firms	38	n/a	n/a	n/a	1
18	University/industry research collaboration	25	15	8	26	27
19	State of cluster development	30	6	9	27	26
20	Knowledge absorption	66	3	2	16	12
21	Knowledge creation	55	49	30	3	4
22	Knowledge impact	42	21	13	38	2
23	Knowledge diffusion	25	18	4	15	22
24	Intangible assets	85	32	44	2	1
25	Creative goods and services	63	8	19	37	28
26	Online creativity	67	14	32	37	84
	Overall Global Innovation Index Ranking Out of 126	**57**	**14**	**5**	**12**	**17**

Source: Global Innovation Index (2018)

1.4 MSMEs in India

The MSMED Act, 2006 classifies MSMEs into two broad categories as manufacturing and service sector MSMEs. The classification is done on the basis of investment in plant and machinery for manufacturing sector and investment in equipment for service sector. The detailed classification is presented in Table 1.3.

Table 1.3 Classification of MSMEs as per MSMED Act, 2006

Manufacturing Sector	
Criteria	Investment in plant & machinery
Micro Enterprises	Does not exceed twenty five lakh rupees
Small Enterprises	More than twenty five lakh rupees but does not exceed five crore rupees
Medium Enterprises	More than five crore rupees but does not exceed ten crore rupees
Service Sector	
Criteria	Investment in equipment
Micro Enterprises	Does not exceed ten lakh rupees:
Small Enterprises	More than ten lakh rupees but does not exceed two crore rupees
Medium Enterprises	More than two crore rupees but does not exceed five core rupees

According to new definition by government of India in 2018, businesses with revenue of as much as 5 crore will be called a micro enterprise, those with sales between 5 crore and 75 crore will be deemed as small and those with revenue between 75 crore and 250 crore will be classified as medium-sized enterprises. The Micro Small and Medium Enterprises (MSME) is next only to agriculture sector in terms of generating employment. Over the last five decades, the MSME sector has emerged very dynamic and vibrant. It not only generates employment but also stimulates economic and social growth of the country. It has contributed significantly towards the industrial development of the country by fostering entrepreneurship and acting as ancillary units to large organizations. The share of manufacturing MSME in GDP of India is about 28.77 %. There are total 633.88 lakh MSMEs in India out of which about 196.65 lakh (31%) are manufacturing MSMEs. The MSME sector generates around 11.10 crore jobs in India and out of which manufacturing MSMEs alone generate about 360.41(32%) lakh jobs (Annual Report, MSMEs, 2017-18). The above data shows the importance of MSMEs in economic and social growth of India. For Indian economy to boom, it is necessary that Indian MSMEs also grow and be an integral part of overall growth of the country. But MSMEs have various challenges like Inadequate access to market and marketing platform, Lack of access to new technology, Lack of required credit and cumbersome regulatory practices. Thus the need of the hour is to overcome these challenges so that MSMEs can grow. One such approach to overcome these challenges is through technological innovations by MSMEs. With challenges come some opportunities also like leveraging the e-commerce trend, wherein the MSMEs can go digital and make their presence felt in the business environment, this will give them the required edge over their competitors. Other can be adoption of technology, adoption of social media and cloud technology to manage and promote their business can have impact on their growth and operation efficiency. Various schemes like 'Skill India', 'Startup India' and 'Make in India' are being promoted by government. The MSMEs need to make use of these schemes for their benefit. With a significant rise in technology and innovation, a business-friendly atmosphere for the SMEs will become a reality.

1.5 Types of Innovation

- ***Technological innovation***: A technological innovation process is defined as "the adoption of new technology or implementation of an improved production process at the organization. Technological innovation might involve change in organization structure, working processes or new and innovative ways of human resource management" **(***Madrid-Guijarro et al., 2009*).
- ***Product innovation***: These represents significantly enhanced product characteristics and the intended use of the goods or services (OECD and Eurostat, 2005).
- ***Process innovation***: These represents substantial changes in methods, tools and software. It also include better production or delivery methods.
- ***Marketing innovation***: It refers to new and improved ways to promote the product, through better packaging, improved product design and competitive pricing strategy.
- ***Organizational innovation***: It refers to reorienting the organization workplace using improved or new business methods and practices or through external support.
- ***Green innovation*****:** "Green innovations are solutions that are intentionally designed to reduce the environmental impact of production, consumption and disposal activities, even if the underlying motive or intention is to reap the benefits of addressing environmental concerns. Green innovation is a relative term that refers to product innovations that differ from conventional product innovations in that they contribute to

the reduction or prevention of environmental damage more than conventional products" (Triebswetter and Wackerbauer, 2008).

1.6 Need for Green Innovation

The UNEP in its annual meeting in 2016 has laid out an agenda for Sustainable development. Resource efficiency and sustainable consumption and production is the main goal for UNEP 2030 agenda for sustainable growth and development. This goal not only impacts the environmental improvement, but also involves sustained economic growth of the country through reduction in poverty, climate change and creating a sustained environment to live. The UNEP (2016) meeting came out with three main focus areas for sustained growth. These are:

Enabling Environment – It refers to giving support to participating countries in terms of creating an environment in which various policies are made that promotes the change to green through better resource efficiency and sustainable production and consumption methods.

Sectors and Supply – It refers to the adoption of sustainable consumption and production practices in various sectors across the supply chain globally through participation of various regulatory bodies and business units.

Lifestyle and consumption – It refers to enhancing the lifestyle of the consumers in various countries and businesses so that they can make sustainable consumption and production as integral part of their day to day life through proper decision making.

Under *Sectors and Supply* key area, following areas have been identified as critical for sustainable development: Tourism, Building and Construction, *Green Innovation and Supply Chains.*

1.7 Types of Green Innovation

Andersen (2008) demonstrated that functional and operational dimensions of green innovation are of five types:

- ***Add-on green innovations*** (pollution- and resource handling technologies and services): The technologies and services typically have limited systemic effect as they generally are added-on to existing production and consumption practices (which is cost effective) without influencing these significantly.

- ***Integrated green innovations*** (cleaner technological processes and cleaner products): In this type of green innovation process followed for the production the product obtained is more eco-efficient through technical or organizational changes.
- ***Alternative product green innovations*** (new technological paths): In this type of green innovation, there is no drastic change in environmental impact of the product. But this type of innovation involves finding alternate technological solutions for the existing process which in turn will lead to gradual decrease in environmental impact of the product. Example include use of renewable energy technologies in turn of fossil fuels.
- ***Macro-organizational green innovations*** (new organizational structures): This type of green innovation involves reorganizing organizational structures that allow better interrelationship between different functional departments, organization and workplaces so that technological infrastructure could be optimally utilized.
- ***General purpose innovations:*** These type of innovation refers to general use technologies that are commonly not in picture but have indirect effect on both economy and innovation process of the organization.

Another classification of green innovations is given by Reid and Miedzinski (2008) as:
Target based: The target is the focus area of the green innovation. It includes –

- Institutions
- Organisations and marketing
- Products and processes

Mechanism based: The mechanism is the method or nature of change of a target. It includes –

- Modification
- Re-design
- Alternatives
- Creation

Impact based: Impact of green innovation is the targets effect on the environment**.** It includes –

- Pollution reduction
- Cleaner Production
- Increasing green efficiency

- Life-cycle thinking
- Closed-loop production
- Industrial environment

1.8 Comparison between conventional and green innovation

Conventional innovations are different from green innovations in some aspects. The difference between green and conventional innovation is discussed in Table 1.4.

Table 1.4 Comparison of Conventional and Green Innovation

	Conventional innovation	**Green innovation**	**Source**
Externalities	• Knowledge externalities	• Knowledge externalities • Environmental externalities	Jaffe et al., (2005); Dean (2013)
Drivers	• Technology push • Market pull	• Technology push • Market pull • Regulatory push/pull	De Marchi (2012); Higgins and Yarahmadi (2014); Pinget et al. (2015)
Barriers	• Economic barriers (costs, risks, customer responsiveness) • Technological barriers • Organizational barriers	• Similar, but barriers are likely to be higher, due to more uncertainties	Abdullah et al. (2016) ; Madrid-Guijarro et al. (2009) ; Pinget et al. (2015)
Level of uncertainty	• High	• Higher	Bönte and Dienes (2013); De Marchi (2012); De Marchi and Grandinetti (2013)

1.9 Green Innovation/Eco-Innovation performance comparison of India

The Asia-Europe Meeting (ASEM) SMEs Eco-Innovation Center (ASEIC) came into origin in the year 2011. The purpose of the collaboration of Asian and European countries is to promote green technological growth and green innovation implementation in SMEs of both the continents. ASEIC defines green/eco-innovation as “an idea to achieve environmental improvements, to enhance competitiveness of enterprise and to provide new business opportunities by means of using low cost and non-technology intensive methods”. ASEM has developed an eco-innovation index (ASEI). It evaluates the eco-innovation performance of ASEM member countries and serves as a basis for future strategy development on spreading and improving eco-innovation in Asia and Europe. Table 1.5 shows the eco-innovation performance comparison of India with Singapore which is ranked 2nd in Global Competitiveness Index (as shown in Table 1.1).

Table 1.5 Comparison of Green/eco-innovation parameters

S.No.	Parameters	India's Score	Singapore's Score	Korea's Score	China's Score
1	Eco-innovation Capacity	49.35	80.62	74.88	67.44
2	Economic Competitiveness	39.43	97.97	69.92	67.07
3	Country's General Innovation Capacity	31.15	87.73	78.93	59.66
4	Awareness of Sustainability Management	77.46	56.15	75.79	75.60
5	Eco-Innovation Supporting Environment	35.03	93.85	44.12	32.89
6	Implementation of Environmental Regulations	35.03	93.85	44.12	32.89
7	Eco-Innovation Activities	17.73	13.41	21.80	33.13
8	Firm's participation on Environmental Management System	3.59	17.28	9.05	25.35
9	Green Patents	15.70	19.73	53.81	59.42
10	Activeness of Renewable Energy Utilization	33.89	3.22	2.55	14.63
11	Eco-Innovation Performance	25.36	65.18	54.24	50.00
12	Level of Environmental Impact on Society	4.01	100.00	74.30	17.84
13	CO2 Emission Intensity	63.08	93.85	52.31	21.54
14	Country's Energy Sustainability Level	0.37	34.75	34.94	27.73
15	Water Consumption Intensity	11.93	95.52	95.84	82.88
16	Green Industry Market Size	47.41	1.80	13.81	100.00
	Overall ASEI (2015)	**31.86**	**63.26**	**48.76**	**45.87**

Source: ASEIC, 2015

India’s eco-innovation capacity is quite low as compared to its Asian neighbors. This shows the need for infrastructure and technology development to carry out green/eco-innovations. Similarly the supporting environment score for eco-innovation is also quite low (higher only than China). Further, eco-innovation performance is significantly low as compared to other Asian countries. These scores shows that neither we have resources, infrastructure, trained manpower and nor we have strong management commitment towards eco-innovation. Contrary to other parameters, the green industry market size is quite high in India as compared to its Asian neighbors. But still we are not able to fully develop green innovation capabilities. So there is need to identify barriers to green innovation in Indian SMEs that have led to poor scores in various green innovation parameters and after that there is need to effectively design a model for green innovation adoption/implementation in Indian SMEs.

1.10 Green innovation and SMEs

SMEs are under constant pressure for greening their products, but they are often stuck in the dilemma whether to maximize their profits or reduce environmental impacts of their products. Green innovation acts as bridge between these two thoughts for SMEs. It provides them necessary opportunities to reduce costs, environmental impacts and also increase their share of profits. Green innovation not only improves company’s image and maximize profits, it also helps in adhering to the number of environmental regulations and standards being implemented by the regulatory bodies across the globe. SMEs are under constant risks due to various reasons and government in every country is facing challenge to provide a conducive and constructive environment for SMEs to explore avenues of green growth and carry out innovative activities. There are numerous barriers faced by SMEs, which include, limited availability of the finances, lack of knowledge about products and processes, poor managerial skills and lack of knowledge to protect intellectual property. Green innovation which is becoming a global phenomenon can help overcome these barriers and thus in turn help review the economy across the globe and also build a sustainable future for all (ASEIC, 2015).

The ‘green innovation’ can help solve a variety of issues related to environment that are now faced by countries across the globe. These issues include,

• *Green (or cleaner) products* – These include developing products that can be easily remanufactured or refurbished and have minimum effect on environment throughout their life cycle;

• *More efficient processes* – It includes the modified processes that can help minimize the waste and also effectively reuse or recycle it;

• *Alternative technologies* – It involves development of alternate technologies like renewable energy in place of fossil fuels that can help decrease the greenhouse gas emissions and other harmful gases also;

• *Systems innovation* – It refers to development of system to assess the negative impact of industrial processes on the environment (Vickers and Vaze, 2009).

Figure 1.2 represents the typology of innovations. In Figure 1.2, the vertical axis measures the "*degree of novelty of the knowledge"* involved and the horizontal axis measures the "*degree of novelty of the application"* of that knowledge.

Knowledge	New	Development of alternative technologies in existing applications	Co-evolution of new socio-technical systems
	Existing	Improvements in the performance and quality of existing products and services	Creation of novel product and service niches
		Existing	New

Application

Source: Bessant and Tidd (2007)

Figure 1.2 Typology of the innovations

The lower left bottom part of the matrix represents the phase in which existing knowledge is applied to existing products and services. It is also called "incremental innovations". The second part of matrix that is top left part represents the phase in which existing products are dealt with new knowledge. It can include development of alternative technologies that can reduce emissions, using alternate energy efficient materials for the same existing process. The third part is the top right of the matrix in which new knowledge is applied to new systems. It leads to development on new systems. This type of system and innovations are very important from sustainability perspectives. It depends on all the stakeholders like suppliers, regulatory bodies and manufacturer. It also depends on various external factors like availability of finances and technological infrastructure etc. The fourth part of the matrix is the lower right part of the matrix. It represents the phase in which the existing knowledge is applied to the new systems and technologies. It is also called as "architectural innovations". During these types of innovations, new products and services are developing in co-existence with the existing products and services and sometimes these new products can help boom growth of existing products also. This type of innovations are also very helpful in green and sustainable growth of the industry (Vickers and Vaze, 2009).

SMEs being small are considered more flexible to customer needs and can easily make changes as per their requirements due to greater flexibility. But the ability to innovate is limited to small innovations which are generally incremental changes rather than radical changes. It is due to the fact that SMEs are dependent on various external resources like technological support and also in the responsiveness of its supply chain partners (Shenoi et al., 2016). Thus the decision for environmental upgradation of the SME through adoption of green practices and technologies is basically dependent on routine activities and willingness of the partners. However, the traditional large organizations have wider access to the technologies and have greater knowledge base and can optimally take decisions by measuring various pros and cons of the change and also they can perform radical innovations due to greater access to technologies and other resources. Thus they have the advantage of early adoption of green technology and practices as compared to their small counterparts (Hansen et al., 2002).

SMEs have certain strengths and weaknesses when it comes to innovation related activities. Hansen et al. (2002) presents some strengths and weaknesses of SMEs for innovation (Table 1.6). The challenge is to utilize these strengths and overcome their weaknesses so that they can adopt green practices and technologies and perform rapid green innovations so as to reduce the negative impact on the environment.

Table 1.6 Strength and weaknesses of SMEs with regards to innovation

Strengths	Weaknesses
Greater flexibility	Limited availability of finances
Close relationships to customers	Limited knowledge base and lack of training of its manpower
Capacity for adaption to new situations: SMEs tend to adapt to new situations and react quickly to the demand	Dependency on existing network: They generally lack the ability to develop new contacts
Faster decision making process	Lack of vision and innovation capacity
SMEs are customer oriented	

1.11 Organization of the Thesis

The write-up of the thesis is divided into eight chapters as follows. The overall structure of the thesis is presented in Figure 1.3.

Chapter I presents the basic background and the need for the study. It highlights the importance of SMEs in economic growth of the country and also in innovation process. The basic definition of SMEs and various types of innovations are discussed at length. The need for green innovation in SMEs is also discussed and it also presents the basis structure of the whole thesis.

Chapter II provides an in-depth and exhaustive review of literature on green innovation. This chapter through extensive review of literature attempts to record in brief the definitions of green innovation, various barriers to green innovations, solutions/strategies to overcome these barriers to green innovation and various enablers of green innovation which can act as criteria for selection of suppliers among SMEs. The gaps of previous studies and consequently the objectives of this study that emerged out of literature review have also been presented in this chapter.

Chapter III presents overall design of the study, which includes methodology adopted for carrying out the research work as well as various phases of the study. The details of various techniques/tools/methodologies employed for each phase of the study is presented in this chapter.

Chapter IV presents the current status of green innovation adoption/implementation in Indian SMEs. The survey results presents the status of various criteria of green innovation in SMEs and also the overall status of SMEs in these criteria.

Chapter V deals with the identification, finalization and prioritization of barriers to green innovation in SMEs. It also identifies, finalizes and suggests solutions/strategies to overcome these barriers. This chapter proposes a framework using two integrated methodologies i.e. BWM and fuzzy TOPSIS. The framework helps to first rank barriers to green innovation and then prioritize the solutions to overcome these barriers.

Chapter VI deals with the objectives 3 and 4 of the study i.e. Identifying, prioritizing and finding the relationship among the enablers of green innovation adoption in SMEs and Selecting component suppliers among SMEs for large manufacturing organization based on green innovation ability of SMEs. The chapter is divided into two parts, in first part the identification and prioritization of enablers of green innovation and selecting supplier among SMEs on the basis of these enablers is done using an integrated BWM and fuzzy TOPSIS methodology. The second part deals with the identifying the relationship among some selected enablers of green innovation using Grey DEMATEL methodology.

Chapter VII This chapter presents a green technology development and innovation implementation program for SMEs through the use of literature review, learning from case studies, and quantitative and qualitative modelling. Using literature review, case studies and discussion with experts various profiles are generated for adoption and implementation of green innovation in SMEs. Mixed method approach in which various methodologies like OPM, OFM, BWM and FST are used to develop a conceptual framework for implementation of green innovation in SMEs.

Chapter VIII provides a comprehensive overview of the research work conducted and the major findings along with the contribution of the present study in the existing set of literature. Besides, this chapter also provides the managerial implications of the present study. The last section of this chapter provides the limitation of the study. This chapter concludes by highlighting the suggestions related to scope of future work.

1.12 Chapter Summary

This chapter presents the basic background and the need for the study. It highlights the importance of SMEs in economic growth of the country and also in innovation process. The basic definition of SMEs and various types of innovations are discussed at length. Global competitiveness ranking comparison on various parameters of technology development and innovation is done for various Asian countries. After that the need for green innovation is discussed. The ranking of various India with other Asian countries on various parameters of green innovation is also done to assess the current situation of green innovation in India. The aim and scope of green innovation in SMEs along with various typologies of innovation and strength and weakness of SMEs in adapting the innovation is also discussed. In the last section, the complete organization of the thesis is provided. Further in this, all sections mentioned in this chapter are discussed in detail in the subsequent chapters.

Review of the literature is the first logical step in a research effort and the next chapter is devoted to the same.

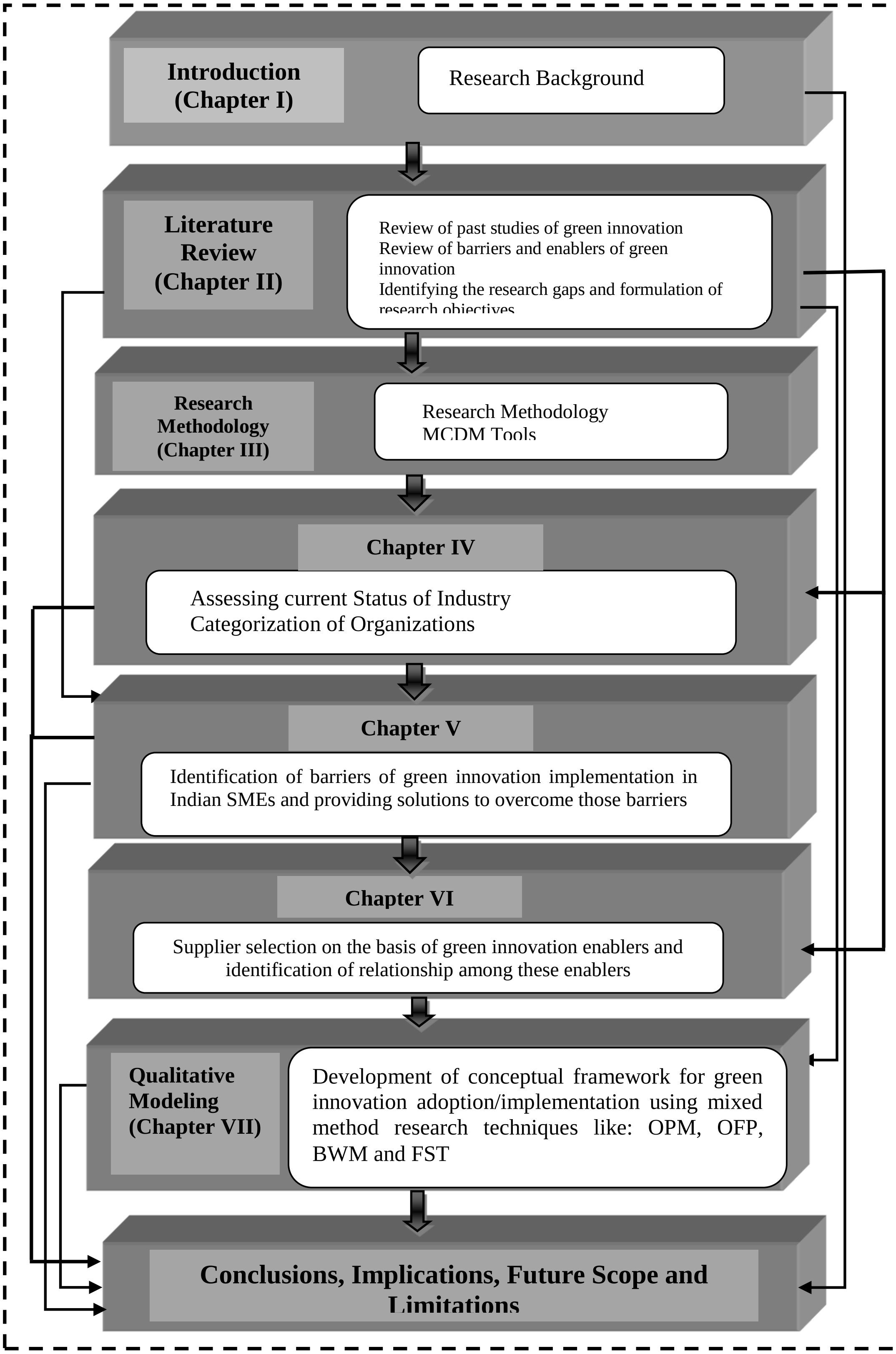

Figure 1.3 Thesis Structure

CHAPTER - II
LITERATURE REVIEW

2.1 Introduction

This chapter provides an in-depth and exhaustive review of literature on green innovation. Any research is incomplete without reviewing and analysing the past literature relevant to the research topic. This chapter through extensive review of literature attempts to record in brief the definitions of green innovation, various barriers to green innovations, solutions/strategies to overcome these barriers to green innovation and various enablers of green innovation which can act as criteria for selection of suppliers among SMEs. The gaps of previous studies and consequently the objectives of this study that emerged out of literature review have also been presented in this chapter.

2.2 Literature Review at a Glance

According to Webster and Watson (2002) "A review of prior, relevant literature is an essential feature of any academic project. An effective review creates a firm foundation for advancing knowledge. It facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed". On similar lines Fink (2005) defines literature review as "A literature review is a systematic, explicit, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners".

Through extensive literature review, this study tries to address following issues:

- Exploring the background and definitions of green innovation
- Identifying the various barriers and enablers of green innovation
- Identifying the gaps in past literature and to formulate research objectives for this research

2.3 Literature Review Process

2.3.1 Units of Analysis and Delimiting

The primary criteria for selecting the papers were the papers published in English language in peer reviewed journals. It included papers from various journals, published book chapters, conference papers, few working papers, thesis related to the topic and case studies. The papers that were published in other languages were excluded from the literature review.

2.3.2 Method of Searching Literature

Following keywords were used for searching articles namely, green innovation, green product innovation, green process innovation, green innovation capabilities, barriers to green innovation, barriers to green innovation capabilities, SMEs, small scale industries etc. The various databases were searched using the above mentioned keywords, these included, EBSCO, Elsevier, ProQuest, Wiley, Emerald, Tylor and Francis, J-STOR, Shodganga etc. Hundreds of articles resulted through searching of databases. First articles which were relevant from the title of the paper were selected. The articles whose scope was still not clear were judged after reading their abstracts and keywords. If further doubt was there on the scope, than articles were quickly reviewed by giving a brief reading to the articles to further narrow down the articles.

2.4 Definitions of Green Innovation

In literature the terms green innovation and eco-innovation have been used interchangeably. For the purpose of this study the term eco-innovation is used as green innovation. Green et al. (1994) defined green innovation as "inventing, innovating and diffusing new sets of products and processes which somehow or other are inherently more environmentally friendly than the sets we currently make and use". 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). Green innovations address the environmental issues originating from various activities of organizations starting from production to disposal of the products. Green innovation consists of both product and process innovation but is different from this conventional innovation in the sense that green innovation is more focused on preventing environmental damage due to the products and processes rather than conventional innovations (Triebswetter and Wackerbauer 2008). 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). Halila and Rundquist (2011) define green innovation as "the development and implementation of new products and processes for the achievement of eco-targets and reduction of the ecological footprint throughout the entire manufacturing process and product life cycle". Green innovation can be inferred to as a means to subdue the organizations effect on environment and accomplish organizations environmental targets and achieve benefits through it (Wong et al., 2014). 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).

Green innovations are classified as green product innovations, green process innovations and green managerial/organizational innovations.

Green product innovations: It includes modifying existing products or introduction of new products that address the environmental concerns of the organizations. It can include, raw materials that are non-toxic, design for green products, using products and materials that are energy efficient, techniques for pollution prevention and control, recycling of waste material, techniques for waste minimization. It can include innovations in packaging so that the material can be reused (Shrivastava, 1995; Chan et al., 2006; Wong et al., 2013; Lin et al., 2014).

Green process innovations: It includes modifying production systems and manufacturing processes to achieve the targets of greening the organizations and producing environmental friendly products. Green process innovations can lead to ecofriendly products that are more energy efficient, emit less pollution, can be recycled and are cost effective (Meeus and Edquist, 2006; Kammerer, 2009; Lambertini and Mantovani, 2009; Lin et al., 2014).

Green organizational innovation: It includes changing organizations routines, management structure, business methods and models, decision making, human resource and training practices which in turn leads to development of environmental friendly products and processes in the organization (Macron et al., 2017).

2.5 Review of Enablers of and Barriers to Green Innovation

Chen et al. (2006) studied the impact of green innovation performance on organizations competitive environment in electronics industry of Taiwan. Both green product innovation and green process innovation performance is found to be positively related with corporate competitive advantage.

Chen (2008) conducted a study aimed to explore the effect of green competence with green innovation performance i.e. both product and process innovation and green image of the organizations in SMEs as well as large enterprises of Taiwan. Results of regression analysis indicate that investment in enhancing green competencies have positive impact on both green innovation performance and green image of the firm.

Dangelico and Pujari (2010) based on case studies of 12 manufacturing SMEs in Canada and Italy presented a conceptual model indicating the dimensions of green innovation as - energy minimization, materials reduction, and pollution prevention.

Chiou et al. (2011) studied the impact on organizations environmental performance and competitive advantage through green innovation and green supply chain. Data was collected from 124 companies across 8 sectors in Taiwan. The findings indicate that firms' competitive position and environmental performance is largely impacted by green innovation practices.

Chen et al. (2012) conducted a two stage study using both qualitative and quantitative approaches to find out the difference between proactive and reactive green innovations. They categorized the green innovations into two main categories, internal and external green innovations. Internal green innovation capabilities included environmental leadership, environmental culture and environmental capabilities and external green innovations included environmental regulations by government and external investments for green innovation. Both internal and external capabilities were found to cause reactive green innovations, but it is only internal capabilities that lead to proactive green innovations in the organization.

Zhu et al. (2012) studied green supply chain management innovation diffusion and its relationship to organizational improvement, Data was collected from 245 Chinese manufacturing organizations. Results show that varying organizational characteristics and top managers' attitudes cause organizations to adopt innovations. The results also indicate that manufacturing organizations can be categorized as early adopters, followers and laggards on the basis of innovation diffusion and adoption.

Tseng et al. (2013) conducted a study to identify and analyze the criteria for green innovation performance in Taiwanese electronics manufacturing organizations. Their focus was on managerial, technological, product and process based green innovation practices. A total of twenty two criteria were identified and analyzed using fuzzy set theory and ANP. They suggested that firms should focus on management innovation and product life cycle assessment to succeed in their environmental goals.

Amores-Salvadó et al. (2014) tested the impact of green product innovation on firm performance with the moderating role of green corporate image. It was found that organizations commitment towards green product innovation has positive effect on firm performance. Also, the green corporate image significantly enhances the firm performance.

Cuerva et al. (2014) conducted a quantitative study to identify the drivers of green and non-green innovation in low-tech SMEs. Regression analysis was used for quantifying the relations between different variables. They identified that technological and R&D capabilities are most important for non-green innovations and for green innovations, QMS and product differentiation are found to be most important drivers.

De Medeiros et al. (2014) studied about critical factors for green product innovation, findings indicate that knowledge about government policies and market, collaborations within departments, learnings related to innovation and investments in research are critical for green product innovation success.

Klewitz and Hansen (2014) studied regarding sustainability-oriented innovation of SMEs. They identified green innovations as – green product innovations, green process innovations and organizational innovations. They also identified that past studies lack research related to green innovation from triple bottom line perspective i.e. economic, social and environmental dimension.

Li (2014) in their study examined the relationship between organizational performance and environmental innovation along with institutional pressures. Moderating effect of resource commitment was tested for environmental innovation. The results indicated that environmental innovation has significant impact on environmental performance of the firm. Also due to moderating effect of resource commitment the financial performance of the firm increases in relationship with environmental innovation.

Lin et al. (2014) studied about green innovation in the automotive sector, the study sought to examine the effects of market demand on firm performance using green innovation and environmental performance as mediators in Taiwanese hybrid vehicle industry. They found green innovations to significantly impact organizations performance.

Gabler et al. (2015) introduced environmental orientation and organizations innovation as antecedents of firm's eco-capability. Data was collected form fourteen industries and it was found that environmental orientation and organizational innovation are predictors of eco-capability of an organizations. Also, eco-capability in turn is positively related to market and financial performance of the firm. This signifies that organizations green orientation and innovation leads to better performance in the market.

Yang et al. (2015) carried out a study to test the impact of environmental management practices on technological innovations, also effect of supply chain integration was studied. The findings indicate a positive relationship between environmental management practices and firms technological innovation initiatives, also supply chain integration has moderating effect on these two.

Zailani et al. (2015) in their studied the effect of green innovation adoption on organizations performance. Data was collected from 153 automotive component suppliers in Malaysia. Regulations related to environment, demand for green products and internal environmental initiatives by organization impact green innovations and further analysis indicate that green innovations substantially improves organizations sustainable performance.

Dangelico (2016) studied about green product innovation (GPI). Author classified the factors for green innovation into internal as well as external, internal factors include, competitive advantage among other manufacturers, price cut, better chances of acquiring business due to enhanced reputation, external factors include, environment related policies and demand for green products. Few other factors are also identified such as, effective leadership, networking, and resources for green innovation.

Bossle et al. (2016) did a review of drivers of green innovation. They found that green innovation is an emerging research topic and many studies have been done in recent few years. They identified the drivers of green innovation into external and internal drivers. External factors included regulatory pressures, normative pressures, external cooperation, expanding market and technological factors. Internal factors include efficiency, cost saving, environmental certifications, environmental leadership, environmental capability and human resources. They found that internal drivers are more important for adoption of green innovation than external factors since they can be controlled within the organization.

De Medeiros et al. (2016) performed qualitative analysis to establish the relationship between various drivers of green innovation. Most important factor for green innovation has been identified as availability of technological skills. Among other important factors are the ‘‘meeting consumer expectations’’ and ‘‘following law and legislation’’ factors.

Dangelico et al. (2017) studied green product innovation in 189 Italian manufacturing firms from Sustainability-Oriented Dynamic Capability (SODC) perspective. SODCs are considered to be consisting of external resource integration, internal resource integration and resource building and reconfiguration. The effect of SODCs on Sustainability Oriented Ordinary Capabilities (SOOC) was tested. SOOCs involve green innovation capabilities and eco-design capabilities. Structural equation modeling (SEM) was sued to test the hypothesized model. The effect of SODCs on market performance was also tested. Results indicate that resource building and reconfiguration is the only SODC that affect market performance (both directly and indirectly). Also, all three SODCs effect eco-design capabilities of the firm and lastly only external resource integration affects the green innovation capabilities.

de Jesus Pacheco et al. (2017) conducted a systematic literature review to identify the determinants of green innovation in manufacturing organizations. They identified twenty three determinants of green innovation which were categorized into seven main categories. The important determinants identified include government policy supporting green innovation, availability of resources, perception of strategies related to green innovation, external relations, product and process oriented innovations and organizational structure and management support.

Fernando and Wah (2017) empirically tested the effect of green innovation drivers on environmental performance of green technology firms in Malaysia. Cross-functional coordination, market focus, regulations, suppliers and use of latest technology were taken as indicators of green innovation. Their impact on environmental performance of the firm was tested through PLS-SEM. Results indicate that compliance with environmental regulations is the most profound driver of green innovation which leads to better environmental performance of the organization apart from market focus and use of latest technology which are also positively related to environmental performance of the organization.

Huang and Li (2017) tested the effect of green innovation on environmental and organizational performance from the view of organizational capability and social reciprocity. The data was collected from ICT firms of Taiwan and SEM analysis was used to test the hypothesis. To measure green innovations, green product and process innovations are taken as variables. The effect of dynamic capability, coordination capability and social reciprocity was tested on green innovation. Coordination capability and social reciprocity are found to be significantly related green innovations. Both green process and product innovation are positively related to environmental and organizational performance.

Rodriguez and Wiengarten (2017) builds their paper around resource management framework and analyzed the impact of organizations process innovations on green innovation capabilities. They concluded that green innovation capabilities are developed through a two stage bundling process. They found that organizational resources like R&D cooperation, new machinery, software and technologies help in building process innovations in the organization and these process innovations in turn leads to building green innovation capabilities of the organization. Data from 2008 community innovation survey of Germany was used for the analysis.

Tsai and Liao (2017) examined the moderating role of sustainable strategies like market demand, innovation intensity and government subsidies on green innovation of the organization. The study was conducted on 2955 Taiwanese manufacturing firms and data was collected form Community Innovation Survey of Taiwan. The variable used for the study are market demand, technology push, and government subsidy. Logit moderation modeling was used. The results reveal that demand of green products in market and subsidies provided by government has positive moderating effect on proactive environmental strategies and green innovation of the organization.

Tseng and Bui (2017) in their study of green innovation in industrial symbiosis found four important factors of green innovations namely 'environmental sustainability, collaboration regulation and perception and waste management synergies'. Further these four factors were classified into eighteen different attributes. Regulations and waste management synergies were found to be most important factors for green innovation.

Sun et al. (2017) carried out a study to evaluate the impact of green innovation on ecological-economic efficiency of emerging industries. Entropy weighted TOPSIS method is used to develop a framework for evaluating the ecological efficiency of six selected industries. Green innovation factors were studied and were used to develop the positive and negative indicators of ecological issues. Binary logistic regression was used to examine the relationship between drivers of green innovation. Regulatory factors emerged very important apart from satisfying customer demands, training of employees, and access to various sources of knowledge for managing green innovations.

Yu et al. (2017) explored the mediating role of environmental innovation strategy on environmental pressures and environmental and financial performance. Also the moderating role of marketing capability is also tested in the same model. Data was collected from 121 UK based manufacturing organizations. Both mediation and moderation relationships were found to be significant in their study, thus concluding that environmental innovation strategy successfully mediates the relationship between environmental pressures and performance.

El-Kassar and Singh (2018) developed and tested a model to evaluate the impact and interrelationship among green innovation, its drivers, big data application, management commitment and organizations sustainable performance and competitive advantage. Data was collected from 215 organizations across Middle East and North Africa region. PLS SEM was used to test the proposed hypothesis and all the hypothesis were found significant. Green product and process innovation successfully moderates the relationship between green innovation factors and organizations environmental performance.

Joo et al. (2018) examined the effect of government interventions on firms environmental and technological innovation capabilities and also environmental and export sales performance. The results indicate that government intervention is helpful in improving environmental innovation and technological innovation capabilities of the firm, which in turn significantly improves the environmental performance of the firm. However, environmental innovation capabilities are not significantly improving export performance of the firm, but technological innovation capabilities significantly improves export performances of the firm.

Leal-Rodríguez et al. (2018) tested the mediating role of realized absorptive capacity in potential absorptive capacity and green product and process innovation performance framework. Data from 112 Spanish automotive component manufacturers were taken. PLS SEM was used to test the proposed framework. The results shows that potential absorptive capacity is significantly impacting realized absorptive capacity, which in turn has significant positive relationship with green product and process innovation performance.

Sanni (2018) in his paper identified the drivers of green innovation in Nigerian manufacturing sector. They used data from Nigerian innovation survey. They identified and divided the factors into regulatory factors, demand-pull factors, technology-push factors, knowledge based factors and firm-specific factors.

Saunila et al. (2018) investigated the role of various dimensions of sustainability in exploitation of and investment in green innovation. Data was collected from horse industry of Finland. Regression analyses was used to test the hypothesis. The results indicate that economic, institutional and social sustainability leads to greater investment in green innovation. Moreover, organizations willingness to exploit green innovation also increases due to high valuation of economic and institutional sustainability.

Tang et al. (2018) studied the moderating role of managerial environmental concerns on green process and product innovations and firm performance. Data from 188 manufacturing firms of China was taken. Regression analysis is used to test the hypothesis. Green product and process innovations are found to be significantly impacting firm performance. Also, they found that managerial environmental concerns strengthen the positive relationship between green process innovation and firm performance but it doesn't affect the relationship between green product innovations and firm performance.

Table 2.1 lists the important studies on green innovation and Table 2.2 lists the studies on barriers to green innovation.

Table 2.1 Past studies on enablers of Green Innovation

Author(s) and Year	**Methodology/Method**	**Key Findings**
Dangelico and Pujari (2010)	Case Study, Personal Interviews	They studied 12 manufacturing SMEs in Italy and Canada. Based on the case studies and interviews, they presented a conceptual model indicating that reduction in material, reduction in pollution level and energy efficiency are three important dimensions of green innovation.
Chiou et al. (2011)	Structural Equation Modeling	Data were collected from 124 companies across 8 sectors in Taiwan. The findings indicate that environmental and financial performance of the firm can be significantly improved through greening of the suppliers.
Messeni Petruzzelli et al. (2011)	Correlation and Regression	Green patents are used as a measure of green innovations. Findings indicate that collaboration between internal departments is instrumental in developing green innovations and hence green patents in the organization.
Zhu et al. (2012)	Principal Component Analysis, ANOVA	Data was collected from 245 Chinese manufacturing organizations. Findings indicate the importance of top executive of the organization for the adoption of green innovations. The results also indicate that manufacturing organizations can be categorized as early adopters,

Author(s) and Year	Methodology/Method	Key Findings
		followers, and laggards on the basis of innovation diffusion and adoption.
Lin et al. (2013)	Regression Analysis	The study was conducted on Vietnamese automobile companies and findings indicate that market demand has a significant positive correlation with green product innovations and hence firms performance.
Klewitz and Hansen (2014)	Literature Review	84 papers were selected from various journals for review. They identified green innovations as – green product innovations, green process innovations, and organizational innovations. They also identified that past studies lack research related to green innovation from triple bottom line perspective.
Lee et al. (2014)	Partial Least Square - SEM	This study aims to identify the relationship between GSC practices and technological innovations. Data was collected from 133 manufacturing organizations in Malaysia. The study found a significant correlation between green design, IR and internal environmental management with innovations.
Lin et al. (2014)	Structural Equation Modelling	This study was carried out in Taiwanese hybrid vehicle industry and found that green innovations significantly impact organizations overall performance.
De Medeiros et al. (2014)	Literature Review	Total 67 papers were selected from various journals. The study indicates that knowledge related to marked demand and governmental regulations, collaborations between internal departments,

Author(s) and Year	Methodology/Method	Key Findings
		knowledge related to innovation and investment in research are critical for green innovation success.
Yang et al. (2015)	Regression Analysis	Data was collected from 154 manufacturing firms in China. The results indicate that supply chain integration along with environmental management practices has positive impact on innovation performance of the company.
Zailani et al. (2015)	Partial Least Square - SEM	Data was collected from 153 automotive component suppliers in Malaysia. Governmental regulation on the environment, market demand and internal initiatives at firm level have a significant impact on green product innovations.
Dangelico (2016)	Literature Review	This study included a review of 63 papers and found enhancement of company's image, cost reduction, regulations related to environment and demand for green products as important factors of green product innovation.
Iranmanesh et al. (2016)	Partial Least Square - SEM	Data was collected from 191 electrical component manufacturing organizations in Malaysia. The study pointed out that green product and process innovations have a positive impact on job intensity.
De Medeiros et al. (2016)	Relationship System Analysis	Data were collected from 100 Brazilian manufacturing organizations. The study established that technological expertise is required to sustain green innovation in the organizations.
Roscoe et al. (2016)	Grounded Theory	They developed a framework which suggests that green innovations can be developed incrementally over the time through strong ties with strategic suppliers.

Table 2.2 Past studies on barriers to green innovation/green practices

Author(s) and Year	**Region/Context**	**Methodology/Method**	**Key Findings/Issues**
Hillary (2004)	European Union	Literature Review	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".
Runhaar et al. (2008)	Netherlands	Exploratory study/ Interviews	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.

Author(s) and Year	Region/Context	Methodology/Method	Key Findings/Issues
Walker et al. (2008)	Australia	Literature Review	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.
Arundel and Kemp (2009)	Japan	Survey-based research	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.
Del Río et al. (2010)	Generalized	Conceptual Study	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.

Author(s) and Year	Region/Context	Methodology/Method	Key Findings/Issues
Matus et al. (2012)	China	Semi-structured interviews	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".
Marin et al. (2015)	European Union	Cluster analysis, Principal Component Analysis (PCA)	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.
Pinget et al. (2015)	France	Multinomial logit estimation and regression	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.

Author(s) and Year	**Region/Context**	**Methodology/Method**	**Key Findings/Issues**
Abdullah (2016)	Malaysia	Partial Least Square (PLS)	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.
Cecere et al. (2016)	Europe	Logit regression	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.
Hojnik and Ruzzier (2016)	Slovenia	Case study	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.

Author(s) and Year	Region/Context	Methodology/Method	Key Findings/Issues
Ghisetti et al. (2017)	European Union	Simultaneous Equation Modelling	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.

2.6 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 are presented in Table 2.3 below.

Table 2.3 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; 2014; Solazzoet 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., 2012; 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; 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

S.No.	Solutions/Strategies	Reference
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.,

S.No.	Solutions/Strategies	Reference
		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

2.7 Review of Supplier Selection Methodologies

Supplier selection is a strategic decision which requires a wide range of factors and techniques, which can be both qualitative and quantitative. Choosing right criteria is very important for undertaking the process of supplier selection to get the desired results, but choosing appropriate methodology is equally important to get the desired results. Wide range of techniques like AHP, Fuzzy AHP, TOPSIS, Fuzzy TOPSIS, DEMATEL, VIKOR, COPRAS, BWM, ELECTRE, MILP etc. are available in literature. Use of these techniques vary depending upon the objectives of the study and the accuracy of these techniques in meeting those objectives. Just selecting the right criteria will not solve the purpose unless the correct methodology is applied. This section aims to review the important methodologies applied by various authors for supplier selection. Many authors have used single methodology for supplier selection like Liu et al., 2000 (DEA); Ghodsypour and O'Brien, 2001 (Mixed Integer Non Linear Programming); Sarkis and Talluri, 2002 (ANP);

Rezaei et al., 2015, 2016 (BWM), but most of the authors have used hybrid of two methodologies for supplier selection, like, Ghodsypour and O'Brien, 1998 (AHP and Linear Programming); Thakkar et al., 2005 (ISM and ANP); Xia and Wu, 2007 (AHP and Rough Set Theory); Thongchattu and Siripokapiram, 2010 (AHP and ANN); Kannan et al., 2013 (Fuzzy AHP, Fuzzy TOPSIS and MOLP); Prakash and Barua, 2016 (Fuzzy AHP and Fuzzy TOPSIS); Luthra et al., 2017 (AHP and VIKOR), this shows an emerging trend of use of hybrid methodologies for supplier selection. Also, some new methodologies have emerged like COPRAS and BWM which are used very recently and are widely accepted by the researchers due to their ease of applicability and consistency in results. Table 2.4 presents a brief overview of the methodologies applied for supplier selection by various authors.

Table 2.4 Few important studies of supplier selection

Authors	**Techniques employed**
Ghodsypour and O'Brien (1998)	AHP and Linear programming
Liu et al. (2000)	DEA
Ghodsypour and O'Brien (2001)	Mixed Integer Non Linear Programming
Sarkis and Talluri (2002)	ANP
Kahraman et al. (2003)	Fuzzy AHP
Thakkar et al. (2005)	ISM and ANP
Amid et al. (2006)	Fuzzy MOLP
Chen et al. (2006)	Fuzzy TOPSIS
Gencer and Gürpinar (2007)	Analytical network process (ANP)
Xia and Wu (2007)	AHP, Rough Set Theory and MOLP
Chan et al. (2008)	Fuzzy AHP
Boran et al. (2009)	Intuitionistic Fuzzy and TOPSIS
Lee et al. (2009)	Fuzzy AHP
Bai and Sarkis (2010)	Grey System and Rough Set Theory
Kuo et al. (2010)	ANN – MADA and DEA
Sanayei et al. (2010)	Fuzzy VIKOR
Thangchattu and Siripokapiram (2010)	AHP and ANN

Authors	**Techniques employed**
Amindoust et al. (2012)	Fuzzy inference system
Kuo and Lin (2012)	DEA and ANP
Shaw et al. (2012)	Fuzzy AHP and Fuzzy MOLP
Hsu et al. (2013)	DEMATEL
Kannan et al. (2013)	Fuzzy AHP, Fuzzy TOPSIS and MOLP
Deng et al. (2014)	AHP and D numbers
Kumar et al. (2014)	DEA
Rezaei et al. (2014)	Screening method and Fuzzy AHP
Senthil et al. (2014)	AHP and Fuzzy TOPSIS
Hashemi et al. (2015)	ANP and Grey relational analysis
Igoulalene et al. (2015)	Fuzzy TOPSIS and Goal programming
Kannan et al. (2015)	Fuzzy Axiomatic Design (FAD) approach
Karsak and Dursun (2015)	QFD and Intuitionistic Fuzzy
Rajesh and Ravi (2015)	Grey relational analysis
Rezaei et al. (2015)	Best Worst Method
Sarkis and Dhavale (2015)	Bayesian Framework
Sivrikaya et al. (2015)	Fuzzy AHP and Goal programming
Awasthi and Kannan (2016)	NGT and VIKOR
Dweiri et al. (2016)	AHP
Govindan and Sivakumar (2016)	Fuzzy TOPSIS and MOLP
Prakash and Barua (2016)	Fuzzy AHP and Fuzzy TOPSIS
Rezaei et al. (2016)	Best Worst Method
Luthra et al. (2017)	AHP and VIKOR
Qin et al. (2017)	Fuzzy TODIM
Yazdani et al. (2017)	QFD, DEMATEL, COPRAS and MOORA

2.8 Review of Studies on Green Supplier Selection

Table 2.4 in section provides a brief of various methodologies used in supplier selection. These studies varied from green supplier selection to third party selection and also included supplier selection for aviation industry. But considering the focus of this study i.e. Green innovation, the current section aims to briefly review the past studies on green supplier selection. Table 2.5 provides a brief overview of the few important past studies on green supplier selection.

Table 2.5 Review of past studies on green supplier selection

Authors	Key area	Key criteria	Methodology used
Lee et al. (2009)	Green Supplier selection	Quality, Finance, Organization, Technology Capability and Service	DELPHI and Fuzzy AHP
Bai and Sarkis (2010)	Sustainable supplier selection	Environmental management system, Pollution control, Resource consumption, Health and safety and Stakeholders influence	Grey systems and Rough set
Kuo et al. (2010)	Green Supplier Selection	Corporate Social Responsibility, Service, Delivery, Cost, Quality and Environment	ANN and MADA
Büyüközkan and Çifçi (2011)	Sustainable supplier selection	Organization, Financial performance, Service quality and Technology	Fuzzy ANP
Amindoust et al. (2012)	Sustainable supplier selection	Economic, Environmental and Social	Fuzzy set theory
Shaw et al. (2012)	Supplier selection for low carbon supply chain	Cost, Quality percentage, Greenhouse gas emission, Market demand	Fuzzy AHP and Fuzzy MOLP
Hsu et al. (2013)	Supplier selection in green	Carbon governance, Training related to	DEMATEL

Authors	Key area	Key criteria	Methodology used
	supply chain management	carbon management, Supplier collaboration, Carbon accounting and inventory	
Kannan et al. (2013)	Green supplier selection and order evaluation	Cost, Technology capability, Environmental competency	Fuzzy AHP, TOPSIS and MOLP
Dobos, and Vörösmarty (2014)	Green Supplier Selection	Reusability, CO_2 emission, Quality and Price	DEA type composite indicators
Kumar et al. (2014)	Green Supplier Selection	Price, Lead time and Carbon foot-print	DEA
Tsui and Wen (2014)	Hybrid decision making approach for green supplier selection in electronics industry	Environmental factor, R&D capability, current capability	AHP and ELECTRE 111
Cao et al. (2015)	Green Supplier Selection	Environmental costs, Remanufacturing activities, Reverse logistics, Energy consumption and Waste management	Fuzzy TOPSIS
Freeman and Chen (2015)	Green Supplier Selection	Environmental management performance, Green competency, Cost, Quality and Delivery Schedule	AHP, Entropy and TOPSIS
Hashemi et al. (2015)	Green supplier selection	Technology, Innovativeness, Eco-design, Environmental management system	ANP and Grey relational analysis
Kannan et al. (2015)	Green supplier selection	Quality, Price, Capability of suppliers, Environmental management, Green innovation	Fuzzy Axiomatic Design (FAD)
Awasthi and Kannan (2016)	Green supplier development	Resources, Emissions, Green Packaging,	Fuzzy NGT and VIKOR

Authors	Key area	Key criteria	Methodology used
		Green manufacturing, Green product design	
Fallahpour et al. (2016)	Green supplier selection under fuzzy environment	Environmental management studies, Supplier’s green image, Green competencies, Green product innovation, Eco design	DEA and Genetic programming
Govindan, and Sivakumar (2016)	Green Supplier Selection	Cost, Quality, Delivery, Recycle capability and GHS emissions	Fuzzy TOPSIS and MOLP
Rezaei et al. (2016)	Supplier selection life cycle approach	Resource consumption, Environmental costs, Green R&D, Green Design, Recycling	Best worst method
Bakeshlou et al. (2017)	Green Supplier Selection	Environment, Technology capability, Service, Quality and Cost	Fuzzy ANP, Fuzzy DEMATEL and Fuzzy MOLP
Luthra et al. (2017)	Sustainable supplier selection	Environmental costs, Quality of product, Price of product, Environmental competencies	AHP and VIKOR
Qin et al. (2017)	Green Supplier Selection	Green product innovation, Green image, Resource consumption, Green competencies and Staff environmental training	Fuzzy TODIM
Yazdani et al. (2017)	Green Supplier Selection	Financial stability, Management commitment, Facility, Reverse logistics, green design and environmental management system	QFD, DEMATEL, COPRAS and MOORA

2.9 Research Gaps, highlights and problem formulation

Greening the manufacturing operations has become the need of the hour. 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. The performance of SMEs especially in developing countries is dismal in context of developing and applying green innovations due to numerous barriers. There is no data available on the level of green innovations that are adopted and applied by SMEs in India. 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.

Very recently many authors have focused on incorporating green practices in the supply chain of the organizations (Hashemi et al., 2015; Awasthi and Kannan, 2016; Govindan and Sivakumar, 2016; Rezaei et al., 2016; Luthra et al., 2017). Most of the studies conducted in past have focused on greening the supply chain using various factors, however there are limited number of studies done solely considering the factors of green innovations in organizations, few of the important studies are mentioned in Table 2, Further most of the studies done on green innovation are in the context of developed countries (Dangelico and Pujari, 2010; Chiou et al., 2011; De Medeiros et al., 2014; Klewitz and Hansen, 2014; Dangelico, 2016; De Medeiros et al., 2016) and there is no study on green innovation for India and to the best of authors knowledge, this is the first such study in the context of India.

Further, as shown in Table 2.1, all the studies on green innovation are done taking only a few factors at a time and are often focused on finding the relationship of one or few factors on others. This study is first attempt taking a large number of factors (twenty-one) of green innovation into consideration and for finding the cause and effect relationship among various factors of green innovation.

Supplier selection is significant in achieving the goal of greening the supply chain and producing sustainable products. Many studies have been carried out in the past for green supplier selection (Kuo et al., 2010; Thongchattu and Siripokapiram, 2010; Amindoust et al., 2012; Shaw et al., 2012; Hashemi et al., 2015; Awasthi and Kannan, 2016; Govindan and Sivakumar, 2016; Rezaei et al., 2016; Luthra et al., 2017), all the studies mentioned here have focused on green supplier selection based on certain criteria of green supply chain management, however this is the first study considering green innovation criteria for supplier selection in a supply chain. Further all the studies mentioned above have considered supplier selection amongst large organizations only, there is dearth of literature and studies indicating a comprehensive model where large organizations are selecting supplier among SMEs on the basis of their innovation ability, so this is the first attempt to develop a framework for supplier selection among SMEs based on their green innovation ability.

Notably few studies have been pursued in the field of green innovation, but predominantly most of these works have been done in the context of developed countries (Dangelico and Pujari, 2010; Chiou et al., 2011; De Medeiros et al., 2014; Klewitz and Hansen, 2014; Dangelico, 2016; De Medeiros et al., 2016). There are very few studies that are done in context of developing countries (Zhu et al., 2012; Lin et al., 2014; Yang et al., 2015) and till date there is no study done in context of India with regard to green innovation in SMEs, so this study is a first attempt to provide a framework for supplier selection among SMEs based on their green innovation ability. Further, as mentioned in Table 1, all the previous studies on supplier selection have used a variety of methodologies both individual and integrated, however most of the studies have used integrative approach for supplier selection and that too they have used AHP for calculating weights of criteria for supplier selection.

Therefore, after extensive literature review following gaps have been identified:

- Almost all of the studies on green innovation are based in context of foreign countries and there is dearth of studies in context of developing nations especially India.
- Also most of the studies on green innovation are based on large organizations and very few studies have taken small and medium enterprises for analysis of green innovation implementation.
- Several researchers have worked on identifying the conditions, norms and factors which facilitate the promotion and implementation of technology upgradation and green innovations in manufacturing units. However, most of the academic writings focus only on few factors at a time. There is a lack of studies providing holistic perspectives on managing green innovations comprehensively in an organizational setting.
- Further, very few empirical studies and quantitative research have been reported to support the theoretical findings. There are remote cases where the relative impact of green innovation on performance improvements, especially in the small sector manufacturing sector have been reported.
- There are almost no study relating large and small organizations in the supply chain, especially there is lack studies on selection of suppliers (small or medium organizations) by large organizations on the basis of green innovation ability of small and medium organizations.
- Finally there is no past study depicting an effective model for green innovation adoption in small scale manufacturing organizations.

2.10 Objectives of the Research

The literature review shows that there are still large gaps in the literature of green innovation which needs to be addressed. The extensive literature review and identification of the gaps have to lead to formulation of the research objectives. The following research objectives have been formulated for this study and are listed below:

The study will be based on following research objectives:

Objective 1: To assess the current situation of green innovation adoption/implementation in Indian SMEs.

Objective 2: Identification of barriers of green innovation implementation in Indian SMEs and providing solutions to overcome those barriers.

Objective 3: Identifying, prioritizing and finding the relationship among the enablers of green innovation adoption in SMEs.

Objective 4: Selecting component suppliers among SMEs for large manufacturing organization based on green innovation ability of SMEs.

Objective 5: Developing a model for management and adoption of green innovations in SMEs of India.

2.11 Chapter Summary

This chapter summarized the review of studies on green innovation. To begin with, the concept of literature review was defined. Next, green innovation as defined by various authors was presented. The chapter summarizes the various studies on barriers and enablers of green innovation in context of various countries. The review of various MCDM techniques along with studies on green supplier selection is also presented. The extensive review indicates the various gaps in the literature. These gaps were analyzed and finally research objectives for the study were formulated and presented in this chapter.

The next chapter presents the details of overall design of the study and present the various phases of methodologies employed to achieve the objectives formulated through literature review.

CHAPTER - III
RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents overall design of the study, which includes methodology adopted for carrying out the research work as well as various phases of the study. The details of various techniques/tools/methodologies employed for each phase of the study is presented in this chapter.

3.2 Research Approach

According to Creswell (2003), the research approach (Qualitative, Quantitative, or Mixed Methods) is decided based on interrelated levels of decisions which when made dictate the approach and the research design process. These decisions are based on which knowledge claims, strategies of inquiry, and research method is used. The following Creswell definitions explain how these are combined:

"A quantitative approach is one in which the investigator primarily uses post positivist claims for developing knowledge (i.e. cause and effect thinking, reduction to specific variables and hypotheses and questions, use of measurement and observation, and the test of theories), employs strategies of inquiry such as experiments and surveys, and collects data on predetermined instruments that yield statistical data" (Creswell, 2003).

"A qualitative approach is one in which the inquirer often makes knowledge claims based on constructivist perspectives (i.e. multiple meaning of individual experiences, meanings socially and historically constructed, with an intent of developing a theory or pattern) or advocacy/participatory perspectives (i.e. political, issue orientated, collaborative, or charge orientated) or both. It also uses strategies of inquiry such as narratives, phenomenology's, ethnography's, grounded theory studies, or case studies. The researcher collects open-ended, emerging data with the primary intent of developing themes from the data" (Creswell, 2003).

"A mixed methods approach is one in which the researcher tends to base knowledge claims on pragmatic grounds (e.g. consequence-orientated, problem-centered, and pluralistic). It employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand research problems. The data collection also involves gathering both numeric information (e.g. on instruments) as well as text information (e.g. on interviews) so that the final database represents both quantitative and qualitative information" (Creswell, 2003).

Based on these definitions and the work of O'Leary (2004) this can be summarised as shown in Figure 3.1.

Therefore, based on Figure 3.1, both Mixed Method Approach i.e. mixture of Quantitative Research Approach and Qualitative Research Approach would appear to be the approaches to be used in this thesis. First Quantitative Approach will be employed to collect the data and do analysis of the data using various tools like MCDM tools available after that Mixed Method Research Approach will be employed to synthesize the findings of survey using Qualitative tools like OFM, OPM, BWM and FST.

3.3 Phases of Research

The present study is divided into three main parts namely 'Review', 'Analysis' and 'Design'. Review part includes extensive literature review regarding the topic of study. Analysis includes gathering information about current status of the implementation of research subject in the selected industry. It also includes quantitative analysis of the problems to give a solution for the various research problems. Design phase involves using mixed method (Qualitative and Quantitative) techniques for developing an effective model for the research problem. Based on this, the research work has been carried out in four phases:

Phase I : Clarifying the context

Phase II : Understanding and assessing the current situation

Phase III : Developing a model for overcoming barriers and supplier selection

Phase IV : Evolving a management process

Fig. 3.1 Research Approach Flow Charts (O'Leary, 2004)

Figure 3.2 depicts the relevance and importance of each phase for meeting the objective of design of a generalized '*Green Innovation Implementation and Adoption*' program. Details regarding the work undertaken in each phase and the tools and techniques employed for analysis are discussed.

3.3.1 Clarifying the Context

This phase reviews the literature on green innovation in manufacturing organizations. Various barriers that lead to poor adoption of green innovation in SMEs along with the solutions to overcome these barriers have been explored. Fundamental issues and factors that can help to initiate and motivate practicing and adoption of green innovation have also been explored. This phase also involves feedback from experts in industry and academia for finalizing the barriers, solutions and criteria of green innovation for further analysis and exploration to achieve the research objectives.

3.3.2 Understanding and Assessing the Situation

The second phase assesses the status of Green Innovation implementation and adoption initiatives in the small and medium scale industrial sector, through a questionnaire based survey of manufacturing units. The sampling method used is purposive sampling. The manufacturing units selected are electrical, electronics and automotive component manufacturing units of Punjab, Uttrakhand and NCR. The sample has been selected due to proximity and also because electrical, electronics and auto component manufacturing SMEs are among top manufacturing SMEs in India having highest manufacturing output.

To understand and assess the current situation of green innovation implementation/adoption in Indian SMEs, a simple five point scale questionnaire has been prepared and administered to the SMEs. The five point scale has following grading from ‘Very Low’ to ‘Very High’ where ‘Very Low = 1’ and ‘Very High = 5’.

Through extensive literature review and discussion with experts, seven main criteria (key issues) and forty two sub criteria (issues) have been identified for the implementation and adoption of green innovation practices in SMEs. These criteria were used for understanding and assessing the current scenario of green innovation in selected SMEs as well as for achieving objectives 3 and 4 (which will be discussed in coming sections).

Firstly, in the analysis of questionnaire, the status of all the issues under each component of green innovation adoption and implementation in the manufacturing sector has been assessed. The *Percent Points Score (P.P.S)* for each set of questions which reflect different issues under each component has been calculated. These measures reflect as to how well the area (issue) represented by that question is being looked in the industry.

Secondly, the status of manufacturing units in different key factors has been evaluated and the manufacturing units have been classified in to different categories. The score of each unit (in terms of Percent Points Score, PPS) in individual components has been calculated from the raw score of issues under each component. The criterion reported in earlier research studies has been used to classify the industries into different categories (Nanda and Singh, 2009).

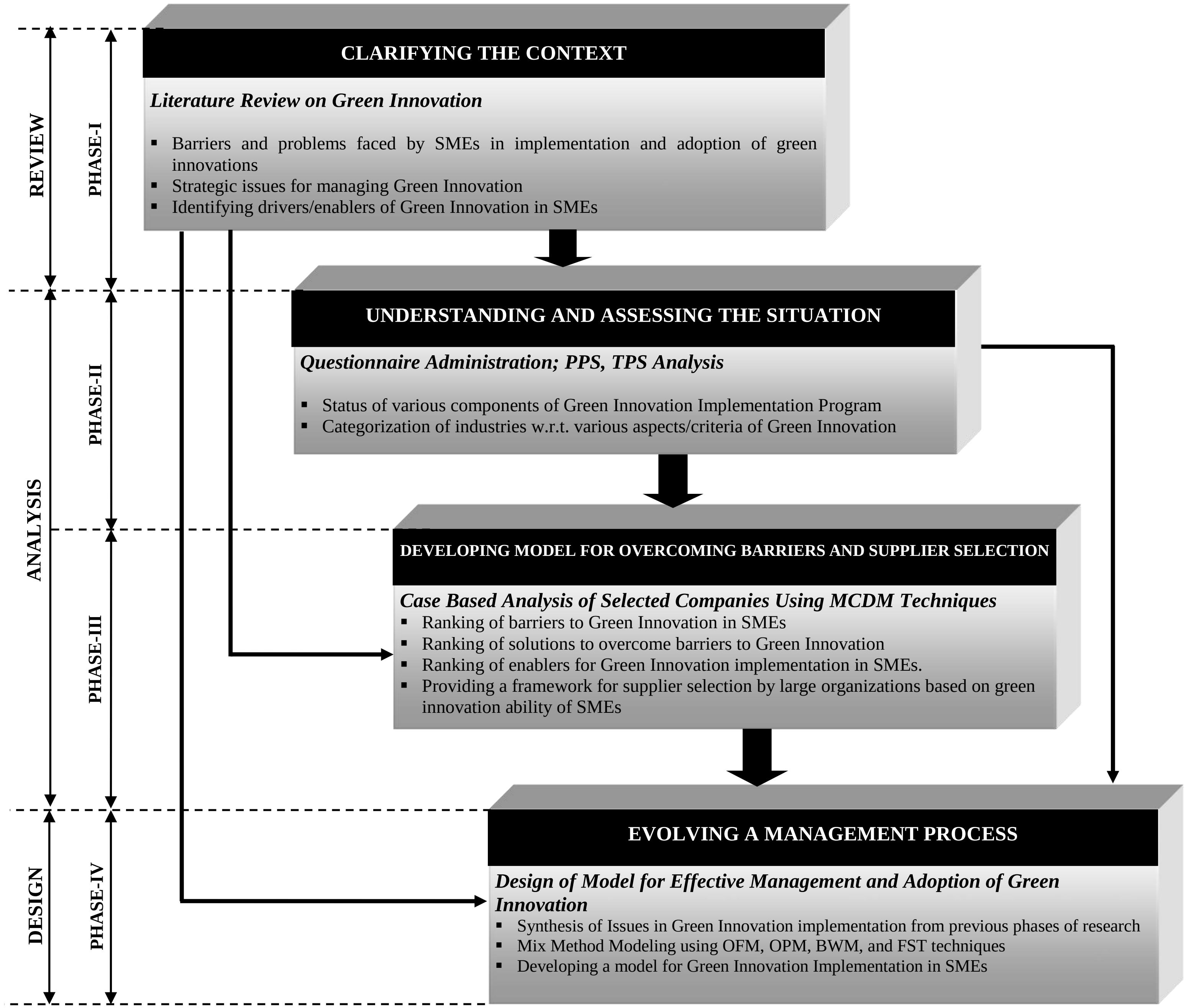

Figure 3.2 Design of the Study

3.3.3 Developing a model for overcoming barriers and for supplier selection

This is the third phase of the study and it helps in achieving objective two, three and four of the study i.e. Identification of barriers of green innovation implementation in Indian SMEs and providing solutions to overcome those barriers (Objective 2), Identifying, prioritizing and finding the relationship among the enablers of green innovation adoption in SMEs (Objective 3) and Selecting component suppliers among SMEs for large manufacturing organization based on green innovation ability of SMEs (Objective 4). Three methodologies have been selected to achieve these objectives. These are:

- Best Worst Method (BWM)
- Fuzzy TOPSIS and
- Grey DEMATEL

The steps involved in each of these methodologies are discussed in following sections:

3.3.3.1 Best-Worst methodology

Multi criteria decision making (MCDM) techniques are utilized in situations of complex problems where decision makers are assigned a task of selecting a best alternative among many alternatives. A new MCDM method known as Best Worst Method has been developed by Rezai (2015) is used to calculate the weights of the criteria.

This technique has been successfully utilized by Rezaei et al., (2015); Rezaei et al., (2016); Ahmadi et al. (2017); van de Kaa et al. (2017a,b); Gupta (2018). The various steps in application of this methodology as described by (Rezaei, 2015; Rezaei, 2016) are discussed below:

Step 1: Finalization of decision criteria.

Decision criteria finalized in phase one of the study will be taken and are denoted as $\{c_1, c_2, \ldots..,c_n\}$ for n main criteria.

Step 2: Determination of best and worst criteria among main as well as sub criteria.

Step 3: Next give preference rating for the best criteria over other criteria on a scale of 1 to 9.One a scale of 1 to 9 determine the preference of the best criteria over all other criteria. The best criteria over other criteria vector can be written as:

$A_B = (a_{B1}, a_{B2}, \ldots\ldots,a_{Bn})$,

Where a_{Bj} represents the rating of best selected criteria B over any other criteria j. In this case, $a_{BB} = 1$.

Consensus of various experts is taken for finalization of preference ratings.

Step 4: Similarly using a scale of 1 to 9, calculate the ratings of all other criteria over one worst criteria, the worst criteria is to be determined by experts. The comparison of other criteria to worst criteria can be attributed in the form of a vector as:

$A_W = (a_{1W}, a_{2W}, \ldots\ldots, a_{nW})^T$,

Where a_{jW} represents the rating of any criteria j with the worst selected criteria W. In this case, $a_{WW} = 1$.

In this case also the final value can be arrived by consensus of all the experts involved in decision making.

Step 5: Next step is to optimize the weights of all the criteria ($w_1^*, w_2^*, \ldots\ldots, w_n^*$).

The objective is to calculate the weights of criteria so that the maximum absolute differences for all j are minimized of the following set $\{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$. Following minimax model can be formulated:

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

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

$$w_j \geq 0, \text{ for all j} \qquad (3.1)$$

Model (3.1) discussed above can be solved by representing it in the form of a linear model as:

$$\min \xi^L$$

s.t.

$$|w_B - a_{Bj}w_j| \leq \xi^L, \text{ for all j}$$

$$|w_j - a_{jW}w_W| \leq \xi^L, \text{ for all j}$$

$$\sum_j w_j = 1$$

$$w_j \geq 0, \text{ for all j} \qquad (3.2)$$

Solving the above model (3.2) optimized weights ($w_1^*, w_2^*, \ldots\ldots, w_n^*$) and optimal value ξ^L will be obtained.

Consistency (ξ^L) of comparisons also needs to be determined. A value closer to 0 is desired for consistency (Rezaei, 2015b).

3.3.3.2 Fuzzy TOPSIS methodology

The TOPSIS technique was first evolved by Hwang and Yoon (1981). According to TOPSIS methodology the best alternative among all the alternatives will be one that is closest to positive ideal solution and farthest from the negative ideal solution. Although being a very useful tool for ranking alternatives traditional TOPSIS suffers from the limitation that it uses crisp values for selecting the alternatives, however, human in some situations like preference ratings human judgements can be imprecise due to the crisp value ranking of alternatives (Chang et al., 2008), to overcome this limitation Fuzzy TOPSIS using a linguistic scale for comparison of alternative is utilized for this research.

The Fuzzy TOPSIS methodology utilized in this paper is discussed below:

Step 1: Construct a comparison matrix ($\widetilde{k_{ij}}$) of alternatives with different criteria using linguistic variables discussed in Table 3.1. The linguistic rating mentioned in Table 3.1 and used in this methodology uphold the property that normalized triangular fuzzy numbers lie in the range [0,1] thus eliminating the need for normalization (Dağdeviren, et al., 2009).

Step 2: Next step is to obtain a weighted, normalized decision matrix using equation mentioned below.

$\breve{V} = \left[\widetilde{v_{ij}}\right]_{m\times n}$ where i = 1, 2, 3, ….m and j = 1, 2, 3, ….n and

$$\widetilde{v_{ij}} = \widetilde{k_{ij}} \otimes w_j \tag{3.3}$$

Step 3: Next step is to determine FPIS and FNIS where FPIS and FNIS is fuzzy positive ideal and the fuzzy negative ideal solution respectively:

$$A^{+} = \{v_1^{+}, \dots \dots \dots, v_n^{+}\}, \;\; where\; v_j^{+} = \{\max(v_{ij})\; if\; j\varepsilon J; \min(v_{ij})\; if\; j\varepsilon J'\}, \quad j = 1 \dots . n \tag{3.4}$$

$$A^{-} = \{v_1^{-}, \dots \dots \dots, v_n^{-}\}, \;\; where\; v_j^{-} = \{\min(v_{ij})\; if\; j\varepsilon J; \max(v_{ij})\; if\; j\varepsilon J'\}, \quad j = 1 \dots . n \tag{3.5}$$

Step 4: Next, calculate distance of each alternative from FPIS and FNIS using equations discussed below:

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

(3.6)

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

Step 5: Next, calculate Closeness coefficient (CC_i) of each alternative by using Eq. below:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+} \; i = 1 \ldots \ldots \ldots m \quad CC_i \varepsilon (0,1) \tag{3.7}$$

Step 6: Final step is to rank the alternatives to select the supplier on the basis of CC_i values in descending order.

Table 3.1 Linguistic scale for alternatives selection

Linguistic Variables	**Corresponding Fuzzy Numbers**
Very Low (VL)	(0, 0, 0.2)
Low (L)	(0, 0.2, 0.4)
Medium (M)	(0.2, 0.4, 0.6)
High (H)	(0.4, 0.6, 0.8)
Very High (VH)	(0.6, 0.8, 1)
Excellent (E)	(0.8, 1, 1)

3.3.3.3 Grey DEMATEL methodology

Present work uses coalescence of grey and DEMATEL approaches to identify the relationships among enablers of green innovation. The steps to be followed for Grey– DEMATEL method are discussed as follows:

Step1: Developing initial relationship matrix for all experts

Consider ‘n’ as the number of enablers of green innovation and ‘k’ the number of respondents chosen for the study. Each respondent is assigned job of assessing the direct impact of facilitator ‘i’ over facilitator ‘j’ on an integer scale varying from 0, 1, 2, 3, 4, 5, representing ‘‘no influence’’, ‘‘very low influence’’, ‘‘low influence’’, medium influence’’, ‘‘high influence’’ and ‘‘very high influence’’ respectively among ‘n’ identified facilitators. The linguistic assessment and their corresponding grey numbers are presented in Table 3.2. Thus a total of ‘k’ initial relation matrices was formulated based on the influence ratings from respondents.

Table 3.2 Linguistics assessment and associated grey scales

Linguistics assessment	**Related grey numbers**
No influence (N)	(0.0, 0.1)
Very low influence (VL)	(0.1, 0.3)
Low influence (L)	(0.2, 0.5)
Medium influence (M)	(0.4, 0.7)
High influence (H)	(0.6, 0.9)
Very high influence (VH)	(0.9, 1.0)

Step 2: Computing the corresponding grey matrix for each initial relationship matrix

Using Table 3.2 and values obtained in step 1, the corresponding grey matrices are obtained by specifying an upper range and a lower range of values as given in Table 3 (Julong, 1982, 1989; Rajesh and Ravi, 2015), i.e.

$$\otimes G_{ij}^{l} = \left(\underline{\otimes}\, G_{ij}^{l}, \overline{\otimes}\, G_{ij}^{l}\right) \tag{3.8}$$

Where 1≤ l≤ k; 1 ≤ i≤ n; 1 ≤ j ≤ n.

Step 3: Obtaining the average of grey relation matrices

The average grey relational matrix $\left[\otimes \breve{G}_{ij}\right]$ is computed using ‘k’ grey relation matrices, $[\otimes G_{ij}^{l}]; l = 1 - k\ as,$

$$\otimes \breve{G}_{ij} = \left(\frac{\sum_l \underline{\otimes}\, G_{ij}^{l}}{k}, \frac{\sum_l \overline{\otimes}\, G_{ij}^{l}}{k}\right) \tag{3.9}$$

Step 4: Next step is to compute crisp matrices from average grey matrices

Using three-step procedure as used in a modified-CFCS method involving the crisp matrices are obtained (Xia et al. 2015; Rajesh et al., 2015; Rajesh and Ravi, 2015):

1. Lower and upper normalized values.

$$\underline{\otimes}\, \dot{G}_{ij} = \left(\underline{\otimes}\, \breve{G}_{ij} - {}^{min}{}_{j}\underline{\otimes}\, \breve{G}_{ij}\right) / \Delta_{min}^{max} \tag{3.10}$$

Where $\underline{\otimes}\, \dot{G}_{ij}$ represents the normalized lower limit value of the grey number $\underline{\otimes}\, \breve{G}_{ij}$

$$\overline{\otimes}\, \dot{G}_{ij} = \left(\overline{\otimes}\, \breve{G}_{ij} - {}^{min}{}_{j}\overline{\otimes}\, \breve{G}_{ij}\right) / \Delta_{min}^{max} \tag{3.11}$$

Where $\overline{\otimes}\,\dot{G}_{ij}$ represents the normalized upper limit value of the grey number $\overline{\otimes}\,\check{G}_{ij}$

$$\Delta_{min}^{max} = {}^{max}{}_{j}\overline{\otimes}\,\check{G}_{ij} - {}^{min}{}_{j}\underline{\otimes}\,\check{G}_{ij} \quad (3.12)$$

2. Calculate total normalized crisp value

$$X_{ij} = \left(\frac{\left(\underline{\otimes}\,\dot{G}_{ij}(1 - \underline{\otimes}\,\dot{G}_{ij}\right) + (\overline{\otimes}\,\dot{G}_{ij} \times \overline{\otimes}\,\dot{G}_{ij})}{\left(1 - \underline{\otimes}\,\dot{G}_{ij} + \overline{\otimes}\,\dot{G}_{ij}\right)}\right) \quad (3.13)$$

3. Compute final crisp values

$$X_{ij}^{*} = \left(min\,\underline{\otimes}\,\dot{G}_{ij} + (X_{ij} \times \Delta_{min}^{max})\right) \quad (3.14)$$

and $X = \left[X_{ij}^{*}\right]$ (3.15)

Step 5: Obtaining normalized direct-relation matrix

The normalized direct relation matrix 'N' is obtained through equations (3.16) and (3.17). All elements in this matrix lie between 1 and 0.

$$L = \frac{1}{\max_{1 \le i \le n} \sum_{j=1}^{n} X_{ij}^{*}} \quad (3.16)$$

$N = L*X$ (3.17)

Where, N is Normalized direct relation matrix; L is the normalization factor and X is the initial crisp relationship matrix.

Step 6: Determine total relation matrix "S" by using equation (3.18)

$$S = N(I - N)^{-1} \quad (3.18)$$

Where I represent an identity matrix.

Step 7: Obtain causal parameters

R denotes the sum of rows and C denotes the sum of columns. Using equations (3.19) and (3.20) it can be computed as follows:

$$R_i = \sum_{j=1}^{n} s_{ij} \forall i \quad (3.19)$$

$$C_j = \sum_{i=1}^{n} s_{ij} \forall j \quad (3.20)$$

Step 8: Set up causal diagram and digraphs

Using the values obtained through equations (3.19) and (3.20), causal diagram is set up.

3.3.4 Evolving a Management Process

This phase of the research deals in achieving the fifth objective of the thesis i.e. Developing a model for management and adoption of green innovations in SMEs of India. It involves use of mixed method methodology for developing a model for effective implementation/adoption of green innovation in SMEs. The work begins with summarizing the issues faced by SMEs in implementing and adopting green innovation. The exhaustive literature review, discussion with experts and results of previous phase of research helped in synthesizing the various issues faced by the SMEs. Mixed method based research using a mix of qualitative and quantitative tools is used to evolve a model for implementation and adoption of green innovation in SMEs.

This phase involves four techniques for achieving the objective of model development, these Options Field Methodology (OFM) and Options Profile Methodology (OPM) developed by Warfield (1979, 1982, 1990), Best Worst Method (BWM) developed by Rezaei (2015) and Fuzzy Set Theory (FST) methodology developed by Zadeh (1965).

Steps involved in each of these techniques are discussed briefly in the following sections:

Options Field Methodology: Options Field Methodology (OPM) and Options Profile Methodology (OFM) provide a means for thorough development of the design situation and the design target description. The main steps in OFM are:

- *Construction of a Polystructure*: Generate a list of options as a solution to the present research problem using modified idea writing.
- *Initial Structuring*: Place the options into a set of categories.
- *Naming of Categories*: Develop a suitable name for each category.
- *Identification of Design Dimensions*: Identify the dimensions of the target.
- *Determining Clusters of dependent Dimensions*: Put various dimensions together into different clusters based on their proximity and affinity to each other.
- *Sequencing of Clusters*: Structure the clusters on the basis of sequence in which choices of options should be made.
- *Sequencing of Dimensions within Clusters*: Define the initial decision making sequence among dimensions of each cluster.
- *Displaying the completed Options Field*: Organize the Options Field displaying the clusters, dimensions and options in an orderly manner.

Options Profile Methodology: The next technique used in qualitative modeling was Options Profile Methodology (OPM). Here, various courses of actions (Profiles) of the design are developed. These profiles can be employed to achieve overall objective of the research problem. The main steps in OPM are:

- Developing various courses of actions (Profiles) as a solution to the problem.
- Allocating various options to these alternate profiles.

The completed options profiles represent alternative approaches and courses of action to be adopted in each approach.

Best Worst Method: The next step in modeling involves uses of BWM, the steps are already discussed in section 3 above.

Fuzzy Set Theory: The next technique employed in mixed method research is Fuzzy Set Theory (FST). This technique has been used to quantify the contribution of each profile (course of action) towards various objectives (features of design) and to rank the profiles under different situations.

Fuzzy Set Theory (FST) is based on the recognition that certain sets have imprecise boundaries. Fuzzy sets and sub-sets are those ill specified and non-distinct collection of objects which don't have sharp boundaries and in which transition from membership to non-membership is gradual rather than abrupt. A fuzzy set is characterized by a membership function, defined as a real number in the interval (0, 1). For example, a membership measure of X = 0.5 suggests that X is a member of set A to a degree 0.5 on a scale where 0 is no membership at all, and 1 is complete membership. Thus, fuzzy set can be reduced to a crisp set by transforming memberships to extremes of the range 0 or 1 (Zadeh, 1965). FST approach has successfully been applied to system analysis problems, decision theory, man-machine systems, modeling of industrial processes etc. (Chakraborty et al., 2017; Mohanty and Aouni, 2010; Mohanty and Passi, 2010; Gupta and Mohanty, 2017). In the present research work, it has been used for the purpose of ranking of options profiles in an integrated form with BWM.

The fuzzy set methodology for multi-criteria decision making is used to analyze various options. The technique is designed such that quantitative and non-quantitative factors, and viewpoints of the interest groups can be readily incorporated into the decision making process. Ranks of options in a group process are achieved through a dominance matrix designed for the purpose.

In order to represent the views of each of the interest group, a position matrix is prepared from the responses of all the experts in the group by giving numerical values to the qualitative assessment.

Average value of each element representing the group response is worked out by multiplying membership function value of each alternative as given by the respondents with assigned weight (obtained by BWM).This way some of the bias in the matrix is eliminated. The weighted matrices for each of the interest groups are thus, prepared. There are three ways to aggregate the weighted matrix viz. optimistic, average and pessimistic aggregation. The highest value among various group responses represents the optimistic value, the lowest value represents the pessimistic value and the average of all the values represents the average value.

Dominance Matrix (D) of dimensions 'n x n' is prepared to display the dominance structure between all possible pairs of options. The element 'd_{ij}' is the number of features for which membership value of option 'j' dominates or is greater than option 'i'. A dash is entered for the diagonal 'd_{ij}' element. If the K_{th} column is summed, the total number of dominances of option K over all options is obtained. Similarly, if the K_{th} row is summed, the number of times the K_{th} option is being dominated by all other options is determined. Outcomes that are more favorable have higher column sums and lower row sums. In cases where an option is very close to another option on the basis of aggregate weighted position matrix, the dominance among the options exists only if the membership value of second option is outside the specified limit. The options can be considered as equivalent with respect to that feature. This range may be set for each problem (for example ± 0.5 percent of the membership value) but should not be too large; otherwise a lot of information is likely to be lost. As in case of weighted position matrices, three dominance matrices namely optimistic dominance matrix, pessimistic dominance matrix and mean dominance matrix are prepared. The ranks of options are normally decided by examining the ranks obtained from extent of dominance and also extent of being dominated by other options. Although any of the optimistic, pessimistic and average approaches can be used but there are shortcomings in each. The best course of action for a decision maker in such a situation may be to use the Hadley's criteria of cautious optimism (Hadley, 1967). The decision maker may choose different coefficients of optimism (α). If 'A' is the dominance weight of the option as determined from optimistic matrix and 'B' that of the pessimistic dominance matrix, the weight of option according to Hadley's criterion is determined by the relationship:

$$W = \alpha \times A + (1-\alpha) \times B \quad (3.21)$$

Since the process of choosing the coefficient of optimism (α) in Hadley criterion of 'Cautious Optimism' is a judgment based approach, ranks of options from the dominance matrix are considered on the basis of dominance and ignoring the considerations of being dominated.

3.4 Chapter Summary

This chapter presented a step by step approach followed to accomplish each objective in various phase of the research. A mix of qualitative and quantitative methodologies have been used in research and discussed in this chapter. The quantitative techniques are aimed to assess the current situation, rank the various enablers and barriers and explore the relationship among enablers. On the other hand, mixed method research is used to develop a framework/model for the study. The next chapter deals with first objective of the study, i.e. to assess the current situation of green innovation implementation in SMEs.

CHAPTER - IV

ASSESMENT OF CURRENT SITUATION OF GREEN INNOVATION ADOPTION/IMPLEMENTATION

4.1 Introduction

This chapter presents the current status of green innovation adoption/implementation in Indian SMEs. The survey results presents the status of various criteria of green innovation in SMEs and also the overall status of SMEs in these criteria.

4.2 Finalization of key criteria for survey

For conducting the survey, the questionnaire based technique has been used. A relevant and comprehensive questionnaire seeking information on various aspects of green innovation implementation/adoption in SMEs has been specifically designed. For effectively conducting the survey, the questionnaire has been designed through an extensive literature review and validated through peer review from academicians, consultants and practitioners from industry. After various round of discussions with experts a total of 42 sub criteria were finalized for green innovation implementation. These sub criteria were categorized into seven main categories, which are as follows:

- Collaborations
- Environmental investments and Economic benefits
- Resource availability and Green competencies
- Environmental management initiatives
- Research and Design initiatives
- Green purchasing capabilities
- Regulatory Obligations, Pressures and Market Demand

4.3 Industrial Units Surveyed

To assess the current situation of green innovation adoption/implementation, TPS (Total Point Score) and PPS (Percentage Point Score) approach as used by Nanda and Singh (2009) has been employed. Here a pilot study on few selected SMEs (Electric and auto component manufacturers from Uttrakhand, NCR and Punjab region) has been conducted. Total of 22 organizations from Patiala region of Punjab and 33 from Haridwar region in Uttrakhand and 23 from Delhi NCR region were selected. Out of 78 organizations, 48 are auto component manufacturer and 30 are electrical and electronics good manufacturers. For pilot study convenience sampling is used because of the proximity to these clusters and ease of the availability of the data. As this is pilot study no particular sample size was considered. For pilot study the auto component and electrical/electronic component manufacturing industries are chosen because they are the top two sectors in SMEs manufacturing that contribute towards the GDP of the country.

A total of 7 main criteria and 42 sub criteria (issues) of green innovation were identified through literature review and discussions with experts. SMEs were asked to rate their performance on these criteria on a scale of 1 to 5. TPS and PPS were calculated for each criteria as well as sub criteria.

4.4 Analysis of Questionnaire

The analysis of questionnaire has been carried out to assess the following:

1. Status of each component (aspect) of Green Innovation adoption/implementation aspects in the industrial sector.
2. Classification of industrial units in various Green Innovation adoption/implementation aspects.

4.5 Status of key Criteria for Green Innovation implementation/adoption

The present work considers seven main criteria and forty two sub criteria for overall assessment of green innovation adoption/implementation in the small scale sector. The status of each criteria is presented below:

4.5.1 Status of Collaborations

This section discusses the status of '*Collaborations'* issues in the manufacturing sector. The questions in questionnaire for this component aim at collecting the information on the following:

Collaborations with rivals or inter-organizational collaborations, Intra organizational collaborations, Developing suppliers capabilities, Relationship with customers and buyers pressure, Collaborations with research institutes and labs and Collaborations with social and environmental groups.

The response to individual issues on this component is presented in Table 4.1.

Table 4.1 Evaluation of Collaborations Criteria

S No	Topics in the Component	No. of Responses (N)	No. of Units Scoring					Total Point Score (TPS)^	Percent Point Score (PPS) $\frac{TPS}{5*N}100$	Central Tendency (CT) TPS/N
			1 (W_1)	**2 (W_2)**	**3 (W_3)**	**4 (W_4)**	**5 (W_5)**			
1	Collaborations with rivals or inter-organizational collaborations	78	39	29	10	0	0	127	32.56	1.63
2	Intra organizational collaborations	78	33	21	24	0	0	147	37.69	1.88
3	Developing suppliers capabilities	78	23	27	28	0	0	161	41.28	2.06
4	Relationship with customers and buyers pressure	78	28	30	18	2	0	150	38.46	1.92
5	Collaborations with research institutes and labs	78	24	31	23	0	0	155	39.74	1.99
6	Collaborations with social and environmental groups	78	31	26	21	0	0	146	37.44	1.87
Overall Average										**1.89**
	^ Total Point Score (TPS) = $1\times W_1+2\times W_2+3\times W_3+4\times W_4+W_5\times 5$									

The results show that status of collaborations with other industries is very poor (PPS = 32.56). Only about 13 % of the industries are able to collaborate to a medium extent with their rivals. Similarly status of collaborations within the organization is also very poor (PPS = 37.69). Only about 31% of the organizations are able to collaborate within different departments of the unit to a medium extent. Developing capabilities of the suppliers is also poor (PPS = 41.28). Only about 36 % of the organizations are focusing on developing green capabilities of their suppliers to a medium extent. Organizations relationship with customers and buyers is also very poor (PPS = 38.46). Only about 26% of the organizations are able to develop relationships with their buyers to a medium extent to buy green products. Collaboration with research institutes and labs which is helpful for forging collaborations to conducting green innovations at their labs is also very poor (PPS = 39.74). Only about 30% of the organizations accept to form collaborations with research institutes to a medium extent for conducting green innovation activities. Social and environmental groups involved in greening the environment are also a source of greening the organization, but the surveyed organizations have shown very poor collaborations with these groups (PPS = 37.44). Only about 27% of the organizations have shown to form collaboration to a medium extent with these environmental groups. The overall status of collaboration for green initiatives is also very poor as depicted by average score of 1.89.

4.5.2 Status of Environmental investments and Economic benefits

This section discusses the status of '*Environmental investments and Economic benefits'* issues in the manufacturing sector. The questions in questionnaire for this component aim at collecting the information on the following:

Cost Reduction, Ease in getting finance from financial institutes, Investment Recovery, Enhanced productivity and firms performance, Enhanced value to customers and Green operational efficiencies.

The response to individual issues on this component is presented in Table 4.2.

Table 4.2 Evaluation of Environmental investments and Economic benefits Criteria

S No	Topics in the Component	No. of Responses (N)	No. of Units Scoring					Total Point Score (TPS)^	Percent Point Score (PPS) $\frac{TPS}{5*N}100$	Central Tendency (CT) TPS/N
			1 (W_1)	**2 (W_2)**	**3 (W_3)**	**4 (W_4)**	**5 (W_5)**			
1	Cost Reduction	78	20	32	24	2	0	164	42.05	2.10
2	Ease in getting finance from financial institutes	78	19	29	30	0	0	167	42.82	2.14
3	Investment Recovery	78	19	25	34	0	0	171	43.85	2.19
4	Enhanced productivity and firms performance	78	25	26	27	2	0	158	40.51	2.03
5	Enhanced value to customers	78	24	28	26	0	0	158	40.51	2.03
6	Green operational efficiencies	78	20	30	27	1	0	165	42.31	2.12
Overall Average										**2.10**
	^ Total Point Score (TPS) = $1\times W_1+2\times W_2+3\times W_3+4\times W_4+W_5\times 5$									

Cost reduction by incorporating green practices is an important motivation for organizations to adopt green innovation practices at their organization, but SMEs have shown relatively poor response to achieve cost reduction (PPS = 42.05). Only about 33% organizations were able to achieve cost reduction benefits to a moderate extent through green practices. Financial institutions are providing loans to organizations that want to adopt and develop green practices, but SMEs are unable to obtain loans from these institutions to upgrade their technology (PPS = 43.85). Only about 38% of the organizations have shown their ability to obtain loans easily from financial institutions to a moderate extent for green technology upgradation. Investment recovery means that organizations are able to get the benefits of recycling by selling the scrap and reusable waste material. But SMEs have failed to incorporate the benefits of investment recovery (PPS = 43.85).

Only about 44% of the organizations have been able to get benefits of investment recovery to a moderate extent. Green innovation activities are supposed to enhance productivity and firm performance. But SMEs have shown a relatively very low increase in productivity and firm performance due to lack of green innovation practices (PPS = 40.51). Only about 37% of the organizations have shown increased productivity and performance due to green practices. Customers are more aware about greening the environment and prefer products that have less impact on the environment. But SMEs have not been able to enhance the value of their products for customers through green practices (PPS = 40.51). Only about 33% of the organizations are found to enhance the value of their products to a moderate extent. Organizations are also found to be lacking in their green operational efficiencies (PPS = 42.31). Only about 36% of the organizations are able to moderately enhance their green operational efficiencies. The overall status of Environmental investments and economic benefits is poor as depicted by average score of 2.10.

4.5.3 Status of Resource availability and Green competencies

This section discusses the status of '*Resource availability and Green competencies'* issues in the manufacturing sector. The questions in questionnaire for this component aim at collecting the information on the following:

Internal R&D and scientific expertise, Trained human resources, Green warehousing, Green transportation, Green recycling facilities, Green manufacturing capabilities and Carbon reduction initiatives.

The response to individual issues on this component is presented in Table 4.3.

Table 4.3 Evaluation of Resource availability and Green competencies Criteria

S No	Topics in the Component	No. of Responses (N)	No. of Units Scoring					Total Point Score (TPS)^	Percent Point Score (PPS) $\frac{TPS}{5*N}100$	Central Tendency (CT) TPS/N
			1 (W_1)	**2 (W_2)**	**3 (W_3)**	**4 (W_4)**	**5 (W_5)**			
1	Internal R&D and scientific expertise	78	21	18	39	0	0	174	44.62	2.23
2	Trained human resources	78	15	25	36	2	0	181	46.41	2.32
3	Green warehousing	78	14	30	34	0	0	176	45.13	2.26
4	Green transportation	78	19	31	28	0	0	165	42.31	2.12
5	Green recycling facilities	78	22	26	30	0	0	164	42.05	2.10
6	Green manufacturing capabilities	78	23	26	27	2	0	164	42.05	2.10
7	Carbon reduction initiatives	78	16	23	39	0	0	179	45.90	2.29
Overall Average										**2.20**
	^ Total Point Score (TPS) = $1\times W_1+2\times W_2+3\times W_3+4\times W_4+W_5\times 5$									

The status of internal R&D and scientific expertise is quite poor in manufacturing SMEs (PPS = 44.62). About 50% of the organizations have shown their capabilities for internal research and scientific expertise for developing green products to a moderate extent. Trained manpower in green competencies is very beneficial for green innovation, SMEs have relatively low level of trained human resource for green manufacturing available with them (PPS = 46.41). About 50% of the organizations have trained human resources to a moderate extent. Green warehousing facilities means storing products in an environmental friendly manner, SMEs are found to be having poor green warehousing facilities (PPS = 45.13). About 44% of the SMEs have green warehousing facilities to a moderate extent. Green transportation involves transporting products and raw materials in an environmental friendly manner. But SMEs have low access to green transportation facilities (PPS = 42.31). Only about 36% of the organizations show use of some sort of green transportation facilities that to a moderate extent. Green recycling facilities are an integral part of any organization whose goals are to reduce impact on environment. But SMEs are relatively poor in incorporating green recycling facilities (PPS = 42.05). About 38 % of the organizations are using some sort of green recycling facilities that to a moderate extent. Green manufacturing capabilities means involving green practices during manufacturing like energy efficient raw materials, latest technologies that reduce environmental pollution etc. SMEs have shown poor performance in adoption of green manufacturing capabilities (PPS = 42.05). Around 37% of the SMEs have shown adoption of green manufacturing capabilities to a moderate extent. Carbon reduction initiatives involves specially designing ways to reduce emissions. SMEs have shown very less adoption of carbon reduction initiatives at their end (PPS = 45.90). About 50% of the organizations have some sort of plans for reducing carbon footprints to a moderate extent. Overall status of Resource availability and Green competencies is poor as shown by overall average score of 2.20.

4.5.4 Status of Environmental management initiatives

This section discusses the status of '*Environmental management initiatives'* issues in the manufacturing sector. The questions in questionnaire for this component aim at collecting the information on the following:

Communicational practices, Environmental commitment of the firm, Internal environmental management, Green operational practices, and Planning and organizational practices.

The response to individual issues on this component is presented in Table 4.4.

Table 4.4 Evaluation of Environmental management initiatives Criteria

S No	Topics in the Component	No. of Responses (N)	No. of Units Scoring					Total Point Score (TPS)^	Percent Point Score (PPS) $\frac{TPS}{5*N}100$	Central Tendency (CT) TPS/N
			1 (W_1)	**2 (W_2)**	**3 (W_3)**	**4 (W_4)**	**5 (W_5)**			
1	Communicational practices	78	17	29	32	0	0	171	43.85	2.19
2	Environmental commitment of the firm	78	25	30	23	0	0	154	39.49	1.97
3	Internal environmental management	78	22	23	33	0	0	167	42.82	2.14
4	Green operational practices	78	14	35	29	0	0	171	43.85	2.19
5	Planning and organizational practices	78	14	23	41	0	0	183	46.92	2.35
Overall Average										**2.17**
	^ Total Point Score (TPS) = $1\times W_1+2\times W_2+3\times W_3+4\times W_4+W_5\times 5$									

Communication within the organization regarding its green goals is essential to achieve their targets. SMEs are found to be relatively poor in communicational practices within the organization (PPS = 43.85). Only about 41% of the organizations are moderately communicating their green goals within the organizations. Commitment of the organizations towards reducing environmental pollution is very important, but SMEs have very poor score on this parameter (PPS = 39.49), suggesting that SMEs are not committed towards reducing environmental pollution to a great extent. Only about 29% of the SMEs have shown commitment towards environment to a moderate extent. Internal policies and commitment of top management leads to internal initiatives of green innovation and environmental management. SMEs have relatively poor score on internal environmental management practices (PPS = 42.82). Green operation practices involves greening the whole operations in the organization, be it production process, procurement process or storage process. SMEs have poor adoptability of green operation practices at their end (PPS = 43.85). Only about 37% of the SMEs have adopted green operation practices to a moderate extent. Planning and organizational practices are necessary to keep the green organizational culture alive in the organization. SMEs have shown somewhat lower ability in planning and organizational capabilities (PPS = 46.92). Around 53% of the organizations are able to make proper planning for implementing green culture in their organization to a moderate extent. The overall status of Environmental management initiatives is relatively poor with an average score of 2.17.

4.5.5 Status of Research and Design initiatives

This section discusses the status of '*Research and Design initiatives'* issues in the manufacturing sector. The questions in questionnaire for this component aim at collecting the information on the following:

Table 4.5 Evaluation of Research and Design initiatives Criteria

S No	Topics in the Component	No. of Responses (N)	No. of Units Scoring					Total Point Score (TPS)^	Percent Point Score (PPS) $\frac{TPS}{5 * N} 100$	Central Tendency (CT) TPS/N
			1 (W_1)	**2 (W_2)**	**3 (W_3)**	**4 (W_4)**	**5 (W_5)**			
1	R&D investments	78	20	33	25	0	0	161	41.28	2.06
2	Reduced consumption of materials and energy through better design of products	78	19	28	31	0	0	168	43.08	2.15
3	Designing products so that they are easily reusable and recyclable	78	31	28	19	0	0	144	36.92	1.85
4	Reducing hazardous impact of products through better design	78	22	31	25	0	0	159	40.77	2.04
5	Designing energy efficient products	78	24	20	34	0	0	166	42.56	2.13
Overall Average										**2.05**
	^ Total Point Score (TPS) = $1 \times W_1 + 2 \times W_2 + 3 \times W_3 + 4 \times W_4 + W_5 \times 5$									

R&D investments, Reduced consumption of materials and energy through better design of products, Designing products so that they are easily reusable and recyclable, Reducing hazardous impact of products through better design, and Designing energy efficient products. The response to individual issues on this component is presented in Table 4.5.

Investment in Research and Development facilities is essential to initiate green innovations in the organization. SMEs have poor investment in R&D facilities (PPS = 41.28). Only about 32% of the organizations invest in R&D facilities to a moderate extent. Designing initiatives are taken to reduce material and energy consumption. SMEs are not taking much initiatives to design products to reduce material and energy consumption (PPS = 43.08). Only about 40% manufacturing units are making moderate efforts for designing products to reduce material and energy consumption. Reuse and recycling are two strategies that can greatly reduce environmental waste and thus pollution. But to recycle or reuse products we have to modify the designs of the products so that they can be easily recyclable and reusable. SMEs have shown poor designing ability in this aspect (PPS = 36.92). A meagre 24% units show a moderate adoption of designing practices to make products reusable. Proper designing of the products can help reducing hazardous impact of the products. SMEs are unable to reduce the impact of product use through better design (PPS = 40.77). Only about 32% of the units are able to control this aspect to a moderate extent. Energy efficient products can be designed that reduce the overall energy use and cost. SMEs are unable to design and use energy efficient products (PPS = 42.56). About 43% of the units are able to do moderate sort of designing modifications for energy efficient products. The overall status of Research and Design initiatives is very poor in SMEs as depicted by an overall average score of 2.05.

4.5.6 Status of Green purchasing capabilities

This section discusses the status of '*Green purchasing capabilities'* issues in the manufacturing sector. The questions in questionnaire for this component aim at collecting the information on the following:

Trained purchase and supply chain managers, Selecting supplier based on environmental criteria, Purchasing environmentally friendly raw materials, Pressuring suppliers for green initiatives at their end, Ensuring suppliers environmental management system adoption, Participating in design process of upstream and downstream members of supply chain, and Environmental Audits of Suppliers to ensure compliance with standards.

The response to individual issues on this component is presented in Table 4.6.

Table 4.6 Evaluation of Green purchasing capabilities Criteria

S No	Topics in the Component	No. of Responses (N)	No. of Units Scoring					Total Point Score (TPS)^	Percent Point Score (PPS) $\frac{TPS}{5*N}100$	Central Tendency (CT) TPS/N
			1 (W_1)	**2 (W_2)**	**3 (W_3)**	**4 (W_4)**	**5 (W_5)**			
1	Trained purchase and supply chain managers	78	12	25	41	0	0	185	47.44	2.37
2	Selecting supplier based on environmental criteria	78	9	27	42	0	0	189	48.46	2.42
3	Purchasing environmentally friendly raw materials	78	18	26	31	3	0	175	44.87	2.24
4	Pressuring suppliers for green initiatives at their end	78	10	25	43	0	0	189	48.46	2.42
5	Ensuring suppliers environmental management system adoption	78	12	25	41	0	0	185	47.44	2.37
6	Participating in design process of upstream and downstream members of supply chain	78	17	29	30	2	0	173	44.36	2.22
7	Environmental Audits of Suppliers to ensure compliance with standards	78	6	29	43	0	0	193	49.49	2.47
Overall Average										**2.36**
	^ Total Point Score (TPS) = $1\times W_1+2\times W_2+3\times W_3+4\times W_4+W_5\times 5$									

Supply chain managers must be provided with training so that they procure products which are environmentally friendly. But, SMEs lack trained supply chain managers (PPS = 47.44). About 53% of the units have managers to a moderate extent who are trained for procuring green materials. Organizations must select their suppliers considering certain environmental criteria. SMEs are found not be considering environmental criteria much while selecting their suppliers (PPS = 48.46). Around 54% of the SMEs moderately consider environmental criteria while selecting their suppliers. Organizations should try to purchase raw materials that have less impact on the environment. SMEs do not consider purchasing environmental friendly raw materials to a large extent (PPS = 44.87). Only about 44% units purchase environmental friendly raw materials that too a moderate extent. Suppliers must be pressurized to adopt green technologies at their end to green the supply chain. SMEs are found not to pressurize their suppliers for adopting green initiatives to a great extent (PPS = 48.46). Environmental Management Systems which includes ISO 14000 should be adopted by every organization for effectively managing greening of the organizations. SMEs are not found to pressurize their suppliers to adopt EMS to a large extent (PPS = 47.44). Participating in designing process of their upstream and downstream suppliers can help organizations to learn from their upstream supply chain partner and pass on that learning to downstream supply chain partner which can help in greening the organizations. SMEs, are not participating much in the design process with their supply chain partners (PPS = 44.36). Only about 41% organizations moderately participate with their supply chain partners for green designing. One way to enforce the compliance of environmental practices and standards at their suppliers end is to regularly conduct environmental audits of suppliers. But, SMEs are not found to conduct environmental audits of their suppliers to much extent (PPS = 49.49). About 55% of the units conduct some sort of audits for their suppliers. Overall situation of Green purchasing capabilities is average is SMEs as depicted by an overall average score of 2.36.

4.5.7 Status of Regulatory Obligations, Pressures and Market Demand

This section discusses the status of '*Regulatory Obligations, Pressures and Market Demand'* issues in the manufacturing sector. The questions in questionnaire for this component aim at collecting the information on the following:

Technical assistance for technology upgradation, Tax cuts and incentives for producing green products, Implementation of environmental policy, Stringency in enforcement of green design norms, Market demand for green products, and Competitive pressures to outperform competitors. The response to individual issues on this component is presented in Table 4.7.

Government needs to regularly provide assistance about technology upgradation to SMEs so that they can carry out new product and process development initiatives. SMEs are not being provided technology upgradation assistance to a great extent by the government (PPS = 46.67). About 53% of the SMEs feel to a moderate extent that they are provided some assistance with respect to technology upgradation. Tax cuts and incentives motivates SMEs to produce green products. SMEs feel that they are not provided with significant incentives and tax cuts to produce green products (PPS = 50.77). Only 42% of the SMEs are moderately satisfied with tax benefits provided by the government. Government has formulated many policies for environmental protection and monitoring but these policies often fail to reach SMEs. Surveyed SMEs believe that environmental policies are not being implemented by government (PPS = 50.77). About 54% of the SMEs believe that environmental policies are being implemented that too a moderate extent. Apart from environmental policies, government has also proposed some design norms for green products. But these norms are not being implemented stringently among SMEs (PPS = 48.72). Organizations will change their technologies and processes for producing environmental friendly products when they will see a demand of these products in the market. SMEs don't believe that there is a large market for green products (PPS = 48.21). Only about 50% of the SMEs see a moderate demand for green products in the market. Organizations are constantly under pressure from their competitors to come up with better products that are having more functional value. This leads to organizations to come up with innovative ideas. But the survey results indicate that SMEs are not in such kind of competitive pressure to outperform their competitors primarily due to limited customer base (PPS = 47.95). Only about 46% of the SMEs believe that they have some sort of pressure to outperform their competitors. The overall status of Regulatory Obligations, Pressures and Market Demand is average as is depicted by an average score of 2.40.

Table 4.7 Evaluation of Regulatory Obligations, Pressures and Market Demand Criteria

S No	Topics in the Component	No. of Responses (N)	No. of Units Scoring					Total Point Score (TPS)^	Percent Point Score (PPS) $\frac{TPS}{5*N}100$	Central Tendency (CT) TPS/N
			1 (W_1)	**2 (W_2)**	**3 (W_3)**	**4 (W_4)**	**5 (W_5)**			
1	Technical assistance for technology upgradation	78	15	22	41	0	0	182	46.67	2.33
2	Tax cuts and incentives for producing green products	78	13	32	33	0	0	176	45.13	2.26
3	Implementation of environmental policy	78	2	34	40	2	0	198	50.77	2.54
4	Stringency in enforcement of green design norms	78	12	21	44	1	0	190	48.72	2.44
5	Market demand for green products	78	9	30	37	2	0	188	48.21	2.41
6	Competitive pressures to outperform competitors	78	5	37	36	0	0	187	47.95	2.40
Overall Average										**2.40**
	^ Total Point Score (TPS) = $1\times W_1+2\times W_2+3\times W_3+4\times W_4+W_5\times 5$									

4.6 Classification of Manufacturing Organizations

The purpose of this section is to evaluate the performance of manufacturing organizations in different criteria of green innovation implementation and thus to classify them into different categories. The overall standing of various units in different components has been assessed. The score of each organization (in terms of percent points scored, PPS) in criteria of green innovation has been calculated from the raw score of issues under each component.

Table 4.8 Criteria for Classification of Industries

Category	**Range of Percent Score**	***Inference***	***Grading***
1	25-35	Industry at the lowest stage. Nearly all responses to the lowest choice box on an average	Very Poor
2	36-55	Industry at a poor stage. Nearly ass responses to the third or fourth choice on an average	Poor
3	56-75	Nearly all responses to the second or third choice on an average	Fair
4	76-90	Industry at a good stage. Nearly all responses to the first and second choice on an average	Good
5	91-100	Industry at the highest stage. Nearly all responses to the highest choice box on an average	Very Good

While deciding upon the choice carrying highest marks in each issue, the levels achievable by small scale manufacturing industry in India have been taken into consideration. Requirements for highest score are definitely less than those for best in the world. Thus, a score close to 100% (PPS≈100) obtained by an organization has been graded as *Very Good* only and not *Excellent*. Further, the organizations score just 20% marks (PPS= 20) in a component if all responses to various issues of that component fall at the lowest choice and score 100% marks if all responses correspond to the best choice. The criterion used to classify the industries into different categories is presented in Table 4.8. Figure 4.1 presents the performance rating of organizations in various criteria of green innovation implementation.

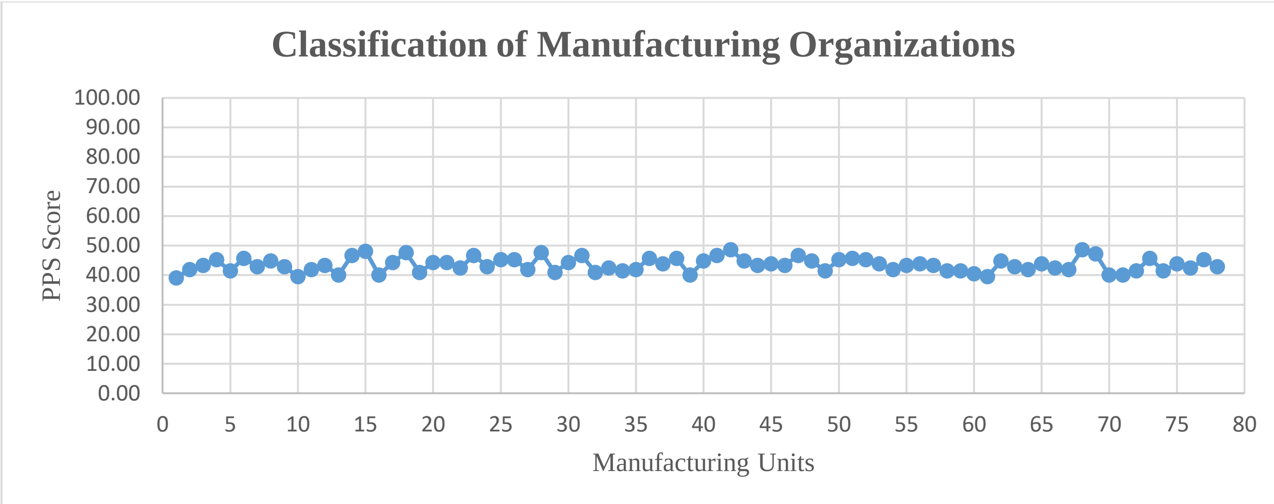

Figure 4.1 Classification of Manufacturing Organizations

As can be seen from Figure 4.1 the PPS score of all the units fall under the range of 36-55 Percentage Point Score. Thus it signifies that all the units are under poor category which in turn implies that the implementation/adoption of green innovation in SMEs are at very nascent stage and thus a model needs to be developed for SMEs regarding adoption/implementation of green innovation at their end.

4.7 Chapter Summary

This chapter was aimed to assess the current situation of green innovation SMEs in selected SMEs. A pilot survey was done in few selected SMEs through questionnaire based survey method. TPS and PPS scores for each criteria of green innovation were calculated to assess the adoption of green innovation criteria in SMEs. Finally PPS score for all the units was also calculated to assess the status of these SMEs in green innovation implementation. The results have revealed that overall status of green innovation adoption/implementation is poor in Indian SMEs. Thus the second objective of the research is completed. The next chapter is aimed to identify the barriers to green innovation in SMEs.

CHAPTER - V

ANALYSIS OF BARRIERS AND SOLUTIONS TO GREEN INNOVATION

5.1 Introduction

This chapter deals with the identification, finalization and prioritization of barriers to green innovation in SMEs. It also identifies, finalizes and suggests solutions/strategies to overcome these barriers. This chapter proposes a framework using two integrated methodologies i.e. BWM and fuzzy TOPSIS. The framework helps to first rank barriers to green innovation and then prioritize the solutions to overcome these barriers.

5.2 Proposed framework and identification of barriers and solutions

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 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.

To rank barriers and solutions to overcome these barriers, a three-phase methodology is proposed (Figure 5.1). 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).

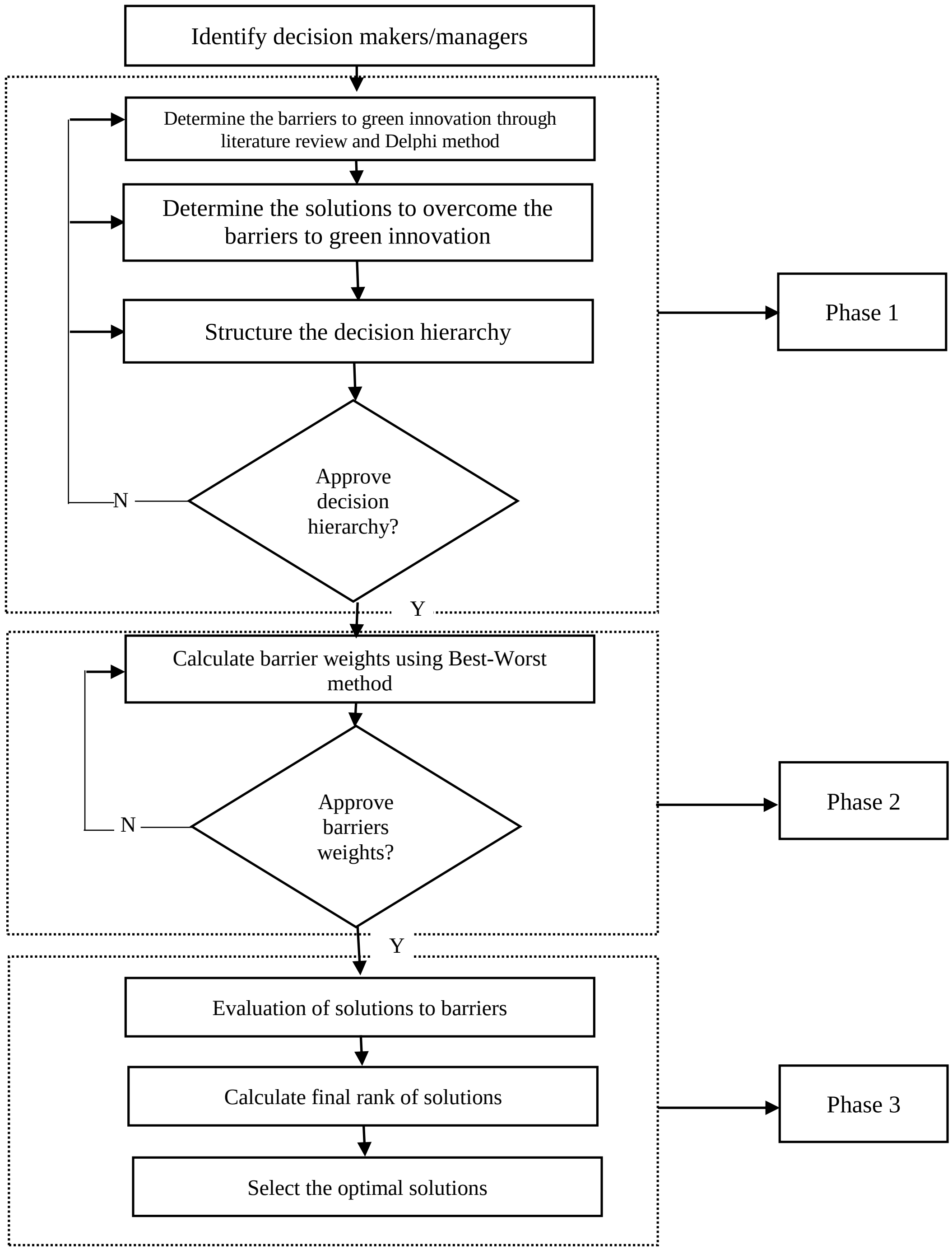

Figure 5.1 Schematic diagram for phases of methodology

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:

5.2.1 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., 2012; Mathiyazhagan et al., 2013; Dubey et al., 2015; Mangla et al., 2017); reluctance to switch to green practices (Ashford, 1993; Zhu et al., 2012; 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).

5.2.2 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 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).

5.2.3 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).

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

5.2.5 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., 2012); poor enforcement of environmental policies thus giving trespassing advantage to few (Runhaar et al., 2008; AlKhidir and Zailani, 2009; Zhu et al., 2012; 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).

5.2.6 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).

5.2.7 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-Guijarra 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). The barriers are summarized in tablurar form in Table 5.1 below.

5.2.8 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 5.2 below.

Table 5.1 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., 2012; Mathiyazhagan et al., 2013; Dubey et al., 2015; Mangla et al., 2017
	Reluctance to switch to green practices (MO2)	Ashford, 1993; Zhu et al., 2012; Lin and Ho, 2008; 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; Mangla et al., 2017
	Lack of human resources for green innovation (MO4)	Collins et al., 2007; 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; Zhu et al., 2012
	Lack of reward systems for green innovations (MO7)	Hadjimanolis, 1999; 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; Pawanchik and Sulaiman 2010
	Technological and market uncertainty and fear of failure related to green innovations (TG2)	Rao and Holt, 2005; 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; Perron, 2005
	Lack of new technology, materials, processes, and skills to innovate (TG5)	Perron, 2005; 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; Hall et al., 2016
Financial and economic barriers (FE)	Less payoff as compared to investment in green innovations (FE1)	Matus et al., 2012; Govindan et al., 2014
	Lack of access to government subsidies and financial incentives (FE2)	EIO, 2011; Cecere et al., 2016; Hojnik and Ruzzier, 2016
	Unavailability of bank loans to promote green practices (FE3)	Mathiyazhagan et al., 2013; Cecere et al., 2016
	High costs of disposing of hazardous wastes (FE4)	Mathiyazhagan et al., 2013; 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

Barriers	**Sub barriers**	**Reference**
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; Dhull and Narwal, 2016
	Lack of understanding regarding green practices by other SMEs (PP2)	Sarkar and Mohapatra, 2006; Wolf and Seuring, 2010; Dhull and Narwal, 2016
	Poor communication with external partners and lack of role clarity (PP3)	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 (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; Zhu et al., 2012; Prakash et al., 2015
	Enforcement of environmental policies thus giving trespassing advantage to few (GS2)	Runhaar et al., 2008; AlKhidir and Zailani, 2009; Zhu et al., 2012; Blok et al., 2015
	Lack of training programs by the government for SMEs to incorporate green practices (GS3)	Runhaar et al., 2008; Zhu et al., 2012
	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 Rutherford, 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-Guijarra 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

Table 5.2 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; 2014; Solazzoet 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., 2012; 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; 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

S.No.	Solutions/Strategies	Reference
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

5.3 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.

5.3.1 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. 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:

5.3.2 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 amongst 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 5.1 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 5.2 above.

5.3.3 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 5.3. 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 chapter 3. The ratings of main criteria barriers by manager 1 are shown in Table 5.4.

Table 5.3 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

Table 5.4 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

The managers from each SME were asked to rate the main criteria barriers as well as sub-criteria barriers using the steps shown in chapter 3. The ratings of manager 1 for sub criteria barriers are shown in Tables 5.5 to 5.11 below.

Table 5.5 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

Table 5.6 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 5.7 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 5.8 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

Table 5.9 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 5.10 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 5.11 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

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 (3.2), 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 5.12. 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.

5.3.4 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 SME was formed and they were asked to rate the solutions using the linguistic scale as shown in Table 3.1.The resultant matrix showing corresponding fuzzy values of linguistic variables for comparison is shown in Table 5.13.

Next step is to calculate weighted normalized fuzzy matrix as per equation (3.3) and is presented in Table 5.14. Also FPIS, A^{+} and FNIS, A^{-}, are determined using equations (3.4) and (3.5). 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 equations (3.6) and (3.7). The corresponding CCi values and ranks of the solutions are presented in Table 5.15.

Table 5.12 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

Table 5.13 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 5.14 Weighted fuzzy evaluation matrix for solutions

	MO1	MO2	MO3	MO4	MO5	MO6	MO7	TG1	TG2			MC3	IK1	IK2	IK3	IK4	IK5
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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

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	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
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	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
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	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
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	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
A^+	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$	$v_1^+ = (0, 0, 0)$
A^-	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$	$v_1^- = (1, 1, 1)$

Table 5.15 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

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>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.

5.4 Result analysis and discussion

Best – Worst analysis is used to rank the barriers to green innovation. Table 5.12 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 amongst 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 more than 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 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).

5.5 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).

Table 5.16 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

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 5.16 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 5.17.

Table 5.17 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

Table 5.17 and Figure 5.2 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.

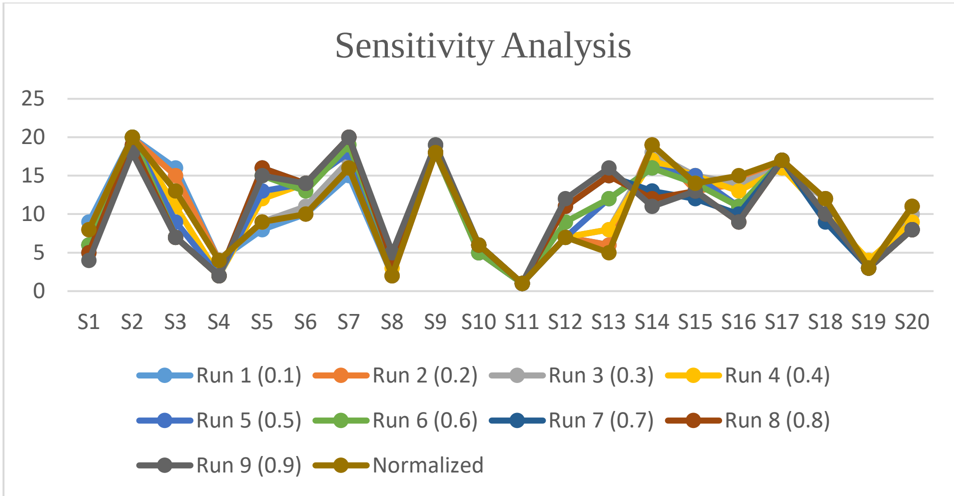

Figure 5.2 Results of sensitivity analysis for solutions

5.6 Chapter Summary

This chapter 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 sub category barriers were identified, along with twenty solutions to overcome these barriers. These barriers were than ranked through BWM and using Fuzzy TOPSIS solutions were ranked. Hence objective two of the research is completed.

Chapter - VI

SUPPLIER SELECTION ON THE BASIS OF GREEN INNOVATION ENABLERS

6.1 Introduction

This chapter deals with the objectives 3 and 4 of the study i.e. Identifying, prioritizing and finding the relationship among the enablers of green innovation adoption in SMEs and Selecting component suppliers among SMEs for large manufacturing organization based on green innovation ability of SMEs. The chapter is divided into two parts, in first part the identification and prioritization of enablers of green innovation and selecting supplier among SMEs on the basis of these enablers is done using an integrated BWM and fuzzy TOPSIS methodology. The second part deals with the identifying the relationship among some selected enablers of green innovation using Grey DEMATEL methodology.

6.2 Proposed framework and Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS

Chiou et al. (2011) suggested that in order to relieve pressure of buyer's requirement, companies should work closely by integrating their business processes with their suppliers and also provide technical assistance, guidance to implement environmental management systems and arrange to organize training programs to improve the environmental performance of their suppliers. Thus organizations need to invest in greening their suppliers and also in green innovations to meet stringent requirements of regulators and customers. However due to financial constraints, organizations are not always able to invest much at their suppliers end for greening their operations, hence these large organizations needs to strategically select their suppliers among SMEs, such that these small enterprises are self-reliant and capable in terms of their green operations.

With this in mind, this chapter has following sub-objectives:

- To identify the criteria of green innovation for SMEs and present a novel framework for supplier selection among the selected SMEs on the basis of their green innovation capabilities/capacities.
- To distinguish relative importance weight of each criteria for green innovation.
- To select the most efficient supplier among the various set of alternatives in green supply chain.

A novel three phase methodology (see Figure 6.1) is proposed for supplier selection problem in this study. The first phase involves finalization of criteria for supplier selection through extant literature review and discussions with experts, the second phase involves calculating weights of each criteria and sub criteria using Best-Worst multi criteria method and final phase involves ranking of suppliers using the Fuzzy TOPSIS methodology.

Based on extensive literature review and discussion with experts various criteria of green innovation are identified and are listed below:

6.2.1 Collaborations

Collaboration means bringing together persons from different functional groups within an organization or from different organizations and jointly working on achieving the organizations green goals. Success of green implementation program in any organization depends upon collective participation of all the members involved in various activities like green purchasing, green design, internal environmental management and investment recovery (Zhu et al., 2008).Collaborative networks are an important source of innovation for organizations (Bossink, 2002), as it helps in sharing of various competencies and resources between organizations that are otherwise difficult to obtain by one organization (Powell, 1998). The various dimensions of collaborations as green innovation criteria can be as follows: Collaborations with rivals or inter-organizational collaborations (Grandori and Soda, 1995; Christensen et al., 2005; Chesbrough, 2006; Inkpen and Pien, 2006; Vanhaverbeke, 2006; Messeni Petruzzelli et al., 2011); Intra organizational collaborations (Shrivastava and Hart, 1995; Song et al., 1997; Cabrales et al., 2008; Messeni Petruzzelli et al., 2011; Kusi-Sarpong et al., 2015; 2016); Developing suppliers capabilities (Carter et al., 1998; Geffen and Rothenberg, 2000; Handfield et al., 2006; Vachon and Klassen, 2006;Wagner and Krause, 2009; Large and Thomsen, 2011; Chakraborty et al., 2017); Relationship with customers and buyers pressure (Green et al., 1994; Gonzalez-Benito, 2008; Sandström and Tingström, 2008; Rennings and Rammer, 2009; Bos-Brouwers, 2010; Eltayeb et al., 2011; Keskin et al., 2013; Lee et al., 2014); Collaborations with research institutes and labs (Contributed criteria) and Collaborations with social and environmental groups (Contributed criteria).

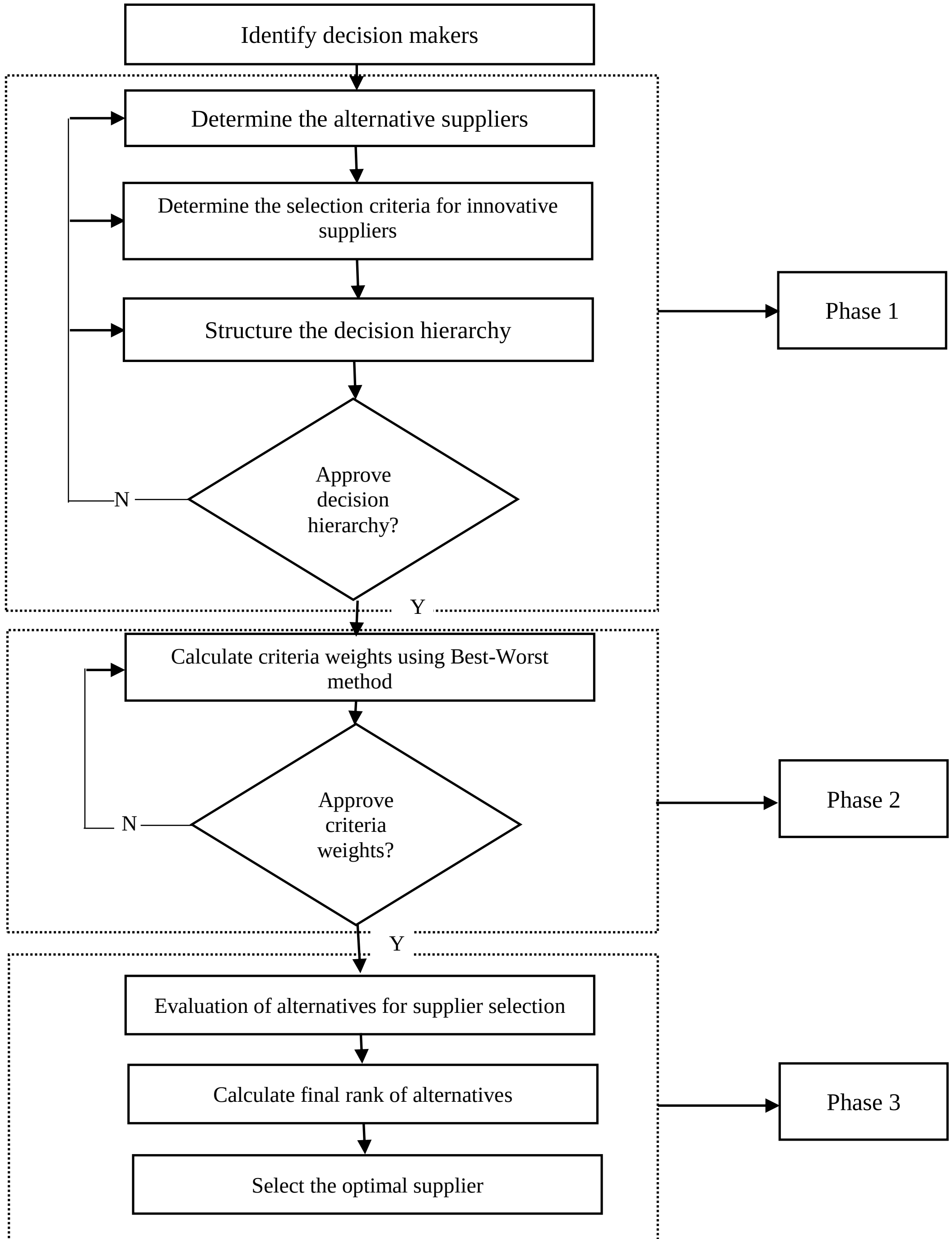

Figure 6.1 Schematic diagram for phases of methodology

6.2.2 Environmental investments and Economic benefits

Environmental investments are the amount of capital allocated from the organizations total budget towards improving and sustaining organizations environmental performance. This allocation can be used either during the product design phase, production phase or during disposing phase, also investments are made to improve end of pipe technologies and reduction in pollutants being disposed (Klassen and Whybark, 1999a). These spending's by organization positively impact organizational economic and environmental performance (Lucas, 2010). The various dimensions of Environmental investments and Economic benefits as green innovation criteria can be as follows: Cost reduction (Hilson and Nayee, 2002; Azapagic, 2004; Berkel, 2007; Lee, 2008; Chiou et al., 2011; Mathiyazhagan and Haq, 2013; Mathiyazhagan et al., 2013; Govindan et al., 2016); Ease in getting finance from financial institutes (Hilson and Nayee, 2002; Azapagic, 2004; Jenkins and Yakovleva, 2006; Mathiyazhagan et al., 2013; Govindan et al., 2016); Investment recovery (Zsidisin and Hendrick, 1998; Atkinson, 2002; Zhu and Sarkis, 2004; Franke et al., 2006; Zhu et al., 2008; Wooi and Zailani, 2010; Kapetanopoulou and Tagaras, 2011; Lee, et al., 2014); Enhanced productivity and firms performance (Chen et al., 2006; Rex and Baumann, 2007; Chen, 2008; Oltra and Saint Jean, 2009; Tseng et al., 2009; Chiou et al., 2011); Enhanced value to customers (Contributed criteria); Green operational efficiencies (Contributed criteria).

6.2.3 Resource availability and Green competencies

Resources can be defined as "stocks of available factors that are owned or controlled by the firm whereas capabilities refer to 'a firm's capacity to deploy resources usually in combination, using organizational processes, to effect a desired end" (Amit and Schoemaker, 1993, p. 35).Green manufacturing capabilities are a combination of monetary, skilled workforce, latest technological and managerial resources (Grant, 1991). SMEs are often resource constrained and when the resources are rare, it leads to competitive advantage and firms need to innovatively manage resources for sustained growth (Barney, 1991). The various dimensions of Resource availability and Manufacturing capabilities as green innovation criteria can be as follows: Internal R&D and scientific expertise (Green et al., 1994; Rennings and Rammer, 2009; Huang and Wu, 2010; Horbach et al., 2012; Dangelico, 2016); Trained human resources (Kivimaa, 2008; Sandström and Tingström, 2008; Keskin et al., 2013; Dangelico, 2016); Green warehousing (Rao, 2002; Rao and Holt, 2005; Hervani et al., 2005; Zhu et al., 2008; 2010; Kannan et al., 2014); Green transportation

(Liu et al. 2011; Böttcher and Müller, 2015; Jabbour et al., 2015; Somsuk and Laosirihongthong, 2016); Green recycling facilities (Srivastava 2007; Nikbakhsh, 2009; Somsuk and Laosirihongthong, 2016); Green manufacturing capabilities (Grant, 1991; Klassen and Whybark, 1999b; Zhu et al., 2008; Nelson and Winter, 2009; Nikbakhsh, 2009; Maruthi and Rashmi 2015; Somsuk and Laosirihongthong, 2016); Carbon reduction initiatives (Kannan et al., 2014; Böttcher and Müller, 2015; Jabbour et al., 2015).

6.2.4 Environmental management initiatives

Hajmohammad et al. (2013) described these practices as "the level of resources invested in activities and know-how development that lead to pollution reduction at the source". Environmental management can be referred to as various modes of management practices that aim at greening the products and processes at the organization in order for sustainable development and reducing the impact of organizations activities on environment (Gotschol et al. 2014). Various strategies could include pollution prevention, waste disposal technologies development, ISO certification and environmental auditing (Zhu et al., 2007). The various dimensions of Environmental management initiatives as green innovation criteria can be as follows:Communicational practices (Contributed criteria); Environmental commitment of the firm (Henriques and Sadorsky, 1999; Aragon-Correa and Sharma, 2003; Simpson et al., 2007); Internal environmental management (Carter et al., 1998; Melnyk et al., 2003; Zhu and Sarkis, 2006; Bergmiller and McCright, 2009; Hajmohammad et al.,2013; Lee et al., 2014; Somsuk and Laosirihongthong, 2016); Green operational practices (De Ron, 1998; Sarkis, 1998; Angell and Klassen, 1999; Klassen and Whybark, 1999a ; Gilley et al., 2000; Min and Galle, 2001; Zhu et al., 2007); Planning and organizational practices (Aragón-Correa, 1998; Henriques and Sadorsky, 1999; Klassen and Whybark, 1999a).

6.2.5 Research and Design initiatives

Green design can be defined as the initiatives taken during the design and product development phase so as to minimize the negative impact caused by product on environment during its entire life cycle (Eltayeb et al., 2011). R&D initiatives helps build technological competencies which is a driving factor for green innovation (Horbach, 2008). Further, green innovations require certain skill sets to be developed and these skills are function of research and development (Hermosilla et. al., 2009). The various dimensions of Research and Design initiatives as green innovation criteria can be as follows: R&D investments (Hemel and Cramer, 2002; Montalvo, 2003; Horbach, 2008; Halila and Rundquist, 2011; Testa et al., 2011; Horbach et al., 2012; Zailani et al., 2012); Reduced consumption of materials and energy through better design of products (APO, 2004; Gonzalez et al., 2008; Tseng and Chiu, 2012; Govindan et al., 2016); Designing products so that they are easily reusable and recyclable (Sarkis, 1998; Lin et al., 2011; Govindan et al., 2013; Govindan et al., 2016); Reducing hazardous impact of products through better design (Zsidisin and Siferd, 2001; Tseng, 2011; Tseng and Chiu, 2012; Singh and Trivedi, 2016); Designing energy efficient products (Contributed criteria).

6.2.6 Green purchasing capabilities

Green purchasing is defined as "environmental plans for a firm's long-term material, component or system requirements" thus indirectly tracking the amount of waste flowing into or out of the system (Zhu and Sarkis, 2007, p. 321). It can also be called as purchasing environmentally favorable products thus causing no negative impact on environment (Joshi and Rahman, 2015). It also means working in close coordination with suppliers by providing them design specifications so as to integrate environmental factors during manufacturing and design phase (Zsidisin and Hendrick, 1998). The various dimensions of Green purchasing capabilitiesas green innovation criteria can be as follows: Trained purchase and supply chain managers (Contributed criteria); Selecting supplier based on environmental criteria (Carter and Carter, 1998; Zhu et al., 2008; Kannan et al., 2014); Purchasing environmentally friendly raw materials (Sarkis, 2001; Wang, 2005; Zhu et al., 2007; Awasthi et al., 2010; Lee, et al., 2014); Pressuring suppliers for green initiatives at their end (Zhu et al., 2005; Chan et al. 2012; Mahmood et al., 2013; Kannan et al., 2014); Ensuring suppliers environmental management system adoption (Sarkis, 1998; Hsu and Hu, 2009; Eltayeb et al., 2011; Tseng, 2011; Chan et al. 2012; Tseng and Chiu, 2012; Shen et al., 2013; Somsuk and Laosirihongthong, 2016); Participating in design process of upstream and downstream members of supply chain (Zsidisin and Hendrick, 1998; Zhu and Sarkis, 2007; Large and Thomsen, 2011; Hassan et al., 2016); Environmental Audits of Suppliers to ensure compliance with standards (Mahmood et al., 2013; Kannan et al., 2014; Hassan et al., 2016; Somsuk and Laosirihongthong, 2016).

6.2.7 Regulatory Obligations, Pressures and Market Demand

Environmental regulations motivate organizations to devote some amount of the turnover in clean technologies and incorporate these technologies in their production and design processes (Fergusson and Langford, 2006; Qi et al., 2010).These regulations also include some time frames and policies that need to be followed to implement innovative solutions at the organizations so as to control negative impact on environment (Eiadat et al., 2008). Government support and regulations are especially necessary in SMEs to trigger green innovations (Noci and Vergandi, 1999). Market demand is also essential for organizations success (Zhou et al., 2009). Green market demand combined with regulatory obligations push organizations to carry out green innovations at their end (Triebswetter and Wackerbauer, 2008; Chiou et al., 2011; Halila and Rundquist, 2011). The various dimensions of Regulatory Obligations, Pressures and Market Demandas green innovation criteria can be as follows: Technical assistance for technology upgradation (Blayse and Manley, 2004; Fergusson and Langford, 2006; Qi et al., 2010); Tax cuts and incentives for producing green products (Green et al., 1995; Bowen et al., 2001; Zhu et al., 2005; Johnstone et al., 2010; Kiss et al., 2013; Govindan et al., 2016); Implementation of environmental policy (Frondel et al., 2004; Rehfield et al., 2007; Horbach, 2008); Stringency in enforcement of green design norms (Frondel et al., 2004; Rehfield et al., 2007; Horbach, 2008; Govindan et al., 2016); Market demand for green products (Kammerer, 2009; Zhou et al., 2009; Horbach et al., 2012; Lin et al., 2013; Chiou et al., 2011; Zhu et al., 2012); Competitive pressures to outperform competitors (Bueno et al., 2004; Alegre and Chiva, 2008; Zhou et al., 2009; Chiou et al., 2011).

The finalized criteria and sub-criteria for green innovation are summarized in Table 6.1 below.

6.3 Illustrative application

This section will briefly illustrate the background of the company taken for case study. The application of three phase methodology will be done on case company to develop a robust model of supplier selection for them among multiple suppliers. The application of this methodology in real world example signifies its validity and robustness.

Table 6.1 Criteria and sub criteria for green innovation

Main Criteria	Sub Criteria
Collaborations (GI1)	Collaborations with rivals or inter-organizational collaborations (C1)
	Intra organizational collaborations (C2)
	Developing suppliers capabilities (C3)
	Relationship with customers and buyers pressure (C4)
	Collaborations with research institutes and labs (C5)
	Collaborations with social and environmental groups (C6)
Environmental investments and Economic benefits (GI2)	Cost Reduction (E1)
	Ease in getting finance from financial institutes (E2)
	Investment Recovery (E3)
	Enhanced productivity and firms performance (E4)
	Enhanced value to customers (E5)
	Green operational efficiencies (E6)
Resource availability and Green competencies (GI3)	Internal R&D and scientific expertise (R1)
	Trained human resources (R2)
	Green warehousing (R3)
	Green transportation (R4)
	Green recycling facilities (R5)
	Green manufacturing capabilities (R6)
	Carbon reduction initiatives (R7)
Environmental management initiatives (GI4)	Communicational practices (EN1)
	Environmental commitment of the firm (EN2)
	Internal environmental management (EN3)
	Green operational practices (EN4)
	Planning and organizational practices (EN5)
Research and Design initiatives (GI5)	R&D investments (RD1)
	Reduced consumption of materials and energy through better design of products (RD2)
	Designing products so that they are easily reusable and recyclable (RD3)
	Reducing hazardous impact of products through better design (RD4)
	Designing energy efficient products (RD5)
Green purchasing capabilities (GI6)	Trained purchase and supply chain managers (GP1)
	Selecting supplier based on environmental criteria (GP2)
	Purchasing environmentally friendly raw materials (GP3)
	Pressuring suppliers for green initiatives at their end (GP4)
	Ensuring suppliers environmental management system adoption (GP5)
	Participating in design process of upstream and downstream members of supply chain (GP6)
	Environmental Audits of Suppliers to ensure compliance with standards (GP7)
Regulatory Obligations, Pressures and Market Demand (GI7)	Technical assistance for technology upgradation (RO1)
	Tax cuts and incentives for producing green products (RO2)
	Implementation of environmental policy (RO3)
	Stringency in enforcement of green design norms (RO4)
	Market demand for green products (RO5)
	Competitive pressures to outperform competitors (RO6)

6.3.1 Case company background and experts' background

The company 'ABC', taken up for study is a leading automobile company having pan country supply of products. The company is in inception for past more than 30 years and is a market leader in its segment of products. However, in spite of being in operations for past so many years, company is not having a strong framework for selecting its suppliers on the basis of certain criteria. Recently company has committed to working towards environmental improvement through adoption of green practices at its end, in order to accomplish this goal of going green, company requires its suppliers also to follow green practices. This study aims at developing a robust framework for company to help them select suitable supplier for their raw materials and components. For the purpose of selecting suitable suppliers, four experts have been chosen for study, Expert 1 is a senior manager in supply chain department of the company, Expert 2 is a manager in supply chain department of the company, Expert 3 is also a manger in supply chain manager of the company and Expert 4 is chosen from academia having experience in innovations, SMEs and supply chain management. All the experts are chosen because of their vast experience (more than 10 years at least) in the field of supplier selection and innovations. The panel consensus approach is used for obtaining expert opinion. Panel consensus approach has the assumption that opinion of several experts can lead to achieve a better solution than opinion of a single expert (Hirschey, 2008). Panel was made to meet and first finalize the criteria and sub criteria for the analysis, after that experts were asked to arrive at common consensus regarding the score (mentioned in Table 6.2) for pairwise comparison of all the criteria and sub criteria, the panel discussion lasted for about three hours until all the experts arrived at a common solution through various round of deliberations. The application of three phase methodology on case company is illustrated below:

6.3.2 Finalization of selection criteria

Extensive literature review is done to identify the criteria for green innovations in SMEs, apart from criteria identified through literature review, experts were also asked to suggest some other criteria not identified through literature review. A total of 7 main criteria and 42 sub criteria were finalized by experts and are taken up for study.

6.3.3 Calculation of criteria weights using Best – Worst methodology

After finalization of selection criteria by the experts, next step is to determine the best and worst criteria among the main criteria, after selecting best and worst criteria the next step is to determine preference of best criteria over all other criteria and also preference rating of all the criteria over worst criteria on a scale of 1 to 9. The subsequent best to others rating and others to worst ratings obtained are represented in Table 6.2 below,

Table 6.2 Main criteria comparison

BO	**Collaborations (GI1)**	**Environmental investments and Economic benefits (GI2)**	**Resource availability and Green competencies (GI3)**	**Environmental management initiatives (GI4)**	**Research and Design initiatives (GI5)**	**Green purchasing capabilities (GI6)**	**Regulatory Obligations, Pressures and Market Demand (GI7)**
Best criteria: **Resource availability and Green competencies (GI3)**	8	2	1	9	3	6	2

OW	**Worst criteria: Environmental management initiatives (GI4)**
Collaborations (GI1)	2
Environmental investments and Economic benefits (GI2)	4
Resource availability and Green competencies (GI3)	9
Environmental management initiatives (GI4)	1
Research and Design initiatives (GI5)	3
Green purchasing capabilities (GI6)	2
Regulatory Obligations, Pressures and Market Demand (GI7)	5

Similar to the pairwise comparison of main criteria, all the sub criteria are subjected to similar pairwise comparison on a scale of 1 to 9 after identifying their respective best and worst criteria. The pairwise comparison of collaborations sub criteria is presented in Table 6.3 below,

Table 6.3 Pairwise comparison for Collaborations sub criteria

BO	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**
Best criteria: **C_4**	4	3	2	1	7	9

OW	Worst criteria: C_6
C_1	2
C_2	3
C_3	4
C_4	9
C_5	2
C_6	1

The pairwise comparison of Environmental investments and Economic benefits sub criteria is presented in Table 6.4 below,

Table 6.4 Pairwise comparison for Environmental investments and Economic benefits sub criteria

BO	E_1	E_2	E_3	E_4	E_5	E_6
Best criteria: E_3	8	2	1	4	3	4

OW	Worst criteria: E_1
E_1	1
E_2	4
E_3	8
E_4	2
E_5	3
E_6	3

The pairwise comparison of Resource availability and Green competencies sub criteria is presented in Table 6.5 below,

Table 6.5 Pairwise comparison for Resource availability and Green competencies sub criteria

BO	R_1	R_2	R_3	R_4	R_5	R_6	R_7
Best criteria: R_5	8	9	6	6	1	2	4

OW	Worst criteria: R_2
R_1	2
R_2	1
R_3	2
R_4	2
R_5	9
R_6	4
R_7	2

The pairwise comparison of Environmental management initiatives sub criteria is presented in Table 6.6 below,

Table 6.6 Pairwise comparison for Environmental management initiatives sub criteria

BO	EN_1	EN_2	EN_3	EN_4	EN_5
Best criteria: **EN_3**	8	2	1	3	6

OW	Worst criteria: EN_1
EN_1	1
EN_2	4
EN_3	8
EN_4	3
EN_5	2

The pairwise comparison of Research and Design initiatives sub criteria is presented in Table 6.7 below,

Table 6.7 Pairwise comparison for Research and Design initiatives sub criteria

BO	RD_1	RD_2	RD_3	RD_4	RD_5
Best criteria: **RD_3**	2	5	1	3	9

OW	Worst criteria: RD_5
RD_1	4
RD_2	2
RD_3	9
RD_4	3
RD_5	1

The pairwise comparison of Green purchasing capabilities sub criteria is presented in Table 6.8 below,

Table 6.8 Pairwise comparison for Green purchasing capabilities sub criteria

BO	**GP_1**	**GP_2**	**GP_3**	**GP_4**	**GP_5**	**GP_6**	**GP_7**
Best criteria: **GP_2**	8	1	2	4	5	9	7

OW	**Worst criteria: GP_6**
GP_1	2
GP_2	9
GP_3	4
GP_4	3
GP_5	2
GP_6	1
GP_7	2

The pairwise comparison of Regulatory Obligations, Pressures and Market Demand sub criteria is presented in Table 6.9 below,

Table 6.9 Pairwise comparison for Regulatory Obligations, Pressures and Market Demand sub criteria

BO	**RO_1**	**RO_2**	**RO_3**	**RO_4**	**RO_5**	**RO_6**
Best criteria: **RO_2**	9	1	5	2	3	4

OW	**Worst criteria: RO_1**
RO_1	1
RO_2	9
RO_3	2
RO_4	4
RO_5	3
RO_6	2

After pairwise comparison of all the main criteria and sub criteria by decision makers, the next step is to obtain weights of main criteria and subsequently sub criteria. Using equation 3.1 discussed in section 3.2, weights of main criteria are obtained as shown in Table 6.10.

The results also shows a consistency value ξ^L equal to 0.026, values closer to zero shows high consistency among pairwise comparison.

Similar to the weights of main criteria the weights of sub criteria are also obtained by formulating the criteria as a linear programming model (3.2) and solving, the weights obtained are shown in Table 6.11.

Table 6.10 Optimal weights for main criteria

Criteria	Weights	ξ^L
Collaborations (GI1)	0.048	0.026
Environmental investments and Economic benefits (GI2)	0.173	
Resource availability and Green competencies (GI3)	0.358	
Environmental management initiatives (GI4)	0.037	
Research and Design initiatives (GI5)	0.128	
Green purchasing capabilities (GI6)	0.064	
Regulatory Obligations, Pressures and Market Demand (GI7)	0.192	

Table 6.11 Weights of Main and sub criteria

Main Criteria	Weights Main Criteria	Sub Criteria	Weights Sub Criteria	Global weights	Ranking
Collaborations (GI1)	0.048	C1	0.113	0.005	35
		C2	0.150	0.007	31
		C3	0.203	0.010	26
		C4	0.426	0.020	18
		C5	0.064	0.003	38
		C6	0.045	0.002	41
Environmental investments and Economic benefits (GI2)	0.173	E1	0.045	0.008	29
		E2	0.211	0.037	8
		E3	0.392	0.068	4
		E4	0.106	0.018	19
		E5	0.141	0.024	14
		E6	0.106	0.018	19
Resource availability and Green competencies (GI3)	0.358	R1	0.057	0.020	17
		R2	0.044	0.016	23
		R3	0.076	0.027	11
		R4	0.076	0.027	12
		R5	0.426	0.153	1
		R6	0.206	0.074	3
		R7	0.114	0.041	6
Environmental management initiatives (GI4)	0.037	EN1	0.054	0.002	42
		EN2	0.243	0.009	27
		EN3	0.459	0.017	21
		EN4	0.162	0.006	33
		EN5	0.081	0.003	39
Research and Design initiatives (GI5)	0.128	RD1	0.221	0.028	9
		RD2	0.098	0.013	25
		RD3	0.467	0.060	5
		RD4	0.164	0.021	16
		RD5	0.049	0.006	32
Green purchasing capabilities (GI6)	0.064	GP1	0.057	0.004	37
		GP2	0.424	0.027	13
		GP3	0.206	0.013	24
		GP4	0.114	0.007	30
		GP5	0.091	0.006	34
		GP6	0.044	0.003	40
		GP7	0.065	0.004	36
Regulatory Obligations, Pressures and Market Demand (GI7)	0.192	RO1	0.044	0.008	28
		RO2	0.416	0.080	2
		RO3	0.088	0.017	22
		RO4	0.197	0.038	7
		RO5	0.146	0.028	10
		RO6	0.109	0.021	15

The weights are used to rank sub criteria and get importance of each criteria and sub criteria. Results show Resource availability and green competencies as the most important criteria followed by Regulatory obligations, pressures and market demand. Similarly among sub criteria, Green recycling facilities has highest weightage followed by tax cut and incentives for producing green products and green manufacturing capabilities. The next step is to rank the suppliers with respect to these criteria.

6.3.4 Ranking the alternatives using Fuzzy TOPSIS

After obtaining weights of all the criteria for supplier selection next step is select the best alternative (supplier) with respect to these criteria. Fuzzy TOPSIS as discussed in section three above has been used for obtaining the ranks of alternatives. Decision makers were asked to evaluate all the seven small scale suppliers with respect to criteria using linguistic variables discussed in Table 3.1. The resultant matrix showing corresponding fuzzy values of linguistic variables for comparison is shown in Table 6.12.

Table 6.12 Fuzzy comparison matrix for supplier alternatives

	C1	C2	C3	C4	C5	C6	E1	E2	E3	E4	E5	E6
SP1	0, 0.2, 0.4	0.6, 0.8, 1	0, 0, 0.2	0.6, 0.8, 1	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0, 0, 0.2	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.2, 0.4, 0.6
SP2	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.6, 0.8, 1	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	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.2, 0.4, 0.6
SP3	0.2, 0.4, 0.6	0.6, 0.8, 1	0.6, 0.8, 1	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.6, 0.8, 1	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.6, 0.8, 1	0.6, 0.8, 1	0.6, 0.8, 1	0.8, 1, 1
SP4	0.8, 1, 1	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.6, 0.8, 1	0, 0.2, 0.4	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	0.6, 0.8, 1	0.8, 1, 1
SP5	0.2, 0.4, 0.6	0, 0, 0.2	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, 0, 0.2	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
SP6	0.4, 0.6, 0.8	0.6, 0.8, 1	0.4, 0.6, 0.8	0.6, 0.8, 1	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	0.2, 0.4, 0.6	0.6, 0.8, 1	0.4, 0.6, 0.8
SP7	0.4, 0.6, 0.8	0, 0.2, 0.4	0, 0, 0.2	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	0.4, 0.6, 0.8	0.6, 0.8, 1	0.2, 0.4, 0.6	0.4, 0.6, 0.8
Criteria Weights	0.005	0.007	0.010	0.020	0.003	0.002	0.008	0.037	0.068	0.018	0.024	0.018

	R1	R2	R3	R4	R5	R6	R7	EN1	EN2	EN3	EN4	EN5	RD1	RD2	RD3	RD4	RD5
SP1	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.6, 0.8, 1	0.4, 0.6, 0.8	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	0.6, 0.8, 1	0, 0, 0.2	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.2, 0.4, 0.6
SP2	0.2, 0.4, 0.6	0.8, 1, 1	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0, 0.2, 0.4	0.2, 0.4, 0.6	0.6, 0.8, 1	0, 0.2, 0.4	0.6, 0.8, 1	0.8, 1, 1	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0, 0.2, 0.4	0.6, 0.8, 1
SP3	0.6, 0.8, 1	0.8, 1, 1	0.6, 0.8, 1	0.4, 0.6, 0.8	0.8, 1, 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	0.6, 0.8, 1	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.6, 0.8, 1	0.2, 0.4, 0.6	0.6, 0.8, 1	0.8, 1, 1
SP4	0.4, 0.6, 0.8	0.8, 1, 1	0.4, 0.6, 0.8	0.6, 0.8, 1	0.8, 1, 1	0.2, 0.4, 0.6	0.6, 0.8, 1	0.6, 0.8, 1	0.6, 0.8, 1	0.8, 1, 1	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.8, 1, 1	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.6, 0.8, 1	0.8, 1, 1
SP5	0.2, 0.4, 0.6	0, 0, 0.2	0.4, 0.6, 0.8	0.4, 0.6, 0.8	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, 0.2, 0.4	0.6, 0.8, 1	0, 0.2, 0.4	0, 0, 0.2	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0, 0, 0.2	0.6, 0.8, 1
SP6	0.4, 0.6, 0.8	0.6, 0.8, 1	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	0.2, 0.4, 0.6	0.6, 0.8, 1	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.6, 0.8, 1	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.6, 0.8, 1	0.4, 0.6, 0.8
SP7	0, 0.2, 0.4	0.6, 0.8, 1	0.6, 0.8, 1	0.4, 0.6, 0.8	0.4, 0.6, 0.8	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	0.6, 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	0.2, 0.4, 0.6	0.2, 0.4, 0.6
Criteria Weights	0.020	0.016	0.027	0.027	0.153	0.074	0.041	0.002	0.009	0.017	0.006	0.003	0.028	0.013	0.060	0.021	0.006

	GP1	GP2	GP3	GP4	GP5	GP6	GP7	RO1	RO2	RO3	RO4	RO5	RO6
SP1	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.6, 0.8, 1	0.4, 0.6, 0.8	0.4, 0.6, 0.8	0.6, 0.8, 1	0.4, 0.6, 0.8	0, 0, 0.2	0.6, 0.8, 1	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.4, 0.6, 0.8
SP2	0.2, 0.4, 0.6	0.2, 0.4, 0.6	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	0.2, 0.4, 0.6	0.6, 0.8, 1	0.6, 0.8, 1	0.2, 0.4, 0.6	0.8, 1, 1
SP3	0.6, 0.8, 1	0.6, 0.8, 1	0.6, 0.8, 1	0.8, 1, 1	0.6, 0.8, 1	0.6, 0.8, 1	0.8, 1, 1	0.6, 0.8, 1	0.6, 0.8, 1	0.6, 0.8, 1	0.8, 1, 1	0.6, 0.8, 1	0.6, 0.8, 1
SP4	0.4, 0.6, 0.8	0.8, 1, 1	0.4, 0.6, 0.8	0.8, 1, 1	0.4, 0.6, 0.8	0.6, 0.8, 1	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.8, 1, 1	0.6, 0.8, 1	0.8, 1, 1	0.4, 0.6, 0.8	0.8, 1, 1
SP5	0.2, 0.4, 0.6	0, 0, 0.2	0.4, 0.6, 0.8	0.8, 1, 1	0.4, 0.6, 0.8	0, 0.2, 0.4	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.8, 1, 1	0.4, 0.6, 0.8	0.6, 0.8, 1	0.2, 0.4, 0.6	0.4, 0.6, 0.8
SP6	0.4, 0.6, 0.8	0.6, 0.8, 1	0.2, 0.4, 0.6	0.2, 0.4, 0.6	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	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.2, 0.4, 0.6
SP7	0.4, 0.6, 0.8	0.6, 0.8, 1	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	0.6, 0.8, 1	0.6, 0.8, 1	0.4, 0.6, 0.8	0.2, 0.4, 0.6	0.4, 0.6, 0.8	0.2, 0.4, 0.6
Criteria Weights	0.004	0.027	0.013	0.007	0.006	0.003	0.004	0.008	0.080	0.017	0.038	0.028	0.021

After obtaining the fuzzy relation matrix, the next step is to obtain the weighted, normalized fuzzy relation matrix using equation (3.3), the weighted matrix is presented in Table 6.13. Also FPIS, A^{+} and FNIS, A^{-}, are determined using equations (3.4) and (3.5). FPIS and FNIS in this case can be defined as $v_1^{+} = (1, 1, 1)$ and $v_1^{-} = (0, 0, 0)$ respectively, for benefit criteria and as$v_1^{+} = (0, 0, 0)$ and $v_1^{-} = (1, 1, 1)$ for cost criteria, but in this case all the criteria are considered benefit criteria since the target is to achieve maximum green innovativeness among SMEs, so the values of FPIS and FNIS will be selected accordingly.

Table 6.13 Weighted fuzzy evaluation matrix for alternatives

	C1	C2	C3	C4	C5	C6	E1	E2	E3	E4	E5	E6
SP 1	(0.000, 0.001, 0.002)	(0.004, 0.006, 0.007)	(0.000, 0.000, 0.002)	(0.012, 0.016, 0.020)	(0.001, 0.002, 0.002)	(0.000, 0.001, 0.001)	(0.000, 0.000, 0.002)	(0.007, 0.015, 0.022)	(0.027, 0.041, 0.054)	(0.007, 0.011, 0.015)	(0.005, 0.010, 0.015)	(0.004, 0.007, 0.011)
SP 2	(0.001, 0.002, 0.003)	(0.001, 0.003, 0.004)	(0.006, 0.008, 0.010)	(0.008, 0.012, 0.016)	(0.001, 0.002, 0.002)	(0.000, 0.001, 0.001)	(0.003, 0.005, 0.006)	(0.015, 0.022, 0.029)	(0.014, 0.027, 0.041)	(0.004, 0.007, 0.011)	(0.005, 0.010, 0.015)	(0.004, 0.007, 0.011)
SP 3	(0.001, 0.002, 0.003)	(0.004, 0.006, 0.007)	(0.006, 0.008, 0.010)	(0.008, 0.012, 0.016)	(0.001, 0.002, 0.002)	(0.001, 0.002, 0.002)	(0.003, 0.005, 0.006)	(0.015, 0.022, 0.029)	(0.041, 0.054, 0.068)	(0.011, 0.015, 0.018)	(0.015, 0.020, 0.024)	(0.015, 0.018, 0.018)
SP 4	(0.004, 0.005, 0.005)	(0.003, 0.004, 0.006)	(0.002, 0.004, 0.006)	(0.012, 0.016, 0.020)	(0.000, 0.001, 0.001)	(0.002, 0.002, 0.002)	(0.002, 0.003, 0.005)	(0.007, 0.015, 0.022)	(0.027, 0.041, 0.054)	(0.004, 0.007, 0.011)	(0.015, 0.020, 0.024)	(0.015, 0.018, 0.018)
SP 5	(0.001, 0.002, 0.003)	(0.000, 0.000, 0.001)	(0.002, 0.004, 0.006)	(0.008, 0.012, 0.016)	(0.001, 0.001, 0.002)	(0.001, 0.001, 0.002)	(0.000, 0.000, 0.002)	(0.015, 0.022, 0.029)	(0.014, 0.027, 0.041)	(0.007, 0.011, 0.015)	(0.010, 0.015, 0.020)	(0.007, 0.011, 0.015)
SP 6	(0.002, 0.003, 0.004)	(0.004, 0.006, 0.007)	(0.004, 0.006, 0.008)	(0.012, 0.016, 0.020)	(0.001, 0.001, 0.002)	(0.001, 0.001, 0.002)	(0.005, 0.006, 0.008)	(0.015, 0.022, 0.029)	(0.041, 0.054, 0.068)	(0.004, 0.007, 0.011)	(0.015, 0.020, 0.024)	(0.007, 0.011, 0.015)
SP 7	(0.002, 0.003, 0.004)	(0.000, 0.001, 0.003)	(0.000, 0.000, 0.002)	(0.004, 0.008, 0.012)	(0.001, 0.001, 0.002)	(0.001, 0.001, 0.002)	(0.003, 0.005, 0.006)	(0.015, 0.022, 0.029)	(0.027, 0.041, 0.054)	(0.011, 0.015, 0.018)	(0.005, 0.010, 0.015)	(0.007, 0.011, 0.015)
A^+	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$
A^-	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$

	R1	R2	R3	R4	R5	R6	R7	EN1	EN2	EN3	EN4	EN5	RD1	RD2	RD3	RD4	RD5
SP1	(0.008, 0.012, 0.016)	(0.006, 0.009, 0.013)	(0.011, 0.016, 0.022)	(0.016, 0.022, 0.027)	(0.061, 0.092, 0.122)	(0.030, 0.044, 0.059)	(0.025, 0.033, 0.041)	(0.001, 0.001, 0.002)	(0.004, 0.005, 0.007)	(0.007, 0.010, 0.014)	(0.004, 0.005, 0.006)	(0.000, 0.000, 0.001)	(0.006, 0.011, 0.017)	(0.005, 0.008, 0.010)	(0.024, 0.036, 0.048)	(0.004, 0.008, 0.013)	(0.001, 0.003, 0.004)
SP2	(0.004, 0.008, 0.012)	(0.013, 0.016, 0.016)	(0.005, 0.011, 0.016)	(0.005, 0.011, 0.016)	(0.061, 0.092, 0.122)	(0.000, 0.015, 0.030)	(0.008, 0.016, 0.025)	(0.001, 0.002, 0.002)	(0.000, 0.002, 0.004)	(0.010, 0.014, 0.017)	(0.005, 0.006, 0.006)	(0.001, 0.001, 0.002)	(0.011, 0.017, 0.023)	(0.003, 0.005, 0.008)	(0.012, 0.024, 0.036)	(0.000, 0.004, 0.008)	(0.004, 0.005, 0.006)
SP3	(0.012, 0.016, 0.020)	(0.013, 0.016, 0.016)	(0.016, 0.022, 0.027)	(0.011, 0.016, 0.022)	(0.122, 0.153, 0.153)	(0.044, 0.059, 0.074)	(0.025, 0.033, 0.041)	(0.000, 0.001, 0.001)	(0.005, 0.007, 0.009)	(0.010, 0.014, 0.017)	(0.004, 0.005, 0.006)	(0.001, 0.002, 0.002)	(0.011, 0.017, 0.023)	(0.008, 0.010, 0.013)	(0.012, 0.024, 0.036)	(0.013, 0.017, 0.021)	(0.005, 0.006, 0.006)
SP4	(0.008, 0.012, 0.016)	(0.013, 0.016, 0.016)	(0.011, 0.016, 0.022)	(0.016, 0.022, 0.027)	(0.122, 0.153, 0.153)	(0.015, 0.030, 0.044)	(0.025, 0.033, 0.041)	(0.001, 0.002, 0.002)	(0.005, 0.007, 0.009)	(0.014, 0.017, 0.017)	(0.002, 0.004, 0.005)	(0.001, 0.001, 0.002)	(0.023, 0.028, 0.028)	(0.005, 0.008, 0.010)	(0.012, 0.024, 0.036)	(0.013, 0.017, 0.021)	(0.005, 0.006, 0.006)
SP5	(0.004, 0.008, 0.012)	(0.000, 0.000, 0.003)	(0.011, 0.016, 0.022)	(0.011, 0.016, 0.022)	(0.000, 0.000, 0.031)	(0.000, 0.000, 0.015)	(0.000, 0.000, 0.008)	(0.001, 0.001, 0.002)	(0.004, 0.005, 0.007)	(0.000, 0.003, 0.007)	(0.004, 0.005, 0.006)	(0.000, 0.001, 0.001)	(0.000, 0.000, 0.006)	(0.003, 0.005, 0.008)	(0.024, 0.036, 0.048)	(0.000, 0.000, 0.004)	(0.004, 0.005, 0.006)
SP6	(0.008, 0.012, 0.016)	(0.009, 0.013, 0.016)	(0.005, 0.011, 0.016)	(0.011, 0.016, 0.022)	(0.092, 0.122, 0.153)	(0.015, 0.030, 0.044)	(0.025, 0.033, 0.041)	(0.000, 0.001, 0.001)	(0.005, 0.007, 0.009)	(0.003, 0.007, 0.010)	(0.002, 0.004, 0.005)	(0.002, 0.002, 0.003)	(0.011, 0.017, 0.023)	(0.003, 0.005, 0.008)	(0.012, 0.024, 0.036)	(0.013, 0.017, 0.021)	(0.003, 0.004, 0.005)
SP7	(0.000, 0.004, 0.008)	(0.009, 0.013, 0.016)	(0.016, 0.022, 0.027)	(0.011, 0.016, 0.022)	(0.061, 0.092, 0.122)	(0.030, 0.044, 0.059)	(0.025, 0.033, 0.041)	(0.000, 0.001, 0.001)	(0.002, 0.004, 0.005)	(0.007, 0.010, 0.014)	(0.004, 0.005, 0.006)	(0.001, 0.002, 0.002)	(0.011, 0.017, 0.023)	(0.005, 0.008, 0.010)	(0.024, 0.036, 0.048)	(0.004, 0.008, 0.013)	(0.001, 0.003, 0.004)
A^+	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$
A^-	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$

	GP1	GP2	GP3	GP4	GP5	GP6	GP7	RO1	RO2	RO3	RO4	RO5	RO6
SP1	(0.001, 0.002, 0.003)	(0.011, 0.016, 0.022)	(0.008, 0.011, 0.013)	(0.003, 0.004, 0.006)	(0.002, 0.003, 0.005)	(0.002, 0.002, 0.003)	(0.002, 0.002, 0.003)	(0.000, 0.000, 0.002)	(0.048, 0.064, 0.080)	(0.007, 0.010, 0.013)	(0.008, 0.015, 0.023)	(0.011, 0.017, 0.022)	(0.008, 0.013, 0.017)
SP2	(0.001, 0.001, 0.002)	(0.005, 0.011, 0.016)	(0.008, 0.011, 0.013)	(0.006, 0.007, 0.007)	(0.001, 0.002, 0.003)	(0.001, 0.001, 0.002)	(0.002, 0.002, 0.003)	(0.002, 0.003, 0.005)	(0.016, 0.032, 0.048)	(0.010, 0.013, 0.017)	(0.023, 0.030, 0.038)	(0.006, 0.011, 0.017)	(0.017, 0.021, 0.021)
SP3	(0.002, 0.003, 0.004)	(0.016, 0.022, 0.027)	(0.008, 0.011, 0.013)	(0.006, 0.007, 0.007)	(0.003, 0.005, 0.006)	(0.002, 0.002, 0.003)	(0.003, 0.004, 0.004)	(0.005, 0.007, 0.008)	(0.048, 0.064, 0.080)	(0.010, 0.013, 0.017)	(0.030, 0.038, 0.038)	(0.017, 0.022, 0.028)	(0.013, 0.017, 0.021)
SP4	(0.001, 0.002, 0.003)	(0.022, 0.027, 0.027)	(0.005, 0.008, 0.011)	(0.006, 0.007, 0.007)	(0.002, 0.003, 0.005)	(0.002, 0.002, 0.003)	(0.002, 0.002, 0.003)	(0.002, 0.003, 0.005)	(0.064, 0.080, 0.080)	(0.010, 0.013, 0.017)	(0.030, 0.038, 0.038)	(0.011, 0.017, 0.022)	(0.017, 0.021, 0.021)
SP5	(0.001, 0.001, 0.002)	(0.000, 0.000, 0.005)	(0.005, 0.008, 0.011)	(0.006, 0.007, 0.007)	(0.002, 0.003, 0.005)	(0.000, 0.001, 0.001)	(0.001, 0.002, 0.002)	(0.003, 0.005, 0.007)	(0.064, 0.080, 0.080)	(0.007, 0.010, 0.013)	(0.023, 0.030, 0.038)	(0.006, 0.011, 0.017)	(0.008, 0.013, 0.017)
SP6	(0.001, 0.002, 0.003)	(0.016, 0.022, 0.027)	(0.003, 0.005, 0.008)	(0.001, 0.003, 0.004)	(0.001, 0.002, 0.003)	(0.001, 0.002, 0.002)	(0.002, 0.003, 0.004)	(0.002, 0.003, 0.005)	(0.048, 0.064, 0.080)	(0.003, 0.007, 0.010)	(0.008, 0.015, 0.023)	(0.011, 0.017, 0.022)	(0.004, 0.008, 0.013)
SP7	(0.001, 0.002, 0.003)	(0.016, 0.022, 0.027)	(0.008, 0.011, 0.013)	(0.003, 0.004, 0.006)	(0.002, 0.003, 0.005)	(0.001, 0.002, 0.002)	(0.002, 0.002, 0.003)	(0.005, 0.007, 0.008)	(0.048, 0.064, 0.080)	(0.007, 0.010, 0.013)	(0.008, 0.015, 0.023)	(0.011, 0.017, 0.022)	(0.004, 0.008, 0.013)
A^+	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$	$v_1^+ = (1, 1, 1)$
A^-	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$	$v_1^- = (0, 0, 0)$

Next step is to obtain the closeness coefficient value CC_i and final ranking of alternatives using equations (3.6) and (3.7). The CCi values and ranking of alternatives is shown in Table 6.14.

Table 6.14 Final ranking of alternatives

	D+	D-	CCj	Ranks
SP1	41.414	0.610	0.015	5
SP2	41.503	0.527	0.013	6
SP3	41.220	0.795	0.019	1
SP4	41.273	0.744	0.018	2
SP5	41.601	0.432	0.010	7
SP6	41.369	0.654	0.016	3
SP7	41.399	0.625	0.015	4

The three phase methodology results indicate that supplier 3 (SP3) is top supplier among all the seven suppliers with respect to green innovation criteria, the ranking of all the suppliers is SP3>SP4>SP6>SP7>SP1>SP2>SP5. The three phase analysis can help decision makers to narrow down their choice from multiple suppliers to only one supplier and thus select a supplier that is best at green innovation.

6.4 Discussions of findings

From Table 6.10 and 6.11, weights and rankings of main criteria as well as sub criteria is obtained, the weights of the main criteria and sub criteria are obtained through best worst analysis and global weights of sub criteria are obtained by multiplying criteria weights with each of sub criteria weights as shown in Table 6.11. Amongst seven main criteria, Resource availability and green competencies (GI3) obtains first rank, resources can be in form of human resources or staff with necessary skills, they can be technological resources or financial resources, organizations are often marred by scarcity of these resources and thus for managers of small enterprises, it is a challenge to identify the requisite resources and manage them for uninterrupted operations (Horbach et al., 2012; Dangelico, 2016). Lack of these resources many a times forces the managers to carve out innovative ways to manage operations with limited resources thus giving rise to product and process innovations. Developing green competencies is equally important for SMEs to acquire business from large counterparts; green competencies include recycling facilities, green warehouse facilities, green packaging and green logistics (Nikbakhsh, 2009; Srikantha Dath et al., 2009; Somsuk and Laosirihongthong, 2016). Having these competencies help organizations to easily acquire business from organizations that are converting into green operations. This criteria has further seven sub criteria under it, they are ranked according to their global weights as follows

R5>R6>R7>R3>R4>R1>R2, Green recycling facilities (R5) is ranked first among all the sub criteria, past studies also support the finding, recycling aims at recovering the cost of the product through disassembling the used product and taking out the parts that can be either reused or sold out, it thus has high economic value for the manufacturers as they can recover a substantial amount of money invested in the product (Srivastava 2007; Nikbakhsh, 2009) and this money can be further utilized for other activities. Second among the ranking is Green manufacturing capabilities (R6), green manufacturing capabilities itself refers to a set of resources which includes physical, human as well as organizational resources deployed inside the manufacturing plant so as to improve the environmental performance of the plant and also help in developing innovative products that are environmental friendly (Nelson and Winter, 2009; Nikbakhsh, 2009; Maruthi and Rashmi 2015). These two sub criteria are followed by Carbon reduction initiatives (R7), Green warehousing (R3), Green transportation (R4), Internal R&D and scientific expertise (R1) and Trained human resources (R2) in the ranking.

Ranked second among main criteria is Regulatory Obligations, Pressures and Market Demand (GI7). SMEs being smaller in size and market occupancy often face cash and resource crunch and depend on government support to carry out any new innovative activity at their end (Noci and Vergandi, 1999). Further environmental regulations force organizations to follow green practices at their end thus promoting environment improvement (Eiadat et al., 2008). Market demand is also essential for success of any business, as customers are becoming very selective and demanding the right product according to their requirement, managers need to be very careful about changing market needs and subsequently change their products and operations so as to stay afloat in business (Kirca et al., 2005; Zhou et al., 2009). This criteria has further six sub criteria and are ranked as R02>R04>R05>R06>R03>R01. Tax cuts and incentives for producing green products (R02) is ranked first among sub criteria of this main criteria, to meet their goals of environment protection, government is giving heavy incentives and tax benefits to organizations engaged in producing green products, SMEs can especially benefit from these tax cuts. Also these incentives act as motivator for organizations to engage in green practices and focus on producing environmental friendly products (Zhu et al., 2005; Johnstone et al., 2010; Kiss et al., 2013; Govindan et al., 2016). Ranked second among sub criteria is Stringency in enforcement of green design norms (RO4), organizations often tend to flout many norms being laid down by the government in order to evade costs associated with these policies and norms, government need to enforce these policies stringently in order to make organizations comply with these norms and hence reap the benefits of these policies in long run (Rehfield et al., 2007; Horbach, 2008). Rest of the sub criteria are ranked as follows, Market demand for green products (RO5), Competitive pressures to outperform competitors (RO6), Implementation of environmental policy (RO3) and Technical assistance for technology upgradation (RO1).

Ranked third among main criteria is Environmental investments and Economic benefits (GI2). Like technological resources, investments related to environment are quintessential for sustaining the goal of going green and improving environmental performance, environmental spending by organization positively impact organizational economic and environmental performance (Lucas, 2010). This criteria has six sub criteria and are ranked as follows, E3>E2>E5>E4>E6>E1. Investment recover (E3) is ranked as first among these sub criteria, investment recovery helps organizations to obtain higher returns on existing products through recovery and reselling of existing products (Zhu et al., 2008). Ease in getting finance from financial institutes (E2) is ranked second among sub criteria, financial institutions providing assistance to organizations for carrying out environmental friendly practices are increasingly considered important nowadays and can help boost environmental performance of the organizations (Mathiyazhagan et al. 2013; Govindan et al., 2016). Other sub criteria in this category are ranked as follows, Enhanced value to customers (E5), Enhanced productivity and firms performance (E4), Green operational efficiencies (E6) and Cost Reduction (E1). Similarly other main criteria are ranked as follows, Research and Design initiatives (GI5), Green purchasing capabilities (GI6), Collaborations (GI1) and Environmental management initiatives (GI4). Further, this study provides a framework for supplier selection using seven criteria of green innovation. All the past studies have given different criteria for green supplier selection and this study differs from those past studies in terms of various criteria being used.

6.5 Sensitivity Analysis

To check the robustness of the framework and eliminate any possible biasness, sensitivity analysis as suggested by Mangla et al. (2015) and Prakash and Barua (2015) is used in this paper. To perform sensitivity analysis weight of criteria that got highest weightage (GI3 in this case) among all the main criteria is varied from 0.1 to 0.9 and correspondingly weights of all other criteria changed. The resultant change in ranking of criteria and sub criteria is observed and finally the suppliers are ranked using Fuzzy TOPSIS for 10 different runs and their rankings compared. Table 6.15 shows the corresponding weights of main criteria when weight of GI3 is varied from 0.1 to 0.9 in ten different runs.

Table 6.15 Variation in weights value for all criteria when varying GI3 weight value

Criteria	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)
GI3	0.358	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
GI7	0.192	0.269	0.239	0.209	0.179	0.149	0.120	0.090	0.060	0.030
GI2	0.173	0.243	0.216	0.189	0.162	0.135	0.108	0.081	0.054	0.027
GI5	0.128	0.179	0.159	0.139	0.120	0.100	0.080	0.060	0.040	0.020
GI6	0.064	0.090	0.080	0.070	0.060	0.050	0.040	0.030	0.020	0.010
GI1	0.048	0.067	0.060	0.052	0.045	0.037	0.030	0.022	0.015	0.007
GI4	0.037	0.052	0.046	0.040	0.034	0.029	0.023	0.017	0.011	0.006
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

After getting the weights of all main criteria, corresponding global weights of sub criteria are calculated for each different runs, after that these weights are again put in Fuzzy TOPSIS analysis to rank the suppliers and 10 different rankings of suppliers are obtained as per the weights obtained above, the ranking of suppliers for 10 different runs is shown in Table 6.16.

Table 6.16 Ranking of suppliers by sensitivity analysis when weight of criteria GI3 varies from 0.1 to 0.9

Suppliers	Normalized Ranking	Run 1 ranking	Run 2 ranking	Run 3 ranking	Run 4 ranking	Run 5 ranking	Run 6 ranking	Run 7 ranking	Run 8 ranking	Run 9 ranking
SP1	5	5	5	5	5	5	5	4	4	5
SP2	6	6	6	6	6	6	6	6	6	6
SP3	1	1	1	1	1	1	1	1	1	1
SP4	2	2	2	2	2	2	2	2	2	2
SP5	7	7	7	7	7	7	7	7	7	7
SP6	3	3	3	3	3	3	3	3	3	4
SP7	4	4	4	4	4	4	4	5	5	3

The sensitivity analysis results presented in Table 6.16 indicate that the model adopted for analysis is free from any biasness and results are robust as SP3 acquired first rank and SP5 acquired last rank among suppliers in all the subsequent trials.

6.6 Determining the interrelationship among enablers of green innovation

Various authors have done studies regarding green innovation and through detailed literature review thirty-two enablers were identified. These enablers were then put for deliberation by experts using Delphi method to select the relevant factors for our case study. Finally, twenty-one enablers were finalized and are listed in Table 6.17.

6.6.1 Internal environmental management practices

Environmental management practices include a wide range of activities inside an organization which includes: inputs regarding raw materials, information regarding production activities, packaging of materials, the design of products, manufacturing equipment and technologies being used in the organization and also waste management practices (Shrivastava and Hart, 1995). Through proper planning and support of top management for environmental management and improvement, significant innovations can be achieved (Lee et al., 2014).

6.6.2 Environmental commitment of the firm

Environmental commitment can be interpreted as organizations policies towards environmental management, awareness of employees regarding benefits of various environmental programs and their values (Simpson et al., 2007). Firms reaction to its stakeholders requirement for environmentally friendly products is largely governed by its environmental commitment (Henriques and Sadorsky, 1999; Aragon-Correa and Sharma, 2003).

6.6.3 Green operational and communication practices

Green operational practices can be classified as both product and process related activities which aim to reduce the impact of these activities on the environment (Gilley et al., 2000). Product-related activities involve designing and developing ecological products that promote reusability, recyclability and easy disposal of products (De Ron, 1998). Process-related practices involve evolving and practicing manufacturing processes that have minimum impact on the environment and thereby cause almost zero generation, this can be achieved through utilizing cleaner technologies, developing efficient waste management and disposal systems (De Ron, 1998; Klassen and Whybark, 1999a). Communication practices, on the other hand, aims at improving firms image and profile both socially and among stakeholders through publicizing environmental achievements and practices of the firm (Aragón- Correa, 1998; Florida and Davison, 2001).

6.6.4 Intra organizational collaborations

Inter-functional collaborations or collaborations between various departments is necessary for implementing green innovations in the organization (Shrivastava and Hart, 1995). It involves collaboration among various departments such as R&D, marketing, and manufacturing to develop and implement eco-friendly products and processes (Foster and Green, 2000; Pujari, 2006; Cabrales et al., 2008). These collaborations provide sustainable solutions for future (Messeni Petruzzelli et al., 2011).

6.6.5 External collaborations

For sustainable product development and green innovations, synergy with external stakeholders is as important as inter-functional collaborations (Byrne and Polonsky, 2001; Carrillo-Hermosilla et al., 2010; Albino et al., 2012). Information and technology exchange from external stakeholders is essential for the success of green innovations (Aschehoug et al., 2012; De Marchi, 2012).

6.6.6 Supplier development for green innovations

Component suppliers are an important element in the supply chain and they must comply with the original equipment manufacturers requirements in order to achieve the goal of developing environmentally friendly products. Organizations can work directly to develop their suppliers for greater benefits (Krause et al., 1998). These type of collaborations can involve collaborative production planning, mentoring and development of joint capabilities at both the ends (Handfield et al., 2006; Wagner and Krause, 2009; Large and Thomsen, 2011; Singh, 2014; 2015).

6.6.7 Investment recovery

Investment Recovery (IR) is defined as “a firm’s strategic usage of recovery, redeployment, and reselling to obtain a higher value from existing products and materials” (Zhu et al., 2008). Investment recovery is an important source of income for many organizations as about 70% of returns generated through the sale of waste and scrap forms the profit for an organization (Cottrill, 1997; Franke et al., 2006). Sale of waste and scrap material not only increases companies profit but it also helps in reproducing and recovering new materials and products that are more favorable to the environment (Lee, et al., 2014).

6.6.8 Ease of getting loans from financial institutions

Financial institutions are more concerned about environmental protection and are willing to fund projects that are causing positive impact on environment, companies can benefit by getting easy and subsidized loans for developing new green and sustainable products (Hilson and Nayee, 2002; Azapagic, 2004; Jenkins and Yakovleva, 2006; Mathiyazhagan et al., 2013; Govindan et al., 2016).

6.6.9 Cost reduction and new business opportunities

Adopting green practices in the supply chain helps the organizations to achieve higher operational efficiencies and cost benefits as the green products will be of higher value to customers especially large organizations and small organizations can quote higher prices for their products (Lee, 2008). Further by adopting innovative methods to produce new products, financial benefits in terms of price reduction can be achieved (Berkel, 2007; Govindan et al., 2016). Green innovation practices also exposes the organizations to reach international markets and thereby acquire new businesses (Chiou et al., 2011; Mathiyazhagan and Haq, 2013; Mathiyazhagan et al., 2013; Govindan et al., 2016).

6.6.10 Green purchasing

Green purchasing refers to practice of purchasing products that considers various environmental concerns viz. minimum impact on environment through product use, minimum toxic elimination in environment, minimization of waste generation and recycling and reuse of products. Green purchasing enables organizations to interact with their suppliers regarding the issues of sustainable development and results in continuous and innovative development of greener environmentally friendly products (Zhu and Sarkis, 2006; Ninlawan et al. 2010; Eltayeb et al. 2011; Chan et al. 2012; Lee, et al., 2014; Govindan et al., 2016; Hassan et al., 2016; Somsuk and Laosirihongthong, 2016).

6.6.11 Developing green manufacturing capabilities

Green manufacturing capability can be defined as “the set of physical, financial, human, technological, and organizational resources” (Grant, 1991) “coordinated by organizational routines" (Nelson and Winter, 2009) and "deployed inside a manufacturing plant to improve its environmental performance". Developing green manufacturing capabilities at the organization means adopting methods which aim at waste minimization, pollution control and prevention, designing products accordingly to environmental friendly criteria and incorporating environmental management systems like ISO into the production system (Sarkis, 2001; Zhu et al., 2008; Nikbakhsh, 2009; Maruthi and Rashmi 2015; Somsuk and Laosirihongthong, 2016).

6.6.12 Green logistics facilities

A large quantity of products are being transported throughout the supply chain, transportation facilities accounts for a major source of environmental pollution (Böttcher and Müller, 2015; Jabbour et al., 2015). Developing green logistics facilities can help reduce environmental pollution and resource consumption (Liu et al., 2011). It not only includes using cleaner technologies for transportation of materials, but also involves route optimization, use of advanced packaging material that can be easily disposed of or recycled and also reduction in carbon footprint (Somsuk and Laosirihongthong, 2016).

6.6.13 Reverse logistics

Reverse logistics involves designing a network so as to facilitate the collection of waste products, inspection of these products, source for recycling and refurbishing and disposal of end products without causing negative impact on environment (Srivastava 2007; Nikbakhsh 2009; Somsuk and Laosirihongthong, 2016). The major goal of reverse logistics is to allow reuse of products and materials as far as possible, this leads to substantial saving in materials and processing cost thus reducing overall cost of manufacturing.

6.6.14 Designing to produce green and sustainable products

Designing for green products refers to process followed while designing the product so as to reduce the environmental impact of the product throughout its entire lifecycle. The designing is done such that it leads to reduction in material and energy consumption of the product and also eliminate the hazardous by-products being generated by the product and also facilitate reuse and recycling of the product without adding to the overall cost of the product (Sarkis, 2003; Mudgal et al. 2009; Eltayeb et al. 2011; Hassan et al., 2016; Somsuk and Laosirihongthong, 2016). Due to lesser use of material, and production of innovative green products the overall cost of product will be reduced thus giving more market share to organization (Lee et al., 2014).

6.6.15 Investment in research and design

Technological competencies and resources apart from external factors are essential for environmental innovations in an organization (Horbach et al., 2012). Technological competencies can be acquired through investment in latest technology and equipment (Lucas, 2010; Testa et al., 2011). Investment in research and design can substantially improve organizations ability to embrace environmental innovations (Porter and Linder, 1995). The firms with higher R&D spending tends to develop higher designing competencies among its designers and thus can efficiently handle the requirements of customers and stakeholders regarding environmental requirements (Zailani et al., 2012).

6.6.16 Environmental regulations

Environmental regulations refer to the pressure created and policies being imposed by the government at regional as well as national level (Govindan et al., 2016). Green innovations are positively correlated with stringent environmental policies and regulation (Rehfield et al., 2007; Horbach, 2008). Government can support in terms of financial or technical help or support through tax cuts and infrastructure developments support (Lee, 2008). Regulations and policies encourage organizations to induce more environmentally friendly methods into their working (Lopez-Gamero et al., 2010). Governmental support and policies are essential to trigger green innovations in SMEs (Noci and Verganti, 1999).

6.6.17 Green warehousing

Green warehousing refers to adoption of green and mechanized operations for storage of products. It means storing goods in such a manner that they cause minimum impact to environment and surroundings (Jumadi and Zailani, 2010). It includes introducing environmentally friendly packaging, sale of excessive inventories and scrap material so as to recover some capital from these items (Zhu et al., 2010; Kannan et al., 2014). Green warehousing also aims at minimizing the carbon footprint of the organizations (Rostamzadeh et al., 2015).

6.6.18 Human resource practices

In order to push innovations and innovative activities, organizations must develop strong human resource practices (Jimenez-Jimenez and Sanz-Valle, 2005). Green innovations are supported by various human resource factors: training on environmental issues, developing green teams, rewards related to environmental activities and developing environmental learning and culture in the organization (Abdulrahman et al., 2014; Jackson et al., 2014; Kannan et al., 2014; Longoni et al., 2014; Jabbour et al., 2015).

6.6.19 Knowledge management practices

Organizations especially smaller ones are unaware of the economic and social benefits of green manufacturing practices and have very little knowledge regarding adoption of these practices (Porter and Van Der Linde, 1995; Brammer et al., 2012). Knowledge flow to and fro from an organization is critical for green innovations. It means understanding market requirements; searching for innovation from various sources and tapping knowledge sources for environmental innovations (Noci and Verganti, 1999; Foster and Green, 2000; Rennings and Rammer, 2009; Ray and Ray, 2010; Dangelico and Pujari, 2010).

6.6.20 Resources for green innovation

Resources are termed as "stocks of available factors that are owned or controlled by the firm" and capabilities are defined as "a firm's capacity to deploy resources usually in combination, using organizational processes, to effect a desired end" (Amit and Schoemaker, 1993, p. 35). Key Resources for green innovation includes investments in research and development; training of employees for environment management practices; developing new and environmental friendly materials and technological know-how for green competencies (Sandström and Tingström, 2008; Rennings and Rammer, 2009; Huang and Wu, 2010; Horbach et al., 2012; Driessen et al., 2013; Keskin et al., 2013).

6.6.21 Market demand

Understanding demand for green products help organizations devising a roadmap for green innovations (Lin et al., 2014). Customers these days are becoming more aware regarding friendly products and are extremely sensitive while demanding green products (Chen, 2008; Zhou et al., 2009). Small organizations are mostly dependent on large organizations for their business and are forced by large organizations to adopt green practices in their manufacturing thus causing growth of green innovations (Chiou et al., 2011; Hsu and Hu, 2009).

Table 6.17 Enablers of green innovation

Enabler	Code	Supporting Literature
Environmental management practices	GI01	Shrivastava and Hart, 1995; Theyel, 2000; Zhu and Sarkis, 2006, 2007; Bergmiller and McCright, 2009; Hajmohammad et al., 2013; Lee et al., 2014; Weng et al., 2015
Environmental commitment of the firm	GI02	Henriques and Sadorsky, 1999; Aragon-Correa and Sharma, 2003; Simpson et al., 2007
Green operational and communication practices	GI03	Aragón- Correa, 1998; De Ron, 1998; Florida and Davison, 2001; Klassen and Whybark, 1999a; Gilley et al., 2000
Intra organizational collaborations	GI04	Shrivastava and Hart, 1995; Foster & Green, 2000; Pujari, 2006; Cabrales et al., 2008; Messeni Petruzzelli et al., 2011
External collaborations	GI05	Byrne and Polonsky, 2001; Chen, 2008; Carrillo-Hermosilla et al., 2010; Albino et al., 2012; Aschehoug et al., 2012; De Marchi, 2012; Jabbour et al., 2015; Keskin et al., 2013
Supplier development for green innovations	GI06	Krause et al., 1998; Handfield et al., 2006; Vachon and Klassen, 2006; Wagner and Krause, 2009; Large and Thomsen, 2011
Investment recovery	GI07	Cottrill, 1997; Franke et al., 2006; Zhu et al., 2008; Wooi and Zailani, 2010; Lee, et al., 2014
Ease of getting loans from financial institutions	GI08	Hilson and Nayee, 2002; Azapagic, 2004; Jenkins and Yakovleva, 2006; Mathiyazhagan et al., 2013; Govindan et al., 2016
Cost reduction and new business opportunities	GI09	Berkel, 2007; Lee, 2008; Chiou et al., 2011; Mathiyazhagan and Haq, 2013; Mathiyazhagan et al., 2013; Govindan et al., 2016
Green purchasing	GI10	Zhu and Sarkis, 2006; Ninlawan et al. 2010; Eltayeb et al. 2011; Chan et al. 2012; Lee, et al., 2014; Govindan et al., 2016; Hassan et al., 2016; Somsuk and Laosirihongthong, 2016
Developing green manufacturing capabilities	GI11	Grant, 1991; Sarkis, 2001; Zhu et al., 2008; Nelson and Winter, 2009; Nikbakhsh, 2009; Maruthi and Rashmi 2015; Somsuk and Laosirihongthong, 2016
Green logistics facilities	GI12	Liu et al., 2011; Böttcher and Müller, 2015; Jabbour et al., 2015; Somsuk and Laosirihongthong, 2016
Reverse logistics	GI13	Srivastava 2007; Nikbakhsh 2009; Eltayeb et al., 2011; Mahmood et al., 2013; Somsuk and Laosirihongthong, 2016
Designing to produce green and sustainable products	GI14	Sarkis, 2003; Mudgal et al. 2009; Eltayeb et al. 2011; Lee et al., 2014; Hassan et al., 2016; Somsuk and Laosirihongthong, 2016
Investment in research and design	GI15	Porter and Linder, 1995; Lucas, 2010; Testa et al., 2011; Horbach et al., 2012; Zailani et al., 2012
Environmental regulations	GI16	Noci and Verganti, 1999; Rehfield et al., 2007; Eiadat et al., 2008; Horbach, 2008; Lee, 2008; Johnstone et al., 2010; Lopez-Gamero et al., 2010; Govindan et al., 2016
Green warehousing	GI17	Jumadi and Zailani, 2010; Zhu et al., 2010; Kannan et al., 2014; Rostamzadeh et al., 2015
Human resource practices	GI18	Jimenez-Jimenez and Sanz-Valle, 2005; Abdulrahman et al., 2014; Jackson et al., 2014; Kannan et al., 2014; Longoni et al., 2014; Jabbour et al., 2015
Knowledge management practices	GI19	Porter and Van Der Linde, 1995; Noci and Verganti, 1999; Foster and Green, 2000; Rennings and Rammer, 2009; Ray and Ray, 2010; Dangelico and Pujari, 2010; Brammer et al., 2012
Resources for green innovation	GI20	Sandström and Tingström, 2008; Rennings and Rammer, 2009; Huang and Wu, 2010; Horbach et al., 2012; Driessen et al., 2013; Keskin et al., 2013
Market Demand	GI21	Chen, 2008; Kammerer, 2009; Zhou et al., 2009; Chiou et al., 2011; Hsu and Hu, 2009; Horbach et al., 2012; Lin et al., 2014

6.7 Case study of the proposed model

To check the effectiveness of the proposed study and methodology, a case company is taken up for the application of proposed methodology on enablers identified through literature review. The company taken up for the study is in inception for past more than 20 years and is leading component supplier for all the major automobile companies in India. They have now expanded their operations and are also exporting their products to other countries of the world. To cope with increasing government pressure to adopt green practices and also to continue on their mission to become a market leader, the company is focusing on green innovations at their end, so that they can develop green products that too at competitive price than their competitors.

Step 1: First step in Grey DEMATEL analysis is to set up direct influence matrix for all the enablers taken in the study. Four experts having experience of minimum ten years were identified and asked to rate the enablers of green innovation on the basis of linguistic scales as represented in Table 3. Four experts were chosen based on the past paper of Grey DEMATEL by Rajesh and Ravi (2015), Seker et al. (2017), Wang et al. (2017), Bouzon et al. (2018) and Xia et al. (2015). One of the experts is chairman of the company and is involved in all the decision making related to new technologies and products, second expert is senior manager of operations and looks after shop floor activities related to production and innovations, he also handles environmental unit of the organization, third expert is a senior manager of supply chain group and is responsible for material selection and procurement and also vendor development, fourth expert is an Associate Professor in a reputed university and is associated with many industries for work related to greening of the organizations and innovations. He is also handling technology incubation and innovation section of his university and has vast experience in industrial innovation activities.

Step 2: Using equation (3.8) and linguistic scale for grey values, four different initial relationship matrices are developed. The initial grey relation matrix for expert 1 is represented in Table 6.18.

Step 3: Using equation (3.9), average grey relational matrix $\left[\otimes \check{G}_{ij}\right]$ is computed. In order to ensure homogeneity in the results, equal weightage is assigned to each expert. The resultant matrix is shown in Table 6.19.

Step 4: Using equations 3.10 – 3.15 a crisp relation matrix X is obtained as shown in Table 6.20.

Step 5: Normalized direct relation matrix (N) is computed using equations (3.16) and (3.17) which is given in Table 6.21.

Step 6: Then total relation matrix S is obtained using equation (3.18), is shown in Table 6.22.

Step 7: Let R and C defined to be 21×1 and 1×21 vectors representing the sum of row elements and the sum of column elements for the total relation matrix S, respectively, using Eqs (3.19) and (3.20). The total relation matrix for values i = j is presented in Table 6.23.

Step 8: In order to plot causal relation among enablers of green innovation a threshold value (θ) was set by adding 1 times standard deviation to the mean of the elements in total relation matrix S, so as to eliminate negligible cause/effects among enablers. Diagraph describing the causal relation among enablers obtained from values in Table 6.23 is represented in Figure 6.2. The direction of cause enabler to effect enabler is represented by a solid arrow and dotted arrows are used to represent two-way relationships.

6.8 Discussion of Results

Many times a complex decision problem is encountered in which we come across several criteria which either influences other criteria (cause group criteria) or they get influenced by some criteria (effect group criteria). It's not the case that if we improve any one factor or criteria the whole system will improve because of dependence relationship among various factors, so it is imperative to find this dependence relationship so as to identify the factors in causal groups which can be improved upon to improve the effect group criteria or factors and thus the whole system (Govindan et al., 2016).

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Table 6.18 Grey relation matrix for enablers of green innovation as given by expert 1

	GI01	GI02	GI03	GI04	GI05	GI06	GI07	GI08	GI09	GI10	GI11	GI12	GI13	GI14	GI15	GI16	GI17	GI18	GI19	GI20	GI21
GI01	0 0.1	0.9 1	0.6 0.9	0.2 0.5	0.2 0.5	0.4 0.7	0.2 0.5	0.1 0.3	0.2 0.5	0.2 0.5	0.4 0.7	0.4 0.7	0.2 0.5	0.4 0.7	0.1 0.3	0.1 0.3	0.2 0.5	0.2 0.5	0.1 0.3	0.2 0.5	0.1 0.3
GI02	0.4 0.7	0 0.1	0.4 0.7	0.1 0.3	0.2 0.5	0.4 0.7	0.4 0.7	0.2 0.5	0.4 0.7	0.4 0.7	0.6 0.9	0.4 0.7	0.4 0.7	0.9 1	0.6 0.9	0.1 0.3	0.6 0.9	0.1 0.3	0.1 0.3	0.6 0.9	0.1 0.3
GI03	0.4 0.7	0.4 0.7	0 0.1	0.6 0.9	0.4 0.7	0.6 0.9	0.9 1	0.2 0.5	0.6 0.9	0.6 0.9	0.6 0.9	0.6 0.9	0.4 0.7	0.6 0.9	0.6 0.9	0.4 0.7	0.6 0.9	0.2 0.5	0.2 0.5	0.6 0.9	0.2 0.5
GI04	0.6 0.9	0.4 0.7	0.4 0.7	0 0.1	0.2 0.5	0.2 0.5	0.6 0.9	0.2 0.5	0.4 0.7	0.2 0.5	0.6 0.9	0.6 0.9	0.4 0.7	0.6 0.9	0.4 0.7	0.2 0.5	0.2 0.5	0.2 0.5	0.4 0.7	0.4 0.7	0.2 0.5
GI05	0.2 0.5	0.2 0.5	0.2 0.5	0 0.1	0 0.1	0.6 0.9	0.4 0.7	0.9 1	0.4 0.7	0.6 0.9	0.6 0.9	0.6 0.9	0.4 0.7	0.4 0.7	0.6 0.9	0.4 0.7	0.4 0.7	0.2 0.5	0.6 0.9	0.6 0.9	0.2 0.5
GI06	0.2 0.5	0.2 0.5	0.4 0.7	0.2 0.5	0.4 0.7	0 0.1	0.4 0.7	0.4 0.7	0.6 0.9	0.9 1	0.6 0.9	0.4 0.7	0.4 0.7	0.4 0.7	0.2 0.5	0.2 0.5	0.4 0.7	0.2 0.5	0.2 0.5	0.4 0.7	0.2 0.5
GI07	0.4 0.7	0.2 0.5	0.6 0.9	0.2 0.5	0.2 0.5	0.2 0.5	0 0.1	0.2 0.5	0.6 0.9	0.4 0.7	0.6 0.9	0.6 0.9	0.4 0.7	0.4 0.7	0.6 0.9	0.2 0.5	0.4 0.7	0.2 0.5	0.2 0.5	0.6 0.9	0.2 0.5
GI08	0.4 0.7	0.2 0.5	0.6 0.9	0.2 0.5	0.2 0.5	0.4 0.7	0.4 0.7	0 0.1	0.4 0.7	0.4 0.7	0.9 1	0.9 1	0.6 0.9	0.6 0.9	0.9 1	0.2 0.5	0.6 0.9	0.4 0.7	0.4 0.7	0.6 0.9	0.2 0.5
GI09	0.4 0.7	0.2 0.5	0.6 0.9	0.2 0.5	0.2 0.5	0.2 0.5	0.2 0.5	0.2 0.5	0 0.1	0.4 0.7	0.6 0.9	0.4 0.7	0.4 0.7	0.6 0.9	0.6 0.9	0.2 0.5	0.4 0.7	0.2 0.5	0.2 0.5	0.6 0.9	0.2 0.5
GI10	0.2 0.5	0.4 0.7	0.9 1	0.2 0.5	0.4 0.7	0.6 0.9	0.2 0.5	0.2 0.5	0.4 0.7	0 0.1	0.6 0.9	0.4 0.7	0.4 0.7	0.6 0.9	0.2 0.5	0.2 0.5	0.4 0.7	0.2 0.5	0.2 0.5	0.6 0.9	0.2 0.5
GI11	0.4 0.7	0.4 0.7	0.6 0.9	0.2 0.5	0.2 0.5	0.4 0.7	0.6 0.9	0.2 0.5	0.4 0.7	0.6 0.9	0 0.1	0.6 0.9	0.6 0.9	0.6 0.9	0.6 0.9	0.2 0.5	0.6 0.9	0.4 0.7	0.4 0.7	0.6 0.9	0.4 0.7
GI12	0.2 0.5	0.4 0.7	0.6 0.9	0.2 0.5	0.4 0.7	0.4 0.7	0.4 0.7	0.2 0.5	0.2 0.5	0.2 0.5	0.6 0.9	0 0.1	0.6 0.9	0.2 0.5	0.2 0.5	0.2 0.5	0.6 0.9	0.2 0.5	0.2 0.5	0.6 0.9	0.2 0.5
GI13	0.2 0.5	0.2 0.5	0.4 0.7	0.2 0.5	0.2 0.5	0.2 0.5	0.4 0.7	0.2 0.5	0.6 0.9	0.2 0.5	0.4 0.7	0.2 0.5	0 0.1	0.2 0.5	0.2 0.5	0.2 0.5	0.4 0.7	0.2 0.5	0.2 0.5	0.4 0.7	0.2 0.5
GI14	0.4	0.4	0.6	0.2	0.2	0.2	0.4	0.2	0.4	0.2	0.9	0.4	0.4	0	0.4	0.2	0.4	0.2	0.2	0.6	0.2

	0.7	0.7	0.9	0.5	0.5	0.5	0.7	0.5	0.7	0.5	1	0.7	0.7	0.1	0.7	0.5	0.7	0.5	0.5	0.9	0.5
GI15	0.4	0.4	0.6	0.2	0.2	0.2	0.4	0.2	0.4	0.2	0.9	0.4	0.4	0.4	0	0.2	0.4	0.2	0.2	0.6	0.2
	0.7	0.7	0.9	0.5	0.5	0.5	0.7	0.5	0.7	0.5	1	0.7	0.7	0.7	0.1	0.5	0.7	0.5	0.5	0.9	0.5
GI16	0.6	0.4	0.6	0.2	0.4	0.4	0.6	0.4	0.2	0.4	0.6	0.4	0.4	0.6	0.6	0	0.4	0.4	0.2	0.6	0.4
	0.9	0.7	0.9	0.5	0.7	0.7	0.9	0.7	0.5	0.7	0.9	0.7	0.7	0.9	0.9	0.1	0.7	0.7	0.5	0.9	0.7
GI17	0.2	0.2	0.4	0.2	0.2	0.4	0.6	0.2	0.4	0.2	0.6	0.6	0.4	0.2	0.2	0.2	0	0.2	0.2	0.6	0.2
	0.5	0.5	0.7	0.5	0.5	0.7	0.9	0.5	0.7	0.5	0.9	0.9	0.7	0.5	0.5	0.5	0.1	0.5	0.5	0.9	0.5
GI18	0.4	0.4	0.4	0.4	0.4	0.4	0.6	0.4	0.2	0.4	0.6	0.4	0.4	0.4	0.2	0.2	0.2	0	0.4	0.6	0.2
	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.7	0.5	0.7	0.9	0.7	0.7	0.7	0.5	0.5	0.5	0.1	0.7	0.9	0.5
GI19	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.4	0.2	0.4	0.2	0.2	0.2	0.4	0	0.6	0.2
	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.7	0.5	0.7	0.5	0.5	0.5	0.7	0.1	0.9	0.5
GI20	0.4	0.4	0.9	0.2	0.4	0.4	0.6	0.2	0.4	0.6	0.6	0.6	0.6	0.4	0.6	0.2	0.4	0.2	0.4	0	0.2
	0.7	0.7	1	0.5	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.9	0.9	0.7	0.9	0.5	0.7	0.5	0.7	0.1	0.5
GI21	0.4	0.4	0.9	0.2	0.4	0.6	0.4	0.2	0.2	0.6	0.9	0.6	0.6	0.6	0.6	0.2	0.6	0.4	0.4	0.9	0
	0.7	0.7	1	0.5	0.7	0.9	0.7	0.5	0.5	0.9	1	0.9	0.9	0.9	0.9	0.5	0.9	0.7	0.7	1	0.1

Table 6.19 Average grey relation matrix for enablers of green innovation

	GI01	GI02	GI03	GI04	GI05	GI06	GI07	GI08	GI09	GI10	GI11	GI12	GI13	GI14	GI15	GI16	GI17	GI18	GI19	GI20	GI21
GI01	0	0.675	0.6	0.2	0.35	0.4	0.2	0.175	0.35	0.2	0.4	0.4	0.2	0.25	0.325	0.1	0.2	0.2	0.175	0.2	0.1
	0.1	0.925	0.9	0.5	0.65	0.7	0.5	0.45	0.65	0.5	0.7	0.7	0.5	0.55	0.6	0.3	0.5	0.5	0.45	0.5	0.3
GI02	0.4	0	0.4	0.175	0.2	0.55	0.4	0.2	0.4	0.4	0.6	0.4	0.25	0.9	0.6	0.175	0.6	0.1	0.175	0.6	0.175
	0.7	0.1	0.7	0.45	0.5	0.85	0.7	0.5	0.7	0.7	0.9	0.7	0.55	1	0.9	0.45	0.9	0.3	0.45	0.9	0.45
GI03	0.4	0.3	0	0.6	0.4	0.6	0.9	0.3	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.4	0.6	0.15	0.2	0.6	0.2
	0.7	0.6	0.1	0.9	0.7	0.9	1	0.6	0.9	0.9	0.9	0.9	0.7	0.9	0.9	0.7	0.9	0.4	0.5	0.9	0.5
GI04	0.6	0.4	0.4	0	0.2	0.2	0.6	0.2	0.4	0.2	0.6	0.6	0.4	0.6	0.4	0.2	0.2	0.2	0.4	0.4	0.2
	0.9	0.7	0.7	0.1	0.5	0.5	0.9	0.5	0.7	0.5	0.9	0.9	0.7	0.9	0.7	0.5	0.5	0.5	0.7	0.7	0.5
GI05	0.2	0.2	0.2	0.05	0	0.6	0.4	0.9	0.4	0.6	0.5	0.6	0.4	0.5	0.6	0.4	0.4	0.2	0.6	0.6	0.2
	0.5	0.5	0.5	0.2	0.1	0.9	0.7	1	0.7	0.9	0.8	0.9	0.7	0.8	0.9	0.7	0.7	0.5	0.9	0.9	0.5
GI06	0.2	0.2	0.4	0.125	0.4	0	0.4	0.4	0.6	0.9	0.6	0.4	0.4	0.4	0.2	0.125	0.4	0.2	0.2	0.4	0.2
	0.5	0.5	0.7	0.35	0.7	0.1	0.7	0.7	0.9	1	0.9	0.7	0.7	0.7	0.5	0.35	0.7	0.5	0.5	0.7	0.5

GI07	0.25	0.2	0.6	0.2	0.2	0.35	0	0.125	0.6	0.4	0.6	0.6	0.25	0.4	0.6	0.2	0.4	0.2	0.2	0.6	0.125
	0.55	0.5	0.9	0.5	0.5	0.65	0.1	0.35	0.9	0.7	0.9	0.9	0.55	0.7	0.9	0.5	0.7	0.5	0.5	0.9	0.35
GI08	0.4	0.35	0.6	0.2	0.35	0.4	0.4	0	0.4	0.4	0.9	0.9	0.6	0.6	0.9	0.125	0.6	0.4	0.4	0.6	0.35
	0.7	0.65	0.9	0.5	0.65	0.7	0.7	0.1	0.7	0.7	1	1	0.9	0.9	1	0.35	0.9	0.7	0.7	0.9	0.65
GI09	0.4	0.2	0.6	0.2	0.3	0.15	0.3	0.2	0	0.4	0.6	0.4	0.4	0.6	0.6	0.2	0.4	0.2	0.15	0.6	0.15
	0.7	0.5	0.9	0.5	0.6	0.4	0.6	0.5	0.1	0.7	0.9	0.7	0.7	0.9	0.9	0.5	0.7	0.5	0.4	0.9	0.4
GI10	0.3	0.3	0.9	0.2	0.4	0.5	0.3	0.2	0.4	0	0.6	0.4	0.4	0.6	0.15	0.15	0.4	0.2	0.2	0.6	0.15
	0.6	0.6	1	0.5	0.7	0.8	0.6	0.5	0.7	0.1	0.9	0.7	0.7	0.9	0.4	0.4	0.7	0.5	0.5	0.9	0.4
GI11	0.4	0.4	0.6	0.2	0.25	0.4	0.6	0.2	0.45	0.6	0	0.6	0.6	0.675	0.6	0.175	0.6	0.4	0.4	0.6	0.4
	0.7	0.7	0.9	0.5	0.55	0.7	0.9	0.5	0.75	0.9	0.1	0.9	0.9	0.925	0.9	0.45	0.9	0.7	0.7	0.9	0.7
GI12	0.2	0.4	0.6	0.2	0.4	0.4	0.4	0.2	0.2	0.2	0.6	0	0.6	0.2	0.2	0.2	0.6	0.2	0.2	0.6	0.2
	0.5	0.7	0.9	0.5	0.7	0.7	0.7	0.5	0.5	0.5	0.9	0.1	0.9	0.5	0.5	0.5	0.9	0.5	0.5	0.9	0.5
GI13	0.2	0.2	0.4	0.15	0.2	0.2	0.4	0.2	0.6	0.2	0.4	0.2	0	0.2	0.2	0.2	0.4	0.2	0.2	0.4	0.125
	0.5	0.5	0.7	0.4	0.5	0.5	0.7	0.5	0.9	0.5	0.7	0.5	0.1	0.5	0.5	0.5	0.7	0.5	0.5	0.7	0.35
GI14	0.4	0.4	0.6	0.2	0.2	0.2	0.4	0.2	0.4	0.2	0.9	0.4	0.4	0	0.4	0.2	0.4	0.2	0.2	0.6	0.2
	0.7	0.7	0.9	0.5	0.5	0.5	0.7	0.5	0.7	0.5	1	0.7	0.7	0.1	0.7	0.5	0.7	0.5	0.5	0.9	0.5
GI15	0.4	0.4	0.6	0.2	0.2	0.2	0.4	0.2	0.4	0.2	0.9	0.4	0.4	0.4	0	0.2	0.4	0.2	0.2	0.6	0.125
	0.7	0.7	0.9	0.5	0.5	0.5	0.7	0.5	0.7	0.5	1	0.7	0.7	0.7	0.1	0.5	0.7	0.5	0.5	0.9	0.35
GI16	0.5	0.4	0.6	0.15	0.4	0.4	0.6	0.4	0.15	0.4	0.6	0.4	0.5	0.6	0.6	0	0.4	0.4	0.3	0.6	0.4
	0.8	0.7	0.9	0.4	0.7	0.7	0.9	0.7	0.4	0.7	0.9	0.7	0.8	0.9	0.9	0.1	0.7	0.7	0.6	0.9	0.7
GI17	0.2	0.125	0.4	0.2	0.125	0.4	0.6	0.2	0.4	0.125	0.6	0.6	0.4	0.2	0.125	0.2	0	0.2	0.2	0.6	0.2
	0.5	0.35	0.7	0.5	0.35	0.7	0.9	0.5	0.7	0.35	0.9	0.9	0.7	0.5	0.35	0.5	0.1	0.5	0.5	0.9	0.5
GI18	0.4	0.25	0.55	0.4	0.4	0.4	0.6	0.4	0.2	0.4	0.6	0.4	0.4	0.4	0.2	0.2	0.2	0	0.4	0.6	0.2
	0.7	0.55	0.85	0.7	0.7	0.7	0.9	0.7	0.5	0.7	0.9	0.7	0.7	0.7	0.5	0.5	0.5	0.1	0.7	0.9	0.5
GI19	0.4	0.3	0.4	0.2	0.5	0.3	0.4	0.2	0.4	0.2	0.4	0.4	0.2	0.4	0.2	0.2	0.2	0.4	0	0.6	0.2
	0.7	0.6	0.7	0.5	0.8	0.6	0.7	0.5	0.7	0.5	0.7	0.7	0.5	0.7	0.5	0.5	0.5	0.7	0.1	0.9	0.5
GI20	0.5	0.4	0.9	0.2	0.4	0.4	0.6	0.2	0.4	0.6	0.6	0.6	0.6	0.4	0.6	0.15	0.4	0.2	0.4	0	0.175
	0.8	0.7	1	0.5	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.9	0.9	0.7	0.9	0.4	0.7	0.5	0.7	0.1	0.45
GI21	0.55	0.4	0.9	0.2	0.4	0.6	0.5	0.125	0.35	0.6	0.9	0.6	0.5	0.75	0.6	0.15	0.6	0.4	0.4	0.9	0
	0.85	0.7	1	0.5	0.7	0.9	0.8	0.35	0.65	0.9	1	0.9	0.8	0.95	0.9	0.4	0.9	0.7	0.7	1	0.1

Table 6.20 Crisp relation matrix for enablers of green innovation

	GI01	GI02	GI03	GI04	GI05	GI06	GI07	GI08	GI09	GI10	GI11	GI12	GI13	GI14	GI15	GI16	GI17	GI18	GI19	GI20	GI21
GI01	0.000	0.854	0.733	0.303	0.575	0.566	0.267	0.227	0.500	0.267	0.500	0.500	0.303	0.325	0.399	0.179	0.303	0.413	0.258	0.267	0.179
GI02	0.566	0.000	0.500	0.258	0.350	0.763	0.500	0.267	0.566	0.500	0.733	0.500	0.369	0.900	0.733	0.350	0.828	0.179	0.258	0.733	0.350
GI03	0.566	0.420	0.000	0.828	0.650	0.828	0.900	0.383	0.828	0.733	0.733	0.733	0.566	0.733	0.733	0.762	0.828	0.290	0.303	0.733	0.413
GI04	0.828	0.548	0.500	0.000	0.350	0.303	0.733	0.267	0.566	0.267	0.733	0.733	0.566	0.733	0.500	0.413	0.303	0.413	0.566	0.500	0.413
GI05	0.303	0.293	0.267	0.061	0.000	0.828	0.500	0.900	0.566	0.733	0.617	0.733	0.566	0.617	0.733	0.762	0.566	0.413	0.828	0.733	0.413
GI06	0.303	0.293	0.500	0.173	0.650	0.000	0.500	0.500	0.828	0.900	0.733	0.500	0.566	0.500	0.267	0.233	0.566	0.413	0.303	0.500	0.413
GI07	0.369	0.293	0.733	0.303	0.350	0.500	0.000	0.153	0.828	0.500	0.733	0.733	0.369	0.500	0.733	0.413	0.566	0.413	0.303	0.733	0.233
GI08	0.566	0.484	0.733	0.303	0.575	0.566	0.500	0.000	0.566	0.500	0.900	0.900	0.828	0.733	0.900	0.233	0.828	0.762	0.566	0.733	0.675
GI09	0.566	0.293	0.733	0.303	0.500	0.214	0.383	0.267	0.000	0.500	0.733	0.500	0.566	0.733	0.733	0.413	0.566	0.413	0.214	0.733	0.290
GI10	0.434	0.420	0.900	0.303	0.650	0.697	0.383	0.267	0.566	0.000	0.733	0.500	0.566	0.733	0.189	0.290	0.566	0.413	0.303	0.733	0.290
GI11	0.566	0.548	0.733	0.303	0.425	0.566	0.733	0.267	0.631	0.733	0.000	0.733	0.828	0.783	0.733	0.350	0.828	0.762	0.566	0.733	0.762
GI12	0.303	0.548	0.733	0.303	0.650	0.566	0.500	0.267	0.303	0.267	0.733	0.000	0.828	0.267	0.267	0.413	0.828	0.413	0.303	0.733	0.413
GI13	0.303	0.293	0.500	0.214	0.350	0.303	0.500	0.267	0.828	0.267	0.500	0.267	0.000	0.267	0.267	0.413	0.566	0.413	0.303	0.500	0.233
GI14	0.566	0.548	0.733	0.303	0.350	0.303	0.500	0.267	0.566	0.267	0.900	0.500	0.566	0.000	0.500	0.413	0.566	0.413	0.303	0.733	0.413
GI15	0.566	0.548	0.733	0.303	0.350	0.303	0.500	0.267	0.566	0.267	0.900	0.500	0.566	0.500	0.000	0.413	0.566	0.413	0.303	0.733	0.233
GI16	0.697	0.548	0.733	0.214	0.650	0.566	0.733	0.500	0.214	0.500	0.733	0.500	0.697	0.733	0.733	0.000	0.566	0.762	0.434	0.733	0.762
GI17	0.303	0.167	0.500	0.303	0.198	0.566	0.733	0.267	0.566	0.153	0.733	0.733	0.566	0.267	0.153	0.413	0.000	0.413	0.303	0.733	0.413
GI18	0.566	0.357	0.675	0.566	0.650	0.566	0.733	0.500	0.303	0.500	0.733	0.500	0.566	0.500	0.267	0.413	0.303	0.000	0.566	0.733	0.413
GI19	0.566	0.420	0.500	0.303	0.800	0.434	0.500	0.267	0.566	0.267	0.500	0.500	0.303	0.500	0.267	0.413	0.303	0.762	0.000	0.733	0.413
GI20	0.697	0.548	0.900	0.303	0.650	0.566	0.733	0.267	0.566	0.733	0.733	0.733	0.828	0.500	0.733	0.290	0.566	0.413	0.566	0.000	0.350
GI21	0.763	0.548	0.900	0.303	0.650	0.828	0.617	0.153	0.500	0.733	0.900	0.733	0.697	0.827	0.733	0.290	0.828	0.762	0.566	0.900	0.000

Table 6.21 Normalized direct crisp relation matrix for enablers of green innovation

	GI01	**GI02**	**GI03**	**GI04**	**GI05**	**GI06**	**GI07**	**GI08**	**GI09**	**GI10**	**GI11**	**GI12**	**GI13**	**GI14**	**GI15**	**GI16**	**GI17**	**GI18**	**GI19**	**GI20**	**GI21**
GI01	0.000	0.065	0.055	0.023	0.043	0.043	0.020	0.017	0.038	0.020	0.038	0.038	0.023	0.025	0.030	0.013	0.023	0.031	0.019	0.020	0.013
GI02	0.043	0.000	0.038	0.019	0.026	0.058	0.038	0.020	0.043	0.038	0.055	0.038	0.028	0.068	0.055	0.026	0.063	0.013	0.019	0.055	0.026
GI03	0.043	0.032	0.000	0.063	0.049	0.063	0.068	0.029	0.063	0.055	0.055	0.055	0.043	0.055	0.055	0.058	0.063	0.022	0.023	0.055	0.031
GI04	0.063	0.041	0.038	0.000	0.026	0.023	0.055	0.020	0.043	0.020	0.055	0.055	0.043	0.055	0.038	0.031	0.023	0.031	0.043	0.038	0.031
GI05	0.023	0.022	0.020	0.005	0.000	0.063	0.038	0.068	0.043	0.055	0.047	0.055	0.043	0.047	0.055	0.058	0.043	0.031	0.063	0.055	0.031
GI06	0.023	0.022	0.038	0.013	0.049	0.000	0.038	0.038	0.063	0.068	0.055	0.038	0.043	0.038	0.020	0.018	0.043	0.031	0.023	0.038	0.031
GI07	0.028	0.022	0.055	0.023	0.026	0.038	0.000	0.012	0.063	0.038	0.055	0.055	0.028	0.038	0.055	0.031	0.043	0.031	0.023	0.055	0.018
GI08	0.043	0.037	0.055	0.023	0.043	0.043	0.038	0.000	0.043	0.038	0.068	0.068	0.063	0.055	0.068	0.018	0.063	0.058	0.043	0.055	0.051
GI09	0.043	0.022	0.055	0.023	0.038	0.016	0.029	0.020	0.000	0.038	0.055	0.038	0.043	0.055	0.055	0.031	0.043	0.031	0.016	0.055	0.022
GI10	0.033	0.032	0.068	0.023	0.049	0.053	0.029	0.020	0.043	0.000	0.055	0.038	0.043	0.055	0.014	0.022	0.043	0.031	0.023	0.055	0.022
GI11	0.043	0.041	0.055	0.023	0.032	0.043	0.055	0.020	0.048	0.055	0.000	0.055	0.063	0.059	0.055	0.026	0.063	0.058	0.043	0.055	0.058
GI12	0.023	0.041	0.055	0.023	0.049	0.043	0.038	0.020	0.023	0.020	0.055	0.000	0.063	0.020	0.020	0.031	0.063	0.031	0.023	0.055	0.031
GI13	0.023	0.022	0.038	0.016	0.026	0.023	0.038	0.020	0.063	0.020	0.038	0.020	0.000	0.020	0.020	0.031	0.043	0.031	0.023	0.038	0.018
GI14	0.043	0.041	0.055	0.023	0.026	0.023	0.038	0.020	0.043	0.020	0.068	0.038	0.043	0.000	0.038	0.031	0.043	0.031	0.023	0.055	0.031
GI15	0.043	0.041	0.055	0.023	0.026	0.023	0.038	0.020	0.043	0.020	0.068	0.038	0.043	0.038	0.000	0.031	0.043	0.031	0.023	0.055	0.018
GI16	0.053	0.041	0.055	0.016	0.049	0.043	0.055	0.038	0.016	0.038	0.055	0.038	0.053	0.055	0.055	0.000	0.043	0.058	0.033	0.055	0.058
GI17	0.023	0.013	0.038	0.023	0.015	0.043	0.055	0.020	0.043	0.012	0.055	0.055	0.043	0.020	0.012	0.031	0.000	0.031	0.023	0.055	0.031
GI18	0.043	0.027	0.051	0.043	0.049	0.043	0.055	0.038	0.023	0.038	0.055	0.038	0.043	0.038	0.020	0.031	0.023	0.000	0.043	0.055	0.031
GI19	0.043	0.032	0.038	0.023	0.060	0.033	0.038	0.020	0.043	0.020	0.038	0.038	0.023	0.038	0.020	0.031	0.023	0.058	0.000	0.055	0.031
GI20	0.053	0.041	0.068	0.023	0.049	0.043	0.055	0.020	0.043	0.055	0.055	0.055	0.063	0.038	0.055	0.022	0.043	0.031	0.043	0.000	0.026
GI21	0.058	0.041	0.068	0.023	0.049	0.063	0.047	0.012	0.038	0.055	0.068	0.055	0.053	0.063	0.055	0.022	0.063	0.058	0.043	0.068	0.000

Table 6.22 Total relation matrix for enablers of green innovation

	GI01	GI02	GI03	GI04	GI05	GI06	GI07	GI08	GI09	GI10	GI11	GI12	GI13	GI14	GI15	GI16	GI17	GI18	GI19	GI20	GI21
GI01	0.099	0.146	0.201	0.082	0.149	0.147	0.147	0.090	0.155	0.128	0.196	0.171	0.136	0.144	0.146	0.095	0.139	0.124	0.097	0.171	0.094
GI02	0.172	0.120	0.236	0.102	0.177	0.202	0.210	0.112	0.196	0.183	0.271	0.217	0.188	0.232	0.213	0.141	0.217	0.140	0.124	0.260	0.143
GI03	0.204	0.177	0.242	0.158	0.230	0.235	0.277	0.144	0.250	0.235	0.320	0.278	0.234	0.262	0.249	0.196	0.253	0.180	0.149	0.307	0.169
GI04	0.188	0.157	0.230	0.081	0.174	0.161	0.223	0.109	0.191	0.160	0.264	0.231	0.192	0.219	0.191	0.139	0.175	0.156	0.140	0.236	0.139
GI05	0.166	0.151	0.236	0.090	0.165	0.216	0.226	0.169	0.209	0.216	0.282	0.253	0.213	0.230	0.228	0.180	0.213	0.175	0.173	0.281	0.155
GI06	0.143	0.130	0.221	0.087	0.186	0.135	0.197	0.125	0.203	0.202	0.255	0.205	0.186	0.194	0.165	0.125	0.187	0.151	0.117	0.228	0.135
GI07	0.158	0.135	0.246	0.100	0.172	0.177	0.165	0.099	0.207	0.178	0.261	0.228	0.181	0.198	0.207	0.138	0.191	0.153	0.120	0.252	0.128
GI08	0.202	0.185	0.297	0.121	0.220	0.216	0.248	0.113	0.230	0.215	0.327	0.285	0.251	0.259	0.256	0.158	0.252	0.217	0.167	0.306	0.186
GI09	0.166	0.134	0.244	0.099	0.179	0.157	0.192	0.108	0.148	0.175	0.259	0.208	0.189	0.214	0.205	0.137	0.189	0.152	0.119	0.250	0.127
GI10	0.155	0.142	0.250	0.098	0.188	0.185	0.191	0.108	0.187	0.138	0.257	0.207	0.188	0.214	0.158	0.127	0.189	0.151	0.119	0.248	0.127
GI11	0.200	0.182	0.294	0.120	0.208	0.213	0.263	0.131	0.236	0.230	0.257	0.271	0.247	0.256	0.243	0.164	0.248	0.213	0.164	0.302	0.192
GI12	0.142	0.147	0.236	0.096	0.184	0.173	0.197	0.106	0.165	0.154	0.252	0.165	0.203	0.172	0.164	0.134	0.204	0.149	0.117	0.244	0.134
GI13	0.118	0.106	0.182	0.080	0.138	0.126	0.164	0.088	0.172	0.126	0.194	0.151	0.116	0.142	0.135	0.112	0.155	0.125	0.097	0.188	0.103
GI14	0.164	0.151	0.240	0.097	0.167	0.155	0.199	0.106	0.185	0.155	0.264	0.205	0.186	0.155	0.185	0.135	0.187	0.150	0.117	0.246	0.135
GI15	0.162	0.149	0.237	0.096	0.165	0.153	0.196	0.105	0.182	0.153	0.261	0.203	0.184	0.191	0.145	0.133	0.185	0.148	0.116	0.243	0.124
GI16	0.207	0.182	0.290	0.118	0.224	0.212	0.261	0.149	0.206	0.211	0.310	0.251	0.235	0.254	0.243	0.134	0.227	0.212	0.154	0.299	0.192
GI17	0.129	0.108	0.200	0.088	0.142	0.157	0.199	0.095	0.167	0.131	0.231	0.204	0.169	0.155	0.139	0.121	0.131	0.137	0.106	0.224	0.123
GI18	0.174	0.150	0.245	0.122	0.198	0.185	0.230	0.133	0.178	0.185	0.271	0.219	0.197	0.206	0.178	0.143	0.180	0.132	0.145	0.261	0.144
GI19	0.159	0.137	0.214	0.094	0.191	0.160	0.192	0.105	0.178	0.151	0.229	0.199	0.161	0.187	0.161	0.131	0.161	0.174	0.095	0.239	0.131
GI20	0.195	0.171	0.283	0.111	0.212	0.199	0.246	0.123	0.213	0.217	0.292	0.254	0.231	0.222	0.229	0.145	0.215	0.172	0.154	0.225	0.153
GI21	0.224	0.188	0.311	0.124	0.234	0.239	0.262	0.127	0.235	0.238	0.332	0.280	0.245	0.263	0.250	0.161	0.255	0.219	0.169	0.320	0.141

Table 6.23 Cause/effect parameters for enablers of green innovation

Enablers	R	C	R+C	R-C
GI01	2.858	3.526	6.384	-0.668
GI02	3.855	3.148	7.004	0.707
GI03	4.748	5.135	9.884	-0.387
GI04	3.757	2.163	5.920	1.594
GI05	4.227	3.905	8.131	0.322
GI06	3.576	3.802	7.379	-0.226
GI07	3.695	4.485	8.180	-0.790
GI08	4.711	2.445	7.156	2.265
GI09	3.652	4.090	7.742	-0.438
GI10	3.628	3.780	7.408	-0.152
GI11	4.634	5.583	10.217	-0.949
GI12	3.535	4.686	8.220	-1.151
GI13	2.815	4.131	6.946	-1.315
GI14	3.586	4.369	7.955	-0.783
GI15	3.530	4.090	7.620	-0.560
GI16	4.574	2.947	7.521	1.627
GI17	3.159	4.153	7.312	-0.994
GI18	3.875	3.432	7.307	0.443
GI19	3.447	2.758	6.205	0.689
GI20	4.259	5.333	9.593	-1.074
GI21	4.818	2.977	7.796	1.841

Table 6.24 Assigned weights for different analysts during sensitivity analysis

	Expert 1	Expert 2	Expert 3	Expert 4
Scenario 1	0.40	0.20	0.20	0.20
Scenario 2	0.20	0.40	0.20	0.20
Scenario 3	0.20	0.20	0.40	0.20
Scenario 4	0.20	0.20	0.20	0.40

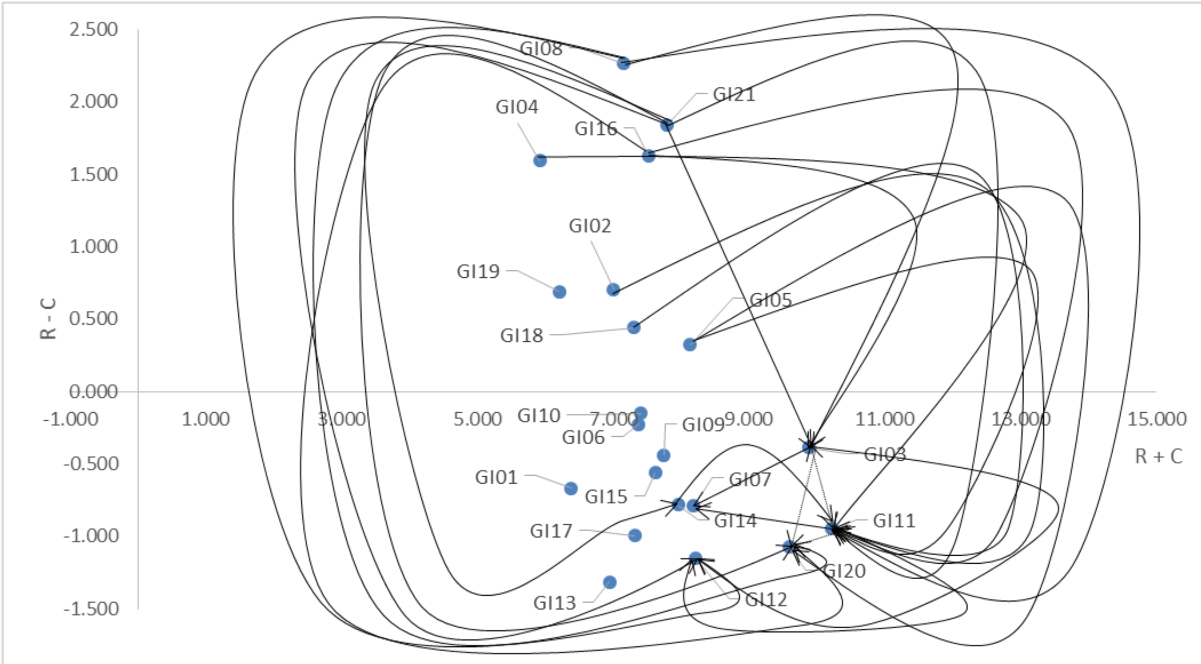

Figure 6.2 Digraph for causal relationship among enablers of green innovation

Keeping the above thing in mind a combination of Grey and DEMATEL techniques were utilized in this study to find out the cause and effect relationship among enablers of green innovation. A threshold value of 0.262 has been set in order to eliminate relatively insignificant effects. The combination of Grey and DEMATEL methodologies have significant contributions for managers of the case company used in the analysis.

Based on the values of (R_i + C_j), the enablers are prioritized as follows, GI11>GI03>GI20>GI12>GI07>GI05>GI14>GI21>GI09>GI15>GI16>GI10>GI06>GI17>GI18>GI08>GI02>GI13>GI01>GI19>GI04. According to this ranking, Developing green manufacturing capabilities (GI11) is the most important enabler for green innovation in manufacturing organizations. Green manufacturing capabilities include various activities like manufacturing facilities for waste reduction and minimization of environmental pollution. Green manufacturing capabilities greatly improve organizations environmental performance. Most of the organizations are using traditional manufacturing technologies and changeover to green manufacturing technologies requires incorporating innovative techniques for cost control and thus promotes innovation at the organizations (Nikbakhsh, 2009; Maruthi and Rashmi 2015; Somsuk and Laosirihongthong, 2016). Green operation and communicational practices which refer to both product and process related activities, is the second most important enabler as per ranking. Past literature also supports the findings and states that green operational practices which include modifying product design and manufacturing processes for improvement in environmental performance of the firm (De Ron, 1998; Gilley et al., 2000).

Third most important enabler for green innovation implementation in manufacturing organizations is Resources for green innovation. Numerous resources which include investment in internal R&D, scientific and technical expertise to carry out green operations, capability to develop new and green materials and capacity to conduct life cycle assessment of both products and processes are instrumental in carrying out green innovations in the organizations (Horbach et al., 2012; Driessen et al., 2013; Keskin et al., 2013). Apart from this marketing capability of an organization to promote its green products and thus improve the social image of the firm is also as important as other capabilities (Dangelico, 2016).

Further, the analysis is done to rank the driver (causal) enablers based upon ($R_i – C_j$) values for all values of i=j. The characterization and prioritizing of enablers in causal group helps to identify the enablers that need to be controlled first since they are not easily moved and also they can cause the effect group enablers to move or change if they are controlled and worked upon properly (Wu and Lee, 2007; Lin et al., 2011). The ranking of causal enablers are obtained as follows GI08>GI21>GI16>GI04>GI02>GI19>GI18>GI05. The ranking shows that ease of getting loans from financial institutions (GI08), market demand (GI21) and environmental regulations (GI16) are the important driving enablers as can be seen from diagraph in figure 1, figure shows that ease of getting loans is driving enabler for green operation and communication practices (GI03), developing green manufacturing capabilities (GI11), green logistics facilities (GI12) and Resources for green innovation (GI20). Similarly market demand (GI21) is driving enabler for many other enablers viz. green operation and communication practices (GI03), developing green manufacturing capabilities (GI11), green logistics facilities (GI12), designing to produce green and sustainable products (GI14) and Resources for green innovation (GI20). Third ranked enabler among the driving enablers i.e. environmental regulations (GI16) is also driving enabler for green operation and communication practices (GI03), developing green manufacturing capabilities (GI11) and Resources for green innovation (GI20). Among all the driving enablers market demand (GI21) has the highest R_i value (4.818) thus further corroborating it's high driving power as discussed above.

Similarly among effect enablers i.e. enablers that are driven by other enablers, the most prominent is developing green manufacturing capabilities (GI11) followed by Resources for green innovation (GI20) and green operation and communication practices (GI03) as also shown in figure (1). Developing green manufacturing capabilities at the organization's end can be driven by various other factors viz. environmental commitment of the firm, green operation and communication practices, intra organizational collaborations, ease of getting loans from financial institutes, environmental regulations, human resource practices, Resources for green innovation and market demand. Also, it is pertinent to mention that green operation and communication practices (GI03) and Resources for green innovation (GI20) have two-way relationships as indicated by dotted arrows in figure (1). Even though these enablers belong to effect group but still they have a dual effect on each other it means they are interdependent on each other. Similarly, green operation and communication practices (GI03) and green manufacturing capabilities (GI11) are also interdepended on each other, same is the case with green manufacturing capabilities (GI11) and Resources for green innovation (GI20).

Further analysis can be done by dividing all the enablers into different zones, enablers above x-axis have most prominence and are called causal enablers and those below x-axis are addressed as effect enablers due to their dependency on causal enablers and this group is also called as dysfunctional group enablers. The whole bunch of enablers can be divided into four different groups as shown in figure 6.3; where zone 1 constitutes of enablers with minimal relations or to say enablers with the lowest significance. Environmental management practices (GI01), Supplier development for green innovations (GI06), Green purchasing (GI10), Reverse logistics (GI13), Investment in research and design (GI15) and Green warehousing (GI17) belongs to this group. Zone 2 constitutes of causal group enablers which have driving effect for other enablers but that driving effect is weaker, Environmental commitment of the firm (GI02), Intra organizational collaborations (GI04), Ease of getting loans from financial institutions (GI08), Environmental regulations (GI16), Human resource practices (GI18) and Knowledge management practices (GI19) are part of this zone. Next zone 3 constitutes enablers with most prominent significance falling in the causal group and are most crucial enablers, External collaborations (GI05) and Market Demand (GI21) belongs to this group thus signifying their prominence for green innovation. Zone 4 constitutes of enablers with high significance among effect group, these enablers need to be looked upon and controlled immediately by management to formulate an effective green innovation program Green operational and communication practices (GI03), Investment recovery (GI07), Cost reduction and new business opportunities (GI09), Developing green manufacturing capabilities (GI11), Green logistics facilities (GI12), Designing to produce green and sustainable products (GI14) and Resources for green innovation (GI20) belongs to this zone.

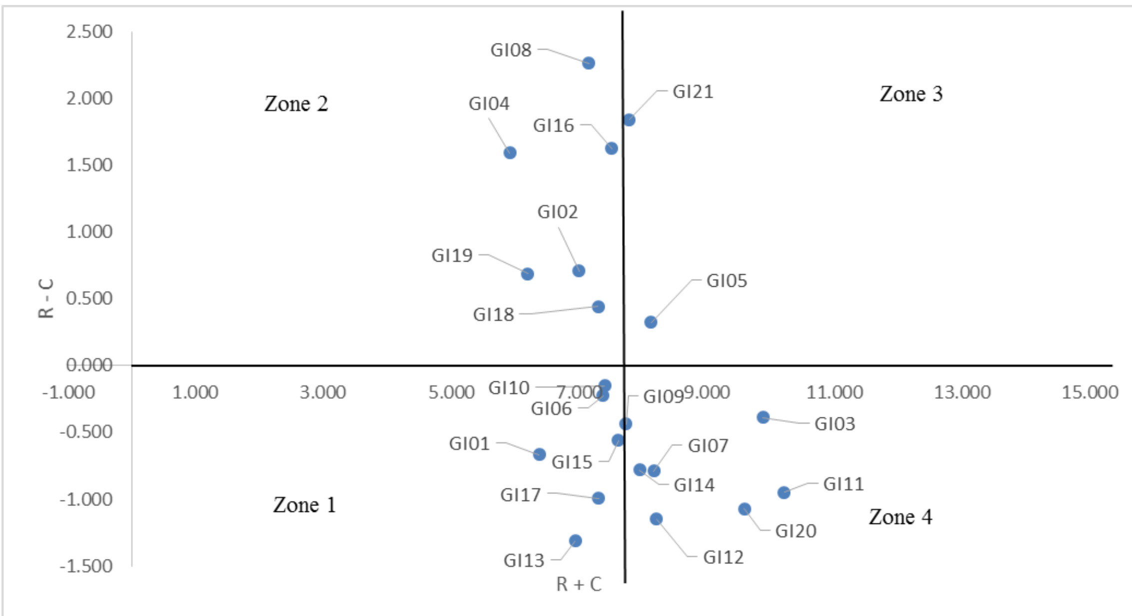

Figure 6.3 Zone wise representations of enablers of green innovation

6.9 Sensitivity Analysis

Sensitivity analysis is basically a process to test the validity and robustness of the methodology. Various methods can be used to perform sensitivity analysis, one such method is to change the weight given to a particular expert to see its effect on overall system (Rajesh and Ravi, 2015; Emovon et al. 2016). Since experts were chosen with criteria of minimum 10 years of experience, so equal weight can be given to each expert and after that weights can be changed for each scenario as done below. Here, one expert is given higher weight and rest of the experts are given equal weight and results are computed.

Similarly, four different scenarios are created by giving higher weight to each of the four experts individually. The four different scenarios are shown in Table 6.24.

For each case, separate total relationship matrix is constructed and on the basis of this separate (Ri + Cj) and (Ri – Cj) values are computed. Table 6.25 representing the ranking of enablers on the basis of their (Ri – Cj) values in different scenarios is depicted below.

The sensitivity analysis shows that there is no biasness in the results obtained through four different scenarios, Table 6.25 clearly shows that in all the four scenarios, the first two ranks are obtained by GI08, GI21 enablers respectively and similar results are obtained for effect group enablers and also for enablers that are ranked last.

Table 6.25 Ranking of cause/effect enablers of green innovation

Ranking order	**Scenario 1**		**Scenario 2**		**Scenario 3**		**Scenario 4**	
	Enabler	**R_i - C_j**	**Enabler**	**R_i - C_j**	**Enabler**	**R_i - C_j**	**Enabler**	**R_i - C_j**
1	GI08	2.191	GI08	2.291	GI08	2.231	GI08	2.245
2	GI21	1.735	GI21	1.840	GI21	1.814	GI21	1.823
3	GI16	1.642	GI16	1.612	GI04	1.605	GI04	1.662
4	GI04	1.572	GI04	1.533	GI16	1.577	GI16	1.524
5	GI19	0.679	GI19	0.730	GI19	0.728	GI02	0.699
6	GI02	0.538	GI02	0.697	GI02	0.694	GI19	0.685
7	GI18	0.439	GI18	0.444	GI18	0.440	GI18	0.439
8	GI05	0.279	GI05	0.286	GI05	0.357	GI05	0.371
9	GI10	-0.100	GI10	-0.150	GI10	-0.148	GI10	-0.107
10	GI06	-0.128	GI06	-0.177	GI06	-0.177	GI06	-0.223
11	GI09	-0.344	GI03	-0.385	GI03	-0.385	GI03	-0.388
12	GI03	-0.376	GI09	-0.520	GI09	-0.481	GI09	-0.445
13	GI01	-0.579	GI15	-0.557	GI15	-0.551	GI15	-0.597
14	GI15	-0.595	GI01	-0.611	GI01	-0.655	GI01	-0.659
15	GI14	-0.767	GI07	-0.750	GI14	-0.769	GI14	-0.727
16	GI07	-0.782	GI14	-0.778	GI07	-0.779	GI07	-0.781
17	GI11	-0.934	GI11	-0.897	GI11	-0.939	GI11	-0.937
18	GI17	-0.979	GI17	-1.037	GI17	-1.031	GI17	-1.036
19	GI20	-1.057	GI20	-1.118	GI20	-1.055	GI20	-1.060
20	GI12	-1.137	GI12	-1.143	GI12	-1.133	GI12	-1.139
21	GI13	-1.296	GI13	-1.308	GI13	-1.343	GI13	-1.349

6.10 Chapter Summary

Supplier selection is a strategic decision and is very important for a company to keep running its operations. This section dealt with supplier selection by large organizations among SMEs on the basis of their green innovation ability. A comprehensive and robust framework using integrated methodology has been developed for organizations to effectively select their suppliers. This section also dealt with ranking various enablers of the green innovation and also finding the causal relationship among the enablers, thus establishing which enablers are important and can influence other enablers and hence whole system. Thus the objectives three and four of the research are achieved. Next chapter deals with the development of conceptual framework.

CHAPTER - VII

DESIGN OF CONCEPTUAL FRAMEWORK

7.1 Introduction

This chapter presents a green technology development and innovation implementation program for SMEs through the use of literature review, learning from case studies, and quantitative and qualitative modelling.

In initial phase extensive literature review was done to find out the barriers of green innovation in SMEs. After that current scenario of selected sample of SMEs was assessed in terms of green innovation implementation. Case analysis using quantitative techniques was done for barriers and enablers of green innovation. Results and findings were presented to expert for their opinion. After that qualitative modeling involving OPM and OFM was done to derive the various profiles and approaches/strategies to overcome these barriers to implementation of green technology development and innovation in SMEs. Next, BWM, FST and Dominance matrix approach was used to map the identified strategies with the main objective and sub objectives of green technology development and innovation program. The options profiles generated through expert opinion were first put into eight main categories and then mapped with five identified strategies through brainstorming with experts. Main objective of green technology development and innovation implementation was decomposed into four sub objectives, these sub objectives were than ranked using BWM. In the next step, FST and dominance matrix approach was used to find the relationship/dominance of five strategies on achieving these objectives. The final analysis results in development of a framework which indicates the dominance relationship between these strategies and objectives.

7.2 OFM based Modeling

The issues and solutions to these issues identified in the previous chapters have been structured here to convert them into options of the Options Field Methodology (OFM). A total of 121 options were initially proposed by the experts as solution to the present research problem. Some of these options were overlapping. After scrutinizing and combining them, 78 independent options were made and the polystructure was completed. These options have been displayed in the completed options profiles in Figure 7.1.

7.2.1 Dimensions of the Design

The above categories were scrutinized to include them or exclude any of them for the design. All of these have been included and considered as dimensions of the design.

7.2.2 Clusters of the Design

The dimensions were put into broader categories called clusters. Eight main clusters have been identified in the present work through clustering of dimensions. These clusters are presented in the next section and shown in Figure 7.1.

7.2.3 Sequencing of Clusters

Following the clustering of dimensions, the clusters were put into sequence as per the importance of an area. The sequencing of dimensions within clusters was then carried out. The resultant clusters are given below:

1. Financial Support for Green Development
2. Green Collaborations and Networking for Sustainable Development
3. Policies and Regulations for Greening the Industry
4. Green Product and Process related Innovations and Development
5. Research and Design for Green Development
6. Use of Sustainable and Green Technologies
7. Green Human Resource Capabilities and Management Support
8. Environment and Quality related Standards

7.3 OPM based Modeling

In OPM based modeling, possible strategies are explored to achieve various objectives of the research problem. These strategies/profiles represent alternative approaches which can be used to achieve different dimensions of green innovation implementation program. The discussion about various approaches is presented below:

1) **Green Competency Building based approach (C_{ba}):** This approach motivates employees to build a supportive environment for green competency development and building green capabilities. The course of action is based on the following:

- Developing the technical know-how for adapting green technologies and pollution abatement technologies to reduce environmental pollution.
- Providing adequate training to staff on skills related to life cycle thinking, environmental assessment and green marketing etc.
- Proper management support and commitment in communicating green goals to the employees, recruiting staff who possess skills like green manufacturing and green marketing.

2) **Green Technology and Research based approach (T_{ba}):** This approach focuses on building proper resources and research infrastructure for carrying out green product and green process innovations. The course of action is based on the following:
   - Allocation of financial and human capital for carrying out green R&D.
   - Accumulating green resources like latest production machinery, latest technology, trained human capital, energy efficient materials etc. for green manufacturing.
   - Adapting R&D capabilities of large suppliers and OEMs for higher value addition and greening of the process.

3) **Regulatory and Environmental Policies based approach (R_{ba}):** This approach is based on building supportive policies by government for promoting green manufacturing and use of green technologies by SMEs. The course of action is based on the following:
   - Strong public policies for accumulating and disseminating the information regarding green technologies and infrastructure.
   - Providing tax relief and incentives for SMEs carrying out green manufacturing.
   - Framing strong policies and developing a framework for waste management, green procurements and securing intellectual property of SMEs.

4) **Green Networking based approach (N_{ba}):** This approach is based on acquiring knowledge and capabilities regarding green technologies through mutual learning from various partners in the network. The course of action is based on the following:
   - Forming ties with other SMEs, large enterprises, universities, research labs etc. to develop green technologies so that these can be shared by them.

- Developing partnerships to strategically exchange financial, technical and human resources with other industries.

5) **Mixed approach (M_a):** This approach uses a mix of features of the above profiles. It strategically utilizes the key elements of different profiles to implement required options to meet an objective.

After deciding upon various profiles, the next task has been to find out the options from each cluster contributing to each profile. The completed ‘options fields’ have been displayed in Figure 7.1. A tie line has been drawn on the bottom. Each option contributing to a profile has been joined to the tie line through its bullet.

Financial Support for Green Development

- Allowing FDI in SMEs through which they can use product design of parent firm
- Providing incentives for private R&D by SMEs
- Invest in your suppliers and increase trust
- Public investment in R&D, research infra and human capital
- Support for restructuring of 'sunset' technologies (which are no longer competitive)
- Provide permanent incentives to innovate and diffuse technologies that support sustainable development objectives by expanding use of market based approaches in environmental policies
- Approaching green fundraising and green venture capitalists for environmentally conscious projects

Green Collaborations and Networking for Sustainable Development

- Universities and polytechnics capable of generating skilled technicians, engineers and scientists
- Setting up IPR cells and technology transfer offices at universities and research institutes for technology capability upgradation
- Sharing research infrastructure among SMEs to improve knowledge base
- Use leverage, e.g. SMEs associations to put pressure on Government to increase subsidies.
- Join SME associations and use the leverage to influence the rules
- Informal meetings like 'green drinks' to meet people working in environmental field to discuss problems related to green innovation
- Consider where users in other industries and markets may have encountered an analogous problem for implementation of green innovation
- Begin by engaging large companies that may have more influence over the supply chain
- Identify the partners that are already pro-actively addressing sustainability issues
- Build up collection of case studies on successful green innovations
- Organize a seminar where companies facing a common challenge can discuss ideas how to overcome those challenges
- Selecting suppliers on the basis of lowest costs that their products have on environment and society
- Shared savings through collaborative product/component design, distribution, organizational structure and methods

Policies and Regulations for Greening the Industry

- A national innovation system by government for tapping international innovations and technology and dissemination of knowledge to small firms
- Strong public policies for dissemination of new information through new technological infrastructure
- Regional support system that provide access to specific knowledge in green innovation
- Increase their awareness of their environmental impact via NGOs, Government
- Crowd sourcing, subsidy by government for SMEs
- Policy coordination between different agencies of government for forming public-private council
- Tax relief by government for R&D expenditure
- Technology extension programs by government to reduce cost of searching for information on existing technologies
- Policies for protection of intellectual property rights
- Creation of technology parks, establishment of special economic zones, export processing zones, factory shells
- Public institutions to address coordination challenges
- Green public procurement by government to drive innovation towards environmental and social improvements
- Anticipate possible policy changes and propose solutions to meet future requirement and get first mover advantage
- Framing policies to build institution capacities to manage chemicals and waste soundly

Green Product and Process related Innovations and Developments

- Diversification in product range and manufacturing help achieve rapid growth rates and also sustain this growth over longer periods
- More efficient use of natural resources, such as non-renewable energy and materials, helping firms to be more cost competitive
- Re-engineering of production processes to minimize the resource use
- Work on green and energy efficient materials
- Developing an understanding of the main contributors to the overall environmental, social and economic impacts of a product across its life cycle, from raw material extraction through to disposal at end of life
- Taking action to reduce negative sustainability impacts and enhance positive sustainability impacts
- Reducing the mass of packaging to reduce resource consumption and fuel consumed in transportation
- Reduce energy consumption of heating or cooling systems at warehouses

COURSES OF ACTIONS (PROFILES)

- Green Competency Building based Approach
- Green Technology and Research based Approach
- Regulatory and Environmental Policies based Approach
- Green Networking based Approach
- Mixed Approach

Tie Line

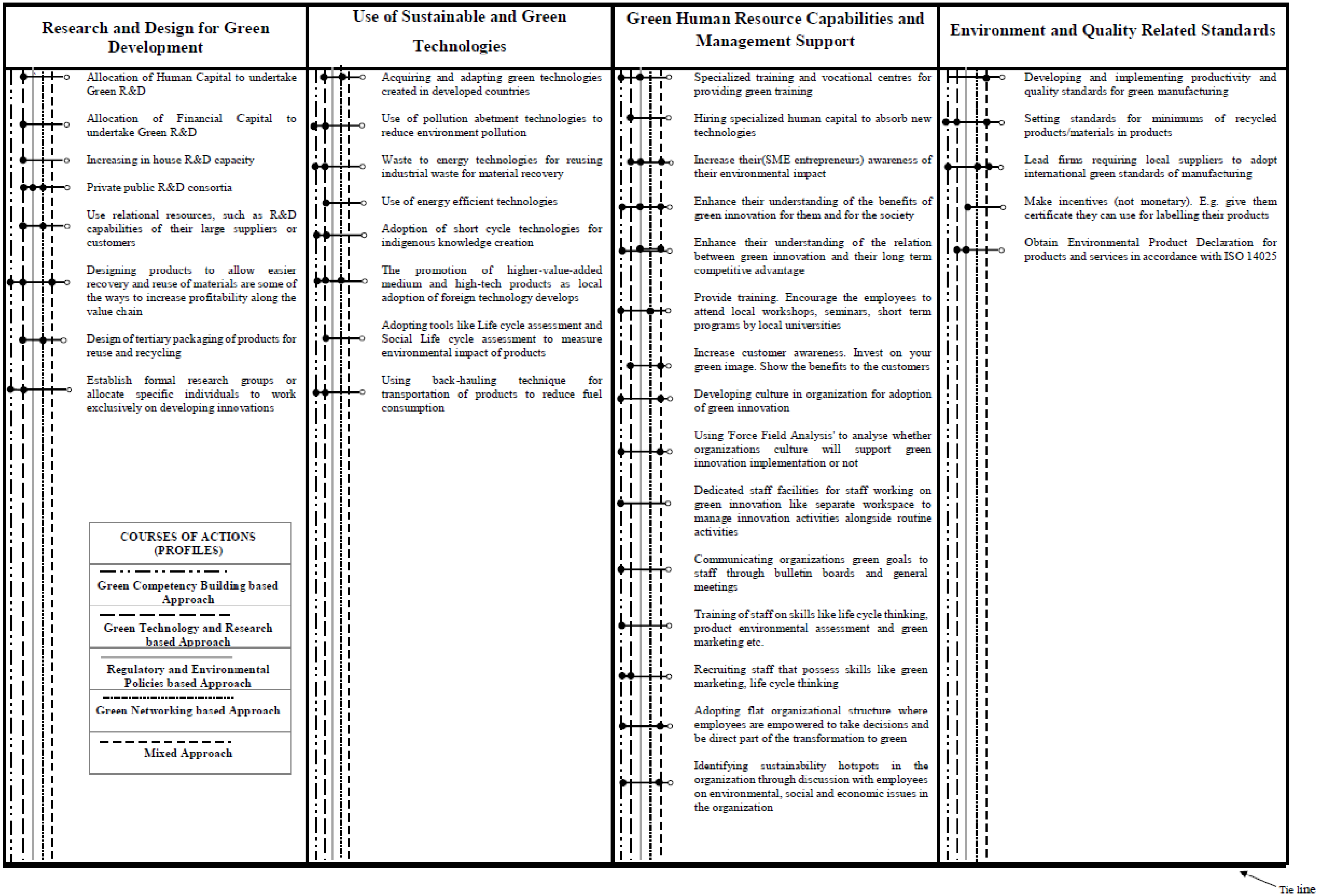

Figure 7.1 Completed Options Profiles

7.4 Best Worst based Modeling

The next step involves BW based modeling, where main research problem is decomposed into a hierarchy of sub problems or sub objectives. The sub-objectives are decided by experts and are also ranked by experts using BWM. The sub-objectives/goals as decided by experts are listed below:

Goal A. To explore avenues and open prominent, constructive in-house research centers for green technology development through maximum industry reception as well as participation.

Goal B. To enable a resource based work environment within the medium and small scale industrial parlance in order to promote the green technological innovation.

Goal C. To develop the green competency skill set, specifically the green creativity and innovative work behavior of the employees in the medium and small scale industries.

Goal D. To create systems and policies which are flexible enough to expedite the green technological interventions in the medium and small scale industries.

BWM is utilized to obtain the weightage of these four goals using ratings by expert. Four experts has been selected for the purpose. The methodology as explained in Chapter 3 has been used to obtain relative weights. Four experts participated in the analysis process and compared each goal with others independently to obtain relative weightage.

The expert 1 is manager/owner of a SME and is involved in the operations and technological developments for the past more than ten years. Expert 2 is also owner of another SME which is supplier of auto components to various large automobile companies for more than twelve years. Expert 3 is a senior manager for a major automobile company and has working experience for more than 8 years. The expert 4 is an academician (associate professor) at a reputed institute and is involved in industry-institute collaborations and teaching innovation related courses at the institute for more than twelve years. The best to others and others to best comparison matrices along with computed weights for each of the expert is presented in Appendix – A. The resulting weights of different goals as decided by various respondents using BWM is shown in Table 7.1.

Table 7.1 Weights of various sub-objectives using BWM

Respondents ⇨ Objectives ⇩	Expert 1	Expert 2	Expert 3	Expert 4	Average
Goal A. To explore avenues and open prominent, constructive in-house research centers for green technology development through maximum industry reception as well as participation.	0.124	0.100	0.156	0.140	**0.130**
Goal B. To enable a resource based work environment within the medium and small scale industrial parlance in order to promote the green technological innovation.	0.598	0.570	0.208	0.520	**0.474**
Goal C. To develop the green competency skill set, specifically the green creativity and innovative work behavior of the employees in the medium and small scale industries.	0.206	0.270	0.571	0.280	**0.332**
Goal D. To create systems and policies which are flexible enough to expedite the green technological interventions in the medium and small scale industries.	0.072	0.060	0.065	0.060	**0.064**

The results of BW analysis indicates that "To enable a resource based work environment within the medium and small scale industrial parlance in order to promote the green technological innovation" hold the most significance to achieve the overall objective of green innovation implementation in SMEs. The emphasis should be on building a green culture wherein employees are self-motivated to carry out green activities like giving ideas on waste minimization, recycling and efficient utilization of resources. The employees should hold regular meetings to discuss ideas for greening of the processes involved in the manufacturing. The top management must also be actively committed towards providing proper resources like energy efficient and recyclable materials, manpower with necessary skill required to green innovate, modified processes to minimize wastages and latest technologies to minimize waste and reduce pollution. Green research and design capabilities must be encouraged by the management through investment in internal green R&D wherein special investment is made on acquiring and developing latest technologies and hiring specialized people to carry out in house design changes to make the product and process more environmental friendly. All these efforts must be backed by suitable rewards and incentives for employees that are actively participating in greening of the industry and also encourage other employees to come up with more innovative ideas to make the overall process greener.

The next sub-objective according to weightage obtained by experts is “To develop the green competency skill set, specifically the green creativity and innovative work behavior of the employees in the medium and small scale industries”. A well-educated and highly trained workforce is always desirable by any organization. SMEs are always resource constrained to provide training on latest tools and technologies to its workforce, this results in lacking on various fronts. Its workforce often lack the necessary skillsets and creativeness to carry out green innovations. SMEs must impart necessary training to its employees on green technologies and capabilities, either through collaboration with large enterprises and universities or conducting in-house training programs for on-hand training of its employees. Only through learning of various waste management techniques, green technologies and latest energy saving processes can an employee contribute towards the goal of green innovation and technological development of an organization.

The next sub-objective according to weightage by the experts is “To explore avenues and open prominent, constructive in-house research centers for green technology development through maximum industry reception as well as participation”. The technology and resources to carry out technology development and green innovations are often very costly and acquiring technologies from outside organizations is always a constraint for the small organizations. They should focus on developing indigenous research facilities. Investment on R&D should be increased so that SMEs are able to develop materials which are of better design and consume lesser energy and also are recyclable. Through better design, the hazardous impact of the materials can also be reduced and goal of green technological development can be achieved with ease.

The least important sub-objective according to weightages given by experts is “To create systems and policies which are flexible enough to expedite the green technological interventions in the medium and small scale industries”. Government must open up various avenues for SMEs through its various policies and regulatory frameworks for carrying out green activities. Proper tax cuts and subsidies should be given to SMEs to acquire technologies for green manufacturing. Apart from financial support, government through its training centers and various programs must impart necessary skills to employees of SMEs to carry out green activities at the organization.

The results have clearly indicated that internal capability (sub-objective: A, B, and C) is decisive for green product innovations to emerge from small scale sector. External support (sub-objectives D) can only play a complementary role.

7.5 FST based Modeling

The next methodology used is Fuzzy Set Theory (FST) based modeling. This methodology quantifies the effect of each of the five strategies decided in previous phase on various goals/sub-objectives.

In this phase the 'position matrices' are prepared. Experts give the rating of each strategy towards each goal on the scale of 0 to 1. The same four experts are consulted for obtaining the ratings for position matrices. The position matrices for four different experts are shown in Appendix B. The next step is to obtain 'weighted position matrices'. The weighted position matrices are obtained by multiplying the weights obtained in pairwise comparison of goals and the ratings obtained in position matrices by experts. The resultant weighted position matrices are shown in Appendix C. From the weighted position matrices, the 'optimistic', 'average' and 'pessimistic' weighted position matrices have been made using Fuzzy Set Theory. For optimistic matrix, the highest value of each position has been selected, for pessimistic the lowest values and for average matrix, the average values have been selected. Table 7.2, Table 7.3 and Table 7.4 show these values respectively.

Table 7.2 Optimistic Weighted Position Matrix

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
Goal **A**	0.098	0.140	0.078	0.126	0.078
Goal **B**	0.538	0.468	0.364	0.399	0.399
Goal **C**	0.514	0.400	0.171	0.400	0.514
Goal **D**	0.022	0.042	0.059	0.042	0.036

Table 7.3 Pessimistic Weighted Position Matrix

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
Goal **A**	0.062	0.090	0.030	0.037	0.042
Goal **B**	0.187	0.146	0.104	0.179	0.146
Goal **C**	0.185	0.140	0.027	0.062	0.103
Goal **D**	0.006	0.007	0.036	0.006	0.030

Table 7.4 Average Weighted Position Matrix

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
Goal **A**	0.077	0.117	0.060	0.086	0.063
Goal **B**	0.375	0.298	0.205	0.256	0.302
Goal **C**	0.299	0.232	0.100	0.212	0.250
Goal **D**	0.016	0.022	0.051	0.026	0.032

India's manufacturing sector is developing at a rapid pace. But, it is also facing stiff competition from other economies like China, Taiwan, Switzerland, Singapore etc. which are global leaders in terms of output from SMEs. These global leaders are also adopting a proactive approach for greening the environment and also adopted latest technologies and processes for pollution reduction and abatement. Due to limited resources and stiff competition from global leaders, the pessimistic approach for designing and adoption of green technology program may not succeed. The preferred approach for the current scenario is a cautious optimism approach with relatively high degree of optimism, because SMEs lack resources and physical infrastructure to carry out green technological development and also government initiatives and schemes related to green technology upgradation fails to reach SMEs due to large bureaucratic hurdles and lengthy process to access these schemes. Moreover, global scenario of stiff competition and manufacturing at lesser costs also does not support a pure optimistic as well as pure pessimistic approach. The outcomes of weighted position matrices (Hadley's matrices of cautious optimism are provided in Appendix - D) computed at various degrees of optimism have been compiled and results are presented in Table 7.5. The results present the preferred strategies for achieving various sub-objectives (goals) under specific levels of optimism situation.

Table 7.5 Preferred Strategies under Cautious Optimism for achieving various Goals

Objectives ⇩	**Optimistic**	**80% Optimistic**	**60% Optimistic**	**40% Optimistic**	**20% Optimistic**	**Pessimistic**	**Average**
Goal **A**	T_{ba}-N_{ba}-C_{ba}	T_{ba}-N_{ba} - C_{ba}	T_{ba}-N_{ba} - C_{ba}	T_{ba}-C_{ba} - N_{ba}	T_{ba}-C_{ba} – N_{ba}	T_{ba}-C_{ba} -M_a	T_{ba}- N_{ba} - C_{ba}
Goal **B**	C_{ba}-T_{ba} -N_{ba}	C_{ba}-T_{ba} - N_{ba}	C_{ba}-T_{ba} - N_{ba}	C_{ba}- T_{ba} - N_{ba}	C_{ba}- N_{ba} – T_{ba}	C_{ba}- N_{ba} – T_{ba}	C_{ba}-M_a -T_{ba}
Goal **C**	C_{ba}-M_a -T_{ba}	C_{ba}-M_a -T_{ba}	C_{ba}-M_a -T_{ba}	C_{ba}-M_a -T_{ba}	C_{ba}-T_{ba} -M_a	C_{ba}-T_{ba} -M_a	C_{ba}-M_a -T_{ba}
Goal **D**	R_{ba}-T_{ba} -N_{ba}	R_{ba}- M_a-N_{ba}	R_{ba}-M_a -N_{ba}	R_{ba}-M_a -T_{ba}	R_{ba}-M_a -T_{ba}	R_{ba}-M_a -T_{ba}	R_{ba}-M_a -N_{ba}

The following inferences can be made from Table 7.5.

- Green Technology and Research based approach (T_{ba}), Green Competency Building based approach (C_{ba}) and Green Networking based approach (N_{ba}) are the most preferred strategies under various degrees of optimism to achieve the goal of maximum industry reception and participation in in-house research avenues for green technology development (Goal A). Allocating ample funds as the proportion of total budget to acquire human resources and technologies proficient at research and development can amplify the research related activities of the organizations. Small organizations that are able to adapt research capabilities of large organizations are also able to perform better on green technology development front. Necessary technical knowledge and skills are required to carry out research and design related activities at the organization. Employees who are expert in latest technologies and have the necessary acumen can only do designing for green and energy efficient products and also develop some technologies at their end. SMEs should focus on enhancing the technical know-how and skill sets of its employees. Also, through collaborations with other organizations like large enterprises and research institutes, SMEs can learn research related skills and these organizations can also help them to setup in-house designing and research facilities.

- Similarly to achieve Goal B i.e. developing green competency skill sets and inculcating green creativity and innovation culture among employees of the organization, Green Competency Building based approach (C_{ba}) is the most preferred strategy. Also Green Technology and Research based approach (T_{ba}) plays a pivotal role for achieving this goal, as green innovation and creativity can be achieved when organizations have latest technologies and research facilities that aims to reduce environmental impacts.
- Green Competency Building based approach (C_{ba}) and Mixed method approach (M_a) are preferred approaches to enable a work culture within the SMEs that promote green technological innovations (Goal C). Green culture is promotes through management as well as employees that are themselves oriented towards greening the environment and have necessary skill sets and capabilities to do so. Apart from that green work environment is a result of mixture of resource availability, research facilities and support from government.
- To create systems and policies which are flexible enough to expedite the green technological interventions in the medium and small scale industries (Goal D), Regulatory and Environmental Policies based approach (R_{ba}) is preferred. SMEs are often resource constraint and needs support from external sources, government policies and schemes are instrumental in achieving the overall goal of green technological developments. Often, government float numerous schemes, but these schemes fail to reach SMEs due to lack of knowledge and information available. Thus mixed approach which includes knowledge and education of SME proprietor is also necessary to achieve this objective.

Further analysis involves preparation of dominance matrices. Dominance matrices are prepared for each of the situation of optimism as well as pessimist and average matrices.

For preparing dominance matrices the various strategies are placed at top row and left column of the matrix and it is counted that how many times each strategy dominates (cell values are greater than) other strategy. In the matrix, profile written on the top, dominates the profile written on the left. The column sum is taken and this value is used to rank the strategy for a particular situation.

The dominance matrices under conditions of pure optimism, pure pessimism, and average optimism are presented in Table 7.6 to Table 7.8.

In the optimism dominance matrix (Table 7.6), 'green technology and research based approach' has emerged as the most preferred strategy for achieving the overall objective of green technology development in SMEs. 'Green competency building approach' and 'green networking based approach' have been ranked second and third respectively.

Table 7.6 Dominance Matrix under Pure Optimistic Situation

Profiles ⇨ ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
C_{ba}	--	2	1	2	1
T_{ba}	2	--	1	0	1
R_{ba}	3	3	--	3	2
N_{ba}	2	2	1	--	1
M_a	2	3	2	2	--
Column Sum	*9*	*10*	*5*	*7*	*5*
RANK	**II**	**I**	**V**	**III**	**IV**

For a completely pessimistic situation, the 'green competency building based approach' is the most preferred situation followed by 'green technology and research based approach' and 'mixed approach' respectively.

Table 7.7 Dominance Matrix under Pure Pessimistic Situation

Profiles ⇨ ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
C_{ba}	--	2	1	0	1
T_{ba}	2	--	1	1	1
R_{ba}	3	3	--	3	3
N_{ba}	3	3	1	--	3
M_a	3	2	1	1	--
Column Sum	*11*	*10*	*4*	*5*	*8*
RANK	**I**	**II**	**V**	**IV**	**III**

The average dominance matrix shows that both 'mixed approach' and 'green competency building based approach' are ranked first for this situation. In case of tie for column sum the next step is to look for row sum, the strategy having least row sum among the two will be ranked first. But, in this case both column sum and row sum are equal. Hence both the strategies are ranked first. 'Green technology and research based approach occupies third rank in this scenario.

Table 7.8 Dominance Matrix under Average Optimistic Situation

Profiles ⇨ ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
C_{ba}	--	2	1	2	1
T_{ba}	2	--	1	1	3
R_{ba}	3	3	--	3	3
N_{ba}	2	3	1	--	3
M_a	3	1	1	1	--
Column Sum	*10*	*9*	*4*	*7*	*10*
RANK	**I**	**III**	**V**	**IV**	**I**

Dominance matrices for various degrees of optimism (80%, 60%, 40% and 20%) have been compiled in Appendix – E. The results of all these dominance matrices have been summarized in Table 7.9.

Table 7.9 Compiled outcomes of various Dominance Matrices

Degree of Optimism ⇨ Profile ⇩	**Optimistic**	**80% Optimistic**	**60% Optimistic**	**40% Optimistic**	**20% Optimistic**	**Pessimistic**	**Average**
	Rank under various degrees of Optimism						
C_{ba}	II	**I**	II	I	I	I	I
T_{ba}	I	**II**	I	I	I	II	III
R_{ba}	V	**V**	V	V	V	V	V
N_{ba}	III	**III**	IV	IV	III	IV	IV
M_{a}	IV	**IV**	III	III	III	III	I

In the present work, a cautious approach with high degree of optimism has been considered as most appropriate. Thus, dominance matrix with 80% degree of optimism has been considered as providing the most realistic industrial situation in the region (*highlighted in Table 7.9*). This dominance matrix has been used to identify preferred strategies for meeting the overall objective of technology development in small scale sector.

7.6 Preferred Approaches for Green Technology Innovation and Development

The results of the mixed method approach adopted reveal that 'green competency building based approach' is the most suitable approach for the development and implementation of green technology innovation program in SMEs. 'Green technology and research based approach' and 'green networking based approach' occupies second and third places respectively. 'Mixed approach' and 'regulatory and environmental policies based approach' are least preferred approaches for the current scenario.

The top three approaches for green innovation and technology development program are listed below:

1. Green competency building based approach
2. Green technology and research based approach
3. Green networking based approach

7.6.1 Green Competency Building based Approach

According to the results of mixed method analysis, 'green competency building based approach' has emerged as the most preferable approach for green technology development and innovation adoption program. It is also the most preferred approach to meet the goals B and C of the research problem. Green competency building focuses on enhancing the technical skills and know-how of the employees in green technologies through proper training so as to reduce environmental impact of the products and pollution abatement. Top management role is very important in building green competencies among employees. Management has to effectively communicate the goals of green management among employees so as to enhance their understanding about the benefits of green innovation to the organization and to the society at large. It will also enhance their understanding about the long term benefits of benefits in terms of competitive advantage of competitors. In this approach management provides green training to its employees and encourages them to attend seminars and workshops on green practices, short term programs by local universities on green supply chain management. Management provides training on skills like life cycle thinking, environmental assessment of products and green marketing and packaging of products. Special and dedicated staff for carrying out green innovation activities, having their dedicated workplace for the same also enhances green competencies among employees. Management can adopt a flat organizational structure, where employees are empowered to take decisions by themselves and contribute at each stage of the product cycle thus making them a direct part of transforming to green. Developing green skills and keeping employees updated about latest technologies is the core of this strategy, this will help enhance operation and production efficiencies and develop the skill sets at intermediate level. Employees must be encouraged for cross-functional deployment, where they learn skills on green technologies from other employees and can work in every division of the organization thus inculcating in them a culture of problem solving in every area.

7.6.2 Green Technology and Research based Approach

'Green technology and Research based Approach' is the second most preferred strategy for green technology development and innovation program. It is also the most preferred strategy for achieving Goal A i.e. 'To explore avenues and open prominent, constructive in-house research centers for green technology development through maximum industry reception as well as participation'. It is also second most preferred strategy for achieving Goal B and third most preferred strategy for achieving Goal C. This approach involves allocation of human capital for green R&D, accumulating green resources like latest production machinery, latest technology, trained human capital, and energy efficient materials etc. for green manufacturing. This strategy can include allocating of human and financial capital to undertake green R&D s that green and energy efficient processes and products can be developed. Allowing FDI in SMEs, providing incentives to SMEs and public investment in R&D, research infrastructure and human capital can be a major source to boost research related activities. Designing should not only be limited to products but auxiliary activities like tertiary packaging for products to allow reuse and recycling. Approaching green fundraising units and green venture capitalist for environmentally conscious products can also be beneficial. This strategy also involves acquiring and adapting green technologies from developed countries, this can include pollution abatement technologies, waste to energy technologies for reusing industrial waste for material recovery, adopting short cycle technologies for indigenous knowledge creation. Accumulating green technologies and resources will help in overhauling the whole process of manufacturing at the organization and also develop green thinking among employees. Providing a platform for research and design in green processes will enhance the green thinking and skills of the employees and ultimately will lead to cleaner technologies and production processes which will be less harmful to environment and more energy efficient.

7.6.3 Green Networking based Approach

The results of the mixed method based approach indicates that green networking based approach is the third most preferred strategy for implementation of green technological development and innovation program in SMEs. It is also second most preferred approach for achieving Goal A and third most preferred approach for achieving Goal B. Small firms often fail under the pressure of intense competition and competitive pressure. Most of the times they lack behind in terms of limited resources and technical know-how. As they also lack necessary capital to acquire these technologies and skills, one of the beneficial approach can be to collaborate with other organizations for technology and knowledge exchange. Collaborations can be done with local universities engaged in evolving latest and cutting edge technologies and also producing skilled manpower (e.g. collaboration can be done with local polytechnics which are producing trained engineers). Local universities and research centers can also be approached for developing green technologies in collaboration at their research labs which are already well equipped with latest machinery and devices to perform this kind of research. Collaboration with large enterprises especially OEMs can be highly beneficial as they are using latest technologies and are already involved in greening of their operations, technologies can be directly adapted from these large enterprises. SMEs can join hands with other local SMEs to form associations through which government can be pressurized to draft special packages and incentives for green development technologies and also for acquiring technologies from developed nations. Through SME associations they can exchange and use each other technologies as well, which otherwise would be costlier to purchase individually and they can also learn the best practices followed by other organizations.

7.7 Development of a Conceptual Framework

This section presents the conceptual framework for implementation and development of green technology development and innovation program in SMEs. The framework is the outcome of earlier phases of research which involves, extensive literature review, case based studies, use of quantitative and qualitative modelling techniques. The framework represents the linkages of various issues, objectives and strategies for development of effective green technology and innovation implementation program for SMEs. The framework is presented in Figure 7.2.

The conceptual model/framework represents the overall goal of green technology development and innovation program and its sub objectives (goals). The goals are represented by different color intensities where darkness of color represents higher weightage of a sub-objective in meeting the main objective of green technology development and innovation in small scale sector. The strategies to meet each objective is also represented with different colors and their length depicts the importance of these strategies in achieving the various sub objectives and also overall objective.

The conceptual framework indicates that to meet the overall objective of green technology development and innovation in small scale sector, ‘green competency building approach’ has shown maximum contribution and hence is the most preferred strategy.

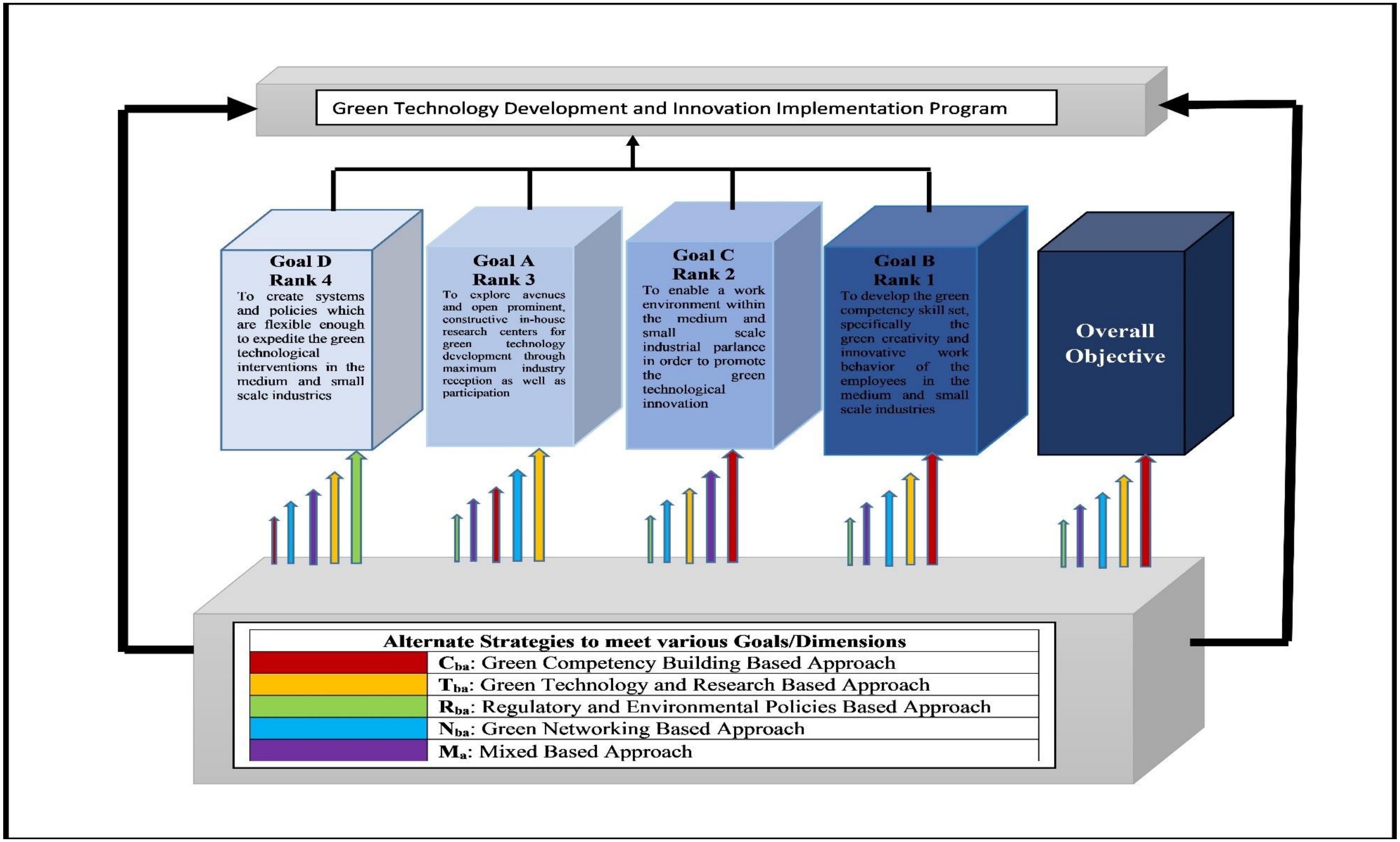

Figure 7.2 Conceptual model for green technology development and innovation implementation program

7.8 Chapter Summary

This chapter presents a synthesis of learning issues of all previous phases (literature review, survey and case studies) of the research work. The outcomes have been utilized through a qualitative model to evolve a green technology development and innovation implementation program for SMEs. Mix method modeling involved deriving expert opinion and using this along with findings of previous phases in a structured manner. Four main techniques have been utilized in qualitative modeling. Options Field Methodology converted the learning issues into independent options (78 options were generated) as a solution to the research problem. Options Profile Methodology planned five different profiles or courses of actions to meet various dimensions of the research problem. Best Worst method decomposed the decision problem into a hierarchy of four sub-problems and decided their relative weightage in achieving the overall objective of green technology development and innovation implementation. Fuzzy Set Theory quantified the contribution of each profile towards various features of design and ranked the profiles under different situations of cautious optimism. Finally, a conceptual framework has been developed which represents the linkage between essential components of 'Green Technology Development and Innovation Implementation Program' and elaborates on their relative contribution in meeting the overall research objective.

The findings of qualitative modeling are in the context of small manufacturing units of the region (states of Punjab, Uttrakhand and NCR in northern India), yet their implications and suggested management approaches are generic and can also be applied to industrial units in other parts of the country.

CHAPTER - VIII

RESEARCH SUMMARY AND CONTRIBUTIONS, CONCLUSIONS, IMPLICATIONS, LIMITATIONS, AND FUTURE SCOPE

8.1 Preview

This chapter summarizes the work carried out in the research. The key findings and major outcomes of the results have also been discussed. The unique contributions, theoretical and practical implications of the study are also highlighted so that academicians and practitioners can utilize the implications of the present research work. Lastly, the limitations and future scope of the study have been presented.

8.2 Summary and Contributions

A brief summary and contributions made in this research work is given as follows:

Chapter I

This chapter presents the basic background and the need for the study. It highlights the importance of SMEs in economic growth of the country and also in innovation process. The basic definition of SMEs and various types of innovations are discussed at length. Global competitiveness index and Global innovation index ranking comparison on various parameters of technology development and innovation is done between India and various Asian countries. The details about MSMEs and their classification in India is also discussed. Further various types of innovations including green innovation are also discussed. After that the need for green innovation and types of green innovations are also described. The ranking of various India with other Asian countries on various parameters of green innovation is also done to assess the current situation of green innovation in India. The aim and scope of green innovation in SMEs along with various typologies of innovation and strength and weakness of SMEs in adapting the innovation is also discussed. In the last section, the complete organization of the thesis is provided.

Chapter II

This chapter provided an in-depth and exhaustive review of literature on green innovation. It presented the method and steps of literature review. Detailed definitions of green innovation and types of green innovation were also discussed. An extensive review of literature on enablers and barriers to green innovation in SMEs is also presented in this chapter. The solutions to overcome these barriers are also discussed and a total of twenty solutions were identified. After that an extensive review of supplier selection methodologies was done. Through extensive review of literature, various gaps have been identified. The identification of these gaps have led to formulation of research objectives for this thesis and a total of five research objectives were formulated based on the literature review and identified gaps.

Chapter III

This chapter presents the research approach followed for the accomplishment of the research objectives. Various types of approaches viz. Qualitative, Quantitative and Mixed method were discussed briefly in this chapter. Four phases of research viz. clarifying the context, understanding and assessing the current situation, developing a model for overcoming barriers and supplier selection and evolving a management process are also discussed in detail. Clarifying the context involved literature review on green innovation, understanding and assessing the situation involved discussion about PPS and TPS methodologies, developing a model for overcoming barriers and supplier selection involved detailed discussion about various steps of three MCDM techniques namely – Best Worst Method, Fuzzy TOPSIS and Grey DEMATEL and evolving a management process used a mix of qualitative and quantitative techniques namely – Options Field Methodology, Options Profile Methodology, Best Worst Method and Fuzzy Set Theory. Details about each of these methodologies were also discussed in this chapter.

Chapter IV

This chapter was aimed to assess the current situation of green innovation SMEs in selected SMEs. A pilot survey was done in few selected SMEs through questionnaire based survey method. TPS and PPS scores for each criteria of green innovation were calculated to assess the adoption of green innovation criteria in SMEs. Finally PPS score for all the units was also calculated to assess the status of these SMEs in green innovation implementation. The results have revealed that overall status of green innovation adoption/implementation is poor in Indian SMEs.

Chapter V

This chapter 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 sub category 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 expertise" 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.

Chapter VI

Supplier selection is a strategic decision and is very important for a company to keep running its operations. Cooperation from all its business partners is vital to accomplish this goal especially the suppliers of components and raw materials. Cooperating with business partners for green initiatives is difficult as it requires many changes at suppliers end, especially SMEs which are often resource constrained are reluctant to incorporate changes required for green initiatives. Green innovation is vital for SMEs to perform satisfactorily according to the requirements of large enterprises. For large enterprises the challenge is to select suitable suppliers among many suppliers so as to realize their goals of greening the supply chain. Hence, in this chapter a three phase methodology has been used to select suppliers on the basis of green innovation ability of SMEs. The proposed methodology is best suited for organizations seeking to select suppliers either for new products or in cases like this where company is considering to change its operations into green supply chain management. First phase involved finalization of selection criteria for green innovation, literature review and expert opinion was used for selecting and finalizing the criteria for green innovation in SMEs, a total of seven main criteria and 42 sub criteria were selected for study. Second phase involved utilizing best worst methodology to calculate weights and ranks of all the main as well as sub criteria in the study, best worst methodology being an extension of AHP methodology has advantage of providing consistent results with lesser pair wise comparisons. Final phase involved ranking of the suppliers by utilizing criteria weights obtained through best worst method and utilizing it in Fuzzy TOPSIS methodology, supplier 3 emerged as best supplier among all the seven suppliers taken up for analysis. This chapter also dealt with more sub objective i.e. to find the relationship among enablers of green innovation in SMEs, grey DEMATEL methodology was applied to establish the causal relationship among the enablers. A case study of a company was taken and a total of twenty one enablers were selected for the analysis. The cause and effect relationship among these enablers was established using grey DEMATEL methodology.

Chapter VII

To achieve the overall objective of green technology development and innovation implementation in SMEs, a management process has been developed using mixed methodology modeling. Mixed method modeling involved deriving expert opinion and using this along with findings of previous phases (outcomes of survey and case studies) in a structured manner. Four main techniques have been used for the purpose. The first technique called options field methodology generates a list of options as solution to the present research problem. It places the options into a set of categories and develops suitable names for each category. It identifies the dimensions of the target and puts them into various clusters. This is followed by sequencing of clusters and sequencing of dimensions within clusters. Finally the completed ‘options fields’ are displayed. In the present work, 78 options have been generated. The next technique used is options profile methodology. Here, various courses of actions (profiles/ strategies) of the design are developed which can be employed to achieve the overall objective of research problem. In the present work, five different profiles have been planned using this technique. These included, ‘*green competency building based approach*’, ‘*green technology and research based approach*’, ‘*regulatory and environmental policies based approach*’, ‘*green networking based approach*’, and ‘*mixed approach*’. The various options generated through options field methodology are then allocated to these alternate profiles to complete the ‘options profiles’. The completed options profiles represent alternative approaches and courses of action to be adopted under each. The next technique used is best worst method. It decomposed the decision problem into a hierarchy of four sub-problems and decided their relative weightage in achieving the overall research objective. The fourth technique used for qualitative modeling has been fuzzy set theory. This approach has been used to quantify the contribution of each profile towards each objective and to rank the various profiles under different situations. For this, position matrices and weighted position matrices have been prepared. The weighted position matrices have been aggregated in three ways: optimistic, average and pessimistic aggregation. Following this, dominance matrices have been prepared to display dominance structure between all possible pairs of profiles. Based on these matrices, the ranks of various profiles under different situations of cautious optimism have been determined. In the present work, a cautious approach with high degree of optimism has been considered as most appropriate. Thus, dominance matrix with 80% degree of optimism has been considered as providing the most realistic industrial situation in the region. The results have indicated that a ‘green competency building based approach’ is the key strategy to solve the present research problem. ‘Green technology and research based approach’ and ‘green networking based approach’ have occupied the second and third positions respectively. ‘Mixed approach’ and ‘regulatory and environmental policies based approach’ have been the least preferred profiles.

8.3 Implications of the study

The outcomes of the current research work has certain practical as well as theoretical implications for the green innovation literature. The main aim of this research is to develop a management process for green technology development and innovation implementation in SMEs. The other objectives included identification of barriers and solutions to overcome these barriers and developing a framework for supplier selection amongst SMEs by large organization on the basis of their green innovation ability. The outcome of the study will help managers and practitioners to make informed choices regarding the green innovation implementation in SMEs. The key implications of this study are as follows:

- Enumerating the various criteria of green innovation for supplier selection among SMEs. From large organizations perspective, this study reveals seven main criteria and forty two sub criteria for supplier selection among SMEs. Apart from economic basis, organizations these days are forced to compete on environmental basis also, they need to develop their organizations to sustain the competition on environmental front also. To accomplish this, managers of case organization need to be aware of various criteria of green innovation. Green innovation can help accomplish the goal of economic and environmental competitiveness. The current research work is a first such attempt to enumerate various criteria of green innovation for organizations. Based on extant literature review and various round of discussions with experts seven main criteria viz. Collaborations, Environmental investments and Economic benefits, Resource availability and Green competencies, Environmental management initiatives, Research and Design initiatives, Green purchasing capabilities, Regulatory Obligations, Pressures and Market Demand were identified. All these criteria are beneficial for managers of large organizations as well as owners of SMEs that supply components to these large organizations, SMEs can work on these factors and develop environmentally friendly and economical products for their large counterparts which in turn can accomplish their goal of becoming an organization complying to environmental norms set by government and to garner new businesses based on their green image.
- Developing a novel and robust framework for supplier selection among SMEs by large organizations. Managers of large organizations often face the problem of selecting component suppliers, especially among SMEs. This study presents a novel framework for supplier selection among SMEs. Best worst and Fuzzy TOPSIS methodologies have been used for supplier selection. Best worst method being more consistent than AHP

is used to calculate weights and consequently ranks of each criteria as well as sub criteria. Managers and supply chain analysts benefit from this framework by easily identifying the important criteria for green innovation and hence working on these factors to improve their green image and producing green products. The proposed framework is tested on a case company taken from automotive sector. This framework helped the managers of case company to select green and innovative supplier among various SMEs taken for the study.

- 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.
- 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.

- The current research work can act as benchmark for managers of other organizations who wish to implement green innovation. The barriers and solution framework can be adopted by other companies for find the barriers relevant to their organization type and also find the solutions to overcome those barriers. Similarly, the supplier selection framework can act as benchmark for other large enterprises of different sectors to select supplier among SMEs using the proposed framework of this study.
- The major objective of this study was to develop a framework for green technology development and innovation implementation in SMEs. The result of the whole process can be very beneficial for the managers as well as practitioners. They can make use of different qualitative techniques to accumulate the solutions for the problems faced at their end and they can also formulate strategies to overcome problems according to these profiles. The results of mixed method research indicate that green competency based approach is most suitable for green technology development and innovation implementation in SMEs. This approach is followed by green technology and research based approach and green networking based approach. The managers can work on developing technical know-how, providing adequate training to staff on environmental thinking and management, recruit staff who possess skills like green manufacturing and green marketing, allocate financial and human capital for carrying out green R&D, Accumulating green resources like latest production machinery, latest technology, trained human capital, energy efficient materials etc. for green manufacturing, Adapting R&D capabilities of large suppliers and OEMs and building strong relationship with other SMEs, large enterprises, universities and research institutes for effective green technology development and green innovation implementation/adoption at their end.

8.4 Limitations of the Study

The main limitations of the study are as follows:

- The work has been limited to SMEs in the northern region of India mainly Punjab, Uttrakhand and NCR. The study covers tool industry, auto-component units, electric and electronics manufacturing units only.
- Most of the results are dependent on the opinion and judgement of the experts and results might change if the experts are changed.
- No mathematical model or quantitative relationship (using SEM) has been derived to calculate the contribution of various main criteria of green innovation in overall green innovation implementation/adoption process.
- Due to unavailability of sufficient data and research literature on green innovation in Indian context, case study based approach has been used. The analysis is based on certain manufacturing industries and hence results cannot be generalized.
- This study has utilized a hybrid of BWM and Fuzzy TOPSIS for identification and ranking of barriers of green innovation in SMEs and solutions to overcome these barriers. The study identified seven main category barriers, thirty six sub category barriers and twenty solutions to overcome these barriers. These numbers are for certain selected case companies. There might be other barriers and solutions that are left and are not discussed in this study.
- This study has utilized a hybrid of BWM and Fuzzy TOPSIS for identification and ranking of enablers of green innovation in SMEs and supplier selection among SMEs using these enablers. The study identified seven main category enablers and forty two sub category enablers. These numbers are for certain selected case companies. There might be other enablers that are left and are not discussed in this study.
- The study has identified seventy eight options profiles and five strategies for green technology development and innovation implementation in SMEs. There might be numerous other option profiles and few other strategies that may arise for different case companies.

8.5 Scope for Future Work

While carrying out the present study, a number of areas have come to focus, where detailed research can be taken up. These areas demand more exploration and analysis through further research. The scope for future work has been presented as follows:

- The study has been limited to SMEs. It can be conducted for large scale manufacturing organizations also.
- The present work has concentrated on manufacturing industry only. The work can be extended to other categories like process industry, service industry etc.
- All the manufacturing organizations taken in this study were from India, future work may involve organizations from both developed and developing countries, so that a comparative study can be done for both the countries.
- All manufacturing units have been treated alike, irrespective of the specific requirements of various sectors. Minor changes might have to be incorporated for effectively managing green technology management initiatives in varying situations. Thus, sectors wise analysis can also be conducted for appropriately dealing with varying requirements of different sectors.
- The present study involved only four or five experts for each objective, future studies can be conducted by taking a larger data set of experts so that more robust results can be obtained.
- The study involved the use of MCDM techniques for quantitative analysis and no statistical technique is used for the analysis. Future studies can involve use of statistical techniques like SEM to find out the relationship among different variables of green innovation.
- This study can be further carried out to compare the results using different MCDM techniques like AHP, ANP, VIKOR, MAUT, ELECTRE either in integrated or individual form for supplier selection and prioritizing the barriers and its solutions.
- The results of grey DEMATEL analysis can be compared with ISM analysis which is mostly used to establish the hierarchal relationship among variables.
- Research can be extended further to compare the organizational cultures with regard to R&D and technology development practices in different industries viz. privately

managed enterprises, joint venture companies, public sectors, and foreign subsidiaries in the country.

- The framework developed in this thesis can be applied and tested in other BRIC countries like Brazil, Russia and China for assessing the situation of green innovation implementation in SMEs of these nations and hence doing a comparative analysis.

8.6 Concluding Remarks

This study presents a summary of the research work carried out in this study. A summary of each phase of the study is presented in this chapter. SMEs face a series of challenges which include limited access to finances, resources constraints, lack of technical know-how to name a few. However, the major challenge faced by them is of technological obsolescence to handle the increasing environmental management pressure. They need to develop green technological infrastructure and know-how to handle this pressure from government and competitors. Green innovation is one such solution where resource and financially constrained organizations can effectively handle the environmental management pressure. Lack of technological infrastructure and resources has emerged as the most important barrier to green innovation amongst others. An effective green technology development and innovation implementation program for SMEs should include various strategies like green competency development, green technology upgradation and research, green networking with allies and research centers and regulatory support from government on environmental policies. External support like networking and regulatory support can only be minor factor which complements the major factors that are internal to the organizations like, developing technical know-how, green training, management commitment towards environmental practices, allocation for green R&D, resource accumulation for carrying out green manufacturing activities and adapting/adopting green R&D capabilities The importance of ‘achieving and sustaining competitiveness in the long run’ and ‘investing self-efforts and resources’ needs to be realized by the industry. This will play a crucial role in their long term development in future.

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List of Publications

Journal Publications

- Gupta, H., & Barua, M. K. (2016). Identifying enablers of technological innovation for Indian MSMEs using best–worst multi criteria decision making method. *Technological Forecasting and Social Change*, *107*, 69-79. (SCI IF = 3.129, ABDC – A Ranked).
- Gupta, H., & Barua, M. K. (2017). Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS. *Journal of Cleaner Production*, *152*, 242-258. (SCI IF = 5.651).
- Gupta, H., & Barua, M. K. (2018). A framework to overcome barriers to green innovation in SMEs using BWM and Fuzzy TOPSIS. *Science of The Total Environment*, *633*, 122-139. (SCI IF = 4.610).
- Gupta, H., & Barua, M. K. (2018). A grey DEMATEL-based approach for modeling enablers of green innovation in manufacturing organizations. *Environmental Science and Pollution Research*, 25(10), 9556-9578. (SCI IF = 2.800).
- Gupta, H., & Barua, M. K. (2018). A novel hybrid multi-criteria method for supplier selection among SMEs on the basis of innovation ability. *International Journal of Logistics Research and Applications*, *21*(3), 201-223. (SCI IF = 1.820, ABDC – B Ranked).
- Gupta, H., & Barua, M. K. (2018). Modelling cause and effect relationship among enablers of innovation in SMEs. *Benchmarking: an International Journal*. 25(5), 1597-1622. (ABDC – B Ranked).
- Gupta, H., & Barua, M. (2016). Fuzzy AHP approach to prioritize enablers of green supply chain management practices: A case study of automotive component supplier. *Management Science Letters*, *6*(7), 487-498. (SCOPUS).
- Gupta, H., Prakash, C., Vishwakarma, V., & Barua, M. K. (2017). Evaluating TQM adoption success factors to improve Indian MSMEs performance using fuzzy DEMATEL approach. *International Journal of Productivity and Quality Management*, *21*(2), 187-202. (ABDC – C Ranked).

Conference Publications

- Presented a paper titled "Evaluation of manufacturing organizations on the basis of internal green innovation capabilities" at 4th Management Doctoral Colloquium organized by VGSoM, IIT Kharagpur on 14th -15th March 2018.

Appendix A

Table Pairwise comparison for various Goals/Sub-objectives by Expert 1

BO	**Goal A**	**Goal B**	**Goal C**	**Goal D**
Best criterion: **Goal B**	5	1	3	8

OW	**Worst criterion: Goal D**
Goal A	2
Goal B	8
Goal C	3
Goal D	1

Table Optimal weights for various Goals/Sub-objectives by Expert 1

Criteria	**Weights**	ξ^L
Goal A	0.124	0.021
Goal B	0.598	
Goal C	0.206	
Goal D	0.072	

Table Pairwise comparison for various Goals/Sub-objectives by Expert 2

BO	**Goal A**	**Goal B**	**Goal C**	**Goal D**
Best criterion: **Goal B**	6	1	2	9

OW	**Worst criterion: Goal D**
Goal A	2
Goal B	9
Goal C	4
Goal D	1

Table Optimal weights for various Goals/Sub-objectives by Expert 2

Criteria	**Weights**	ξ^L
Goal A	0.100	0.030
Goal B	0.570	
Goal C	0.270	
Goal D	0.060	

Table Pairwise comparison for various Goals/Sub-objectives by Expert 3

BO	Goal A	Goal B	Goal C	Goal D
Best criterion: **Goal C**	4	3	1	8

OW	Worst criterion: Goal D
Goal A	3
Goal B	4
Goal C	8
Goal D	1

Table Optimal weights for various Goals/Sub-objectives by Expert 3

Criteria	Weights	ξ^L
Goal A	0.156	0.052
Goal B	0.208	
Goal C	0.571	
Goal D	0.065	

Table Pairwise comparison for various Goals/Sub-objectives by Expert 4

BO	Goal A	Goal B	Goal C	Goal D
Best criterion: **Goal B**	4	1	2	8

OW	Worst criterion: Goal D
Goal A	3
Goal B	8
Goal C	4
Goal D	1

Table Optimal weights for various Goals/Sub-objectives by Expert 4

Criteria	Weights	ξ^L
Goal A	0.140	0.040
Goal B	0.520	
Goal C	0.280	
Goal D	0.060	

APPENDIX-B

POSITION MATRICES

Position Matrix: Respondent – Expert 1

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**	**Weight/ (as determined by BWM)**
Goal **A**	0.5	0.9	0.5	0.3	0.5	0.124
Goal **B**	0.9	0.3	0.3	0.3	0.5	0.598
Goal **C**	0.9	0.7	0.3	0.3	0.5	0.206
Goal **D**	0.3	0.3	0.5	0.5	0.5	0.072

Position Matrix: Respondent – Expert 2

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**	**Weight/ (as determined by BWM)**
Goal **A**	0.7	0.9	0.3	0.7	0.7	0.100
Goal **B**	0.9	0.7	0.3	0.7	0.7	0.570
Goal **C**	0.9	0.9	0.1	0.7	0.7	0.270
Goal **D**	0.3	0.7	0.9	0.7	0.5	0.060

Position Matrix: Respondent – Expert 3

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**	**Weight/ (as determined by BWM)**
Goal **A**	0.5	0.9	0.5	0.7	0.5	0.156
Goal **B**	0.9	0.7	0.5	0.9	0.7	0.208
Goal **C**	0.9	0.7	0.3	0.7	0.9	0.571
Goal **D**	0.3	0.1	0.9	0.3	0.5	0.065

Position Matrix: Respondent – Expert 4

Profile ⇨ Objectives ⇩	Green Competency Building based approach	Green Technology and Research based approach	Regulatory and Environmental Policies based approach	Green Networking based approach	Mixed Approach	Weight/ (as determined by BWM)
Goal **A**	0.7	0.9	0.5	0.9	0.3	0.140
Goal **B**	0.5	0.9	0.7	0.5	0.7	0.520
Goal **C**	0.9	0.5	0.5	0.7	0.7	0.280
Goal **D**	0.1	0.3	0.9	0.1	0.5	0.060

APPENDIX-C

WEIGHTED POSITION MATRICES

Weighted Position Matrix: Respondent – Expert 1

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
Goal **A**	0.062	0.112	0.062	0.037	0.062
Goal **B**	0.538	0.179	0.179	0.179	0.299
Goal **C**	0.185	0.144	0.062	0.062	0.103
Goal **D**	0.022	0.022	0.036	0.036	0.036

Weighted Position Matrix: Respondent – Expert 2

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
Goal **A**	0.070	0.090	0.030	0.070	0.070
Goal **B**	0.513	0.399	0.171	0.399	0.399
Goal **C**	0.243	0.243	0.027	0.189	0.189
Goal **D**	0.018	0.042	0.054	0.042	0.030

Weighted Position Matrix: Respondent – Expert 3

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
Goal **A**	0.078	0.140	0.078	0.109	0.078
Goal **B**	0.187	0.146	0.104	0.187	0.146
Goal **C**	0.514	0.400	0.171	0.400	0.514
Goal **D**	0.020	0.007	0.059	0.020	0.033

Weighted Position Matrix: Respondent – Expert 4

Profile ⇨ Objectives ⇩	Green Competency Building based approach	Green Technology and Research based approach	Regulatory and Environmental Policies based approach	Green Networking based approach	Mixed Approach
Goal **A**	0.098	0.126	0.070	0.126	0.042
Goal **B**	0.260	0.468	0.364	0.260	0.364
Goal **C**	0.252	0.140	0.140	0.196	0.196
Goal **D**	0.006	0.018	0.054	0.006	0.030

APPENDIX – D

HADLEY'S MATRICES OF CAUTIOUS OPTIMISM

Hadley's Matrix - 80% Optimism

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
Goal **A**	0.091	0.130	0.068	0.108	0.071
Goal **B**	0.468	0.404	0.312	0.355	0.348
Goal **C**	0.448	0.348	0.142	0.332	0.432
Goal **D**	0.018	0.035	0.054	0.035	0.035

Hadley's Matrix - 60% Optimism

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
Goal **A**	0.084	0.120	0.059	0.090	0.064
Goal **B**	0.398	0.339	0.260	0.311	0.298
Goal **C**	0.383	0.296	0.114	0.265	0.350
Goal **D**	0.015	0.028	0.050	0.028	0.034

Hadley's Matrix - 40% Optimism

Profile ⇨ Objectives ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
Goal **A**	0.076	0.110	0.049	0.073	0.056
Goal **B**	0.328	0.275	0.208	0.267	0.247
Goal **C**	0.317	0.244	0.085	0.197	0.267
Goal **D**	0.012	0.021	0.045	0.020	0.032

Hadley's Matrix - 20% Optimism

Profile ⇨ Objectives ⇩	Green Competency Building based approach	Green Technology and Research based approach	Regulatory and Environmental Policies based approach	Green Networking based approach	Mixed Approach
Goal **A**	0.069	0.100	0.040	0.055	0.049
Goal **B**	0.257	0.210	0.156	0.223	0.196
Goal **C**	0.251	0.192	0.056	0.129	0.185
Goal **D**	0.009	0.014	0.041	0.013	0.031

APPENDIX-E

HADLEY'S DOMINANCE MATRICES

Dominance Matrix: Hadley's 80% Optimism

Profiles ⇨ ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
C_{ba}	--	2	1	2	1
T_{ba}	2	--	1	0	1
R_{ba}	3	3	--	3	3
N_{ba}	3	3	1	--	1
M_{a}	3	2	1	2	--
Column Sum	*11*	*10*	*4*	*7*	*6*
RANK	**I**	**II**	**V**	**III**	**IV**

Dominance Matrix: Hadley's 60% Optimism

Profiles ⇨ ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
C_{ba}	--	2	1	2	1
T_{ba}	2	--	1	0	2
R_{ba}	3	3	--	3	3
N_{ba}	2	3	1	--	2
M_{a}	3	2	1	2	--
Column Sum	*10*	*10*	*4*	*7*	*8*
RANK	**II**	**I**	**V**	**IV**	**III**

Dominance Matrix: Hadley's 40% Optimism

Profiles ⇨ ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
C_{ba}	--	2	1	1	1
T_{ba}	2	--	1	0	2
R_{ba}	3	3	--	3	3
N_{ba}	3	4	1	--	2
M_a	3	2	1	2	--
Column Sum	*11*	*11*	*4*	*6*	*8*
RANK	**I**	**I**	**V**	**IV**	**III**

Dominance Matrix: Hadley's 20% Optimism

Profiles ⇨ ⇩	**Green Competency Building based approach**	**Green Technology and Research based approach**	**Regulatory and Environmental Policies based approach**	**Green Networking based approach**	**Mixed Approach**
C_{ba}	--	2	1	1	1
T_{ba}	2	--	1	1	1
R_{ba}	3	3	--	3	3
N_{ba}	3	3	1	--	2
M_a	3	3	1	2	--
Column Sum	*11*	*11*	*4*	*7*	*7*
RANK	**I**	**I**	**V**	**III**	**III**

APPENDIX F

Questionnaire for assessing the current situation of green innovation implementation/adoption in SMEs

- Please rate the performance of your SME in the following categories on a scale of 1 to 5, where 1 indicates Very Poor and 5 indicates Very Good

Evaluation of Collaborations Criteria

S.No.	Key Issues	1	2	3	4	5
1	Collaborations with rivals or inter-organizational collaborations					
2	Intra organizational collaborations					
3	Developing suppliers capabilities					
4	Relationship with customers and buyers pressure					
5	Collaborations with research institutes and labs					
6	Collaborations with social and environmental groups					

Evaluation of Environmental investments and Economic benefits Criteria

S.No.	Key Issues	1	2	3	4	5
1	Cost Reduction					
2	Ease in getting finance from financial institutes					
3	Investment Recovery					
4	Enhanced productivity and firms performance					
5	Enhanced value to customers					
6	Green operational efficiencies					

Evaluation of Resource availability and Green competencies Criteria

S.No.	Key Issues	1	2	3	4	5
1	Internal R&D and scientific expertise					
2	Trained human resources					
3	Green warehousing					
4	Green transportation					
5	Green recycling facilities					
6	Green manufacturing capabilities					
7	Carbon reduction initiatives					

Evaluation of Environmental management initiatives Criteria

S.No.	Key Issues	1	2	3	4	5
1	Communicational practices					
2	Environmental commitment of the firm					
3	Internal environmental management					
4	Green operational practices					
5	Planning and organizational practices					

Evaluation of Research and Design initiatives Criteria

S.No.	Key Issues	1	2	3	4	5
1	R&D investments					
2	Reduced consumption of materials and energy through better design of products					
3	Designing products so that they are easily reusable and recyclable					
4	Reducing hazardous impact of products through better design					
5	Designing energy efficient products					

Evaluation of Green purchasing capabilities Criteria

S.No.	Key Issues	1	2	3	4	5
1	Trained purchase and supply chain managers					
2	Selecting supplier based on environmental criteria					
3	Purchasing environmentally friendly raw materials					
4	Pressuring suppliers for green initiatives at their end					
5	Ensuring suppliers environmental management system adoption					
6	Participating in design process of upstream and downstream members of supply chain					
7	Environmental Audits of Suppliers to ensure compliance with standards					

Evaluation of Regulatory Obligations, Pressures and Market Demand Criteria

S.No.	Key Issues	1	2	3	4	5
1	Technical assistance for technology upgradation					
2	Tax cuts and incentives for producing green products					
3	Implementation of environmental policy					
4	Stringency in enforcement of green design norms					
5	Market demand for green products					
6	Competitive pressures to outperform competitors					