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An empirical investigation and prioritizing critical barriers of green manufacturing implementation practices through VIKOR approach

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Abstract

Purpose – The purpose of this paper is to identify the critical barriers of green manufacturing implementation practices in Indian SME's with the VIKOR approach.
Design/methodology/approach – Challenges faced in the implementation of green manufacturing by Indian SME's have been extracted from literature review, and questionnaire survey of Indian SME's is done. The responses are further annealed and analysed using a factor analysis technique and ranked with the VIKOR technique.
Findings – The literature was studied, and various challenges were listed and were grouped into six critical latent challenges by using the factor analysis technique, and it was found that Economic constraints tops with the VIKOR technique. The recognition of the outcomes of critical barriers was assumed to be substantial in the current scenario.
Originality/value – Present study reveals that green manufacturing implementation in Indian SME's faces many challenges. The outcomes of the study will help green manufacturing practitioners, HR executives and managers in the various manufacturing organizations to develop clarity in understanding and developing strategies for the implementation of green manufacturing. Hence, the information obtained from the empirical examination of barriers in implementing green manufacturing will be helpful in improving the overall implementation plan.

Keywords SMEs, Barriers, VIKOR, Green manufacturing

Paper type Research paper

1. Introduction

The economy is growing at a great pace in all over the world, and industrialization is the main reason behind the growth. Industries are growing and so is the rate of pollution in natural resources, i.e. water, soil and air due to the waste produced by the industries. Nowadays, with the increased pressure from the government and increasing market demand of eco-friendly products, the demand of green manufactured products is increasing and so is the pressure on the various organizations, i.e., organizations are being forced to change adamant norms by various world-wide societies that are proactive in the field of environmental concerns (Gandhi *et al*, 2018). With the increase in demand to implement the green manufacturing techniques in the manufacturing of different products within the organization at different levels, there are various challenges that bar the implementation of green manufacturing within the organization (Govindan, Kannan and Shankar, 2015; Govindan, Diabat and Shankar, 2015). This manuscript is focussed mainly on the various challenges being faced by the organizations towards implementing green manufacturing within the organization.

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The term "green manufacturing" can be understood in two different ways: the production of "green" products, especially those which are used in renewable energy sources and clean technology equipment of all kinds, and the "greening" of manufacturing means the reduction of pollution and waste by limiting the use of natural resources, recycling and reusing the waste, and reducing emissions. The USA remains the world's largest manufacturing economy, producing 21 per cent of global manufactured products. China is second with 15 per cent and Japan is third with 12 per cent production, according to National Association of Manufacturers. Pillars for the coming of the twenty-first century "green" and "zero-carbon" economies quickly developing renewable energy and clean tech divisions are considered among the best chances to understand this objective. According to the Ministry of Micro, Small and Medium Enterprises, existing definition for MSMEs (miniaturized scale, little and medium ventures) in India is characterized below (Table I).

The rest of the paper is as follows: Section 2 gives the literature review on the various parameters of green manufacturing and MCDM techniques along with literature gaps. Section 3 provides the methodology used during the research for the completion of the paper, Section 4 gives the information about the Factor Analysis method, Section 5 provides information on the VIKOR technique and its implementation in the present study, and Section 6 gives the conclusion of the current study and research implications.

2. Literature review

2.1 Green manufacturing literature

Nowadays, industries are adopting green manufacturing practices at every level of procurement especially supply chain management (SCM) considering impact on environment. Furthermore whenever SCM evolved with the flow of activities from control, supply and execute in cost-effective manner to challenge supply demand mismatch with proactive approach. Various problems are encountered while executing Green manufacturing practices, and SMEs still cannot identify barriers or blockages in implemented green supply chain management (GCSM) practices in a better way. Govindan *et al.* (2014) surveyed the work undertaken to identify barriers, and, in total, 47 barriers were identified after examining the detailed pre-defined questionnaire to meet the desired objectives. An approach to identify barriers is processed and analysed using a hierarchy process, and their respective priorities are evaluated based on their stability as designated in different ranks based on processes and their mutual interdependence in a system. However, the application of GCSM system is found in refining, manufacturing, design, packaging and transportation areas, as a result of which companies are setting their own manufacturing plants in Indian Hemisphere citing revenue growth in highly competitive market; in this context, a study has been instigated to develop a structured model that aims to identify different barriers in implementing GCSM system in the automobile industry (Luthra *et al.*, 2011).

Parker *et al.* (2009) discussed factors and imbibed them in internal and external brackets that involves achievable indices in enterprises like domain information about practices, with the attitude to adopt practices with increased deliverables with improvement at the environment level at internal pace. Even though author discussed and emphasized on

Table I. Definition of small and medium enterprises in India

Classification	Micro	Small	Medium
Manufacturing enterprises	Rs 2.5m/Rs 25 lakh ($50)	Rs 50m/Rs 5 crore ($1m)	Rs 100m/Rs 10 crore ($2m)
Service enterprises	Rs 1m/ Rs 10 lakh ($20,000)	Rs 20m/Rs 2 crore ($4,000,000)	Rs 50m/Rs 5 crore ($1m)

regulations of practices involved, financial barriers and factors influencing SMEs in achieved deliverables were also highlighted. It has been observed that with the demand of products and assistance and knowledge provided to adopt green manufacturing while holding the hands of external organization, those already in the process of implementation will boost the business performance in every aspect.

Various observations have been recorded from literature review; various authors (Studer *et al.*, 2008; Gandhi *et al.*, 2018) have discussed legislation as the key factor and a major issue but this factor only stands for large industries compared with SMEs. Legislation is not an profile of large industries but is a valid factor for SMEs and makes a path for more competitive environment instead of harmony in a system. In spite of industry relevance and eagerness to remain active in a system, non-inclusiveness of government plays an important role in slowing down driving practices of green manufacturing. Various authors have highlighted the lack of implementation in government policies and the lack of inclusiveness among top, medium and low level managements. It has also been recorded from the literature that industries and management only want short-term monetary benefits that are not sufficient enough to drive local SMEs towards voluntarily approach from other stakeholders.

There are also various barriers encountered in the implementation of green manufacturing in SMEs in the Indian context as the top level management is not interested in technology inclusiveness and improving legislation approval along with brand image in green manufacturing scenario with future interventions for integrated green manufacturing market in India. Markets are evolved with practices implemented and guided through a proper channel.

Fresner and Engelhardt (2004) also cited two case studies in which it has been observed and proved that coordination among management levels along with their commitment towards deliverables and with continuous support in consideration with environment safety aspects leads to sustainability. It has also been observed that sustainability indices can be improved with qualitative assessment at various inductive levels. Certain authors also considered ISO certification for sustainability like the implementation of measures for reducing pollution, reduction in greenhouse gases (GHG) and material recycling process. All the above processes can be inculcated and adopted by industries acquiring ISO-4000 certification and in the context of green manufacturing practices and small and medium enterprises, this holds a major key issue. Henriques and Catarino (2016) also suggested that objectives of green manufacturing should be framed in order to increase productivity with reduction in energy costs and rendering profitability.

Waste to energy is also an option for reducing energy costs, and renewable energy source can be implemented in the consideration of important features of GM (Islam *et al.*, 2016). Most of industries have also focussed their attention to green manufacturing practices, but the relative size of enterprise and reduction in carbon footprints have prevailed with the lack of environmental aspects feedback and most of SMEs have lost their track and practices are not welcomed. This also suggested an important key factor in the implementation of GM practices due to the lack of awareness of carbon footprints (Bar, 2015).

Earlier it was suggested by Parker *et al.* (2009) that key drives are segregated as internal and external, but Van Hemel and Cramer (2002) considered internal stimuli, however, more dominated as compared with external stimuli in SMEs. Internal factors drive qualitative analysis with increase in the quality of products with predominant market share along with brand image. This kind of stimuli also provides more innovation and wider sketch of enterprises. External stimuli has been observed as catalyst in driving internal stimuli with customer satisfaction with more productivity in terms of recycling, less energy consumption and with more environment friendly design.

Claver *et al.* (2007) also dictated CSFs that involves environmental impacts with regulation, involvement of stakeholders with required strategic requirement from environmental and resource allocation. Lee (2009) observed that green manufacturing requires organizational structure change instead of emphasis on certifications as organization structure leads to reduction in costs along with human resource capability to bring innovation. Some changes incorporated in organizational structure must keep strategic modifications intact but focus should be on management of resources and quality of deliverables (D'Souza, 2001).

Across the globe, various researchers have participated and supported cleaner production to emphasis open; it has been observed by Turkish researchers (Gurbuz *et al.*, 2004) that, while studying 15 olive oil extraction SMEs, with cleaner production, there can be considerable power savings. Various other authors (Henriques and Catarino, 2016) have named information support as major barrier in Portuguese and considered information exchange along with cognitive hand holding can be enhanced.

Various organizations in Brazil are suffering from innovation paralysis; therefore, Pacheco *et al.* (2017) studied SMEs in Brazil with government policy with relevance of innovation considering environmental aspects with different SCM systems. Korean SMEs are lacking the rule of perception to be triggered, and environmental legislation needs to be operational with better productivity (Lee, 2009). In the Chinese context, Kong *et al.* (2016), Zhang *et al.* (2008), Zeng *et al.* (2011) and Liu *et al.* (2017) have discussed GM manufacturers considering energy efficient technologies with more financial support endeavour and encourage SMEs to promote green manufacturing practices in China. However, along with increased productivity and profitability, Employee morale is also enhanced with improved customer satisfaction and better brand image among stakeholders (Simpson *et al.*, 2004).

In Indian scenario, various authors (Singh, Brueckner and Padhy, 2014; Singh, Jha and Prakash, 2014; Sharma *et al.*, 2017) have suggested that product design and packaging are important drivers and need to be highlighted with more stringent regulations from government to reduce the impact on environment. This will help system to emerge with basis amenities required to flourish in a conducive environment.

Thanki *et al.* (2016) also made a mark on expert green manufacturing implementation leading with set of priorities with pre-defined indicators like reduced emission, solid waste and less energy consumption Indian SMEs. Authors also prepared a set of instruction to propose design for environment practices at the early design stage so that packaging and recycling can reduce required inputs for a system and improve contingencies during a life cycle.

Chhabra *et al.* (2017) discussed case studies in the automobile industry while practising green manufacturing practices, and various factors came into light to authors like regulations, customer satisfaction with limited available resources compliance with International Standards to accomplish economic and environmental outcomes. Gadenne *et al.* (2009), Govindan, Kannan and Shankar (2015), Govindan, Diabat and Shankar (2015) observed that management attitude is not only a key factor in implementation of green manufacturing practices. Gurbuz *et al.* (2004), Claver *et al.* (2007), Studer *et al.* (2008), Singh *et al.* (2012), Thanki *et al.* (2016) depicted from literature review that most of authors only focussed on limited parameters of green manufacturing as its evolution and its implementation with less focus on financial limitations with penalty for non-compliance.

2.2 MCDM techniques literature

Green manufacturing techniques not only affect industries but also surpass academicians and develop industry institute interface to study practices of green manufacturing and reduce conventional practices that are harmful to environment and not cost effective. Researchers (Jayanta and Azharb, 2014) depicted the importance of GCSM system and also related the different barrier that are linked together and autonomous and constant variable. Study reveals that out of 47 barriers, 21 barriers are of outmost importance in which 19 are linked one and can be analysed and controlled together in flow processes, and no variable is termed as autonomous or dependent variable. Interpretations of results are carried out by interpretive structural modelling (ISM) technique, which identifies one driver variable and considers it as input of a system. Results pertain to discussion among industry experts at different levels of management and extensive literature, which proves, with a modelling technique, that barriers are experienced at top level management as compared with bottom level management. In other words, the barriers are prioritized in such a way that interdependence of variables can be determined with a fixed number of flow processes. interpretive structured modelling can also be used for organizations working in the production sector and relying on productivity. Balon *et al.* (2016) applied the IISM technique to identify barriers in operational system and problems in implementing GCSM in the operational mode with existing structured environment. Observations from study impact an automobile industry with minimum number of barriers. Study restricts the number of barriers to thirteen in number, keeping six barriers as dependent and three linkage barriers which are too small and less significant as compared to existing studies on GCSM. This study is quite successful in implementing GCSM in the automobile industry. Green manufacturing practices are not limited to medium scale manufacturing units, but owing to competitive market and opportunity for cost effectiveness, the ISM technique also applied by researchers to sustain the system with a limited number of barriers. It has been observed from the literature that Srivastav and Gaur (2015) implemented MICMAC analysis along with the IISM technique to sort out different barriers that can benefit small-scale industries. However, the study reveals that sixteen number of applicable barriers has been identified with four barriers are dependent and six are mutually linked barriers. This study emphasis north India small-scale industries and relate interdependence of barriers. According to various researchers working for the automobile industry and considering internal framework with external environment impacts (Balon *et al.*, 2016) in addition to ISM, mathematical modelling is used to interpret importance of one barrier collection over another. This study develops a relationship between different barriers to overcome linkage barriers in a cost-effective manner. Jayanta and Azharb (2014) demonstrated the effect of linkage barriers with the ISM technique along with driving, and dependence behaviour has been analysed with MICMAC analysis. A structural model has also been proposed to study behaviour of interdependence of barrier in a bigger way considering medium and small-scale industries.

Many of researchers used various techniques mostly the ISM technique to identify barriers and help to drive managerial flow in organizations. Insight covering scarcity and the need of green manufacturing practices developed a structured model to evaluate the impact of different barriers as green practices are not easy to implement. Indeed, not only private organizations but also government organizations and utilities pay attention towards green manufacturing practices, but unfortunately, private companies emit a large amount of GHG and are big threat to sustainable systems; therefore, the implementation of green manufacturing is only possible solution, and Mittal *et al.* (2012) instigated those factors on basis of the fuzzy TOPSIS method from economic, social and environmental perspectives. Although government organizations and Central Government are willing to implement green manufacturing practices in processing and improvement of productivity. Flexibility is a major issue in converting the work flow of existing organization into a new look. Singh *et al.* (2013) demonstrated strategic flexibility as a very important concept in industry in order to respond to uncertainties prevailing in a system. In total, 102 organizations have been extensively surveyed to determine volatility and dynamic changes in organizations using the analytical hierarchy process.

Singla *et al.* (2018) concluded TP-DP strategies in Indian manufacturing industries encountering relevant critical barriers for accomplishing sustainable development. Results held top level and medium level managements responsible for the implementation of TP-DP strategies for sustainable development. Policies can be effectively implemented and can improve the performance of manufacturing organizations in terms of productivity evaluating TP and DP strategies.

2.3 Literature concludes/research objectives

Various barriers are extracted from the literature that is already discussed by many researchers that are as follows: cost of new technology, training and education, compatibility with the new equipment, skill deficiency, adverse effect on work flow, risk of failure, inadequate flexibility in regulations, workers resistance, increased maintenance expenses, need for market expansion, lack of financial justification, lack of qualified personal, lack of information on technology, markets, marketing capabilities, organizational rigidities, lack of financial sources and industry wide standards.

The identified parameters need to be grouped together by the factor analysis method and ranked as no literature by researcher is found using VIKOR technique as this is also an MCDM technique.

3. Research methodology

A questionnaire survey has been conducted in small and medium scale manufacturing organizations that have imbibed or are in the process of imbibing green manufacturing in India. In the current study, 169 manufacturing enterprises that are spread in different geographical locations covering whole India (North (58), South (44), East (34), West (33)) have been relevantly surveyed to report the responses for challenges faced in implementing green manufacturing practices within the organizations. In order to analyse the critical barriers, a comprehensive "Green manufacturing Questionnaire" has been framed after a detailed literature survey, then its scrutiny has been done by consultants, scholars and green manufacturing practitioners in different organizations. Furthermore, the data collected from SME's have been compiled and analysed through the factor analysis method for obtaining concrete validations to present the factors related to critical barriers in imbibing green manufacturing practices. At last, ranking of the factors has been done with the VIKOR method in order to prioritize the factors. The research methodology adopted for achieving the above-mentioned objectives has been illustrated in the block diagram shown in Figure 1.

Furthermore, the questionnaire has been segregated into four virtual sections. It starts with Section 1 that is based on general aspects of companies, which include, name and address of company, present turnover, and number of workers and market share. Sections 2 and 3 seek information about various input and output factors related to green manufacturing. Lastly, Section 4 asks about the critical barriers faced by the organization in implementation of green manufacturing practices.

4. Factor analysis to examine the behaviour of critical barriers in imbibing green manufacturing practices

This section has been devoted to study the factors related to barriers in implementing green manufacturing practices through factor analysis. Factor analysis is a statistical technique and has been applied in the present manuscript to reduce a large set of variables (items) into lesser factors and each indicator has been put under one particular dimension to make it more significant. The technique has been performed on 20 challenges as they are applicable to all respondents. In factor analysis, rotated component matrix using varimax with Kaiser Normalization has been employed.

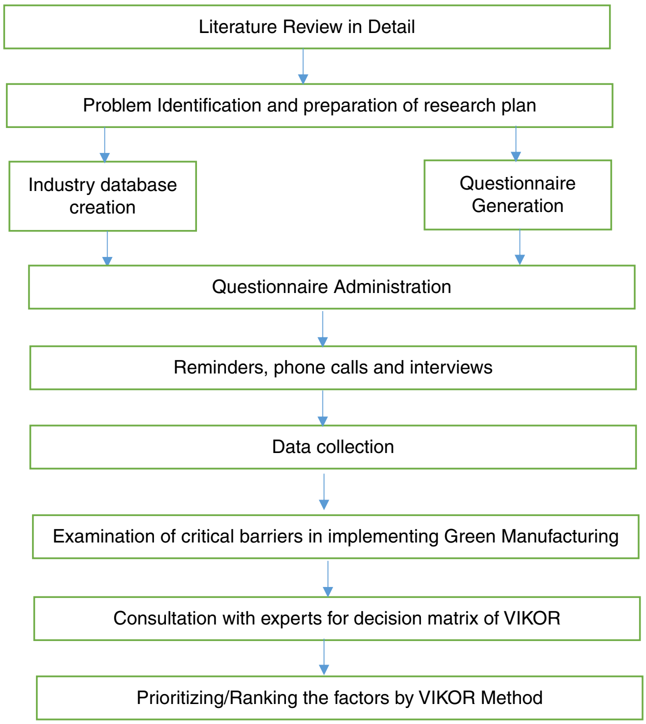

Figure 1.
Research methodology

Various challenges in implementing green manufacturing are depicted in Table II. They are considered in the green manufacturing questionnaire and then the responses are analysed using the factor analysis technique.

4.1 Results and analysis of factor analysis approach employed to critical barriers

The factor analysis approach has been applied based on responses obtained from 169 manufacturing industries to 20 indicators extracted from the study. The results obtained from factor analysis are shown in Tables III and IV. Table III reveals the results of KMO and Bartlett's test. The KMO index comes out to be 0.910 with 0.6 recommended as minimum value for an acceptable factor analysis (Pallant, 2005). Furthermore, the value of the KMO index in the present study is 0.910, which indicates that the sample size is satisfactory to apply factor analysis. Barlett's test of sphericity is also significant with approx. $\chi^2 = 2{,}208.986$, degree of freedom $= 190.000$ at the significance level (p) of 0.000. The results from Table III exhibit that significant correlations existing among the variables under examination. Hence, all the tests reveal that data are fit for factor analysis.

For extraction of factors, principal component analysis using the varimax rotation method with Kaiser Normalization has been deployed in the study. The six extracted factors are shown in second, third, fourth, fifth, sixth and seventh columns of Table IV, whereas the various corresponding items are portrayed in first column where values below 0.4 are dropped out during the selection of factors (Singla *et al.*, 2018).

After extracting six factors, an appropriate name has been given to each factor on the basis of items loaded on a particular factor. Table V portrays the factor-wise list along with critical barriers in each factor. Factor loading attached to each indicator has also been

Sr. No.	Critical barriers
1	Cost of new technology acquisition
2	Cost of training and education
3	Problems with compatibility of equipment
4	Skill deficiency for transitions
5	Adverse effect on work flow
6	Adverse effect on work culture
7	Risk of failure to achieve financial targets
8	Inadequate flexibility in regulations
9	Workers' resistance
10	Increased maintenance expenses
11	Need for market expansion
12	Lack of financial justification
13	Lack of qualified personnel
14	Lack of information on technology
15	Lack of information on markets
16	Lack of marketing capabilities
17	Organizational rigidities within enterprise
18	Lack of appropriate sources of finance
19	Inability to devote staff to projects
20	Lack of industry wide standards

Table II. Critical barriers in implementing green manufacturing

Kaiser–Meyer–Olkin measure of sampling adequacy	0.910
Bartlett's test of sphericity	
Approx. χ^2	2,208.986
df	190
Sig.	0.000

Table III. KMO and Bartlett's test

shown in Table V. Henceforth, six factors have been extracted through factor analysis, which is responsible for examining the behaviour of critical barriers in implementing green manufacturing in SME's. The six critical barriers (name of the factors) are:

- Economic Constraints (Cronbach's α: 0.918); per cent of variance: 24.27.
- Government support (Cronbach's α: 0.706); per cent of variance: 25.83.
- Management's Commitment (Cronbach's α: 0.802); per cent of variance: 19.87.
- Lack of Training/skill (Cronbach's α: 0.780); per cent of variance: 23.93.
- Market Needs (Cronbach's α: 0.634); per cent of variance: 24.49.
- Human Resource (Cronbach's α: 0.737); per cent of variance: 16.10.

These all factors directly relate to the literature available on the green manufacturing and discussed in the literature survey part of this manuscript. Cronbach's α of each of the factor is calculated and results found at higher compatibility end show that relation between each item in the factor have high relation. Per cent of variance is calculated in order to identify that how far is each item from the mean of whole set and is found to be quite relative.

Economic constraints. The factor named includes the six challenges: first among them is the increased maintenance expenses, due to the induction of new and additional machinery for the recycling plants, the maintenance expenses shall also increase; second is the risk of failure to achieve financial targets, for example, all the organizations have their own

Sr. No.	Item	Factor-wise loadings 1	2	3	4	5	6
10	Increased maintenance expenses	0.859					
7	Risk of failure to achieve financial targets	0.855					
2	Cost of training and education	0.812					
12	Lack of financial justification	0.792					
1	Cost of new technology acquisition	0.781					
16	Lack of marketing capabilities	0.686					
8	Lack of industry wide standards		0.787				
15	Lack of information on markets		0.785				
11	Need for market expansion		0.674				
9	Workers' resistance			0.892			
19	Inability to devote staff to projects			0.708			
6	Adverse effect on work culture			0.467			
17	Organizational rigidities within enterprise				0.771		
5	Adverse effect on work flow				0.712		
3	Problems with compatibility of equipment					0.737	
4	Skill deficiency for transitions					0.587	
13	Lack of qualified personnel					0.518	
18	Lack of appropriate sources of finance						0.644
14	Inadequate flexibility in regulations						0.515
20	Lack of information on technology						0.476

Table IV. Rotated component matrix varimax with Kaiser normalization with critical barriers

Item		Factor-wise loadings
Factor 1: Economic constraints (Cronbach's α: 0.918); per cent of variance: 24.27		
10	Increased maintenance expenses	0.859
7	Risk of failure to achieve financial targets	0.855
2	Cost of training and education	0.812
12	Lack of financial justification	0.792
1	Cost of new technology acquisition	0.781
16	Lack of marketing capabilities	0.686
Factor 2: Government support (Cronbach's α: 0.706); per cent of variance: 25.83		
18	Lack of appropriate sources of finance	0.644
14	Inadequate flexibility in regulations	0.515
20	Lack of information on technology	0.476
Factor 3: Management's commitment (Cronbach's α:– 0.802); per cent of variance: 19.87		
17	Organizational rigidities within enterprise	0.771
5	Adverse effect on work flow	0.712
Factor 4: Lack of Training/skill (Cronbach's α: 0.780); per cent of variance: 23.93		
3	Problems with compatibility of equipment	0.737
4	Skill deficiency for transitions	0.587
13	Lack of qualified personnel	0.518
Factor 5: Market needs (Cronbach's α: 0.634); per cent of variance: 24.49		
8	Lack of industry wide standards	0.787
15	Lack of information on markets	0.785
11	Need for market expansion	0.674
Factor 6: Human resource (Cronbach's α: 0.737); per cent of variance: 16.10		
9	Workers' resistance	0.892
19	Inability to devote staff to projects	0.708
6	Adverse effect on work culture	0.467

Table V. Extracted factors with critical barriers financial targets in terms of net market value or net profits; third is the cost of training and education of the workers as for the implementation of new technology the organizations need to train their workers or educate their workers to implement the newer and eco-friendly technology that also needs some economic burden on the organization; and fourth and fifth point is to bear the cost of acquisition of new technology, and its financial justification for the small and medium scale organizations is a big constraint. Lastly, the sixth point is the capabilities of marketing that needs financial support as if the organizations are opting to manufacture the eco-friendly products or are using eco-friendly techniques, then it is also necessary to present their products in the market with full enthusiasm so that their products get most attraction from the customers as nowadays customers are associated with the advertisements on social media most of the times.

Government support. The said factor includes three important challenges faced by the small and medium scale manufacturing organization: first and the most important is the lack of appropriate sources of finance, i.e., bank loans at reasonable interest rates for the implementation of green manufacturing are not available to small and medium scale manufacturing organizations, whereas the government should not provide the flexibility in the rules and regulations like in most of the states, governments do not focus on the implementation of norms on SME's, but should provide financial help and important knowledge on the new technology available in the market and important needs of the market.

Management's commitment. The said factor is an important barrier as the organizations can only implement new technology and flourish when the management of the organization is committed towards the green environment, and it includes the organizational rigidity within the organization, i.e., the management should not be rigid on the traditional tools and principals; the second challenge addressed within this factor is the adverse effect on work flow.

Lack of training/skill. The identified factor is a critical barrier in implementing green manufacturing. The work force employed in the organization faces problems when the technology changes and the organizations are also not able to change the work force employed due to the government, social pressure and worker's union pressure, but it affects the implementation of new technology, many times it is noticed that older workers are not capable of working on new technology machines that adhere the procurement and implementation of new technology; lastly, the organizations lack in qualified workers as all the workers are under qualified as the organizations have to pay less to the under qualified persons and all these constraints are there that can be overcome by the regular trainings to the workers so that they can cope up with the technology being used in the industries after up gradation.

Market needs. The factor named market needs include three important challenges faced by the organizations: first is the lack of industry-wise standards that markets decide and lacks in the small and medium scale manufacturing organizations, second is the lack of the information on the markets that the small and medium scale organizations are not aware about the requirement of needs of the market expansion (third) that the organizations need to focus upon as the success of the organizations depending upon the performance in the market and the organizations should be dynamic in the markets.

Human resource. The last factor or critical barrier named human resource includes three important challenges: first is the worker's resistance towards the implementation of newer technology because the workers are not aware about the merits of the new technology and they do not have proper knowledge to work in synchronization with new technology but are focussed on their jobs related to traditional methods. Second is the inability of the organization to devote staff to the projects that may be due to the shortage of staff or due to non-availability of qualified workers, and last and the third challenge addressed in the factor is the adverse effect on the work culture when the staff is not trained or educated by the human resource department before and during the acquisition of the new technology in order to develop faith in the workers that they should support new technologies.

5. VIKOR method for prioritizing or rankings of the barriers

The VIKOR method was first introduced (Opricovic, 1998) as a technique that is applicable to implement multi-criterion decision-making problems. VIKOR test mainly focusses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. The VIKOR method determines the compromise ranking list and the compromise solution by introducing the multi-criteria ranking index based on particular measure of closeness to the ideal solution.

The purpose of employment of this method on the six factors identified by the factor analysis method is to rank or prioritize the identified factors. First of all, we have to construct the decision matrix as in the case of all MCDM problems, with the help of academicians and industry people who are practicising green manufacturing and know the exact scenario of important barriers. An element X_{ij} of the matrix indicates the performance rating of ith alternative with respect to the jth criterion as depicted in Table V; next step is to determine that best X_j^* and the worst X_j^- values of all criterion functions, where $j = 1, 2, \ldots, n$, depicted in Table V where these are the maximum and the minimum values within that column, respectively (Table VI).

The calculation of range standardized decision matrix is done with the following formula (Table VII):

$$\text{Range standardized decision matrix} \quad X'_{ij} = \frac{X_{ij} - X_j^-}{X_j^* - X_j^-},$$

$$\left(A_{ij} - \text{Min of column}\right)/(\text{Range of column}) X'_{ij} = \frac{X_{ij} - \min\limits_{1 \leqslant j \leqslant n} X_{ij}}{\max\limits_{1 \leqslant j \leqslant n} X_{ij} - \min\limits_{1 \leqslant j \leqslant n} X_{ij}},$$

$$\text{Sum } \sigma_j = \sqrt{\frac{1}{m} \sum_{i=1}^{m} \left(x'_{ij} - \overline{x'_j}\right)^2}.$$

	Economic	Government support	Management commitment	Lack of skill/ training	Market need	Human resources
Economic	1	2	2	5	5	7
Government support	1/2	1	2	7	3	7
Management commitment	1/2	1/2	1	5	1	7
Lack of skill/training	1/5	1/7	1/5	1	1	2
Market need	1/5	1/3	1	1	1	3
Human resources	1/7	1/7	1/7	1/7	1/3	1
Min (X_j^-)	0.14	0.14	0.14	0.5	0.33	1
Max (X_j^*)	1	2	2	7	5	7
Range	0.86	1.86	1.86	6.5	4.67	6

Table VI. Decision matrix

Table VII. Range standardized decision matrix

	Economic	Government support	Management commitment	Lack of skill/ training	Market need	Human resources
Economic	1	1	1	0.692308	1	1
Government support	0.418605	0.462366	1	1	0.571734475	1
Management commitment	0.418605	0.193548	0.462366	0.692308	0.143468951	1
Lack of skill/training	0.069767	0	0.032258	0.076923	0.143468951	0.166667
Market need	0.069767	0.102151	0.462366	0.076923	0.143468951	0.333333
Human resources	0	0	0	0	0	0
Average	0.329457	0.293011	0.492832	0.423077	0.333690221	0.583333
SD	0.376548	0.386405	0.440751	0.423426	0.379614369	0.468449
CV_j	1.142934	1.318742	0.894324	1.000826	1.137625094	0.803055
Weights	0.18149	0.209407	0.142012	0.158924	0.180646937	0.12752

5.1 Coefficient of variation

The weight of the criterion reflects its importance in MCDM. Range standardization was done to transform different scales and units among various criteria into common measurable units in order to compare their weights:

$$CV_j = \frac{\sigma_j}{\overline{x'_j}} W_j = \frac{CV_j}{\sum_{j=1}^{n} CV_j},$$

where $j = 1, 2, \ldots, n$.

Below given is the value of maximum f^* and minimum f^- from Table VI, i.e. range of standardised decision matrix:

Max	f^*	1	1	1	1	1	1
Min	f^-	0	0	0	0	0	0
	Range	1	1	1	1	1	1

Furthermore, the values of S_i (the maximum group utility) and R_i (the minimum individual regret of the opponent), $i = 1, 2, \ldots, m$ by the relations: $S_i = W_i^* (f^* - a_{ij}) / (f^* - f^-)$ are computed with the following formula:

$$S_i = L_{1,i} = \sum_{j=1}^{n} w\,j \left(x_j^* - x_{ij}\right) / \left(x_j^* - x_j^-\right),$$

$$R_i = L_{\infty,i} = \max_{j} \left[\sum_{j=1}^{n} wj \left(x_j^* - x_{ij}\right) / \left(x_j^* - x_j^-\right) \right].$$

Next step is to compute the value of Q_i, $i = 1, 2, \ldots, m$, by the relation where $S^* = \min S_i$, $S^- = \max S_i$, $R^* = \min R_i$, $R^- = \max R_i$ and v is introduced weight of the strategy of S_i and R_i as represented in Table VIII. After the calculations of S, R and Q values, the alternatives are ranked by sorting S, R and Q values in a decreasing order; in other words, we can say that the lower value is better and in the end we get three ranking lists represented in Table IX. The most appropriately considered in the ranking done on the basis of Q which says the order of the critical barriers as Economic constraints on the top and succeeding is

Table VIII. Weights assigned to criteria

	Economic	Government support	Management commitment	Lack of skill/training	Market need	Human resources	S_i	R_i
Economic	0	0	0	0.0489	0	0	0.04889976	0.0489
Government support	0.105517	0.112584	0	0	0.077364855	0	0.29546664	0.112584
Management commitment	0.105517	0.168877	0.076351	0.0489	0.154729711	0	0.55437418	0.168877
Lack of skill/training	0.168828	0.209407	0.137431	0.146699	0.154729711	0.106266	0.92336144	0.209407
Market need	0.168828	0.188016	0.076351	0.146699	0.154729711	0.085013	0.81963655	0.188016
Human resources	0.18149	0.209407	0.142012	0.158924	0.180646937	0.12752	1	0.209407
S_i Max	1				R_i Max		0.209407	
S_i Min	0.04889976				R_i Min		0.0489	

Table IX.
Calculation of S, R and Q

	S_i	S^- S_i Max	S^* S_i min	S'	$\nu = 0.5$	R_i	R^- R_i max	R^* R_i min	R'	$\nu = 0.5$	Q_i
Economic	0.0489	1	0.0489	0	0	0.0489	0.209407	0.0489	0	0	0
Government support	0.295467	1	0.0489	0.259244	0.129621921	0.112584	0.209407	0.0489	0.396771	0.19838558	0.328008
Management commitment	0.554374	1	0.0489	0.531463	0.265731414	0.168877	0.209407	0.0489	0.747486	0.3737428	0.639474
Lack of skill/training	0.923361	1	0.0489	0.919421	0.459710575	0.209407	0.209407	0.0489	1	0.5	0.959711
Market need	0.819637	1	0.0489	0.810363	0.40518168	0.188016	0.209407	0.0489	0.866729	0.43336426	0.838546
Human resources	1	1	0.0489	1	0.5	0.209407	0.209407	0.0489	1	0.5	1

Government support third is the Management's commitment towards implementation of green manufacturing, fourth is the Market needs, fifth ranked is lack of skill/training and at rank sixth is Human Resources (Table X):

$$Q_i = v\frac{(S_i - S^*)}{(S^- - S^*)} + (1-v)\frac{(R_i - R^*)}{(R^- - R^*)}.$$

6. Conclusion

Barriers in the implementation of green manufacturing practices in Indian small and medium scale manufacturing organizations are analysed in this manuscript. Results from the current research are in line with the discussed available literature, and it can be adjudged that implementing green manufacturing in small and medium scale manufacturing organizations is not an easy task. According to the empirical study, results of factor analysis and ranking by VIKOR, economical constraints have emerged as the major factor of critical challenges that Indian SME's are facing. Henceforth, to overcome these challenges, Indian small and medium scale manufacturing organizations need to be financially strong and have to invest more in new techniques for implementing green manufacturing techniques. Second ranked factor with the VIKOR method is government support from the six factors identified with the factor analysis method. The examination depicts that in order to overcome these challenges, government needs to help the organizations in providing proper information on the markets demands and new technology in demand, and government should provide loans at discounted rates to implement eco-friendly new techniques. The third ranked factor barrier is Management's commitment towards the implementation of green manufacturing. Therefore, to overcome these challenges, organizations need to overcome rigidities within enterprise and need to support latest and emerging technology in order to avoid adverse effect on the work flow.

Furthermore, challenges factors named market needs, lack of skill and training and human resources are also important factors but are ranked at number 4, 5 and 6, respectively; hence, they are considered to be the least important among the six identified factors.

The analysis reveals that results obtained are quite significant; Cronbach's α for the first three factors identified is far above the acceptable level and per cent of variance above 19 per cent that depicts quite good variance in the data.

6.1 Practical implications

Current research is carried out in Indian small and medium scale manufacturing organizations for barriers in the implementation of green manufacturing practices; therefore, this manuscript will help the industry people in recognizing the barriers before implementing green manufacturing.

Factor	Rank (Q)
Economic constraints	1
Government support	2
Management commitment	3
Lack of skill/training	5
Market need	4
Human resources	6

Table X. Ranking list

6.2 Limitations and future direction

The research is only focussed on Indian small and medium scale manufacturing organizations which may not be applicable to the developed nation's SMEs as the conditions for operation may be different. Second, this research may not be applicable to large-scale industries as their parameters may be different. This research may be taken forwards by covering the above given limitations of the study.

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