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PRIORITIZATION OF GREEN MANUFACTURING DRIVERS IN INDIAN SMEs THROUGH IF-TOPSIS APPROACH

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The issues of global warming, landfill problems, climate change and depleting natural resources have gained significant attention because of massive environmental pollution by manufacturing industries. Green manufacturing (GM) has been proposed as a solution to overcome these issues. It is important to identify essential drivers that influence adoption of GM in SMEs. Thus, this study investigates the common drivers and their prioritization by employing intuitionistic fuzzy technique for order of preference by similarity to ideal solution approach. Study suggests that "financial benefits" is the most important and "socio-cultural responsibility" is the least important driver for GM implementation in Indian SMEs.

Keywords: Green manufacturing, Drivers, IF-TOPSIS, India, SMEs, Manufacturing

1. Introduction

Various environmental issues have arisen in developing countries owing to the recent growth in the manufacturing sectors. This has led to a huge pressure on the manufacturing companies to improve their environmental performance [1]. The manufacturing industries are well known for fulfilling the requirements of society by producing products as per the customers need. Moreover, they play a significant role in enhancing the lifestyle of the people and society as a whole. The developing countries are continuously working on meeting the demands and uplifting the living style of their rising population that has an adverse effect on the environment. In order to reduce the negative impact on the environment, there is an urgent need to improve manufacturing processes that can reduce the waste generated by industries. In India, large scale industries cause less industrial pollution as compared to small and medium enterprises (SMEs) as they have adopted new technologies which have minimal impact on the environment. Their economic performance has also improved as a result of employing new eco-friendly technologies. SMEs have emerged out as highly prominent sector of the

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Indian economy over the last decade [2]. SMEs are also supporting industrialization of backward and rural areas to reduce the regional disparity and to generate ample of employment opportunity for the youth of the nation [3]. In India, more than 48 million SMEs generate 40% employment of the total Indian workforce and contribute 17% to the total gross domestic product (GDP) of the country [4]. These benefits from SMEs drive it to an important position in one hand but on the other hand they are creating more pollution as compared to large scale industries. The reason behind is lack of adoption of new eco-friendly manufacturing system like green manufacturing (GM). According to Dornfeld David [5] *"Green manufacturing is a process or system which has a minimal, nonexistent, or negative impact on the environment".* In order to sustain and grow in the competitive global market, SMEs need to resolve these critical issues by adopting innovative approaches such as GM, in their operations and supply chain. The sustainability elements of GM process assist the management to effectively address the manufacturing cost, power consumption, waste management, eco-friendliness, operational safety and worker personnel health in organization. Indian SMEs fears to adopt new technology as it is expensive and an endless process with a high obsolescence rate. The management of SMEs tends to view these new technologies as an expense rather than as a strategic investment. Hence, implementation of any new manufacturing strategy particularly in SMEs needs a strong motivational factor that can influence the management to adopt it. Thus, a suitable methodology is required to facilitate the SMEs to identify their key drivers of GM implementation. This study employs integrated intuitionistic fuzzy technique for order performance by similarity to ideal solution (IF-TOPSIS) approach to prioritize the common drivers. The intuitionistic fuzzy based TOPSIS provide comprehensive method for effectively handle the vagueness and uncertainty in complex environments through measuring the inherent ambiguity of decision makers (DMs) judgment in multi criteria decision making (MCDM) area. Based on the literature review and experts opinion, eighteen drivers in the context of Indian SMEs are extracted that influence adoption of GM. The novelty of this research study lies in the fact that it presents a systematic approach to prioritize the common drivers on four different perspectives viz. Industry, Academic, Government and Consumer that influence the implementation of GM in manufacturing SMEs at Indian scenario with the help of intuitionistic fuzzy based TOPSIS approach.

2. Literature review

In the past, plethora of research work has already been conducted on methodology, case study, framework, tools/techniques and benefits of GM. Despite this, there are a limited number of studies that analyzed the drivers of GM in manufacturing SMEs at Indian scenario. Agan et al. [6] averred that rule and regulations, internal motivation, customer demands and firm performance are the key drivers of environmental process. Law and Gunasekaran [7] recognized prime motivating factors in implementation of sustainable strategies in Hong Kong. Singh et al. [8] conducted a survey in Indian industry and identified fourteen drivers that motivate GM practices. Diabat, et al. [9] developed a structural model of drivers while using ISM techniques that affects the implementation of GSCM. Massoud et al. [10] identified the influencing factors in implementation of EMS in the Lebanese food industry. Zhang et al. [11] examined thirteen drivers that influence enterprises to implement environmental management practices in China. Gabzdylova et al. [12] examined the drivers, stakeholders and practices for the wine industry in New Zealand. Yuksel [13] examined the drivers to adopt cleaner production techniques from the survey questionnaire of 105 large scale industries in Turkey. Pun et al. [14] identified the success factors which influence the implementation of EMS and found that competitive pressure, customer requirement and resource conservation are the prime drivers. Hui et al. [15] conducted a survey to investigate influencing factors in adoption of GM in Hong Kong.

It is evident from the review of past literatures that the quantum of research work to identify and prioritize the drivers to implement GM in small and medium manufacturing sector at Indian scenario is not in proportion with the incredible growth in the industrial activities. Therefore, the present study attempts to bridge that gap by identify more influential drivers of GM and subsequently evaluating them to obtain a ranking preorders which shows the most important driver. The list of eighteen common drivers of GM adoption is provided in Table 1.

The key highlights of this study are as follows:

- Identify the common drivers of GM through an extensive literature review and experts suggestions.
- Proposed a framework to prioritize GM drivers in manufacturing SMEs using IF-TOPSIS approach.
- Validate the obtained results with existing literature and feedback from government, industry and academic experts.

3. The framework of the study

The framework of the study to analyze eighteen drivers to implement GM in Indian SMEs is demonstrated in Figure 1, which broadly consists of three main stages. The primary stage encompasses the identification of divers based on past literature and through experts suggestion. In the subsequent stage, IF-TOPSIS approach is utilized to prioritize the drivers based on the opinion of decision makers (DMs) on four different perspective viz. industry, academic, government and consumer. In final phase findings are validated through the literature and feedback of DMs. The linguistic scale and intuitionistic fuzzy (IF) rating for alternative, criteria and relative weights of experts are shown in Table 2 and Table 3.

Table 1

Drivers of green manufacturing

S .No	Drivers	References
1	Environmental conservation	[16]
2	Improve quality	[17]
3	Environmental awareness of consumers	[18]
4	Certification of ISO 14001	[9]
5	Reduce waste disposal and landfill cost	[19], [20]
6	Pressure from stakeholders	[21], [22]
7	Improve working environment	[23]
8	Improve delivery speed and performance flexibility	[17]
9	Financial benefits	[17], [16]
10	Scarcity of natural resources	[20]
11	Government incentives policy	[24]
12	Bolstered corporate image	[25], [20]
13	Legislative and regulatory compliances	[26]
14	Competitiveness	[20]
15	Supply chain pressure	[27]
16	Customer demands	[28]
17	Socio-cultural responsibility	[29], [30]
18	Improve environmental performance	[25]

Table 2

The linguistic scale and intuitionistic fuzzy rating for alternative and criteria

S.No.	Linguistic terms	Intuitionistic fuzzy numbers
1	Unimportant (U)	(0.10,0.90,0.00)
2	Least important (LI)	(0.35,0.60,0.05)
3	Important (I)	(0.50,0.45,0.05)
4	Very important (VI)	(0.75,0.20,0.05)
5	Most important (MI)	(0.90,0.10,0.00)

Table 3

The linguistic scale for decision makers relative importance weight

S.No.	Linguistic terms	Intuitionistic fuzzy numbers
1	Very low (VL)	(0.10,0.90,0.00)
2	Low (L)	(0.35,0.60,0.05)
3	Medium (M)	(0.50,0.45,0.05)
4	High (H)	(0.75,0.20,0.05)
5	Very high (VH)	(0.90,0.10,0.00)

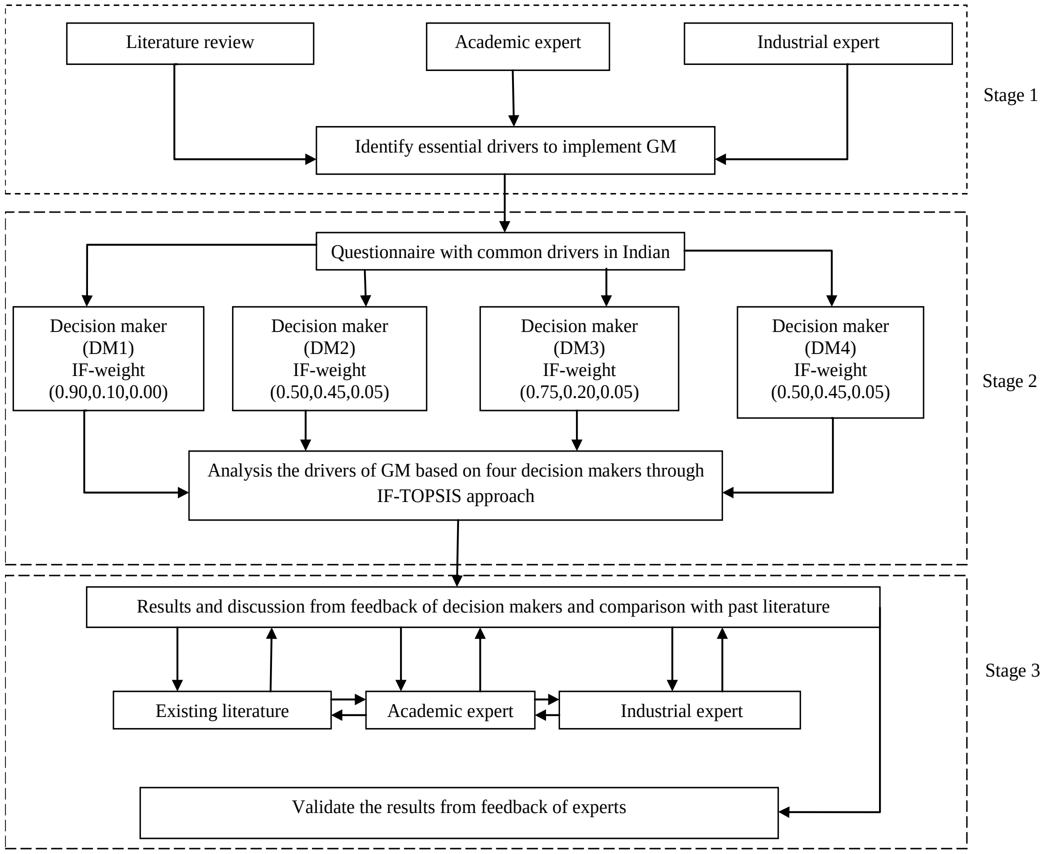

Fig. 1. The proposed framework of the study

4. Application of proposed framework

The stages performed in the proposed framework are described below:

Stage 1: Identification of GM drivers

In this stage common drivers of GM are collected through existing literature and experts suggestion. A systematic literature review approach is employed. The electronic databases such as "Google scholar", "Web of science", "Scopus" etc., is used with search topics that contained combination of exact word like "Green manufacturing", "Cleaner production", "Environmental conscious manufacturing", "Sustainable manufacturing", "Drivers", "SMEs" and time span of search string was 1990 to 2017. After many rounds of discussions and content affirmation with experts eighteen common drivers are considered for the study.

Stage 2: Application of IF-TOPSIS approach

In this stage, firstly data collection process began by scheduling an onsite meeting with DMs and the span of time of interviews with each DMs was approximately one to two hours and subsequently IF-TOPSIS approach is employed. TOPSIS is widely acceptable and very useful technique to solve MCDM problems that was developed in 1981 by Hwang [31]. It worked on the scheme that optimal alternative should have shortest distance from positive ideal solution (PIS) and have a longest distance from negative ideal solution (NIS). TOPSIS method used the distances from PIS and NIS to evaluate the preference order of the relative closeness coefficient. Owing to the massive intricacy in decision making process, fuzzy sets are commonly used by DMs to deal with the ambiguity and uncertainty [32]**.** In 1986 intuitionistic fuzzy set (IFS) is proposed by Atanassov that is extensive form of classical fuzzy set that tackle imprecision in planned manner in uncertain settings [33].

Consider X is finite set then IFS A in X is as follows:

$A = \{(\mathrm{x}, \mu_A(x), \upsilon_A(x)) x \in X\}$

Where, $\mu_A(x): X \to [0.00, 1.00]$, $\upsilon_A(x): X \to [0.00, 1.00]$ represents membership function and non-memberships function respectively

$$0 \le \mu_A(x) + \upsilon_A(x) \le 1, \mathrm{x} \in X \quad (1)$$

The factor $\pi_A(x)$ is represents the hesitation level of $x \in X$ to A and $0 \le \pi_A(x) \le 1, x \in X$ which are calculated as follows:

$$\pi_A(x) = 1 - \mu_A(x) - \upsilon_A(x) \quad (2)$$

If A and B is IFS of set X , then multiplication operator is calculated as:

$$A \otimes B = \{\mu_A(x).\mu_B(x), \upsilon_A(x) + \upsilon_B(x) - \upsilon_A(x).\upsilon_B(x) | x \in X\} \quad (3)$$

The IF-TOPSIS methodology requires the following steps [34]:

Step1: Assessment the rating of drivers and perspectives

Suppose that $A = A_1, A_2, A_3, A_4, ..., A_m$ be the set of possible alternatives and $x = x_1, \mathrm{x}_2, \mathrm{x}_3, \mathrm{x}_4, ..., \mathrm{x}_n$ be the set of criteria and the weight of criteria are represented as $w_j = w_1, w_2, w_3, w_4, ..., w_n$. The ratings of each DMs for each alternative with respect to criteria are denoted λ_k , that is based on position, work experience and education qualification that is shown in Table 4. This study copes with eighteen drivers and four perspectives. The linguistic assessment of drivers and perspectives by the DMs are shown in Table 5 and Table 6 respectively.

Table 4

The Brief profile of DMs

S.No.	Decision makers	Designation	Type of organization	Experience
1	DM 1	Deputy general manager (Subject expert)	Manufacturing industry	16
2	DM2	Senior manager	Manufacturing industry	12
3	DM3	Professor (Subject expert)	Academic institution	20
4	DM4	Manager	Non-governmental organization (CII)	08

Table 5

Linguistic assessment of drivers

S .No.	Driver	Industry perspective	Academic perspective	Government perspective	Consumer Perspective
1	D1	VI	I	VI	I
2	D2	VI	VI	MI	VI
3	D3	I	VI	MI	I
4	D4	MI	I	MI	I
5	D5	VI	MI	MI	I
6	D6	VI	MI	MI	VI
7	D7	MI	VI	VI	VI
8	D8	I	MI	MI	I
9	D9	MI	MI	VI	MI
10	D10	I	MI	I	VI
11	D11	VI	MI	VI	I
12	D12	MI	VI	VI	I
13	D13	MI	MI	MI	I
14	D14	I	MI	VI	VI
15	D15	I	MI	MI	VI
16	D16	I	VI	MI	VI
17	D17	I	I	VI	I
18	D18	VI	VI	MI	I

Table 6

Linguistic assessment of the perspectives

S.No.	Criteria	DM1	DM2	DM3	DM4
1	Industry perspective	MI	MI	VI	MI
2	Academic perspective	VI	MI	I	VI
3	Government perspective	VI	I	MI	MI
4	Consumer perspective	I	I	I	VI

Step2: Calculate the weight of DMs

Suppose $D_k = [\mu_k, \nu_k, \pi_k]$ be an IF number for rating of k^{th} DMs. Then weight of k^{th} DMs are obtained by equation (4) as shown in Table 7.

$$\lambda_k = \frac{\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + \nu_k}\right)\right)}{\sum_{k=1}^{l}\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + \nu_k}\right)\right)} \quad (4)$$

Where, $k = 1, 2, 3, 4, ..., l$

Step3: Construct IF decision matrix

The intuitionistic fuzzy decision matrix (R) for the drivers can be represent as follows and that is shown in Table 8.

$$R = \begin{bmatrix} \mu_{A_1}(x_1), \upsilon_{A_1}(x_1), \pi_{A_1}(x_1) & \mu_{A_1}(x_2), \upsilon_{A_1}(x_2), \pi_{A_1}(x_2) & \cdots & \mu_{A_1}(x_n), \upsilon_{A_1}(x_n), \pi_{A_1}(x_n) \\ \mu_{A_2}(x_1), \upsilon_{A_2}(x_1), \pi_{A_2}(x_1) & \mu_{A_2}(x_2), \upsilon_{A_2}(x_2), \pi_{A_2}(x_2) & \cdots & \mu_{A_2}(x_n), \upsilon_{A_2}(x_n), \pi_{A_2}(x_n) \\ \vdots & \vdots & \ddots & \vdots \\ \mu_{A_m}(x_1), \upsilon_{A_m}(x_1), \pi_{A_m}(x_1) & \mu_{A_m}(x_2), \upsilon_{A_m}(x_2), \pi_{A_m}(x_2) & \cdots & \mu_{A_m}(x_n), \upsilon_{A_m}(x_n), \pi_{A_m}(x_n) \end{bmatrix}$$

Step4: Calculate aggregate weight of the criteria (Perspective)

Suppose $w_j^k = \left[\mu_j^k, \nu_j^k, \pi_j^k\right]$ be the IF number that assigned to criteria x_j by k^{th} DMs. Then aggregate weight of criteria is calculated by utilizing intuitionistic fuzzy weighted averaging (IFWA) operator by equation (5) that is shown in Table 9.

$$\begin{aligned} w_j &= IFWA_\lambda\left(w_j^{(1)}, w_j^{(2)}, w_j^{(3)}, ..., w_j^{(l)}\right) \\ w_j &= \lambda_1 w_j^{(1)} \oplus \lambda_2 w_j^{(2)} \oplus \lambda_3 w_j^{(3)} \oplus .... \oplus \lambda_l w_j^{(l)} \\ w_j &= \left[1 - \prod_{k=1}^{l}\left(1 - \mu_j^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{l}\left(\nu_j^{(k)}\right), \prod_{k=1}^{l}\left(1 - \mu_j^{(k)}\right)^{\lambda_k} - \prod_{k=1}^{l}\left(\nu_j^{(k)}\right)^{\lambda_k}\right] \end{aligned} \quad (5)$$

Where, $j = 1, 2, 3, ..., n$

Table 7

The importance of decision makers and their weights

	DM1	DM2	DM3	DM3
Linguistic terms	MI	I	VI	I
Intuitionistic fuzzy numbers	(0.90,0.10,0.00)	(0.50,0.45,0.05)	(0.75,0.20,0.05)	(0.50,0.45,0.05)
Crisp weight	0.3282	0.1919	0.2878	0.1919

Table 8

The intuitionistic fuzzy decision matrix

S .No	Drivers	Industry perspective	Academic perspective	Government Perspective	Consumer Perspective
1	D1	(0.75,0.20,0.05)	(0.50,0.45,0.05)	(0.75,0.20,0.05)	(0.50,0.45,0.05)
2	D2	(0.75,0.20,0.05)	(0.75,0.20,0.05)	(0.90,0.10,0.00)	(0.50,0.45,0.05)
3	D3	(0.50,0.45,0.05)	(0.75,0.20,0.05)	(0.90,0.10,0.00)	(0.35,0.60,0.05)
4	D4	(0.90,0.10,0.00)	(0.50,0.45,0.05)	(0.90,0.10,0.00)	(0.50,0.45,0.05)
5	D5	(0.75,0.20,0.05)	(0.90,0.10,0.00)	(0.90,0.10,0.00)	(0.90,0.10,0.00)
6	D6	(0.75,0.20,0.05)	(0.90,0.10,0.00)	(0.90,0.10,0.00)	(0.75,0.20,0.05)
7	D7	(0.90,0.10,0.00)	(0.75,0.20,0.05)	(0.75,0.20,0.05)	(0.75,0.20,0.05)
8	D8	(0.50,0.45,0.05)	(0.90,0.10,0.00)	(0.90,0.10,0.00)	(0.50,0.45,0.05)
9	D9	(0.90,0.10,0.00)	(0.90,0.10,0.00)	(0.75,0.20,0.05)	(0.90,0.10,0.00)
10	D10	(0.50,0.45,0.05)	(0.90,0.10,0.00)	(0.50,0.45,0.05)	(0.75,0.20,0.05)
11	D11	(0.75,0.20,0.05)	(0.90,0.10,0.00)	(0.75,0.20,0.05)	(0.90,0.10,0.00)
12	D12	(0.90,0.10,0.00)	(0.75,0.20,0.05)	(0.75,0.20,0.05)	(0.50,0.45,0.05)
13	D13	(0.90,0.10,0.00)	(0.90,0.10,0.00)	(0.90,0.10,0.00)	(0.50,0.45,0.05)
14	D14	(0.50,0.45,0.05)	(0.90,0.10,0.00)	(0.75,0.20,0.05)	(0.75,0.20,0.05)
15	D15	(0.50,0.45,0.05)	(0.90,0.10,0.00)	(0.90,0.10,0.00)	(0.75,0.20,0.05)
16	D16	(0.50,0.45,0.05)	(0.75,0.20,0.05)	(0.90,0.10,0.00)	(0.75,0.20,0.05)
17	D17	(0.50,0.45,0.05)	(0.50,0.45,0.05)	(0.75,0.20,0.05)	(0.50,0.45,0.05)
18	D18	(0.75,0.20,0.05)	(0.75,0.20,0.05)	(0.90,0.10,0.00)	(0.50,0.45,0.05)

Table 9

The aggregate intuitionistic fuzzy weight of criteria

Perspective	DM1	DM2	DM3	DM4	Aggregate weight
P1	(0.90,0.10,0.00)	(0.90,0.10,0.00)	(0.75,0.20,0.05)	(0.90,0.10,0.00)	(0.8698,0.1221,0.0081)
P2	(0.75,0.20,0.05)	(0.90,0.10,0.00)	(0.50,0.45,0.05)	(0.75,0.20,0.05)	(0.7440,0.2212,0.0348)
P3	(0.75,0.20,0.05)	(0.50,0.45,0.05)	(0.90,0.10,0.00)	(0.90,0.10,0.00)	(0.8160,0.1676,0.0164)
P4	(0.50,0.45,0.05)	(0.50,0.45,0.05)	(0.50,0.45,0.05)	(0.75,0.20,0.05)	(0.5623,0.3852,0.0525)

Step5: Compute aggregated weighted IF decision matrix

The aggregated weighted IF decision matrix (R') is evaluated with the help of equation (6) and (7), as shown in Table 10.

$$\pi_{Ai.\mathrm{W}}(x) = 1 - \nu_{Ai}(x) - \nu_w(x) - \mu_{Ai}(x) \cdot \mu_w(x) + \nu_{Ai}(x) \cdot \nu_w(x) \quad (6)$$

$$R \otimes W = \left\{ \left\langle x, \mu_{Ai}(x).\mu_w(x), \nu_{Ai}(x) + \nu_w(x) - \nu_{Ai}(x) \cdot \nu_w(x) \right\rangle | x \in X \right\} \quad (7)$$

The aggregated IF weighted decision matrix (R') is defined as follows:

$$R' = \begin{bmatrix} \mu_{A_1W}(x_1), \upsilon_{A_1W}(x_1), \pi_{A_1W}(x_1) & \mu_{A_1W}(x_2), \upsilon_{A_1W}(x_2), \pi_{A_1W}(x_2) & \cdots & \mu_{A_1W}(x_n), \upsilon_{A_1W}(x_n), \pi_{A_1W}(x_n) \\ \mu_{A_2W}(x_1), \upsilon_{A_2W}(x_1), \pi_{A_2W}(x_1) & \mu_{A_2W}(x_2), \upsilon_{A_2W}(x_2), \pi_{A_2W}(x_2) & \cdots & \mu_{A_2W}(x_n), \upsilon_{A_2W}(x_n), \pi_{A_2W}(x_n) \\ \vdots & \vdots & \ddots & \vdots \\ \mu_{A_mW}(x_1), \upsilon_{A_mW}(x_1), \pi_{A_mW}(x_1) & \mu_{A_mW}(x_2), \upsilon_{A_mW}(x_2), \pi_{A_mW}(x_2) & \cdots & \mu_{A_mW}(x_n), \upsilon_{A_mW}(x_n), \pi_{A_mW}(x_n) \end{bmatrix}$$

Table 10

The aggregate weighted intuitionistic fuzzy decision matrix

Driver	Industry perspective	Academic perspective	Government perspective	Consumer perspective
D1	(0.6523,0.2976,0.0500)	(0.3720,0.6288,0.2510)	(0.6120,0.3340,0.0539)	(0.2811,0.6618,0.0570)
D2	(0.6523,0.2976,0.0500)	(0.5580,0.3769,0.0650)	(0.7344,0.2508,0.0147)	(0.4217,0.5081,0.0696)
D3	(0.4349,0.5171,0.0479)	(0.5580,0.3769,0.0650)	(0.7344,0.2508,0.0147)	(0.2811,0.6618,0.0570)
D4	(0.7828,0.2098,0.0073)	(0.3720,0.6288,0.2510)	(0.7344,0.2508,0.0147)	(0.2811,0.6618,0.0570)
D5	(0.6523,0.2976,0.0500)	(0.6696,0.2990,0.0313)	(0.7344,0.2508,0.0147)	(0.2811,0.6618,0.0570)
D6	(0.6523,0.2976,0.0500)	(0.6696,0.2990,0.0313)	(0.7344,0.2508,0.0147)	(0.4217,0.5081,0.0696)
D7	(0.7828,0.2098,0.0073)	(0.5580,0.3769,0.0650)	(0.6120,0.3340,0.0539)	(0.4217,0.5081,0.0696)
D8	(0.4349,0.5171,0.0479)	(0.6696,0.2990,0.0313)	(0.7344,0.2508,0.0147)	(0.2811,0.6618,0.0570)
D9	(0.7828,0.2098,0.0073)	(0.6696,0.2990,0.0313)	(0.6120,0.3340,0.0539)	(0.5060,0.4466,0.0473)
D10	(0.4349,0.5171,0.0479)	(0.6696,0.2990,0.0313)	(0.4080,0.5421,0.0498)	(0.4217,0.5081,0.0696)
D11	(0.6523,0.2976,0.0500)	(0.6696,0.2990,0.0313)	(0.6120,0.3340,0.0539)	(0.2811,0.6618,0.0570)
D12	(0.7828,0.2098,0.0073)	(0.5580,0.3769,0.0650)	(0.6120,0.3340,0.0539)	(0.2811,0.6618,0.0570)
D13	(0.7828,0.2098,0.0073)	(0.6696,0.2990,0.0313)	(0.7344,0.2508,0.0147)	(0.2811,0.6618,0.0570)
D14	(0.4349,0.5171,0.0479)	(0.6696,0.2990,0.0313)	(0.6120,0.3340,0.0539)	(0.4217,0.5081,0.0696)
D15	(0.4349,0.5171,0.0479)	(0.6696,0.2990,0.0313)	(0.7344,0.2508,0.0147)	(0.4217,0.5081,0.0696)
D16	(0.4349,0.5171,0.0479)	(0.5580,0.3769,0.0650)	(0.7344,0.2508,0.0147)	(0.4217,0.5081,0.0696)
D17	(0.4349,0.5171,0.0479)	(0.3720,0.6288,0.2510)	(0.6120,0.3340,0.0539)	(0.2811,0.6618,0.0570)
D18	(0.6523,0.2976,0.0500)	(0.5580,0.3769,0.0650)	(0.7344,0.2508,0.0147)	(0.2811,0.6618,0.0570)
IFPIS	(0.7828,0.2098,0.0073)	(0.6696,0.2990,0.0313)	(0.7344,0.2508,0.0147)	(0.5060,0.4466,0.0473)
IFNIS	(0.4349,0.5171,0.0479)	(0.3720,0.6288,0.2510)	(0.4080,0.5421,0.0498)	(0.2811,0.6618,0.0570)

Step6: Calculate IF positive ideal solution (IFPIS) and IF negative ideal solutions (IFNIS) with the help of equation (8) and (9).

$$A^{-}=\left(\tilde{r}_1^{-},\tilde{r}_2^{-},\tilde{r}_3^{-},.....,\tilde{r}_n^{-}\right)=(\mu^{-}{}_{A_i.\mathrm{W}}(\mathrm{x}_j),\nu^{-}{}_{A_i.\mathrm{W}}(\mathrm{x}_j),\pi^{-}{}_{A_i.\mathrm{W}}(\mathrm{x}_j)),\ \mathrm{j}=1,2,3,....,\mathrm{n} \quad (8)$$

$$A^{*}=\left(\tilde{r}_1^{*},\tilde{r}_2^{*},\tilde{r}_3^{*},......,\tilde{r}_n^{*}\right)=(\mu^{*}{}_{A_i.\mathrm{W}}(\mathrm{x}_j),\nu^{*}{}_{A_i.\mathrm{W}}(\mathrm{x}_j),\pi^{*}{}_{A_i.\mathrm{W}}(\mathrm{x}_j)),\ \mathrm{j}=1,2,3,.....,\mathrm{n} \quad (9)$$

Where;

$$\mu^{*}{}_{A_i.\mathrm{W}}(\mathrm{x}_j)=\{\max_i \mu_{A_i.\mathrm{W}}(\mathrm{x}_j)\ \mathrm{j}=1,2,3,...,\mathrm{n}\}$$

$$\nu^{*}{}_{A_i.\mathrm{W}}(\mathrm{x}_j)=\{\min_i \mu_{A_i.\mathrm{W}}(\mathrm{x}_j)\ \mathrm{j}=1,2,3,...,\mathrm{n}\}$$

$$\nu^{-}{}_{A_i.\mathrm{W}}(\mathrm{x}_j)=\{\max_i \mu_{A_i.\mathrm{W}}(\mathrm{x}_j)\ \mathrm{j}=1,2,3,...,\mathrm{n}\}$$

$$\mu^{-}{}_{A_i.\mathrm{W}}(\mathrm{x}_j)=\{\min_i \mu_{A_i.\mathrm{W}}(\mathrm{x}_j)\ \mathrm{j}=1,2,3,...,\mathrm{n}\}$$

Step7: Evaluate the distance from the alternatives (Drivers) and IFPIS as well as IFNIS, with the help of equation (10) and (11).

$$S^{*}=\sqrt{\frac{1}{2n}\sum_{j=1}^{n}(\mu_{A_i.\mathrm{W}}(\mathrm{x}_j)-\mu_{A^{*}_i.\mathrm{W}}(\mathrm{x}_j))^2+(\nu_{A_i.\mathrm{W}}(\mathrm{x}_j)-\nu_{A^{*}_i.\mathrm{W}}(\mathrm{x}_j))^2+(\pi_{A_i.\mathrm{W}}(\mathrm{x}_j)-\pi_{A^{*}_i.\mathrm{W}}(\mathrm{x}_j))^2} \quad (10)$$

$$S^{-}=\sqrt{\frac{1}{2n}\sum_{j=1}^{n}(\mu_{A_i.\mathrm{w}}(\mathrm{x}_j)-\mu_{A^{-}_{i}.\mathrm{w}}(\mathrm{x}_j))^2+(\nu_{A_i.\mathrm{w}}(\mathrm{x}_j)-\nu_{A^{-}_{i}.\mathrm{w}}(\mathrm{x}_j))^2+(\pi_{A_i.\mathrm{w}}(\mathrm{x}_j)-\pi_{A^{-}_{i}.\mathrm{w}}(\mathrm{x}_j))^2} \quad (11)$$

Step7: Evaluate the relative closeness coefficient of alternative with respect to IFPIS by utilizing equation (12).

$$C_i^{*}=\frac{S_i^{-}}{S_i^{*}+S_i^{-}} \quad (12)$$

Where, $0 \le C_{i^*} \le 1 (i = 0,1,2,3....,m)$

Step 8: The rank of drivers is evaluated according to score of relative closeness coefficient C_i^{*} as shown in Table 11.

Table 11

Separation measures and the relative closeness coefficient of alternatives

S.No.	Drivers	S^{*}	S^{-}	C_i^{*}	Rank
1	D1	0.2215	0.1501	0.4039	17
2	D2	0.0848	0.2492	0.7461	4
3	D3	0.2042	0.2115	0.5088	15
4	D4	0.2069	0.2263	0.5224	14
5	D5	0.1242	0.2583	0.6753	6
6	D6	0.0689	0.2686	0.7958	2
7	D7	0.0824	0.2527	0.7541	3
8	D8	0.1981	0.2340	0.5415	13
9	D9	0.0540	0.2838	0.8401	1
10	D10	0.2294	0.1900	0.4530	16
11	D11	0.1355	0.2307	0.6299	9
12	D12	0.1322	0.2416	0.6463	7
13	D13	0.1100	0.2862	0.7224	5
14	D14	0.1774	0.2162	0.5492	12
15	D15	0.1690	0.2454	0.5921	10
16	D16	0.1761	0.2239	0.5597	11
17	D17	0.2699	0.1030	0.2762	18
18	D18	0.1337	0.2491	0.6402	8

Stage 3: Result validation

In the last stage, to verify the reliability of the results, the obtained outcomes are discussed with the industrial and academic experts by making an onsite meeting and conversation lasted more than one hours. In the discussion, it was found that the results obtained significantly corroborated with that of the expert opinions. Also, support from the literature is provided to validate the obtained results.

5. Results and discussion

This study prioritized the common drivers in implementation of GM in Indian SMEs through IF-TOPSIS approach with the help of four decision makers having extensive experience and deep knowledge in the manufacturing sector. The prioritization of common drivers of GM is based on relative closeness coefficient (RCC). The findings of the results show that "Financial benefits" is the most essential driver with RCC score 0.8401. Whereas "Socio-cultural responsibility" is the least important driver to implement GM with the score 0.2762.

On the basis of RCC values of common drivers, prioritization of drivers in decreasing order is as follows:D9>D6>D7>D2>D13>D5>D12>D18>D11>D15>D16>D14>D8>D4>D3>D10>D1>D17. D9, D6, D7, D2 and D13 are the top five most important drivers having enormous influence on small and medium manufacturing industries to adopt GM. The management of SMEs recognized various financial benefits in short term and long term tenure from GM practices. In present scenario material, energy and water are the prime concern for the manufacturing industries and it is well known that GM implementation in industries can reduce the cost by smart use of material and energy efficient equipment. Lee [23] divulges in the study of Korean manufacturing SMEs that reduction of material, water usage by 13% and 21% after adoption of GM. Rutherford et al. [35] also advocated that better GM practices improve the costs as well as relationships with the ultimate customers. Pressure from stakeholder (D6) is the second most important drivers. Stakeholder such as media, NGO, local community, etc., is directly influencing the industries to adopt green related practices to reduce the environmental impact. Improve working environment (D7) and improve quality (D2) are the third and fourth essential drivers respectively. Safe working environment is one of the most important considerations for workers performing various activities in the workplace. Better working environment and safety are the prime concern of large scale industries, but SMEs is lacking in these standard. GM practices provided better working environment by reducing pollutants and air emissions on shop floor due to which productivity of worker has drastically improved Lee [23]. GM system is better and more efficient than traditional manufacturing system and has the gigantic ability to produce eco-friendly products with very short period of time at a lesser price with better quality. Pil et al. [36] applied environmental practices in a paint shop and observed that changes in the production process had the additional benefits of quality improvement along with environmental improvements. Legislative and regulatory compliances (D13) are the fifth most important drivers for GM adoption in SMEs. Due to the significant environmental impact from industrial waste, government legislative organizations introduce regulations, policies and laws to control and regulate the environmental performances. Zhu et al. [18] also supported environmental regulation is the one of major drivers to enforce GM practices to protect environment all over the world. Under the regulatory pressure and government efforts, manufacturing sector is driven towards green practices. Government of India also promotes zero effect zero defect (ZED) strategies for micro, small and medium enterprises under the UNIDO-GEPF-MSME scheme. Due to their pertinent benefits, other drivers are also assisting in effective implementation of GM in manufacturing SMEs.

6. Conclusions

GM has become the need of urgency for small and medium manufacturing sector because of the huge amount of waste generated by them. In developing countries, like India penetrations of green practices are still lacking. So, in order to increase the rate of implementation, identification of essential drivers is needed that influence the management of SMEs to adopt GM practices. Therefore, this study provides eighteen essential drivers based on extensive literature and suggestions from experts. Subsequently, intuitionistic fuzzy-TOPSIS approach has been utilized to prioritize the common drivers of GM with the help of four decision makers. Financial benefits (D9), Pressure from stakeholders (D6), Improve working environment (D7), Improve quality (D2) and Legislative and regulatory compliances (D13) are the five most important drivers of GM for manufacturing SMEs. It is well known that implementation of GM strategy will help the SMEs to take competitive advantage and financial benefits through subsidies and tax exemptions. For effective and efficient adoption of GM practices in manufacturing firms, understanding the essential drivers are important. The present study assists the management of SMEs to prioritize the essential drivers for successful implementation of GM practices in their industries. This study collected the data from four decision makers which have vast knowledge and experience in manufacturing sectors. The future scope could be to analyze the essential drivers in different sectors such as food industry, textile industry with more experts opinion.

R E F E R E N C E S

[1]. *Mittal V.K, Sindhwani R, and Kapur P.K*, "Two-Way assessment of Barriers to Lean–Green Manufacturing System: Insights From India", International Journal of System Assurance Engineering and Management., **vol.** *7*(4), 2016, pp.400-407.

[2]. Government of Indian, Annual report 2014-2015, Ministry of Micro, Small and Medium. [online] http://msme.gov.in/sites/default/files/MEME%20ANNUAL%20REPORT%202015-16%20ENG.pdf. (Accessed on march 15, 2017).

[3]. Confederation of Indian industry (CII). A Theme Paper titled 'Building Globally Competitive MSMEs: The Way Forward' was unveiled during the MSME Conclave 2016 held on 1 March, 2016 at Jaipur.

[4]. *Vyas V, Raitani S, Roy A and Jain P,* "Analysing Critical Success Factors in Small and Medium Enterprises Banking", World Review of Entrepreneurship, Management and Sustainable Development., **vol.** 11(1), 2015, pp.106-123.

[5]. *Dornfeld, David, et al*, "Introduction to Green Manufacturing. Green Manufacturing. Springer US., 2013 pp1-23.

[6]. *Agan Y, Acar M.F and Borodin A*, "Drivers of Environmental Processes and Their Impact on Performance: a Study of Turkish SMEs", Journal of Cleaner Production., **vol.** *51*, 2013, pp.23-33.

[7]. *Law, K.M.Y. and Gunasekaran, A*, "Sustainability Development in High-Tech Manufacturing Firms in Hong Kong: Motivators and Readiness", International Journal of Production Economics., **Vol.** 137(1), 2012, pp. 116-125.

[8]. *Singh A, Singh B and Dhingra A.K*, "Drivers and Barriers of Green Manufacturing Practices: A Survey of Indian industries", International Journal of Engineering Sciences., **vol.** 1(1), 2012, pp.5-19.

[9]. *Diabat Ali and Kannan Govindan*, "An analysis of the Drivers Affecting the Implementation of Green Supply Chain Management", Resources, Conservation and Recycling., **vol.** 55(6), 2010, pp.659-667.

[10]. *Massoud, M.A., Fayad, R., Kamleh, R. and El-Fadel, M*, "Environmental Management System (ISO 14001) Certification in Developing Countries: Challenges and Implementation Strategies", *Environmental* Science & Technology., **vol.** 44(6), 2010, pp.1884-1887.

[11]. *Zhang B, Bi J and Liu B*, "Drivers and Barriers to Engage Enterprises in Environmental Management Initiatives in Suzhou Industrial Park, China", Frontiers of Environmental Science & Engineering in China., **vol.** 3(2), 2009, pp.210-220.

[12]. *Gabzdylova B, Raffensperger JF, and Castka P,* "Sustainability in the New Zealand Wine Industry: Drivers, Stakeholders and Practices", Journal of Cleaner Production., **vol.** 17(11), 2009, pp.992-998.

[13]. *Yuksel H*,"An Empirical Evaluation of Cleaner Production Practices in Turkey", Journal of Cleaner Production., **vol.** 16(1), 2008, pp.S50-S57.

[14]. *Pun K.F, Hui, I.K, Lau H.C, Law H.W and Lewis W.G, "*Development of an EMS planning framework for environmental management practices. International Journal of Quality & Reliability Management., **vol.** 19(6), 2002, pp.688-709.

[15]. *Hui I.K, Chan A.H, and Pun K.F,*"A Study of the Environmental Management System Implementation Practices", Journal of Cleaner Production., **vol.** *9*(3), 2001, pp.269-276.

[16]. *Govindan K, Diabat A, and Shankar K.M*, "Analyzing the Drivers of Green Manufacturing with Fuzzy Approach", Journal of Cleaner Production., **vol.** 96, 2015, pp.182-193.

[17]. *Shankar K.M, Kumar P.U, and Kannan D,* “Analyzing the Drivers of Advanced Sustainable Manufacturing System Using AHP Approach”, Sustainability., **vol.** *8*(8), 2016, pp.824(1-10).
[18]. *Zhu Q and Geng Y*, “Drivers and Barriers of Extended Supply Chain Practices For Energy Saving and Emission Reduction Among Chinese Manufacturers”, Journal of Cleaner Production., **vol.** 40, 2013, pp.6-12.
[19]. *Perez-Sanchez D, JR Barton and D Bowe*, “Implementing Environmental Management in SMEs”, Corporate Social Responsibility and Environmental Management., **vol.** 10(2), 2003, pp.67-77.
[20]. *Luthra, Sunil, Dixit Garg, and Abid Haleem*, “Critical Success Factors of Green Supply Chain Management For Achieving Sustainability in Indian Automobile Industry”, Production Planning & Control., **vol.** 26(5), 2015, pp.339-362.
[21]. *Mont O, and Leire C*, “Socially Responsible Purchasing in Supply Chains: Drivers and Barriers in Sweden”, Social Responsibility Journal., **vol.** *5*(3), 2009, pp.388-407.
[22]. *Montalvo C*, “General Wisdom Concerning the Factors Affecting the Adoption of Cleaner Technologies: A Survey 1990–2007”, Journal of Cleaner Production., **vol.** 16(1), 2008, pp.S7-S13.
[23]. *Lee Ki-Hoon*, “Why and How to Adopt Green Management into Business Organizations? The Case Study of Korean SMEs in Manufacturing Industry”, Management Decision., **vol.** 47(7), 2009, pp.1101-1121.
[24]. *Parker C.M, Redmond J, and Simpson M*, “A Review of Interventions to Encourage SMEs to Make Environmental Improvements”, Environment and Planning C: Government and Policy., **vol.** 27(2), 2009, pp.279-301.
[25]. *Tice J, Ahouse L and Larson T*, “Lean Production and EMSs: Aligning Environmental Management with Business Priorities”, Environmental Quality Management., **vol.** 15(2), 2005, pp.1-12.
[26]. *Tyagi M, Kumar P and Kumar D*, “Analysis of Interactions Among the Drivers of Green Supply Chain management”, International Journal of Business Performance and Supply Chain Modeling., **vol.** 7(1), 2015, pp.92-108.
[27]. *Ervin David, et al*, “Motivations and Barriers to Corporate Environmental Management”, Business Strategy and the Environment., **vol.** 22(6), 2013, pp.390-409.
[28]. Giunipero LC, Hooker RE, and Denslow D, “Purchasing and Supply Management Sustainability: Drivers and Barriers”, Journal of Purchasing and Supply Management., **vol.** 18(4), 2012, pp.258-269.
[29]. *Khidir ElTayeb, Tarig, Suhaiza Zailani, and Krishnaswamy Jayaraman*, “The Examination on the Drivers For Green Purchasing Adoption Among EMS 14001 Certified Companies in Malaysia”, Journal of Manufacturing Technology Management., **vol.** 21(2), 2010, pp.206-225.
[30]. *Hsu C.C et al*, “Supply Chain Drivers that Foster the Development of Green Initiatives in an Emerging Economy”, International Journal of Operations & Production Management., **vol.** 33(6), 2013, pp.656-688.
[31]. *Hwang CL and Yoon K*, “Methods For Multiple Attribute Decision Making. In Multiple Attribute Decision Making”, Springer Berlin Heidelberg., 1981, pp58-191.
[32]. *Chang, S.H and Tseng H.E,* “Fuzzy TOPSIS Decision Method For Configuration Management”, International Journal of Industrial Engineering: Theory, Applications and Practice., **vol.** 15(3), 2008, pp304-313.

[33]. *Atanassov K.T*, “Intuitionistic fuzzy sets”, Fuzzy Sets and System., **vol.**, 20(1), 1986, pp87-96.
[34]. *Boran, Fatih Emre, et al*, “A Multi-Criteria Intuitionistic Fuzzy Group Decision Making For Supplier Selection With TOPSIS Method”, Expert Systems with Applications., **vol.** 36(8), 2009, pp.1363-11368.
[35]. *Rutherfoord R, Blackburn R.A and Spence L.J*, “Environmental Management and the Small Firm: an International Comparison”, International Journal of Entrepreneurial Behavior & Research., **vol.** 6(6), 2000, pp.310-326.
[36]. *Pil FK, and Rothenberg S*, “Environmental Performance as a Driver of Superior Quality”, Production and Operations Management., **vol.** 12(3), 2003, pp.404-415.