Green Manufacturing Adoption Enablers for Sustainability Incorporation in Industries: Study and Empirical Investigation

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Abstract

The increased curiosity towards sustainability, environmental regulations has enforced the industrial organizations to incorporate environmental friendly approaches. The green manufacturing practices lead to less carbon footprints, and material efficiency. To deploy green practices the organizations must have a round of preparation. The green manufacturing adoption enablers provides the systematic round of preparation to adopt green manufacturing effectively. The organizations have to invest ample resources for the preparation for a new approach, so it cannot focus on all the enablers. So, the present study also prioritizes the GM adoption barriers using grey relational analysis (GRA). It has been found that organizational readiness for green manufacturing; top management support and linking of business practices with green measures are the top ranked enablers. The GRG of the top ranked enablers using GRA were found to be 0.772, 0.674 and 0.649 respectively. The present study will facilitate the industrial mangers and practitioners to adopt sustainable green manufacturing practices in their respective organizations. The study will also facilitate the manufacturing sector to fulfill their ambitious targets on environ mental emissions.

Keywords: Green manufacturing; Sustainability; Enablers; Grey relational analysis; Clean technologies.

1. Introduction

The rapid industrial growth combined with the use of the natural resources has led to substantial increase in the temperature of our plant since the industrial age . The increased temperature has resulted in the increased duration of rains, draughts, changing pattern of the crop, and endangering of rare earth species . The industries contribute nearly 20% of the greenhouse gases (GHGs). The reasons for the same can be attributed to conventional methods of production and excessive dependency on fossil fuel based energy methods. The green manufacturing is that form of manufacturing that leads to increased material and energy efficiency. The adoption of GM practices leads to healthy work environment and serves the Mother nature. Figure 1 depicts a GM model in the industry.

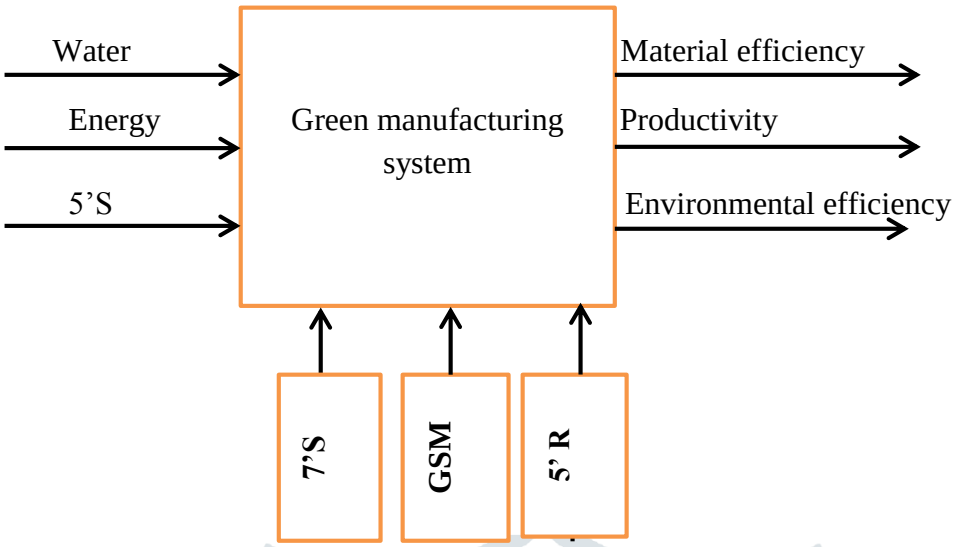

Figure 1: Green manufacturing model

To adopt GM practice in industry the industries need to invest in clean technologies, need major overhauls and induce an ambiance for change (Rathi et al., 2016). The present work deals with the identification and investigation of the GM enablers in the manufacturing enterprises. The industries cannot pinpoint all the enablers during the inception of GM plan. So, there is a need to find out the key enablers that can be addressed at the incremental implementation of GM in a particular section of the industry. The comprehensive literature study pertains to GM, 10 enablers have been found out. To rank the enablers the advance decision making approach, grey relational analysis (GRA) has been used in the present work.

The article has been organized in five sections comprising introduction. The literature survey pertains to GM was done in the 2nd section of the article. The 3rd section of the manuscript is devoted to the adopted research methodology. The results and discussion have been presented in the 4th section of article. The inferences of the present work have been presented in the 5th section of the manuscript.

2. Literature review

To mitigate the environmental concerns the industrial organizations are spending huge capital on the research and development of clean technologies. The industrial organization can take the break through advantages by the adoption of green manufacturing practices in their operations. The GM practices like dry machining, cryogenic machining, near dry machining, additive manufacturing are being adopted by the industrial organizations (Rathi et al., 2015). But to implement GM practices, the organization need a hug changeover together with utilization of the resources. So, the shift from traditional to sustainable manufacturing practices is a huge task. The enabler serve as the readiness measures that facilitates the organization to be prepared before the inception of any novel approach. In the present work the enablers of GM have been found out through the comprehensive literature survey from the electronic data bases of the reputed publishers. Table 1 depicts the GM adoption enablers in the manufacturing sector.

3. Research methodology

The research methodology adopted in this research work consists of two phases. The first is related to the identification of prominent enablers. The second phase deals with the collection of the responses from the manufacturing personnel and prioritization of the enablers using GRA. The responses were collected from the 60 industrial personnel of the 15 manufacturing industries of the national capital region of India. The responses were collected through questionnaire based survey in Likert scale where 1 represent less important and 5 represents the most important. Figure 2 represents the adopted research methodology.

Step 1: In the first step in comparability sequence is made. For this, the normalized values are obtained using equation (2)

$$x_j^*(s) = \frac{x_j^0(s) - \min x_j^0(s)}{max\, x_j^0(s) - min\, x_j^0(s)} \quad (1)$$

Step 2: The grey relational coefficient is calculated in this step

$$B_{ij}(s) = \frac{\Delta_{min} + B.\Delta_{max}}{\Delta_{oi}(s) + B.\Delta_{max}} \quad (2)$$

$\Delta_{oi}=$ the deviation sequence

$$\Delta_{oi} = \|x_o^* - x_1^* s\| \quad (3)$$

Step 3: In this step, the grey relational grade is estimated using equation (4)

$$B_i = \frac{1}{m}\sum_{s=1}^{m} w_k(s) B_i(s) \quad (4)$$

here,

$w_s(s) = 1$

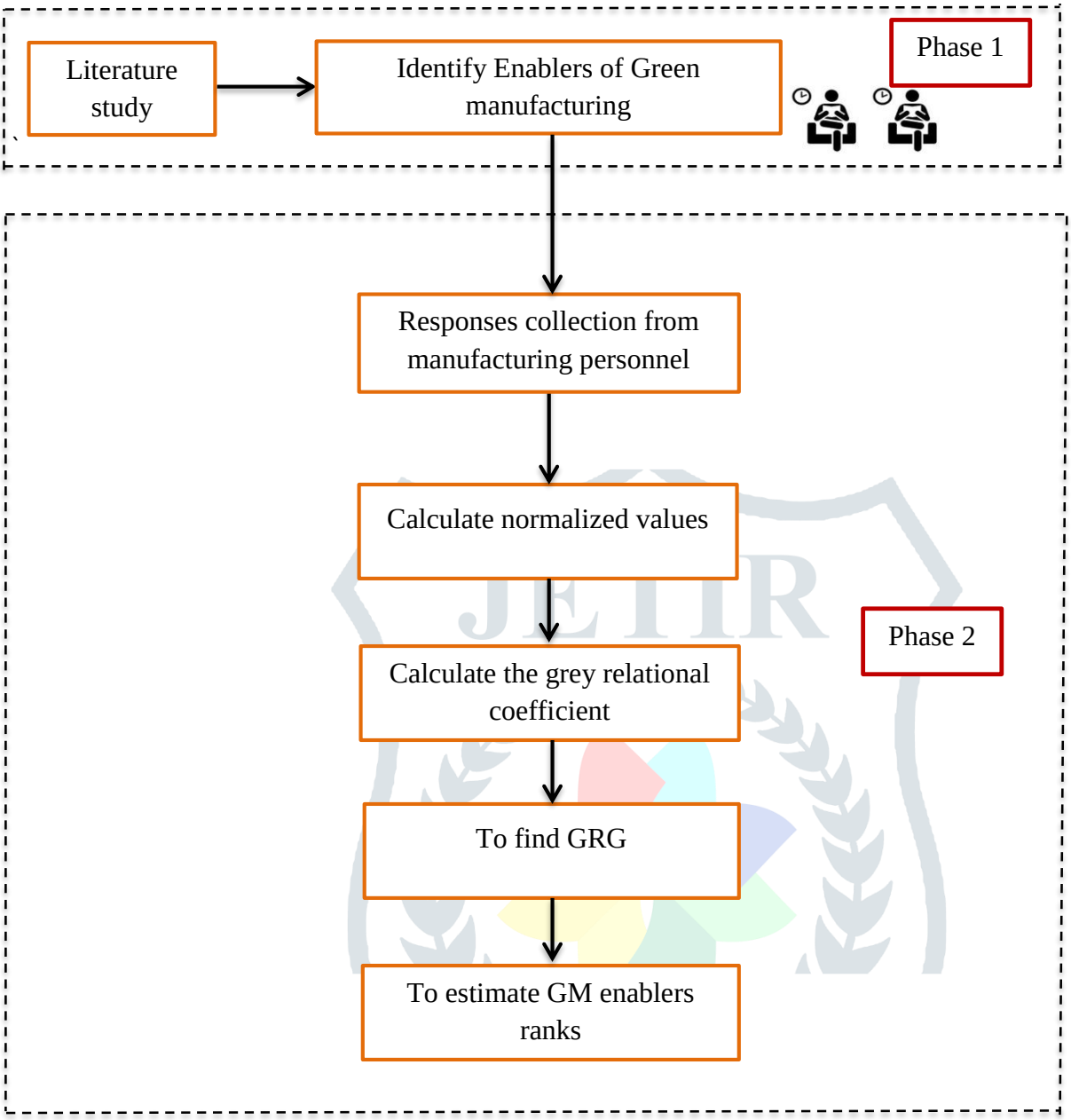

Figure 2: Research Methodology

4. Results and Discussion

The responses collected in the first phase are analyzed using GRA to prioritize the readiness measures. Table 2 depicts the responses collected from the industrial personnel. The various steps associated with GRA are:

Table 2: Responses from the manufacturing personnel

S. No.	Enablers	SM	DM	E	A	AC
1	E1	29	25	22	23	29
2	E2	31	27	32	34	32
3	E3	34	35	34	32	34
4	E4	37	32	31	36	32
5	E5	38	33	37	41	25
6	E6	27	36	35	35	35
7	E7	29	34	34	29	34

8	E8	26	43	39	26	41
9	E9	42	32	41	28	44
10	E10	20	29	28	32	27

Step1: The normalized values are obtained using the equation (1). Table 3 depicts the normalized values.

S. No.	Enablers	SM	DM	E	A	AC
1	E1	0.409	0.000	0.000	0.000	0.211
2	E2	0.500	0.111	0.526	0.611	0.368
3	E3	0.636	0.556	0.632	0.500	0.474
4	E4	0.773	0.389	0.474	0.722	0.368
5	E5	0.818	0.444	0.789	1.000	0.000
6	E6	0.318	0.611	0.684	0.667	0.526
7	E7	0.409	0.500	0.632	0.333	0.474
8	E8	0.273	1.000	0.895	0.167	0.842
9	E9	1.000	0.389	1.000	0.278	1.000
10	E10	0.000	0.222	0.316	0.500	0.105

Step2: The grey relational coefficient is calculated in this step using equation (2). Table 4 depicts the grey relational coefficients.

Table 4: Grey relational coefficients

S. No.	Enablers	SM	DM	E	A	AC
1	E1	0.458	0.333	0.333	0.333	0.388
2	E2	0.500	0.360	0.514	0.563	0.442
3	E3	0.579	0.529	0.576	0.500	0.487
4	E4	0.688	0.450	0.487	0.643	0.442
5	E5	0.733	0.474	0.704	1.000	0.333
6	E6	0.423	0.563	0.613	0.600	0.514
7	E7	0.458	0.500	0.576	0.429	0.487
8	E8	0.407	1.000	0.826	0.375	0.760
9	E9	1.000	0.450	1.000	0.409	1.000
10	E10	0.333	0.391	0.422	0.500	0.358

Step3: The grey relational grade and ranks of the enablers are calculated using equation (3). Table 5 depicts the ranks of green manufacturing enablers.

Table 5: Ranks of the green manufacturing adoption enablers

S. No.	Enablers	SM	DM	E	A	AC	GRG	Rank
1	E1	0.458	0.333	0.333	0.333	0.388	0.369	10
2	E2	0.500	0.360	0.514	0.563	0.442	0.476	8
3	E3	0.579	0.529	0.576	0.500	0.487	0.534	6
4	E4	0.688	0.450	0.487	0.643	0.442	0.542	5
5	E5	0.733	0.474	0.704	1.000	0.333	0.649	3
6	E6	0.423	0.563	0.613	0.600	0.514	0.542	4

7	E7	0.458	0.500	0.576	0.429	0.487	0.490	7
8	E8	0.407	1.000	0.826	0.375	0.760	0.674	2
9	E9	1.000	0.450	1.000	0.409	1.000	0.772	1
10	E10	0.333	0.391	0.422	0.500	0.358	0.401	9

5. Conclusion and future scope

Sustainable development approach leads to increased profitability, productivity and corporate image of the organization in the long run. The demands for the eco-friendly products and environmental regulation policies have enforced the manufacturing organizations to incorporate green technologies in their production system. The present work have identified and prioritized GLS enablers in the manufacturing sector. Through the detailed literature pertains to green manufacturing ten prominent enablers of green manufacturing adoption have been found. The ranking of the enablers has been found using the GRA. It has been found that organizational readiness for green manufacturing; top management support and linking of business practices with green measures are the top ranked enablers. The GRG of the top ranked enablers using GRA were found to be 0.772, 0.674 and 0.649 respectively. The top management provides the resources for finance and incorporation and training of clean or green technologies. The linking of business objectives with green measures make everyone in the system for the increase sustainability of the organization. The present work will facilitate the industrial organization to corporate clean technologies in their operations. The society will be benefitted through this research work in terms of lesser environmental emissions through the incorporation of the green manufacturing.

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