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Adoption of Integrated Lean-Green-Agile Strategies for Modern Manufacturing Systems

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Abstract

Ever increasing customer choices, environmental concerns and competitiveness among manufacturers across the globe has engaged the industry to embrace newer manufacturing strategies. Predominantly, there are three dimensions to modern manufacturing systems *viz.* economic, environmental and social. The integration of lean-green-agile manufacturing strategies would be a complete and comprehensive manufacturing system which is the need of the 21st century. The adoption of Lean-Green-Agile Manufacturing System (LGAMS) would be facilitated by few enablers. The influence of these enablers is a matter of investigation which is addressed by the present study. An attempt has been made to prioritize the facilitating capacity of each enabler. The outcome of the research would facilitate the policy makers in the industry and government to frame policies.

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Keywords: Lean Manufacturing, Green Manufacturing, Agile Manufacturing, Enablers, Multi-Criteria Decision Method, Entropy Approach, MOORA Method, VIKOR Analysis

1. Introduction

The present society is craving for a sustainable system that enables growth without compromising the ability of the future generations to meet their needs and demands [1]. Economic prospects, ecological balance and social responsibility are three very important parameters which are indispensable for achieving sustainability [2]. It is the harmonious interaction among these dimensions which ensures balanced growth and development of the society. The collective approach of addressing these three dimensions is referred to as ‘Triple Bottom Line’ [3].

In the past these dimensions have been studied individually, so the focus lies on green manufacturing or lean manufacturing or agile manufacturing separately. But now the time has come to amalgamate lean, green and agile manufacturing strategy to build a unanimous structure [4].

The lean manufacturing strategy which acts at system’s level saves cost by reducing wastes in the manufacturing system thereby addressing the economic dimension; the green manufacturing strategy which acts at process level saves environment by reducing emissions and resource use thereby addressing the environmental dimension; and the agile manufacturing strategy which acts at product level satisfies the customer in the society by providing the required product of their choice in time thereby addressing the social dimension.

A framework of Lean Green Agile Manufacturing System (LGAMS) developed to integrate lean, green, and agile strategies is presented in figure 1. This provides the holistic

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approach to address the three dimensions of 'Triple Bottom Line'.

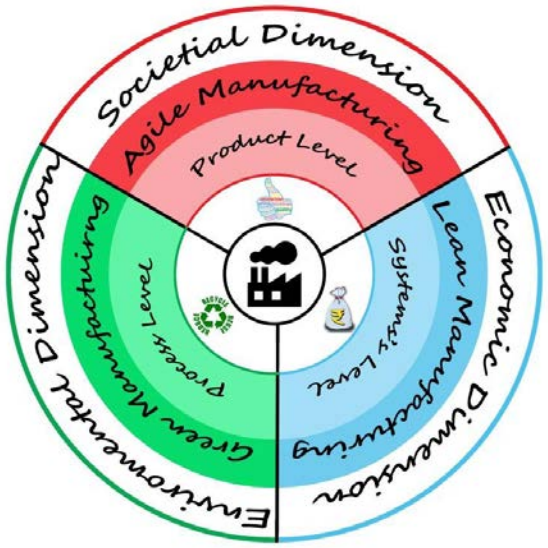

Figure 1: Framework of LGAMS

The implementation of LGAMS in the modern manufacturing system requires facilitation for faster implementation. Particularly, for fortifying the industry, enablers for LGAMS are investigated. So, from the thorough literature survey and with the help of academic and industry professionals 10 enablers have been identified for LGAMS. These enablers are the parameters which can prove very helpful in the establishment of the LGAMS.

The rest of the paper is as follows: section 2 provides research background followed by methodology in section 3. Section 4 provides results and discussion of the research. Section 5 presents the conclusion from the study followed by acknowledgements and references.

2. Research Background

Lean Manufacturing (LM) is defined as an integrated manufacturing system aimed at maximizing the capacity and the utilization without involving any extra cost in it and also minimizing the buffer inventories by applying various techniques in minimizing system variabilities [5]. LM depends on bundles of practices which not only support this system in implementation but also provide a support system. [6]. LM and management system widens its area of influence by covering almost everything starting from product development to product distribution and at the end the customers [7].

During the recent times, the amalgamation of social approach and lean implementation has gained attention in area of academic research [8]. Nevertheless, the results deduced are not systematic. De Treville and Antonakis stated that internal human resources play a major role through which the enforcement of lean practices run into social performance [5].

Many researchers have talked about certain green production practices such as green manufacturing, raw material reduction and environmental design. This has to be delt both quality wise and variety [9]. By doing so, companies can hugely decrease ill effects of their products and production process on the environment.

The interaction between environmental management practices and numerous factors of firm performance which is mainly related to sustainability is very well researched topic [10-11]. Enhanced environmental performance had its benefits on financial performance. A positive impact can be seen on social and environmental performance by implementing environmental management practices and this is achieved by reducing resource consumption as well as improving stakeholder relations.

LM is totally based on the concept of how to response to competitive pressures with limited resources in hand. For the productive use of resources, operational techniques are concentrated upon. But then, agile manufacturing is a response to complexity and dynamism that is brought about by regular change. In this, strategies are developed upon on how to thrive in an unpredictable environment. The prime focus of agile is on the individual customer. Some parameters are exhorted from lean. One such example includes refinement of mass production in which unilateral producer-centered customer-responsive is established. This has been developed as interactive producer-customer relationships in agile [12]. Sharing resources and technologies among companies becomes mandatory and agile enables one to think beyond a single firm. Cooperation with the help of good terms in relationships wins the competitive environment of an enterprise. Flexibility to adopt is the most important key in the agile enterprise which serves as a greater deal for its competitive advantage. However, it is equally important to manage an internal cross-functional team with the inclusion of customers and suppliers. Eventually, this may also be in the form of virtual company or collaborative ventures [13].

Agile manufacturing has started to make a mark in both industrial and academic communities. Extensive programmes are quite beneficial to broadcast certain issues regarding agile manufacturing which ultimately develops agile enterprise prototypes and thus paves the way for an agile industry.

As shown in figure 1, the LGAMS is a system which addresses the triple bottom line dimensions of manufacturing systems. The adoption of the same would enhance the performance and effectiveness of the manufacturing system. The enablement of such new system is required to change the way the manufacturing is done. So, identification and analysis of LGAMS enablers is attempted in the present study.

3. Methodology

Ten enablers are identified through a review of literature and discussion with experts in the industry and academia. The development of these enablers is done while referring to the literature on lean, green and agile strategies to showcase the clear relevance of enablers. Moreover, the actual issues encountered during the implementation of individual manufacturing system by the industry are incorporated

through the discussion with the industry executives. The description of the 10 enablers is mentioned below:
Supplier Involvement (E1): In LM, close contact with supplier for deliveries arrives in right qualities which help in reducing waste. In order to adopt green & clean theory organisations need to align suppliers towards them and impart regular training. In AM, maintain relationship with supplier to spontaneous supply of raw material for satisfying customer's flexible demand [14].
Top Management Commitment (E2): LM advocates as leaders refers to employees as associates not commodities, leading by example, coaching and mentoring [15]. Top management beliefs, practice and commitment towards the green production. Transparency in information sharing, regular conduct of management-employee meetings, participative management are some attributes of agile manufacturing systems.
Flexible Work Force (E3): Flexible workforce, multi skilled personnel, implementation of job rotation system, more aware, trained workforce and higher innovative capacity is in demand in lean, green and agile manufacturing systems [16].
Human Resource Management (E4): Co-cooperativeness, active involvement, firm belief and spirit, decision making capability among the employees are very important for LGAMS setup [17].
Flexible Work place (E5**)**: Eco-friendly and worker friendly work place, highly automated setups, up gradation and retrofitting of setups, usage of collapsible setups, jigs and fixtures, well equipped service centres help in building a flexible workplace [18].
Customer Focus (E6**)**: Close contact with customer, customer give feedback on quality, cost and delivery. Customers are getting more educated about the environment degradation and they want product to be environment friendly [19]. Specification of product life to customer, encourage customer for switching to a new product.
Customer Feedback System (E7): Usage of well define VOC (Voice of customer), customer touch points have been identified, empower employee to resolve customer. Welcome customer's suggestion about green concept and make an environment that customer give feedback easily. Incorporation of customer's fed back into products leads to effective customer feedback and contentment among the customers regarding the service [20].
Information Technology Integration (E8): Increase communication between departments which reduce waste of time. IT resources for implementing green concept, handle material flow and other resources to manage green supply chain efficiently [21]. IT application to eliminate paper work, adoption of multimedia technology for communication is done in LGA systems.
Resource Optimization (E9): Use of advanced optimization techniques to maintain minimum inventory levels and hence reduce waste [22]. The use of natural resources in sustainable manner.
Product Life Cycle management (E10): Recycling of product reduces the waste in environment which help lean concept of waste elimination [16]. Proper disposal of end product may lead to environment protection, efficient reusing and recycling. Reverse logistic techniques increase relationship with customer and easily understand demand.
The six criteria selected for the study are presented in table 1. These criteria are categorised as beneficial and non-beneficial based on the impact of enablers on LGAMS implementation. The importance and weightage of criteria used for the analysis is calculated using entropy approach.

The investigation and prioritization of 10 enablers using MOORA method and VIKOR analysis is done. The inputs for the study are taken (on Likerts' scale of 1 to 10) from four experts *i.e.* two experts from academia which are working in the field of manufacturing engineering and management; two from industry which are responsible for overall performance of the company (see Table 1).

3.1 Entropy approach:

Entropy comes from thermodynamic to information systems and this great work done by Shannon [23]. Information entropy defined as incalculability of signals in communication process and as decrease the information entropy, weight of particular criteria is increase [24]. Entropy approach is very useful for measuring the relative importance of each criterion which represents the inlaying data given to the decision maker [25, 26]. Entropy approach has various advantage as compare to other Multi-Criteria Decision Method (MCDM) processes as easy to understand and solve, less time consuming and easy mathematical calculation.This method is widely used by various researchers like selection of supplier [26], evaluation of products [27], Determination of zero-coupon and spot rates [28] *etc.* Step involved in entropy weight allocation method suggested by [29-31] are as follows:

Table 1: Data collection

Criteria	Beneficial			Non-Beneficial		
Enablers	C1	C2	C3	C4	C5	C6
E1	6	3	5	6	5	8
E2	8	6	8	7	5	7
E3	9	4	6	4	7	7
E4	6	6	6	7	6	7
E5	8	7	8	8	7	7
E6	7	6	9	7	6	6
E7	9	7	9	7	5	5
E8	7	7	7	8	4	7
E9	9	8	8	6	6	7
E10	6	9	6	6	8	8

C1-Productivity Improvement; C2- Emission Curtailment; C3- Customer Satisfaction; C4- Financial Obligation; C5- Regulatory Requirement; C6- Resource Requirement

Step 1: Normalizing of a matrix

Available ratios to normalize the data are Total ratio, Stopp ratio, Weitendorf ratio, Schärlig ratio, Körth ratio, Jüttler ratio *etc.* For this calculation we use total ratio. Equation for total ratio is

$$Xij=\frac{Xij}{\sum_{i=1}^{m} Xij}(j=1,2,3.....n) \qquad 1)$$

Normalized data of table 1 is calculated with the help of equation 1 and shown in 2nd to 11th row of table 2.

Step 2: Calculation of Nj value for each criteria
Equation for Nj value is

$$N_j = -k \sum_{i=1}^{n} X_{ij} * \ln(X_{ij}) \qquad j = 1,2\ldots\ldots m \qquad 2)$$

Where $k = 1/\ln(n)$ 3)

Calculated N_j value using equation 2 is shown in 12th row of table 2.

Step 3: Calculation of Weight for each criteria

Equation for calculating weight for 'j' criteria is

$$w_j = \frac{1-N_j}{\sum_{j=1}^{n}(1-N_j)} \text{ where } j = 1,\ldots,n. \qquad 4)$$

Calculated weight using equation 4 is shown in 14th row of table 2

3.2 VIKOR analysis:

VIKOR analysis is introduced by Opricovic in 1998 to solve Multi-criteria Optimization and Compromise Solution [32]. Extended version of VIKOR analysis is presented by Opricovic and Tzeng [33]. This analysis gives index based multi-criteria ranking on the basis of 'closeness' to the 'ideal' solution [34]. The VIKOR analysis provides the maximum group utility for the majority and a minimum of individual regret for the opponent.

Table 2: Criteria weight calculation using Entropy approach

	C1	C2	C3	C4	C5	C6
E1	0.080	0.048	0.069	0.091	0.085	0.116
E2	0.107	0.095	0.111	0.106	0.085	0.101
E3	0.120	0.063	0.083	0.061	0.119	0.101
E4	0.080	0.095	0.083	0.106	0.102	0.101
E5	0.107	0.111	0.111	0.121	0.119	0.101
E6	0.093	0.095	0.125	0.106	0.102	0.087
E7	0.120	0.111	0.125	0.106	0.085	0.072
E8	0.093	0.111	0.097	0.121	0.068	0.101
E9	0.120	0.127	0.111	0.091	0.102	0.101
E10	0.080	0.143	0.083	0.091	0.136	0.116
N_j	0.904	0.854	0.900	0.895	0.866	0.882
$1- N_j$	0.096	0.146	0.100	0.105	0.134	0.118
W_j	0.138	0.209	0.144	0.150	0.191	0.168

This analysis focuses on selecting the best option from a set of feasible options in presence of mutually conflicting criteria [35]. It is successfully used by various researchers like in machine tool selection [36], green supply chain management [37], outsourcing projects [38], supplier selection [39] *etc*. First step involved in VIKOR analysis is normalizing the matrix which has already done in table 2 and further steps are as follows:

Step 1: Calculation of difference between the ith enabler to the positive ideal solution (E_i value)

For beneficial criteria:

$$E_i = \sum_{j=1}^{n} W_j \frac{X_{ijmax} - X_{ij}}{X_{ijmax} - X_{ijmin}} \qquad 5)$$

For non-beneficial criteria:

$$E_i = \sum_{j=1}^{n} W_j \frac{X_{ij} - X_{ijmin}}{X_{ijmax} - X_{ijmin}} \qquad 6)$$

Calculated value of E_i by using equation 5 and 6 for each enabler shows in 2nd column of table 3.

Step 2: Calculation of difference between the ith alternative to the negative ideal solution (F_i value)

For beneficial criteria:

$$F_i = Maximum\ of\ \frac{W_j(X_{ijmax} - X_{ij})}{X_{ijmax} - X_{ijmin}} \quad \text{(i=1, 2....., n)} \qquad 7)$$

For non-beneficial criteria:

$$F_i = Maximum\ of\ \frac{W_j(X_{ij} - X_{ijmin})}{X_{ijmax} - X_{ijmin}} \quad \text{(i=1, 2....., n)} \qquad 8)$$

Calculated value of F_i using equation 7, 8 for each enabler shows in 3rd column of table 3.

Step 3: Calculation of Pi value

$$P_i = v \left[\frac{E_i - E_{imin}}{E_{imax} - E_{imin}}\right] + (1-v)\left[\frac{F_i - F_{imin}}{F_{imax} - F_{imin}}\right] \qquad 9)$$

Here we assume VIKOR constant v = 0.5. Calculated value of P_i for each enabler shows in 4th column of table 3.

Step 4: Ranking the Enablers

The LGAMS enabler with low P_i value is most effective, whereas, the one with large value is less effective. Ranking of LGAMS enablers is shown accordingly in 5th column of table

3.3 MOORA method

Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method was introduced by Brauers (2004). MOORA method is MCDM technique that can be successfully applied to solve different types of decision making problem [40]. This methodology has been successfully used by various researchers for supplier selection [41], material selection [42], optimizing milling process [43-44], and privatization in a transition economy [45]. Normalize the input matrix is first step towards implementation of MOORA method which is already done in table 2 and further steps used in MOORA method are as follows:

Step 1: Calculation of Y_i

Normalized performances are added in case of maximization (for beneficial attributes) and subtracted in case of minimization (for non-beneficial attributes) give Y_i value. The final equation to calculate Y_i is

$$Y_i = \sum_{j=1}^{g} Xij - \sum_{j=g+1}^{n} Xij \qquad 10)$$

Where '*g*' is the number of beneficial goals, (*n-g*) is the number of non-beneficial goals and Y_i is the normalized assessment value for ith alternative. In the present case some criteria are more important than the others. So, to give more importance to criteria, it is multiplied with its respective weight [43].When these criteria weights are taken into consideration then new equation to calculate Y_i is

$$Y_i = \sum_{j=1}^{g} Wj * Xij - \sum_{j=g+1}^{n} Wj * Xij \quad \text{(j=1, 2, 3.....n)} \qquad 11)$$

Where, W_j is the weight of jth alternative used from table 2. Values of Y_i are calculated for enablers with the help of equation 11 as shown in column 6 of table 3.

Step 2: Ranking of LGAMS Enablers

Any value of Y_i is acceptable *viz.* positive, negative or zero because it depends upon beneficial and non-beneficial criteria and their respective weight total. The most effective cooking fuel is one whose Y_i value is large and less effective is one whose Y_i value is small. Column 7 of table 3 shows ranking of each LGAMS enabler according to Y_i value.

4. Results and Discussion

This section compares the outcomes obtained from VIKOR analysis and MOORA method. Both the approaches provide the ranking of LGAMS enablers. P_i and Y_i values are calculated in column 5 and 7 of table 3 by VIKOR analysis

Table 3: Ranking of LGAMS Enablers by both methods

Enablers	VIKOR analysis				MOORA		R**
	E_i	F_i	P_i	R*	Y_i	R*	
E1	0.2370	0.2092	0.9577	10	-0.0283	10	10
E2	-0.1325	0.1259	0.3799	4	-0.0145	4	4
E3	0.0808	0.1990	0.7947	9	-0.0190	7	9
E4	0.2879	0.1376	0.7673	8	-0.0215	9	8
E5	0.0885	0.1069	0.5019	5	-0.0200	8	5
E6	-0.0820	0.1636	0.5445	6	-0.0172	5	6
E7	-0.3005	0.0553	0.0107	1	-0.0045	1	1
E8	-0.0776	0.0718	0.2496	3	-0.0121	3	3
E9	-0.3134	0.0632	0.0257	2	-0.0070	2	2
E10	0.0555	0.1376	0.5740	7	-0.0181	6	7

R - Rank; R**- Final Rank*

and MOORA method which are also represented in figure 2 and 3 respectively. Combined plot of P_i and Y_i value is represented in figure 4. Higher value of Y_i and lower value of P_i represent best LGAMS enabler and vice versa. Y_i and P_i value of all enablers provide us a succinct way to compare the results of MOORA method and VIKOR analysis. Customer feedback system (enabler 7) achieved highest Y_i value as -0.00456 and lowest P_i value as 0.01407 among other enablers. Therefore it occurs at first rank in comparison with all other enablers. After customer feedback system, enabler 9 (resource optimization) gets Y_i value as -0.0070903 and P_i value as 0.0257 which shows that enabler 9 occurs second rank in all enablers. Enabler 1 (supplier involvement) have maximum distance between Y_i and P_i value as shown in figure 4, which signifies that enabler 1 is less effective among all enablers. The final ranking of all enablers is done accordingly with the help of graph in figure 4 and accessible in column 8 of table 3.

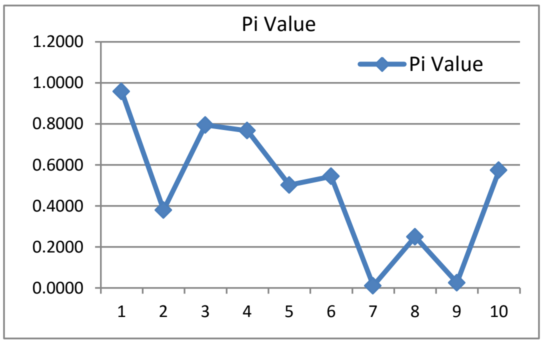

Figure 2: P_i Value by VIKOR Analysis

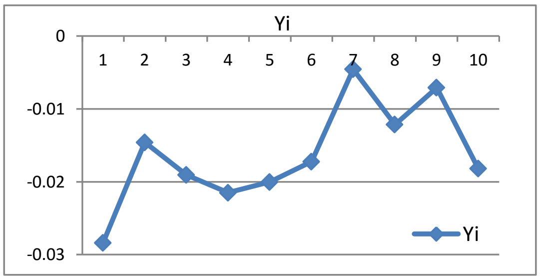

Figure 3: Y_i Value by MOORA Method

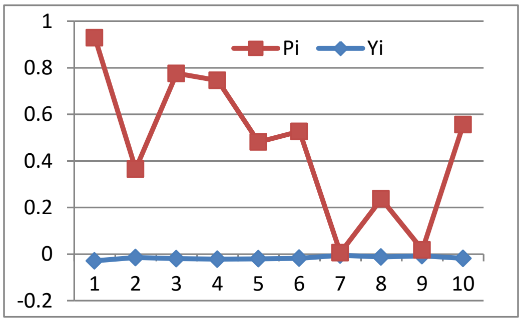

Figure 4: Combined plot of P_i and Y_i values

This ranking of LGAMS enablers can be used as an aid to develop a suitable strategy for design and implementation of LGAMS in any organization. These findings will allow the management to efficiently utilize their resources to focus on the most significant and important enablers. The organization would achieve competitiveness, customer satisfaction and environmental concern *etc.* from the above findings which will help in taking the industry towards advanced manufacturing practices.

5. Conclusion

The application of Entropy approach, VIKOR analysis and MOORA method on LGAMS enablers identified from the exploration of extant literature and discussion with experts from academia and industry yielded a ranking which is presented in table 3. There is a dearth of empirical literature on LGAMS as it is relatively a new concept. An initial analysis of LGAMS enablers will help the policy makers to understand the potential of actual implementation of LGAMS in Indian manufacturing industry. The present work provides the weightage of criteria and ranking of LGAMS facilitators, which will help in identifying the significant enablers which should be given primary consideration during the course of implementation of LGAMS in order to make the manufacturing system efficacious.

A further analysis of the enablers by collecting quantitative data from the academia experts, policy makers, and practitioners in the industry could through more light on the topic to enhance the subject knowledge. The possibility of application of statistical data analysis tools like structural equation modelling can be explored so that the LGAMS could be better understood.

Based on the results obtained from the study, the following actions are suggested to foster the LGAMS implementation in Indian manufacturing industry.

1. The Customer feedback system should be designed in such a way that it will directly link with designing and production department of the organization. There should be a provision of imparting new design of the running product after getting feedback from the customers.

2. There should be proper optimization of the resource available in the organization by applying different optimization technique. It helps to maintain minimum inventory level of the raw material and final products which

would result in improved and expeditious conception of new services.

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References

[1] Choi TM, Yongjian Li. Sustainability in Fashion Business Operations. Sustainability 2015; 7(11): 15400-406.
[2] Savitz AW, Weber K. The Triple Bottom Line; Jossey-Bass: San Francisco, NC, USA, 2006.
[3] Gimenez C, Sierra V, Rodon J. Sustainable Operations: Their Impact on the Triple Bottom Line. IJ Prod. Econ. 2012; 140: 149–159.
[4] Christopher M, Lowson R, Peck H. Creating Agile Supply Chains in the Fashion Industry. IJ Retail Distrib. Manag. 2004; 32: 367–376.
[5] De Treville S, Antonakis J. Could Lean Production Job Design Be Intrinsically Motivating? Contextual, Configurational, and Levels-of-Analysis Issues. J. Oper. Manag. 2006; 24: 99–123.
[6] Yang MG, Hong P, Modi SB. Impact of Lean Manufacturing and Environmental Management on Business Performance: An Empirical Study of Manufacturing Firms. IJ Prod. Econ. 2011;129: 251–61.
[7] Jasti NVK, Kodali R. Lean Production: Literature Review and Trends. IJ Prod. Res. 2014; 53: 867–885.
[8] Martínez-Jurado PJ, Moyano-Fuentes J. Lean Management, Supply Chain Management and Sustainability: A Literature Review. J Clean. Prod. 2013; 85: 134–150.
[9] Gonzalez P, Sarkis J, Adenso-Diaz B. Environmental Management System Certification and Its Influence on Corporate Practices—Evidence From the Automotive Industry. IJ Oper. Prod. Manag. 2008; 28: 1021–41.
[10] Gotschol A, Giovanni PD, Vinzi VE. Is Environmental Management an Economically Sustainable Business? J Environ. Manag. 2014; 144: 73–82.
[11] Pullman ME, Maloni MJ, Carter CR. Food for Thought: Social versus Environmental Sustainability Practices and Performance Outcomes. J. Supply Chain Manag. 2009; 45: 38–54.
[12] Goldman SL, Nagel RN, Preiss K. Agile Competitors and Virtual Organizations: Strategies for Enriching the Customer 1994 (New York: Van Nostrand Reinhold).
[13] Nagel RN, Dove R. 21st Century Manufacturing Enterprise Strategy: An Industry-lead View Volume 1. 1991 (Bethlehem, PA: Iacocca Institute).
[14] Sindhwani, R., & Malhotra, V. Overview and drivers of agile manufacturing system: A review. International Journal of Marketing and Technology. 2013; 3(12), 144-154.
[15] Mittal, V.K., Sangwan, K.S. Ranking of Drivers for Green Manufacturing Implementation using Fuzzy TOPSIS method, Journal of Multi-Criteria Decision Analysis. 2015; 22, (1-2):119-130.
[16] Sindhwani, R., & Malhotra, V. Modelling the attributes affecting design and implementation of agile manufacturing system. International Journal of Process Management and Benchmarking. 2016; 6(2), 216-234.
[17] Mittal, V.K., Sangwan, K.S. Prioritizing Barriers to Green Manufacturing: Environmental, Social and Economic Perspectives, Elsevier - Procedia CIRP. 2014; 17:559-564.
[18] Sindhwani, R., & Malhotra, V. Modelling and analysis of agile manufacturing system by ISM and MICMAC analysis. International Journal of System Assurance Engineering and Management, 1-11.
[19] Sangwan, K.S., Mittal, V.K. A Bibliometric Analysis of Green Manufacturing and Similar Frameworks, Management of Environmental Quality: An Intl. Journal. 2015; 26(4):566-587.
[20] Mittal, V.K., Sangwan, K.S. Prioritizing Drivers for Green Manufacturing: Environmental, Social and Economic Perspectives, Elsevier - Procedia CIRP.2014; 15: 135-140.
[21] Mittal, V.K., Sangwan, K.S., Herrmann, C., Egede, P. Comparison of Drivers and Barriers to Green Manufacturing: A Case of India and Germany. Re-engineering Manufacturing for Sustainability, ISBN: 978-981-4451-47-5 (Eds: Nee, Song and Ong), Singapore. 2013; 723-728.
[22] Mittal, V. K., Sindhwani, R., & Kapur, P. K. Two-way assessment of barriers to Lean–Green Manufacturing System: insights from India. International Journal of System Assurance Engineering and Management 2016; 7(4):400-407.
[23] Shannon CE. A mathematical theory of communication. ACM SIGMOBILE Mobile Computing and Communications Review 2001; 5(1): 3-55.
[24] Ji Y, Huang GH, Sun W. Risk assessment of hydropower stations through an integrated fuzzy entropy-weight multiple criteria decision making method: A case study of the Xiangxi River. *Expert Systems with Applications* 2015; 42(12): 5380-89.
[25] Zeleny M. Multiple criteria decision making. (1996) New York: Springer.
[26] Shemshadi A, Shirazi H, Toreihi M, Tarokh MJ. A fuzzy VIKOR method for supplier selection based on entropy measure for objective weighting. Expert Systems with Applications 2011; 38(10): 12160-67.
[27] Dashore K, Pawar SS, Sohani N, Verma DS. Product Evaluation Using Entropy and Multi Criteria Decision Making Methods. IJ of Engineering Trends and Technology 2013; 4(5): 2183-2187.
[28] Gzyl H, Mayoral S. Determination of zero-coupon and spot rates from treasury data by maximum entropy methods. Physica A: Statistical Mechanics and its Applications 2016; 456: 38-50.
[29] Soleimani-Damaneh M, Zarepisheh M. Shannon's entropy for combining the efficiency results of different DEA models: Method and application. Expert Systems with Applications 2009; 36(3): 5146-5150.
[30] Lihong M, Yanping Z, Zhiwei Z. Improved VIKOR algorithm based on AHP and Shannon entropy in the selection of thermal power enterprise's coal suppliers. In International conference on information management, innovation management and industrial engineering, (2008) pp. 129–133.
[31] Wang TC, Lee HD. Developing a fuzzy TOPSIS approach based on subjective weights and objective weights. Expert Systems with Applications 2009; 36(5): 8980–8985.
[32] Opricovic S. Multi-criteria optimization of civil engineering systems. Faculty of Civil Engineering, Belgrade 1998; 2(1): 5-21.
[33] Opricovic S, Tzeng GH. Extended VIKOR method in comparison with outranking methods. European J of operational research 2007; 178(2): 514-529.
[34] Opricovic S, Tzeng GH. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. European J of Operational Research 2004; 156(2): 445-455.
[35] Ranjan R, Chatterjee P, Chakraborty S. Performance evaluation of Indian Railway zones using DEMATEL and VIKOR methods. Benchmarking: An IJ 2016; 23(1): 78-95.
[36] Wu Z, Ahmad J, Xu J. A group decision making framework based on fuzzy VIKOR approach for machine tool selection with linguistic information. Applied Soft Computing 2016; 42: 314-324.
[37] Rostamzadeh R, Govindan K, Esmaeili A, Sabaghi M. Application of fuzzy VIKOR for evaluation of green supply chain management practices. Ecological Indicators *2015; 49:* 188-203.
[38] Chen LY, Wang TC. Optimizing partners' choice in IS/IT outsourcing projects: The strategic decision of fuzzy VIKOR. IJ of Production Economics 2009; 120(1): 233-242.
[39] Awasthi A, Kannan G. Green supplier development program selection using NGT and VIKOR under fuzzy environment. Computers & Industrial Engineering 2016; 91: 100-108.
[40] Gadakh VS. Application of MOORA method for parametric optimization of milling process. IJ of Applied Engineering Research 2010; 1(4): 743.
[41] Attri R, Grover S. Decision making over the production system life cycle: MOORA method. IJ Systems Assurance Engg. Management 2013; 5(3): 320-28.
[42] Karande P, Chakraborty S. Application of multi-objective optimization on the basis of ratio analysis (MOORA) method for materials selection. Materials and Design 2012; 37: 317–324.
[43] Gadakh VS. Application of MOORA method for parametric optimization of milling process. IJ of Applied Engg. Research, DINDIGUL 2011;1(4):743-58.
[44] Shihab SK, Chanda AK. Multi Response Optimization of Milling Process Parameters Using MOORA Method. IJ of Mechanical and Production Engineering 2015; 3(4): 67-71.
[45] Brauers WKM, Zavadskas EK. The MOORA method and its application to privatization in a transition economy. Control and Cybernetics 2006; 35(2):445-69.