Vol. XII & Issue No. 6 June - 2019
INDUSTRIAL ENGINEERING JOURNAL

ANALYSIS OF DRIVERS FOR GREEN MANUFACTURING USING ISM

Sandeep Handa
Tilak Raj
Sandeep Grover

ABSTRACT:

Business finds it imperative to address challenges of environmental impact due to unbridled use of resources Businesses are addressing the increasing concerns of various stakeholders by re-orienting their manufacturing operation by espousing Green manufacturing. Numerous factors act as vital drivers towards the adoption of green manufacturing. This paper explores the conceptual relationships among the crucial drivers towards green manufacturing. Interpretive Structural Modeling is used to develop a hierarchical model incorporating the drivers for green manufacturing. MICMAC analysis provides meaningful insights portraying the driving and driven powers of identified elements.

KEYWORDS: *Green manufacturing, ISM (interpretive structural modeling), MICMAC analysis*

1. INTRODUCTION

The rapid growth in manufacturing activities over the past few decades through indiscriminate use of natural resources has played havoc on our environment. Businesses now find it imperative to address the challenges of environmental degradation. Organizations are developing strategies to re-orient their manufacturing operations for green manufacturing. Green manufacturing paradigm uses technologies based on green energy, green design and green process to achieve the goals of environmentally benign manufacturing. Green manufacturing increases resource efficiency and reduces waste. Consequently, businesses are leveraging innovative technologies like green computing for reducing energy usage and artificial intelligence to optimize production schedules.

Numerous drivers act as pivots for adopting green manufacturing. These factors act as motivators to propel the innate desire of business to improve their environmental performance.

This paper is based on extensive review of literatures to identify crucial drivers for business to embrace green manufacturing. ISM is used to construct a conceptual co-relational model for green manufacturing. The study provides an insight into clusters of drive/driven factors using MICMAC analysis. These factors complement each other, further strengthening the argument for environmentally benign manufacturing.

2. DRIVERS FOR GREEN MANUFACTURING

This section enumerates a brief description of drivers identified from review of literatures and the discussion held with experts from industry and academia.

2.1 Regulatory Compliance Pressure

The government and regulatory bodies are prescribing strict environment regulations. These laws stem from the recognition of health hazards due to pollution and emissions, **Kassinis and Vafeas [2002]**. The legal framework serves as an important means to force business to invest in green technologies, **Zeng et al. [2011]**. The need for adherence to environmental compliance regulation is driving companies/ businesses to adopt green manufacturing. Regulatory pressure has significant positive impact on training and plays a crucial role in green innovation performance. "Global Climatic Pressure and Ecological Scarcity of Resources" is most influential criterion that may force industries to implement sustainable practices, **Raut R. D. et al, [2017].**

2.2 Impetus of investors

Investors are changing the way they assess business performance. They are making decisions based on criteria that include environmental concerns. A wider range of investors today are interested in environment friendly growth, **Vos et al. [2003]**. Investor activism demands businesses to run their operations in a greener mode to benefit the communities. They demand businesses to reduce toxic emissions and improve waste management. Businesses are under pressure to disclose their non-financial metrics of environmental impact along-with their financial metrics, **Greeno and Robinson, [1992].** Organizations that are motivated by a green production have a greater probability of financial gains, thereby offsetting the cost of regulation or accruing a net gain**, Darnall N. et al. [2009].**

2.3 Eco innovations

The term environmental innovation or eco-innovation relates to innovations aiming at a decreased negative influence of innovations on the natural environment, **Tseng et al. [2012]**. These are classified into add-on eco-innovations, integrated eco-innovations and macro-organizational eco-innovations. Add-on innovations are related to pollution and resource handling technologies and services. Integrated eco-innovations focus cleaner technological processes and cleaner products and macro-organizational eco-innovations which involve developing new organizational structures. Eco-innovation adoption is a key driver in implementing new systems, products and processes for green manufacturing, **Oke A. et al. [2007].**

Focused attention on environmental protection encourages and motivates employees to undertake innovative green manufacturing conduct. Green innovation practices have positive effects on employee conduct**, Weng [2015].**

2.4 Competitor Pressure

To mitigate the challenges posed by their competitors businesses strive to incorporate green manufacturing practices, **Shubham and Murty [2018]**. Manufacturers are adopting the environmental benchmarking frameworks to assess their stature compared to that of their competitors, **Delmas and Toffel [2004]**. To survive the onslaught of competition, companies imitate the environmental activities of the leaders in their peer group, Huang**, Y. et al. [2009].**

2.5 Need for Resource conservation

Businesses are under pressure to conserve and reduce the use of exhaustible resources. Green Manufacturing initiatives evolve practices which aim to optimize the use of resources during the product life cycle, **Rusinko A. [2007]**. Companies aim to optimize production operations to obtain maximum asset efficiency, **Hoffman [2001]**. Manufactures aim to substitute hazardous resources, reduce waste generation, and increase resource efficiency by using reverse manufacturing. Manufacturers need to adopt integrated lean and green manufacturing practices to simultaneously address economic and environmental issues**, Gandhi N. S. et al. [2018].**

2.6 Waste disposal

Problem of effective waste management and its reduction has paramount importance due to policies like "Polluter pay principles". Businesses are espousing policies of waste prevention by focusing on remanufacturing, reduce and reuse, **Dornfeld et al. [2009]**. Use of waste prevention strategies are more cost effective than cost of its disposal. The need to reduce toxicity through recycling, waste and minimization of hazardous by-products are driving businesses to adopt green manufacturing practices, **Von [2004]**. Green manufacturing minimizes waste and emissions resulting in financial gains and better image, **Seth D. [2018].**

2.7 Suppliers Awareness

Supplier awareness towards green manufacturing and their reliability are a vital factor for environmental performance of a business, **Handfield et al. [1997]**. Setting up a green supply chain management system is crucial for achieving green production, **Lee et al. [2001].** The role of suppliers and manufacturers for promoting green manufacturing is complimentary where each has positive effect on one another**, ElTayeb T. K. [2010].** Regulations, customer pressures, social responsibility and expected business benefits are key drivers for green purchasing. A Collaborative Green Transportation with suppliers has a highest influence on operational performance**, Raut R. D. et al. [2019].**

2.8 Financial Incentives

Green footprints help manufactures to reduce the punitive taxes which are levied for polluting the environment. Going green also provides for incentives in form of subsidies, tax exemptions and tradable permits, **Montabon F. et al. [2007]**. These financial instruments stimulate business to innovate and install more efficient technologies to abate pollution. Businesses are developing newer markets and increasing their market share through the use of environmental marketing, **Chen et al. [2006]**. The "green credit" policy governs bank loans to business and the "green trade" seeks to discourage the manufacturing of products generating pollution, **Dauvergne P. et al. 2018].**

2.9 Consumers Pull for greener products

Green consumerism is a socially conscious set of pro-environmental personal values and attitudes, **Anderson and Cunningham [1972]**. Due to the increased consumer inclination for green product, businesses are under pressure to review their manufacturing strategies. Customers may boycott products that are not in consonance with environmental standards, **Sarkis et al. [2010].** Several businesses are introducing green products for enhancing their brand image and better consumers connect, **Qi, G.Y et al. [2018].** Regulatory and customer pressure promotes green organizational responses and enhances green innovation performance, **Huang [2015].** The four dimensions of an environmentally responsible consumer are: opinion and beliefs, willingness, awareness and an ability to act. The dimension of 'ability to move' is most critical because it has a direct influence on the capacity of the consumer to act, **Pawaskar U. S et al. [2018].** Customer pressure has significant positive impact on research and development investments, **Zhu et al. [2012]**.

2.10 Employees welfare

The environmental performance of SMEs is mostly driven by the intention of company owners, **Ghazilla R. et al. [2015].** Employee welfare is essential for the success of any businesses. Business recognizes the need for offering a safe and healthy working environment to their employees, **Buzzelli [1991]**. Businesses endeavor to serve the need of their employees by eliminating the use of hazardous practices and processes, **Fergusson and Langford [2006].** Enhancing awareness and training is resulting in employees becoming the initiators of proactive environmental practices, **Daily and Huang [2001].**

Table 1: List of driver and references

Sl. No.	**Drivers for green manufacturing**	**References**
1	Regulatory compliance Pressure	Kassinis and Vafeas [2002], Zeng, [2011], Zhu et al [2012]. Raut, R. D. et al [2017]
2	Impetus of investors	Vos et al. [2003], Greeno and Robinson, [1992 **],** Darnall N. et al. [2009]

3	Eco innovations	Tseng *et al.* [2012], Oke A . [2007], Weng et al . [2015]
4	Competitor Pressure	Shubham and Murty [2018], Delmas and Toffel [2004], Huang, Y et al [2009].
5	Need for resource conservation	Rusinko, A. [2007], Hoffman [2001], Gandhi, N. S. et al .[2018]
6	Waste disposal	Dornfeld [2009], Von [2004]. Seth, D et al. [2018]
7	Suppliers awareness	Handfield *et al.* [1997], Lee et al. [2001],ElTayeb, T. K [2010], Moktadir M. A et al. [2018], Routroy S. [2009], Raut R. D. et al. [2017]
8	Financial Incentives	Montabon F. et al. [2007], Chen et al. [2006], Dauvergne P. et al. 2018]
9	Consumers pull for greener products	Anderson and Cunningham [1972], Henriques et al. [1996], Qi G.Y. et al. [2018], Huang [2015]. Pawaskar, U. S. et al. [2018]
10	Employees welfare	Buzzelli [1991], Fergusson and Langford [2006], Daily et al. [2001]. Ghazilla, R. et al. [2015]

3. ISM METHODOLOGY

ISM is a powerful tool to develop a comprehensive model involving a set of elements that may be directly or indirectly related. The model helps to structure a complex problem and gives graphical representation. Important steps in ISM are:

i. Identification and listing of variables/ elements of green manufacturing

ii. Development of SSIM (Structural Self Interaction Matrix)

iii. Development of Reachability Matrix

iv. Ranking of variables using Level Partitioning

v. MICMAC analysis for classification of variables based on their drive and dependence power

ISM is a powerful technique, which has been successfully applied in various sectors/areas by many researchers in different fields, Gardas B. B. (2017). Attri R. et al. applied ISM approach for modeling the enablers in the implementation of Total Productive Maintenance. Raj, T.et al. (2011) used ISM to Identify and modeling of barriers in the implementation of TQM. Patra S. K. et al. applied ISM for analyzing and modeling of barriers for sustainable manufacturing system.

3.1 Development of Structural Self Interaction Matrix (SSIM)

With the help of Academicians and Industry Experts' the contextual relationships among the identified drivers of green manufacturing were developed. Symbols V, A, X and O are used to denote the mutual relationships among the driver metrics (a, b):

V: If a help to achieve b

A: If b help to achieve a

X: If both a and b help to achieve each other

O: If a and b has no relation

Table 2 represents the contextual relationships among the drivers for green manufacturing.

Table 2: Contextual relationships among the drivers for green manufacturing

Sl. No.	→	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**
↓	**Drivers for green manufacturing**	**Employees welfare**	**Consumer pull**	**Financial Incentive**	**Supplier awareness**	**Waste disposal**	**Resource conservation**	**Pressures from competitors**	**Eco innovation**	**Imputes of investors**
1	Regulatory compliance Pressure	**V**	**V**	**O**	**A**	**V**	**V**	**V**	**O**	**O**
2	Impetus of investors	**V**	**O**	**V**	**V**	**O**	**V**	**V**	**X**	
3	Eco innovations	**V**	**V**	**O**	**V**	**V**	**V**	**V**		

4	Pressures from competitors	**A**	**A**	**V**	**A**	**V**	**V**			
5	Resource conservation	**A**	**A**	**O**	**A**	**O**				
6	Waste disposal	**O**	**V**	**V**	**V**					
7	Suppliers awareness	**O**	**O**	**V**						
8	Financial incentives	**V**	**O**							
9	Consumers pull	**V**								
10	Employees welfare									

The following rule is used to prepare the Initial reachability matrix. This is given in table 3.

Table 3: Rule adopted for initial reachability matrix

Matrix	Matrix Symbol	Substitution rule followed
$A_{[a,b]}$	V	Put 1 in place of $A_{[a,b]]}$
	A	Put 0 in place of $A_{[a,b]}$ and 1 in place of $A_{[b,a]}$
	X	Put 1 in place of $A_{[a,b]}$ and $A_{[b,a]}$
	O	Put 0 in place of $A_{[a,b]}$ and $A_{[b,a]}$

Table 4 represents the Initial Reachability matrix.

Table 4: Initial Reachability Matrix

Sl. No.	1	2	3	4	5	6	7	8	9	10
1	1	0	0	1	1	1	0	0	1	1
2	0	1	1	1	1	0	1	1	0	1
3	0	1	1	1	1	1	1	0	1	1
4	0	0	0	1	1	1	0	1	0	0
5	0	0	0	0	1	0	0	0	0	0
6	0	0	0	0	0	1	1	1	1	0
7	1	0	0	1	1	0	1	1	0	0
8	0	0	0	0	0	0	0	1	0	1
9	0	0	0	1	1	0	0	0	1	1
10	0	0	0	1	1	0	0	0	0	1

Final reachability matrix (Table 5) is obtained by using the Transitivity rule. Transitivity rule states that if a variable p affects q and q affects r, then p will affect r.

Table 5: Final Reachability Matrix

Sl. No.	1	2	3	4	5	6	7	8	9	10
1	1	0	0	1	1	1	1*	1*	1	1
2	1*	1	1	1	1	1*	1	1	1*	1
3	1*	1	1	1	1	1	1	1*	1	1
4	0	0	0	1	1	1	1*	1	1*	1*
5	0	0	0	0	1	0	0	0	0	0
6	1*	0	0	1*	1*	1	1	1	1	1*
7	1	0	0	1	1	1*	1	1	0	1*
8	0	0	0	1*	1*	0	0	1	0	1
9	0	0	0	1	1	1*	0	1*	1	1
10	0	0	0	1	1	1*	0	1*	0	1

*Transitivity

3.2 Level partitioning

Final reachability matrix contains the reachability set and antecedent set. Reachability set consists of the driver itself and other drivers influenced by it. Antecedent set consists of the driver itself and all other drivers that may influence it. The intersection consists of common sets between the reachability and antecedent sets. Table 6- 10 shows the different iterations of level identification process.

Table 6: First Level of Drivers

Driver no.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,4,5,6,7,8,9,10	1,2,3,6,7	6,7	
2	1,2,3,4,5, 6,7,8,9,10	2,3	2,3	
3	1,2,3,4,5, 6,7,8,9,10	2,3	2,3	
4	4,5, 6,7,8,9,10	1,2,3,4,6,7,8,9,10	4,6,7,8,9,10	
5	5	1,2,3,4,5, 6,7,8,9,10	5	**I**
6	1,4,5, 6,7,8,9,10	1,2,3,4,6,7,9,10	1,4, 6,7,9,10	
7	1,4,5, 6,7,8,9,10	1,2,3,4,6,7	1,4,6,7	
8	4,5,8,10	1,2,3,4,6,7,8,9,10	4,8,10	
9	4,5, 6,8,9,10	1,2,3,4,6,9	4,6,9	
10	4,5, 6,8,10	1,2,3,4,6,7,8,9,10	4,6,8,10	

Table 7: Second Level of Drivers

Driver no.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,4,6,7,8,9,10	1,2,3,6,7	6,7	
2	1,2,3,4,6,7,8,9,10	2,3	2,3	
3	1,2,3,4,6,7,8,9,10	2,3	2,3	
4	4,6,7,8,9,10	1,2,3,4,6,7,8,9,10	4,6,7,8,9,10	**II**
6	1,4,6,7,8,9,10	1,2,3,4,6,7,9,10	1,4, 6,7,9,10	
7	1,4,6,7,8,9,10	1,2,3,4,6,7	1,4,6,7	
8	4,8,10	1,2,3,4,6,7,8,9,10	4,8,10	**II**
9	4,6,8,9,10	1,2,3,4,6,9	4,6,9	
10	4,6,8,10	1,2,3,4,6,7,8,9,10	4,6,8,10	**II**

Table 8: Third Level of Drivers

Driver no.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,6,7,9	1,2,3,6,7	1,6,7	
2	1,2,3,6,7,9	2,3	2,3	
3	1,2,3,6,7,9	2,3	2,3	
6	1,6,7,9	1,2,3,6,7,9	1,6,7,9	**III**
7	1,6,7,9	1,2,3,6,7	1,6,7	
9	6,9	1,2,3,6,9	6,9	**III**

Table 9: Forth Level of Drivers

Driver no.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,7	1,2,3,7	1,7	**IV**
2	1,2,3,7	2,3	2,3	
3	1,2,3,7	2,3	2,3	
7	1,7	1,2,3,7	1,7	**IV**

Table 10: Fifth Level of Driver

Driver no.	Reachability Set	Antecedent Set	Intersection Set	Level
2	2,3	2,3	2,3	V
3	2,3	2,3	2,3	V

3.3 Conical matrix formation

The conical matrix is developed to identify the driving power and dependence power of each driver. This is presented in table 11.

Table 11: Driving and Dependence Power in Reachability Matrix

Sl. No.	5	4	8	10	6	9	1	7	2	3	Drive power
5	1	0	0	0	0	0	0	0	0	0	1
4	1	1	1	1	1	1	0	1	0	0	7
8	1	1	1	1	0	0	0	0	0	0	4
10	1	1	1	1	1	0	0	0	0	0	5
6	1	1	1	1	1	1	1	1	0	0	8
9	1	1	1	1	1	1	0	0	0	0	6
1	1	1	1	1	1	1	1	1	0	0	8
7	1	1	1	1	1	0	1	1	0	0	7
2	1	1	1	1	1	1	1	1	1	1	10
3	1	1	1	1	1	1	1	1	1	1	10
Dependence Power	10	9	9	9	8	7	4	6	2	2	

3.4 Digraph development

The digraph is developed based on the relationships among the various drivers of Green manufacturing. Fig.1 shows the mutual relationships on the basis of conical matrix.

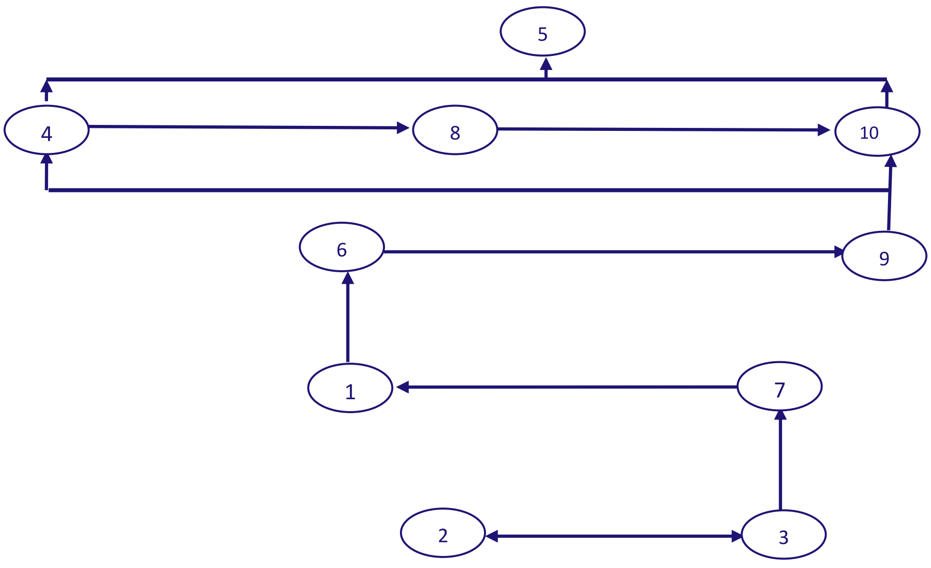

Fig. 1: Digraph showing the various levels of drivers in green manufacturing

3.5 Green manufacturing model based on ISM

The Digraph is converted into an ISM model by replacing the nodes with the driver name. This is shown in Fig. 2.

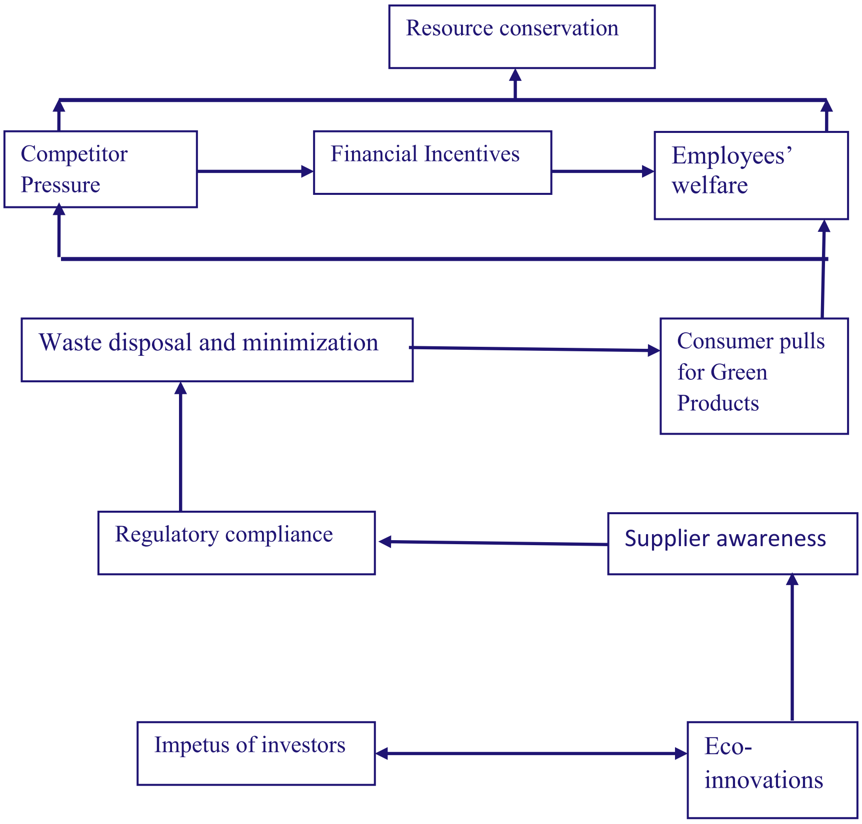

Fig. 2: Green manufacturing model based on ISM

3.6 MICMAC ANALYSIS

MICMAC (Matrice d' Impacts croises multiplication applique' an classment) analysis has been used to analyze the driving power and dependence power of the drivers of green manufacturing. Depending on their driving power and dependence power these are classified into four categories. This is depicted in Fig. 3.

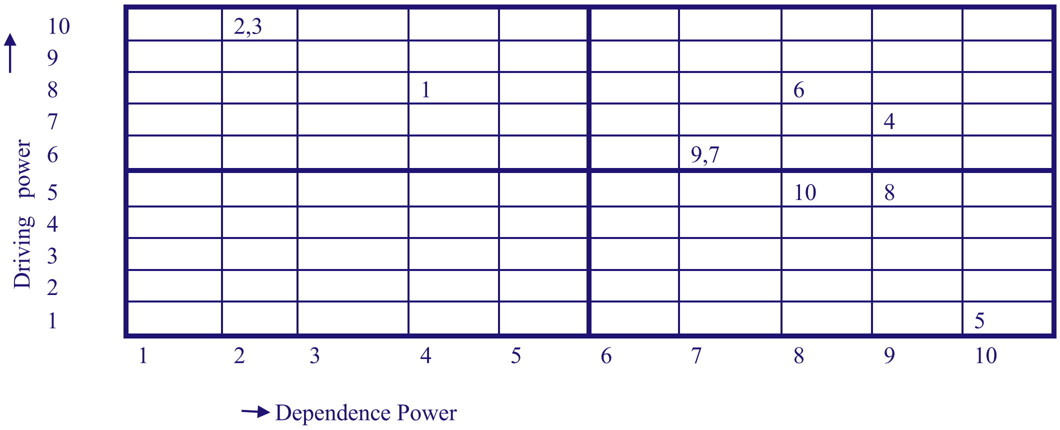

Fig. 3: MICMAC ANALYSIS

4. CONCLUSION

Green manufacturing practices aim for environmental protection by emphasizing on reduction of resource use, pollution abatements and waste management. The adoption of green technologies results in reduction of harmful emissions, minimization of energy and material usage. This paper reveals the linkages amongst the crucial drivers pertaining to green manufacturing. This study offers important insights for policy makers and managers in formulating strategies for promoting green technologies in the manufacturing industry. The study identifies some of the important drivers which influence green manufacturing by attributing 'driving' and 'dependency' power to each driver. These drivers of green manufacturing are ranked using Interpretive Structural Modeling techniques. Drivers of green manufacturing are analyzed to construct a five level hierarchy framework model. A review of the results of MICMAC analysis establish that 'impetus' by investors and 'Eco-innovations' are critical factors in driving the transformation towards green manufacturing. These are independent drivers which have strong 'driving' power and 'weak' dependence power. The results further show that no driver belongs to the autonomous driver group. Need for resource conservation, financial incentives & employee welfare are dependent drivers. These drivers have a weak driving power and strong dependence power. Pressure from competitors, waste disposal, supplier awareness and pressure of consumers are linkage drivers having strong driving power and strong dependence power.

This study offers important managerial insights to the key decision makers in government and manufacturing industry in prioritizing efforts for espousing the cause of green manufacturing practices. This study provides researchers and practitioners to effectively stimulate the necessary set of green drivers for transforming manufacturing practices from conventional to greener ones.

REFERENCE

1. *Anderson, W.T. and Cunningham, W. H. (1972), 'The socially conscious consumer', The Journal of Marketing, July, Vol. 36, pp. 23-31.*

2. *Attri R., Grover, S., Dev, N., & Kumar, D. (2013). An ISM approach for modelling the enablers in the implementation of Total Productive Maintenance (TPM). International Journal of Systems Assurance Engineering and Management, 4(4), 313-326. https://doi.org/10.1007/s13198-012-0088-7*

3. *Buzzelli D.T. (1991), Time to structure an environmental policy strategy, Journal of Business Strategy, Vol. 12, No. 2, 17-20.*

4. *Chen, Y.S, Lai S. B, Wen C.T. (2006), The influence of green innovation performance on corporate advantage in Taiwan. J. Bus. Ethics, 67, 331-339.*

5. *Daily, B.F.; Huang, S.-C. (2001), Achieving sustainability through attention to human resource factors in environmental management. Int. J. Oper. Prod. Manag., 21, 1539-1552.*

6. *Darnall N. (2009). Regulatory stringency, green production offsets, and organizations' financial performance. Public Administration Review, 69(3), 418-434. https://doi.org/10.1111/j.1540-6210.2009.01989.x*

7. *Dauvergne P., Alger, J., & Park, S. (2018). Green finance. In A Research Agenda for Global Environmental Politics (pp. 28-38). Edward Elgar Publishing. https://doi.org/10.4337/9781788110952.00008*

8. *Delmas M., Toffel (2004), M.W. Stakeholders and Environmental Management Practices An Institutional Framework. Bus. Strat. Environ13, 209-222*

9. *Donaldson, T., & Preston, L. E. (1995), The stakeholder theory of the corporation: Concepts, evidence, and implications. Academy of Management Review, 20(1), 65-91.*

10. *ElTayeb T. K., Zailani S., & Jayaraman K. (2010). The examination on the drivers for green purchasing adoption among EMS 14001 certified companies in Malaysia. Journal of Manufacturing Technology Management, 21(2), 206-225. https://doi.org/10.1108/17410381011014378*

11. *Fergusson, H.; Langford, D.A (2006), Strategies for managing environmental issues in construction organizations. Eng. Constr. Archit. Manag, 13, 171-185.*

12. *Gandhi, N. S., Thanki S. J., & Thakkar J. J. (2018). Ranking of drivers for integrated lean-green manufacturing for Indian manufacturing SMEs. Journal of Cleaner Production, 171, 675-689. https://doi.org/10.1016 /j.jclepro. 2017. 10.041*

13. *Gardas B. B., Raut R. D., & Narkhede B. E. (2017). A state-of the-art survey of interpretive structural modeling methodologies and applications. International Journal of Business Excellence, 11(4), 505. https://doi.org/10.1504/ijbex.2017.082576*

14. *Ghazilla R. A. R., Sakundarini N., Abdul-Rashid, S. H., Ayub N. S., Olugu E. U., & Musa, S. N. (2015). Drivers and barriers analysis for green manufacturing practices in Malaysian smes: A preliminary findings. In Procedia CIRP (Vol. 26, pp. 658-663). Elsevier B.V. https://doi.org/10.1016/j.procir.2015.02.085*

15. *Govindan, K., Diabat, A., & Madan Shankar, K. (2015). Analyzing the drivers of green manufacturing with fuzzy approach. Journal of Cleaner Production, 96, 182-193. https://doi.org/10.1016/j.jclepro.2014.02.054*

16. *Greeno, J.L. and Robinson, S.N., (1992), Rethinking corporate environmental management,Columbia Journal of World Business, Vol. 27, No. 3/4, pp. 222-232.*

17. *Handfield R.B., Walton S.V., Seegers L.K., and Melny S.A., (1997), ' green' value chain practices in the furniture industry, Journal of Operations Management, Vol. 15, No.4, pp. 293-315.*

18. Hoffman, A.J., (2001), Linking organizational and field-level analyses - the diffusion of corporate environmental practice, Organization and Environment, Vol. 14, No. 2, 133-156.

19. Huang, X. X., Hu, Z. P., Liu, C. S., Yu, D. J., & Yu, L. F. (2016). The relationships between regulatory and customer pressure, green organizational responses, and green innovation performance. Journal of Cleaner Production, 112, 3423-3433. https://doi.org/10.1016/j.jclepro.2015.10.106

20. Huang, Y.-C.; Ding, H.-B.; Kao, M.-R. (2009), Salient stakeholder voices: Family business and green innovation adoption. J. Manag. Organ, 15, 309-326.

21. Kassinis, G. and Vafeas, N., (2002), Corporate boards and outside stakeholders as determinants of environmental litigation, Strategic Management Journal, Vol. 23,No. 5, pp. 399-415.

22. Lee, S.-Y.; Klassen, (2008), R.D. Drivers and enablers that foster environmental management capabilities in small- and medium-sized suppliers in supply chains. Prod. Oper. Manag. 17, 573-586.

23. Mathiyazhagan, K., Govindan, K., &NoorulHaq, A. (2014). Pressure analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. International Journal of Production Research, 52(1), 188-202. https://doi.org/10.1080/00207543.2013.831190

24. Moktadir, M. A., Rahman, T., Rahman, M. H., Ali, S. M., & Paul, S. K. (2018). Drivers to sustainable manufacturing practices and circular economy: A perspective of leather industries in Bangladesh. Journal of Cleaner Production, 174, 1366-1380. https://doi.org/10.1016/j.jclepro.2017.11.063

25. Montabon, F.; Sroufe, R.; Narasimhan, (2007), R. An examination of corporate reporting, environmental management practices and firm performance. J. Oper. Manag. , 25, 998-1014.

26. Oke, A.(2007),Innovation types and innovation management practices in service companies. Int. J. Oper.Prod. Manag., 27, 564-587.

27. Patra, S. K., Raj, T., & Arora, B. B. (2019). An analysis and modeling of selected barriers for sustainable manufacturing system using ISM technique. International Journal of Operational Research, 1(1), 1. https://doi.org/10.1504/ijor.2021.10019638

28. Pawaskar, U. S., Raut, R. D., &Gardas, B. B. (2018). Assessment of Consumer Behavior Towards Environmental Responsibility: A Structural Equations Modeling Approach. Business Strategy and the Environment, 27(4), 560-571. https://doi.org/10.1002/bse.2020

29. Qi, G.Y.; Shen, L.Y.; Zeng, S.X.; Jorge, O.J.(2010), The drivers for contractors' green innovation: An industry perspective. J. Clean. Prod. 2010, 18, 1358-1365.

30. Raj, T., &Attri, R. (2011). Identification and modelling of barriers in the implementation of TQM. International Journal of Productivity and Quality Management, 8(2), 153. https://doi.org/10.1504/ijpqm.2011.041844

31. Raut, R. D., Luthra, S., Narkhede, B. E., Mangla, S. K., Gardas, B. B., &Priyadarshinee, P. (2019). Examining the performance oriented indicators for implementing green management practices in the Indian agro sector. Journal of Cleaner Production, 215, 926-943, https://doi.org/10.1016/j.jclepro. 2019. 01. 139

32. Raut, R. D., Narkhede, B., &Gardas, B. B. (2017, February 1). To identify the critical success factors of sustainable supply chain management practices in the context of oil and gas industries: ISM approach. Renewable and Sustainable Energy Reviews. Elsevier Ltd. https://doi.org/10.1016/j.rser.2016.09.067

33. Routroy, S. (2009). Antecedents and Drivers for Green Supply Chain Management Implementation in Manufacturing Environment. ICFAI Journal of Supply Chain Management, VI (1), 20-36.

34. Rusinko, A. (2007), "Green Manufacturing: An Evaluation of Environmentally Sustainable Manufacturing Practices and Their Impact on Competitive Outcomes," IEEE Transactions on Engineering Management, vol. 54, no. 3, pp. 445-454.

35. Sarkis, J.; Gonzalez-Torre, P.; Adenso-Diaz, (2010), B. Stakeholder pressure and the adoption of environmental practices: The mediating effect of training. J. Oper. Manag. 28, 163-176.

36. Seth, D., Rehman, M. A. A., & Shrivastava, R. L. (2018). Green manufacturing drivers and their relationships for small and medium (SME) and large industries. Journal of Cleaner Production, 198, 1381-1405. https://doi.org/10.1016/j.jclepro.2018.07.106

37. Shubham, C.P.; Murty,(2018), L.S. Organizational adoption of sustainable manufacturing practices in India: Integrating institutional theory and corporate environmental responsibility. Int. J. Sustain. Dev. World Ecol, 25, 23-34

38. Tseng, M. L., Huang, F. H., & Chiu, A. S. (2012), Performance drivers of green innovation under incomplete information. Procedia-Social and Behavioral Sciences, 40, 234-250.

39. Von Moltke, A. (2004),.The Use of Economic Instruments in Environmental Policy: Opportunities and Challenges. UNEP /Earth print

40. Vos, J.F.J., (2003), Corporate social responsibility and identification of stakeholders, Corporate social

responsibility and environmental management, Vol. 10, No. 3, pp.141-152.

41. *Weng, H. H. R., Chen, J. S., & Chen, P. C. (2015). Effects of green innovation on environmental and corporate performance: A stakeholder perspective. Sustainability (Switzerland), 7(5), 4997-5026. https://doi.org/10.3390 /su 7054997*

42. *Zeng, S.X.; Meng, X.H.; Zeng, R.C.; Tam, C.M.; Tam, V.W.Y.; Jin,T. (2011), How environmental management driving forces affect environmental and economic performance of SMES: A study in the northern China district. J. Clean. Prod., 19, 1426-1437.*

43. *Zhu, Q., & Sarkis, J. (2007). The moderating effects of institutional pressures on emergent green supply chain practices and performance. International Journal of Production Research, 45(18-19), 4333-4355. https://doi.org/ 10.1080/00207540701440345*

AUTHORS

Sandeep Handa, M.Tech Department of Production Engineering, G. B. Pant Institute of Technology, New Delhi, Email ID : India, handasandeep@yahoo.com

Dr. Tilak Raj, PhD, Department of Mechanical Engineering, YMCAUST, Faridabad, India,
Email ID: tilakraj64@rediffmail.com

Dr .Sandeep Grover, PhD, Department of Mechanical Engineering, YMCAUST, Faridabad,
Email ID : groversandeep@hotmail.com