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Advanced Manufacturing Management System for Environmental Sustainability

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Abstract

The contribution of manufacturing in national GDP is around 15-16% despite of many efforts by government of India at different times. In India, adoption of advanced manufacturing techniques is not very encouraging despite the fact that companies which can adopt advanced manufacturing techniques (AMTs) will be leader in manufacturing competitiveness. Government of India has a very ambitious target of achieving 25% contribution in GDP from the manufacturing sector. Therefore, Indian manufacturing sector must adopt AMTs to achieve this target. At the same time, there are regular warning message coming from different corners about sustainability of our activities. The purpose of this paper is to brought the Advanced Manufacturing Techniques (AMTs), managerial practices of manufacturing principles and green manufacturing philosophy under 'Advanced Manufacuring Management System' (AMMS), a umbrella term coined by authors. Incorporating all major techniques, principles and philosophies makes AMMS more robust to organizations seeking sustainability irrespective of their size, sector, location and country. The developed framework of AMMS provides a holistic approach to practitioners for selection of right combination of managerial and technical practices for environmental sustainable manufacturing.

Keywords: Advanced manufacturing techniques, Green manufacturing, Sustainable manufacturing

1. Introduction

Indian manufacturing sector has 15-16 % share in GDP since 1980. This share is low as comparable Asian economies have much higher at 25 to 34 %. To address these problems, Government of India brought 'National Manufacturing Policy-2011' and an initiative of 'Make in India'. While the industrial growth is necessary, the country's environment concerns need to be mitigated. Industry and technology are traditionally associated with negative impacts on the natural environment. Figure 1 is showing the expected size of manufacturing sector in next 8 years.

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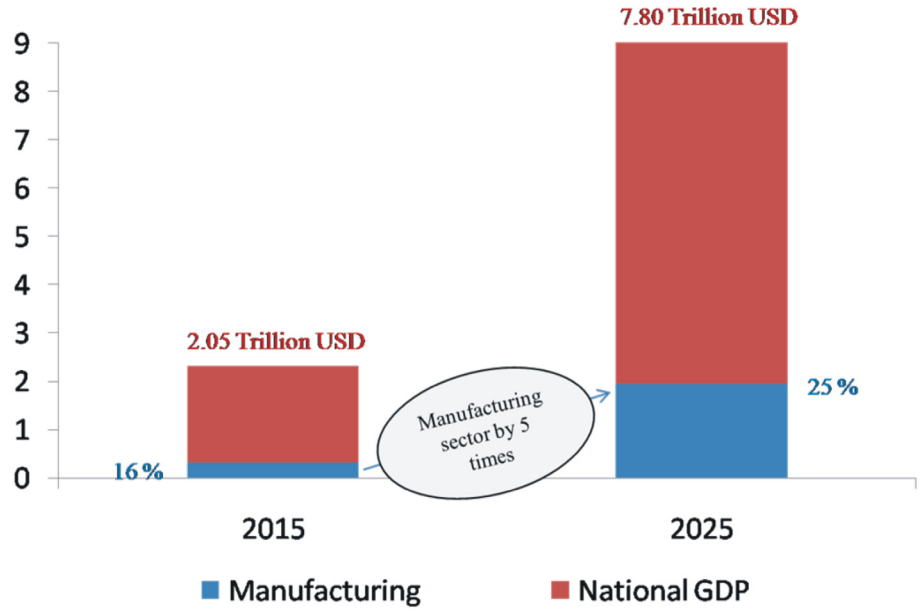

Source: World bank databank and www.makeinindia.com

Figure 1: Rise of Manufacturing Activities in Next Decade

It reveals that in next decade, Indian manufacturing sector would impose high pressure on environment. Manufacturing activities has direct ecological footprints because it consumes natural resources and discharge waste in nature. Johansson (2014) found in systematic literature review that excessive numbers of tools/techniques exists for reducing environmental impacts of manufacturing but no common list exist. There is no specific or unique technique which alone can implement environmental sustainable manufacturing. For each and every process, researchers are identifying the specific ways to reduce environmental impact. To cater the need of Indian manufacturing sector, this paper aims to identify all the techniques based on technology as well as on management system, which are used in manufacturing area for gaining better operational performance (productivity, quality, faster delivery, planning etc) but also capable in yielding goals of environmental sustainable manufacturing. Authors searched existing literature to find out the techniques and methods for achieving environmental ssutainable manufacturing using keywords related to or similar to environmental sustainability. Some researchers did not use phrases such as green manufacturing, sustainablity, sustainable manufacturing etc. but dervided the outcome or establish environmental sustainability with the use of particulal technique. To track such type of papers, authors used another set of keywords which are the desired outcome of environmental sustainabile manufacturing. Literature review was done from year 2000 to 2016 which also includes articles in press. Articles were searched from the electronic database of publishers including Elsevier, Emerald, IEEE, Springer, Taylor & Francis, Wiley and Inderscience. Researchers prefer to publish their research in Journals rather than conferences, but authors also considered conference articles because articles from conferences also have better research content (Freyne, 2010). Identification of techniques was done in three steps as shown in Figure 2.

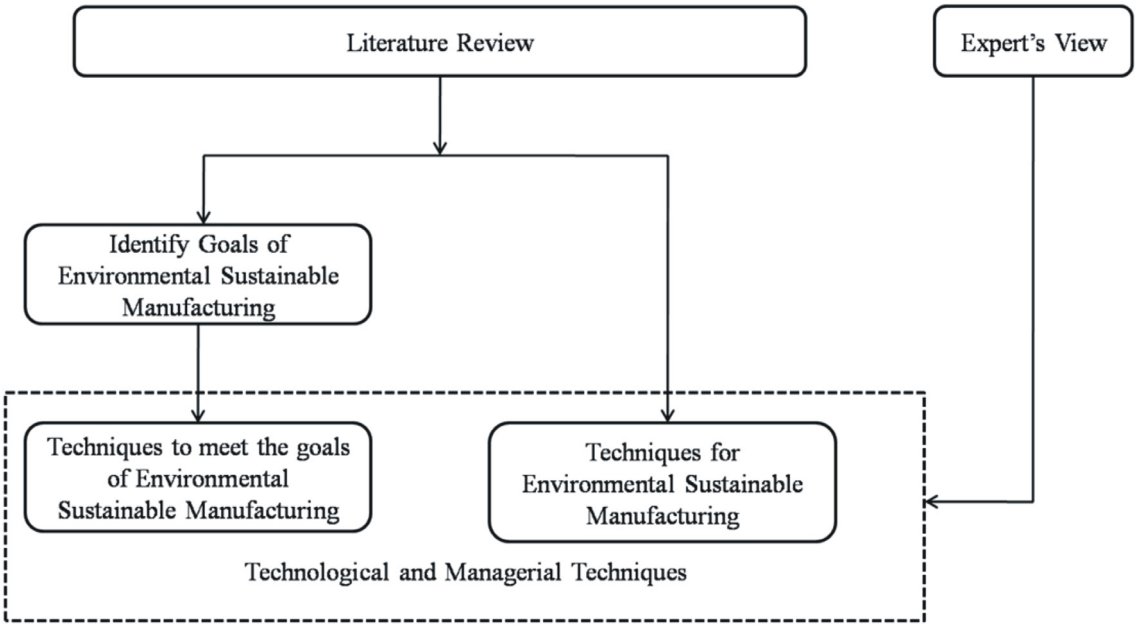

Figure 2: Methodology for Identifying AMMS

A comple list of techniques is further dived in to managerial and technology base with different levels of impleentation through focused Group Discussion (FGD)/interview with experts.

2. Literature Review

Sustainable manufacturing emphasizes on optimum utilization of resources, which further yields reduced pollutions. Pollution represents waste and loss of productivity (Porter and Linde, 1995). Sustainable manufacturing do not concern only for making of more sustainable products but also use more sustainable manufacturing process of those products (Pusavec, 2010). So, sustainable manufacturing not only focus on product but also take care of manufacturing process and whole system.

2.1 Goals of Environmental Sustainable Manufacturing

Global Reporting Initiative (GRI) guidelines suggest 34 indicators which have been adopted by most of the manufacturing companies for disclosure in annual sustainability reporting. International Standard ISO 14004 also suggests various performance indicators. Many researchers such as Van Gerven (2007), Amrina (2011), Joung (2012), K Digalwar (2013), Ahi (2015), Amrina (2015), Harik (2015), Rashidi (2015), Trumpp (2015) and Wu (2016) either proposed new indicators or considered a set of environmental indicators in measuring sustainability of manufacturing companies. Many other researchers such as Ahi (2016) and Panão (2016) identified single metric for in-depth analyzing for sustainable operations. Authors found a large numbers of journal articles on sustainability indicators but these articles contain a certain numbers of indicators which are repeated in journal articles with a variation of nomenclature. Ahi (2015) found 27 metrics which are appeared more than 10 times in 445 articles. From the collective set of indicators, authors are converting these performance indicators into a set of goals for environmental sustainable manufacturing. Comprehensively list of these goals is in Table 1.

Table 1: Goals of Environmental Sustainable Manufacturing

S. No.	Goals
1.	Reduction in raw material consumption
2.	Use of non hazardous material
3.	Replacement of hazardous material with non hazardous materials
4.	Increased use of recycled materials
5.	Reduction in waste generation
6.	Increased recycling/treatment of waste
7.	Reduction in hazardous waste
8.	Reduction in energy consumption
9.	Energy used per unit product
10.	Increased use of renewable (Solar,, water power, wind) energy
11.	Reduction in Greenhouse gas emissions
12.	Less transportation of vehicles
13.	Less emission of pollutants
14.	Reduced water consumption
15.	Increased use of recycled water
16.	Reduction in discharge of waste water
17.	Reduced numbers of environmental accidents and spills and resultant monetary fines
18.	Reduced use of land
19.	Use of green buildings
20.	Quality
21.	Air emission
22.	Reduced cost
23.	Reduction in fuel consumption
24.	Reduction in noise pollution
25.	Conservation of natural habitat

2.2 Advanced Manufacturing Techniques (AMTs)

Reasons to consider AMTs in sustainable manufacturing is that benefits derived from AMTs are relevant in sustainable manufacturing such as improve production output, higher profitability, and reduced waste, reduce labour cost, products with greater reliability, greater precision in product, decreases material cost and better supply chain integration. Advanced Manufacturing techniques help the firm to gain competitive advantage (Boyer K., 2000). Advanced Manufacturing Technologies help the manufacturing firms to produce high volume at low cost and thus rationally

utilize the scarce resources available at its disposal (Goldhar and Jelinek, 1983). AMTs are computer based technologies (Dangayach, 2005) such as computer aided design (CAD), Computer numeric control (CNC) machines, Flexible manufacturing system (FMS), Automatic material handling system (AMHS), Rapid prototyping (RP), Statistical process control (SPC), Material requirement planning (MRP), Manufacturing resources planning (MRP-II), Enterprise resource planning (ERP), Quality function deployment. Authors search literature which links AMTs with the goals of environmental sustainability.

2.3. Manufacturing Techniques for Environmental Sustainability

Goals from Table 1 and other keywords such as advance manufacturing technology, sustainable manufacturing, industrial ecosystem, sustainable production, green manufacturing, green productivity, eco-innovation in industry and environment conscious manufacturing were used to search manufacturing techniques. Filtering was done through studying abstracts and methodology used in paper. A list of techniques was prepared (Table 2) which are used for sustainable manufacturing.

Table 2: Manufacturing Techniques Identified from Literature for Sustainable Manufacturing

Technique	Author	Description
5-S	Jiménez *et al.* (2015) Chiarini, A. (2014)	5-S implementation provides safety at work place. As a lean production tool, it can be useful in avoiding wastage of resources, reducing space requirement, reducing oil leakage and waste management
Additive Manufacturing	Esmaeilian *et al.* (2016)	Manufacturing of complex geometries by stacking layers of material eliminates need of tooling, fixtures, transportation, warehouses, resulting higher efficient, low cost and environmental friendly impact.
Poka-Yoke	Vinod M. *et al.* (2015) Myszewski (2012)	Poko-Yoke provide solution for prevention of medical errors to patient in hospitals. Poka-Yoke devices ensure safety from mistakes
Total Productive Maintenance (TPM)	Chiarini A. (2014)	It reduces emission, oil leakage, chemical fumes from machines
Single Minute Exchange of Die (SMED)	Chiarini A. (2014)	It reduces electricity consumption
Value Stream Mapping (VSM)	Faulkner (2014) Chiarini A. (2014) Brown, A. (2014) Edtmayr T. *et al.* (2016)	Potential of lean production tool VSM extended to identify environmental impacts. To identify environmental impact of production process, ecological parameters are integrated into VSM. Sus-VSM provides sustainability in manufacturing irrespective of system configuration.
Cellular manufacturing	Chiarini A. (2014)	It reduces electricity consumption
Plant certification	Sarkis, J. (2001) Van Gerven, T. *et al.* (2007)	Provide management system and establish system for improvement.
Total Quality Management (TQM)	Ho, S. K. (2010)	Integrated sustainability in TQM model
Statistical process control (SPC)	Garza-Reyes *et al.* (2014)	Statistical tools helps in monitoring emission of green house gases and waste generation.
Just in Time (JIT)	Sarkis, J. (2001) Alan W. (2010)	JIT provides opportunity to keep manufacturing sustainable and Improves manufacturing performance.

Six sigma	George M. L. (2002) Garza-Reyes (2015) Cherrafi *et al.* (2016) Zhang M. (2014) Thomas A. J. (2008) Garza-Reyes (2015) Cherrafi *et al.* (2016)	Integrates lean approach with Six Sigma program and developed a concept of Lean Six Sigma. Considering ecological impact as a problem, it can be Integrated with lean manufacturing for sustainable operation. Combination of sustainable manufacturing with Six Sigma develops a systematic framework for sustainable manufacturing using Six Sigma tools in identifying and solving problems related to sustainability.
Cellular manufacturing	Chiarini (2014)	Reduced energy and reduced setup time helps in better environmental conscious manufacturing
Manufacturing strategy for competitiveness	Kim J. Y *et al.* (2013)	Productivity and environmental aspect can be taken together with proper strategy.
Kaizen	Pampanelli *et al.* (2014)	Integrates kaizen approach to save energy, water along with reduction in waste and resources consumption
Computer aided design (CAD)	Vinodh, S. (2010) Murthy *et al.* (2012).	CAD is used Design of environment conscious product and sustainability is considered during design of products.
MRP, MRP -II and ERP	Sarkis, J. (2001)	Integration of planning in resource utilization gives environmental benefits

2.4 Green Manufacturing as AMMS

Besides these identified techniques, authors came across a large numbers of articles in which researchers such as García-Ten (2011), Chetan (2015), Li K. (2016) and many others did not use any kind of existing or known practice, but adopt innovative approach specific to particular process or design with the aim of implementing green manufacturing. Also, Dornfeld *et al.* (2012) distinguish green manufacturing with sustainable manufacturing as; green manufacturing is only environmental conscious rather than meeting requirement of triple bottom line. From this, authors conclude that thinking of green manufacturing is also a separate technique which emphasis on optimum utilization of resources, yield sustainable development.

2.5 Advanced Manufacturing Management Techniques (AMMS)

Table 3 is enlisting all identified manufacturing techniques and AMTS under a umbrella term; 'Advanced Manufacturing Management Techniques' (AMMS). Any organization can choose appropriate technique suitable for its operations.

Table 3: Manufacturing Techniques for Sustainable Manufacturing

Managerial system	Technologies
Value stream mapping	Computer aided design (CAD)
Plant certification	Local area networks
SMED	MRP, MRP-II AND ERP
Poka-Yoke	Rapid prototyping system (Additive manufacturing)
TQM	Concurrent engineering
TPM	Computer integrated manufacturing (CIM)
5-S	Automated guided vehicles
Cellular manufacturing	Automatic material handling system (AMHS)
Just in Time (JIT)	Robots
Six sigma	Computer driven material handling
	Flexible manufacturing system (FMS)

3. Discussion and Conclusion

Authors focused on manufacturing but the developed framework of AMMS is equally applicable and useful in service sector also. Performance of manufacturing unit and implementation of techniques such as TQM, JIT & TPM are positively related. Through these techniques; quality, scrap cost return on investment are increased. The scope of conventional meaning of AMT has been enhanced by inclusion of management principles for achieving sustainable manufacturing through the proposed framework of AMMS. This enables industries to adopt right combination of techniques from a complete set of manufacturing techniques. Limitation of this study is that authors could not find any literature for famous techniques like benchmarking, Quality circles, theory of constraints etc for environmental sustainable manufacturing. Development of strategies for adoption of AMMS in Indian manufacturing sector is needed for further research.

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