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Analytic Hierarchy Process (AHP) Model for Evaluating Sustainable Manufacturing Practices in Indian Electrical Panel Industries

Sumit Gupta[a]* G. S. Dangayach[b] Amit Kumar Singh[c] P. N. Rao[d]

[a,b,c]*Malaviya National Institute of Technology, J.L.N. Marg, Jaipur, Rajasthan-302017 India*

[d]*Department of Technology, University of Northern Iowa, Cedar Falls, IA 50614-0178*

Abstract

Sustainable Manufacturing and operations has become a crucial issue in present scenario for the manufacturing firms. Today manufacturing firms are keen interested to become sustainable in all three aspect economical social and environmental. There are number of manufacturing practices viz. Eco-design, process design, green supply chain, lean practices, product recovery and cleaner production by which firms should achieve sustainability. This paper present an AHP model of manufacturing sustainability through different manufacturing practices. In the initial stage of this study a survey methodology used from academia and industry after that an AHP model developed. From this study it is identified that firm EP-3 more conscious towards sustainability with respect to other firm. It is suggested that every electrical panel industry should adopt sustainable manufacturing practices to achieving competiveness in the market.

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Keywords: Eco-design, LMP, GSM, Product recovery, cleaner product and AHP

* Corresponding author. Tel.: +91-9461237253
E-mail address: sumitgupta2007@gmail.com

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1.0 Introduction:

Sustainable manufacturing is a term used to describe manufacturing practices that do not harm the environment during any part of the manufacturing process. It emphasizes the use of processes that do not pollute the environment or harm consumers, employees, or other members of the community. Sustainable manufacturing includes recycling, conservation, waste management, water supply, environmental protection, regulatory compliance, pollution control and a variety of other related issue. Sustainable Manufacturing is also known by different names like environmentally conscious manufacturing, environmentally benign manufacturing, environmentally responsible manufacturing, and green manufacturing.

Sustainable manufacturing emphasis on designing and delivering products that minimize negative effects on the environment through their production, use, and disposal. In the current scenario it is better to make product for environmental as well as economic feasibility for the organizations. Also the globalization has forced companies to improve their environmental performance [1]. Thus Sustainable manufacturing is the only visible solution in today's manufacturing scenario. Many manufacturers consider environmental management as an integral part of economic development and a necessity for remaining competitive.

This study identify some prominent sustainable manufacturing practices in Indian electrical panel manufacturing organisations and analyze them using multi-criteria decision modeling through analytic hierarchy process (AHP).

2.0 Literature Review

The concept of sustainability emerged from a series of meetings and reports in the 1970s and 1980s, and was largely motivated by environmental incidents and disasters as well as fears about chemical contamination and resource depletion. As pointed out in the 1987 Brundtland Report, Our Common Future [2]. Sustainable manufacturing has evolved beyond the life cycle view. [3] Traces the evolution of sustainable manufacturing initiatives from traditional pollution control through cleaner production initiatives, to a lifecycle view, to the establishment of closed loop production.

Table: 1 various connotations of Sustainable manufacturing reported in literature

Author	Year	connotations
[4]	2013	Sustainable manufacturing requires simultaneous consideration of economic, environmental, and social implications associated with the production and delivery of goods.
[5]	2011	sustainable manufacturing as "the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound.
[6]	2010	Sustainable manufacturing practices commonly used fall into the pollution prevention
[7]	2003	He proposed a definition relevant to engineering contexts as the "design of human and industrial systems to ensure that humankind's use of natural resources.

Sustainable manufacturing plays an important role for the manufacturing organisations. Sustainable manufacturing practices have major areas which provide a better environment in the organisations. The literature is classified the according to the major sustainable manufacturing practices. The purpose of this literature review is to find out the recent development in the sustainable manufacturing.

2.1 Sustainable Manufacturing Practices

The most significant sustainable manufacture practice are identified from the literature and organized into seven main areas namely eco design, process design, lean practices, Green supply chain, product recovery and Cleaner Production as shown in table -2. From the literature enablers of sustainable manufacturing was identified.

Table: 2 Sustainable Manufacturing Practices

S. No.	Sustainable Manufacturing practices	Authors
1	Eco Design	[8] [9] [10]& [11]
2	Process Design	[12] [13] [15]& [7]
3	Lean practices	[16] [17] [18] [19]& [20]
4	Green Supply Chain	[12] [13] [14] [21] [22]& [23]
5	Product Recovery	[24] [25] [26] [27] & [28]
6	Cleaner Production	[19] [29] [30] & [31]

- ***Eco Design (ED)*** The potential of eco-design to contribute to product sustainability, previous research implies that eco-design is in actuality largely confined to maintaining the minimum legal requirements [9]. [8] Provides the important factors of product design and development. Life cycle analysis is the important tool for the assessment of the product life.

- ***Process Design (PD)*** Process Design is equally important for the sustainability. Manufacturing processes should be designed to minimize the energy and resource consumption [7] air emissions, and generation of solid and liquid wastes. Process design is also minimized the water pollution. In the manufacturing companies it is mandatory that manufacturing process is moving without hazardous waste. [32] Suggested the different advanced manufacturing technologies which are highly associated with optimization of the machining parameters which goes to sustainability. [33]The manufacturing industry is seeking an open, inclusive, and neutral set of indicators to measure sustainability of manufactured products and manufacturing processes. The reduction of defectives of large number of component means lot of saving in the material, machining time, men hours, electricity and overheads in the organisation. In the companies the process is so design that there is no negative effect on the worker's health. Pollution is equivalent to inefficiency. Pollution in the form of wastes is often created by inefficient material utilization and manufacturing processes. Moreover, there are additional costs for handling wastes, which are of no value.

- ***Lean Practices (LS)*** *lean* practices are highly important for the sustainable development [16] investigated that the relationship between environmental management, lean practices and supply relationship. The main findings of this study supplier's environmental management practice raise critical issues of transaction costs and efficacy of approach for the buyer. Development of a model for approaching issues of supplier environmental performance through lean supply. [17] Suggested that lean is rapidly growing in popularity, its implementation is far from problem free and companies may experience difficulties sustaining long term success. It is also suggested that sustainable lean requires attention to both performance improvement and capability development. [31] investigated the implementation of lean and sustainable manufacturing aided by the use of discrete event simulation and optimization to overcome deficits in lean's traditional implementation strategies. Lean and sustainable manufacturing can have a more significant, positive impact on multiple measures of operational performance when implemented concurrently rather than separately.

- **Green Supply Chain Management (GSM)** Green supply chain is defined as "the extension of the traditional supply chains to include activities that aims to minimizing environmental impacts of a product throughout its entire life cycle, such as green design, resource saving, harmful material reduction and product recycle or reuse" [34] Many researchers [10] [14] and [24] found that green supply chain initiatives have significant positive relationship with environmental and economic performance of organizations, [35] and [10] found no significant relationships between green supply chain initiatives and such performance outcomes The study of the outcomes of green supply chain initiatives is expected to portray the extent to which green supply chain initiatives are effectively adopted. The relationship between green supply chain initiatives and performance outcomes has been subject to numerous studies but the results are not conclusive. There is a wide range of initiatives that can be performed within green supply chains. The lack of consensus on green supply chain initiatives is due to the fact that green supply chain is a new area of study and practice, and theory in this area is underdeveloped.

- ***Product Recovery (PR)*** Product recovery operation is widely recognized and practiced as an ecological alternative for end-of-life products processing that promotes the utilization of returned products, components and materials. 6R (reduce, reuse, recycle, recover, remanufacture, redesign) incorporation is a proactive practice that primarily focuses on the improvement of product, process and system levels along supply chains and makes the returned product economically and environmentally viable [36] define the recovery process as a combination of remanufacture, reuse and recycle whereas [26] divide recovery into repair, refurbish, remanufacture, cannibalize and recycle. Material and product recovery are carried out mainly due to three reasons: (1) hidden economic value of solid waste, (2) market requirements and (3) governmental regulations. Material recovery mostly includes disassembly for separation and processing of materials (e.g. carrying out necessary chemical operations) of used products. The main purpose is to minimize the amount of disposal and maximize the amount of the materials returned back into the production cycle.

- ***Cleaner Production (CP)*** Cleaner production was designed to show that the prevention or reduction of wastes and emissions at source can improve the environmental, as well as economic performance of participating organization. [29] described "cleaner production takes a methodological approach and creative questioning of daily activity to make transparent. Cleaner production has the potential to save 0.5-1.5% of the total costs of producing companies by investments paying back according to present economical standard. The description of success cleaner production implementation can promotes facility efficiency, reduces the need for expensive end-of-pipe treatment and disposal technologies, improved material, energy efficiency, quality system and reduces the long-term liabilities associated with releases into the environment

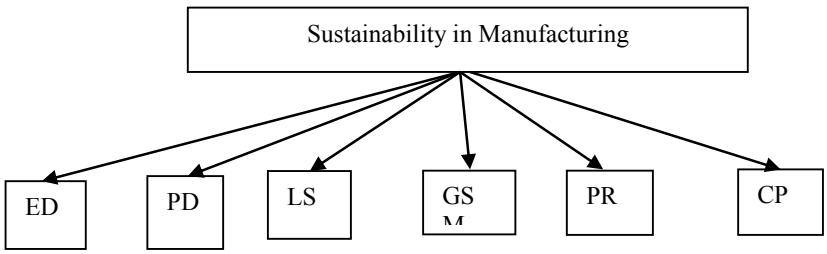

Fig: 1 Different Sustainability in manufacturing in manufacturing environment

These sustainable manufacturing practices a broad outline and variable which can be considered while addressing sustainability in manufacturing, especially for manufacturing environment. Fig 1 presents all these practices present in sustainability in manufacturing. In this study multiple criteria decision modeling (MCDM) is used, which considers more than one criterion in decision-making environments.

3.0 Research Methodology

This study begins with the identification of sustainable manufacturing practices and their factors from literature. This study utilizes the data of a survey conducted for selected practices. The survey is send through email to experts from academia and industry. In survey, the set of questions have been framed and put forwarded after brainstorming session with experts. This study utilizes this survey data to present a comparative study for firms for sustainability environment.

In order to demonstrate the case, a hypothetical situation is considered. The organizations under consideration are electrical panel manufacturing firms. Three electrical panel manufacturing (EPI-1, EPI-2 and EPI-3) firms are considered for study due to confidentiality purposes and are competitor of each other in Indian market. The firm's cumulative annual turnover is more than ₹ 100 million.

An analysis of breakdown sustainable manufacturing practices in to eco design, process design, green supply chain management, lean practices, product recovery and cleaner production are modeled through AHP. Fig. 2 shows AHP model where, estimation of sustainability in manufacturing has been depicted as goal, criteria for the model are different manufacturing practices and alternatives are of three case firms, as discussed in the previous section.

3.1 Analytic hierarchy process (AHP)

This section presents an introduction about the AHP process. AHP is one of the most popular MCDM tools for formulating and analyzing decisions, especially in operation management (OM). The Analytic Hierarchy Process (AHP) is a logical Multi-Criteria Decision-Making technique that allows decision makers to model complex problem based on mathematics and human psychology [37]. It can be defined as an approach to decision making that involves structuring criteria into a hierarchy.

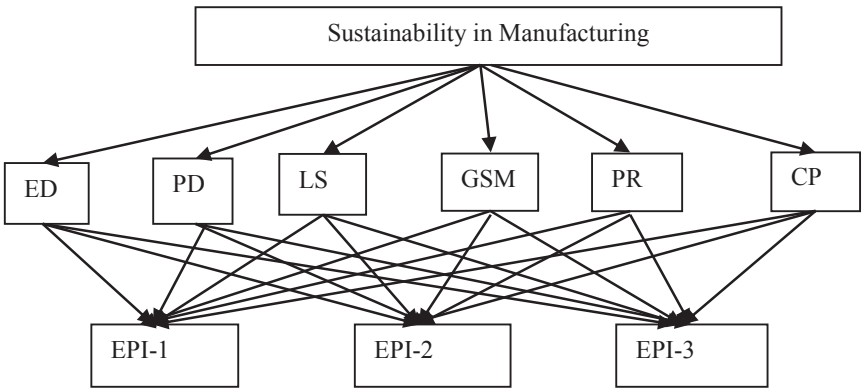

Fig: 2 AHP Model for Sustainability in manufacturing

The relative importance of these criteria is assessed. Alternatives for each criterion are compared that relies on the judgments of experts. An overall ranking scale of the alternatives is then determined [38]. The application of AHP to a decision problem involves following steps [39].

Step 1: Structuring of the decision problem into a hierarchical Model. It includes decomposition of the decision problem into elements according to their common characteristics and the formation of a hierarchical model having different levels. A simple AHP model has three levels that is goal, criteria and alternatives.

Step 2: Making pair-wise comparisons and obtaining the judgmental matrix. In this step, the elements of a particular level are compared with respect to a specific element in the immediate upper level. The resulting weights of the elements may be called the local weights. The opinion of a decision-maker (DM) is elicited for comparing the elements. Elements are compared pair-wise and judgments on comparative attractiveness of elements are captured using a rating scale. Usually, an element receiving higher rating is viewed a superior compared to another one that receives a lower rating. If the property does not hold for all the entries, the level of inconsistency can be captured by a measure called Consistency Ratio [37]. A value of CR less than 0.1 is considered acceptable because human judgments need not be always consistent, and there may be inconsistencies introduced because of the nature of scale used. The ability to identify inconsistent judgments through the calculation of consistency ration is considered one of the strong points of AHP.

Step 3: In this step, local weights of the elements are calculated using the eigenvector method (EVM). The normalized eigenvector corresponding to the principal eigen value of the judgmental matrix provides the weights of the corresponding elements. Though EVM is followed widely in traditional AHP computations When EVM is used, Consistency Ratio (CR) can be computed. For a consistent matrix CR= 0, and if CR for a matrix is more than 0.1, then judgments should be elicited once again from the decision-maker till he gives more consistent judgments. In the next step, this paper presents an implementation of AHP for the sustainability in manufacturing.

4.0 Result and Discussion

Sustainability in manufacturing plays a vital role in every organisation. The process of evaluation of sustainability in manufacturing is begins with identification of manufacturing practices and alternatives from the literature. The pair-wise comparison matrix of alternatives, on the basis of six sustainable manufacturing practices was developed through brain storming sessions in consultation with the experts from academia and industry as shown in table 3-4-5-6-7-8. The normalized weightage of the selected variables was evaluated using user-friendly AHP super decision software. The matrix inconsistency for each pair wise table is also presented. This indicates that judgments made are consistent as CR is below 0.1.

Table 3: Comparison of alternatives with respect to ED

S. No.		EPI-2	EPI-3
1	EPI-1	3	0.5
2	EPI-2		0.25
Inconsistency = 0.01768			

Table 4: Comparison of alternatives with respect to PD

S. No.		EPI-2	EPI-3
1	EPI-1	0.1429	.05
2	EPI-2		7
Inconsistency = 0.04113			

Table 5: Comparison of alternatives with respect to LS

S. No.		EPI-2	EPI-3
1	EPI-1	3	0.25
2	EPI-2		0.20
Inconsistency = 0.08567			

Table 6: Comparison of alternatives with respect to GSM

S. No.		EPI-2	EPI-3
1	EPI-1	5	0.25
2	EPI-2		0.125
Inconsistency = 0.03778			

Table 7: Comparison of alternatives with respect to PR

S. No.		EPI-2	EPI-3
1	EPI-1	1	0.333
2	EPI-2		0.20
Inconsistency = 0.02975			

Table 8: Comparison of alternatives with respect to CP

S. No.		EPI-2	EPI-3
1	EPI-1	2	0.125
2	EPI-2		0.50
Inconsistency = 0.09047			

Table 9: Comparison of criteria (Manufacturing Practices)

	PD	LS	GSM	PR	CP
ED	3	4	4	0.50	6
PD		2	1	0.25	5
LS			3	0.20	7
GSM				0.25	5
PR				0.20	5
Inconsistency = 0.01748					

After applying the AHP, it is expected that organisation which used the sustainable manufacturing practices have best rank and the performance is very good that particular organisations. In the above results it was found that EPI-3 was the best ranked, so that it become more sustainable.

Table 10: Comparison of Electrical Panel industry with weight and rank

S. No.	Electrical Panel Industry	Weight	Rank
1	EPI 3	0.2046	1
2	EPI 2	0.3056	2
3	EPI 1	0.5684	3

Table -10 presents the comparison of criteria or sustainable manufacturing practices with respect to goal considered. It is found that the cleaner production play an important role to achieving sustainability. Through this analysis it can be seen that the best manufacturing practices are differentiating themselves by taking sustainability to its existing technology. The requirement of sustainable manufacturing practice is more important for electrical panel industry to become more competitive in the global market.

5.0 Conclusion

This paper has presented the development of an AHP-based model for sustainable manufacturing practices evaluation in electrical panel industries. The model was developed using Analytic Hierarchy Process (AHP) methodology. The hierarchy structure was established based on the proposed key practices of sustainable manufacturing evaluation electrical panel industries. Then, the importance weights of the measures were assigned by pairwise comparisons and calculated using AHP methodology. The company's score was calculated to assess sustainability in manufacturing against the manufacturing practices. Finally, the industries rank was determined based on their scores. It provides suggestions and directions for industries to take appropriate actions in improving sustainability in manufacturing. Future work will further develop a software based tool of sustainable manufacturing evaluation for electrical Panel Industries.

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