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An Analysis of Selected Parameters in an Energy Efficient Sustainable Manufacturing System Using AHP

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Abstract : Sustainability has taken a pivotal role to enhance the business opportunities by means of producing eco-friendly products using sustainable manufacturing practices. In order to survive in the global competitive market, the need of the hour is to focus on sustainable manufacturing practices. This is furthermore required due to scarcity of natural resources, increased cost of labor/raw material/ machinery/energy, stringent government norms/regulations, higher aspirations of consumers and the like. Increased global competition is forcing the manufacturers to shift towards eco-friendly products - sustainable manufacturing is the pathway in this direction.
This paper will aim to analyze some selected parameters in an energy efficient Sustainable Manufacturing system. In the present work Analytical Hierarchy Process (AHP) has been used as a decision making technique.

Keywords: AHP - Analytical Hierarchy Process, MADM- Multiple Attribute Decision Making, CI- Consistency Index, CR- Consistency Ratio, RI- Random Index

1. INTRODUCTION

Any manufacturing activity is an assortment of men, machine, material, money, method and management. These when coupled together can give rise to the desired output in any manufacturing environment. To carry out any manufacturing activity raw materials are essential in some form or the other. These are extracted from the nature and are then transformed into various kinds of products (semi-finished type or finished type) for end users with the help of appropriate machines/tools/process in a suitable environment by involving workmen. With the declining stock of raw materials and resources and the rising business competition, there is an urgent need for improving the manufacturing effectiveness. As per Subrata Kumar Patra et al. **[2015]** apart from depletion of natural resources various allied problems for the future will be scarcity of water especially potable water, fossil fuel, energy, land filling sites in one hand and increase of pollution level, global warming, chronic diseases etc. on the other. The role of energy in any manufacturing activity is inevitable. There is an urgent need for the manufacturing sector to work towards converting traditional manufacturing system into an energy efficient sustainable manufacturing system.

2. SUSTAINABLE MANUFACTURING

A Traditional manufacturing system eternally focuses for enhancing the quality of manufacture as well as increasing the productivity at the lowest possible cost. Traditional manufacturing system generally has very little focus on conserving natural resources. The environmental damage caused due to the Traditional manufacturing process acts as a barrier towards Sustainable development. On the other hand, Sustainable manufacturing system aims towards manufacturing by conserving natural resources and continually strives towards reducing environmental pollution, waste and emission by adopting efficient environmental friendly practices.

Study of literatures revealed various issues related to Energy efficient Sustainable manufacturing system. These may be broadly categorized as:

- Environmental issues
- Sustainable manufacturing issues
- Energy issues

Further studies helped to identify sub-level elements out of which the following are selected as important parameters for the present work. These are listed in Table 1.1.

Table 1.1: Selected elements in an Energy efficient sustainable manufacturing system

P1	Waste management		P6	Technology issues
P2	Pollution /Emission Control		P7	Manufacturing Process
P3	Environment consciousness		P8	Utilization of Energy
P4	Resource Conservation		P9	Energy Efficiency
P5	Recycling Practices		P10	Use of Alternate Energy

Fig.1.1 depicts the selected issues and the selected parameters in an energy efficient Sustainable Manufacturing System.

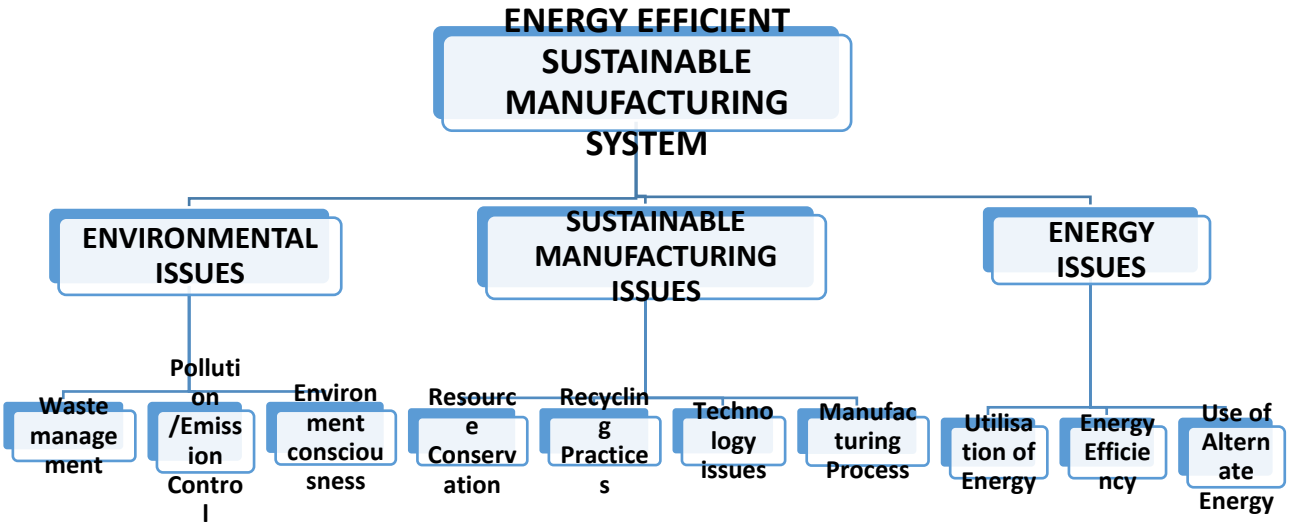

Fig.1.1Various parameters in an energy efficient Sustainable Manufacturing System

3. METHODOLOGY

Any Manufacturing system uses raw materials that are converted into useful products using suitable machines and processes. Various associated parameters are changed from time to time depending on the product and process variability in order to optimize the system. Decision making under such a complex dynamic situation based on multiple alternatives is a challenging task for the engineers, planners, designers, decision makers and the management. Decision making may be done by individual judgment or by a group of experts. In case of subjective opinions decision makers are required to give some subjective values (based on their judgmental power) to quantify them.

Various types of Multiple Attribute Decision Making (MADM) techniques are used to select the appropriate alternatives from a large number of available choices. In the present work Analytical Hierarchy Process (AHP) has been taken up as a decision making tool because of its wider acceptability, adaptability with various situations, easiness to use and the like. Moreover AHP method is capable of solving both objective as well as subjective attributes. Ranking of the alternatives are done using Pair wise comparison of attributes followed by a scale of relative importance. A Questionnaire based survey is used to find the relative importance of these selected parameters (Table 1.1).

The step by step criteria followed in the AHP analysis are:

a. Developing questionnaire for Pair wise comparison
b. Formation of Comparison matrix
c. Normalization
d. Evaluation and Consistency analysis

The scale for comparison used in this paper is given below *(Saaty & Vargas, 1991).*

1- Equal importance of both factors
3-Moderate importance of one factor over another
5-Strong or essential importance
7- Very strong importance
9- Extreme importance.

Integer values of 2, 4, 6, and 8 are used for intermediate values. The scale has been used with the assumption that out of two attributes say P1 and P2, if attribute P1 has very strong importance than P2 and say it is 7, then P2 must be absolutely less important than P1and is valued as 1/7. The matrix formation has been done by pair wise comparison followed by normalizing the matrix and Consistency analysis. Consistency analysis is done by first calculating the consistency measure followed by calculating Consistency Index (CI) and Consistency Ratio (CR). CR is a ratio of CI

and RI where RI is called Random Index and is obtained from RI index chart.

4. RESULTS AND DISCUSSION:

Table 1.2 depicts the calculation chart based on AHP method.

Table 1.2: Calculation chart used in AHP

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Parameters	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	1.000	0.500	6.000	2.000	4.000	1.000	3.000	0.333	1.000	5.000
P2	2.000	1.000	8.000	4.000	6.000	1.000	5.000	1.000	3.000	7.000
P3	0.167	0.125	1.000	0.250	0.500	0.143	0.333	0.111	1.000	1.000
P4	0.500	0.250	4.000	1.000	2.000	1.000	1.000	1.000	0.200	1.000
P5	0.250	0.167	2.000	0.500	1.000	0.200	1.000	0.143	1.000	1.000
P6	1.000	1.000	7.000	1.000	5.000	1.000	4.000	1.000	2.000	6.000
P7	0.333	0.200	3.000	1.000	1.000	0.250	1.000	0.167	0.500	2.000
P8	3.000	1.000	9.000	1.000	7.000	1.000	6.000	1.000	4.000	8.000
P9	1.000	0.333	1.000	5.000	1.000	0.500	2.000	0.250	1.000	4.000
P10	0.200	0.143	1.000	1.000	1.000	0.167	0.500	0.125	0.250	1.000
TOTAL	9.450	4.718	42.000	16.750	28.500	6.260	23.833	5.129	13.950	36.000

P1	Waste management
P2	Pollution /Emission Control
P3	Environment consciousness
P4	Resource Conservation
P5	Recycling Practices
P6	Technology issues
P7	Manufacturing Process
P8	Utilisation of Energy
P9	Energy Efficiency
P10	Use of Alternate Energy

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Parameters	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	TOTAL	AVERAGE	Consistency Measure
P1	0.106	0.106	0.143	0.119	0.140	0.160	0.126	0.065	0.072	0.139	1.176	*0.118*	10.868
P2	0.212	0.212	0.190	0.239	0.211	0.160	0.210	0.195	0.215	0.194	2.037	*0.204*	11.070
P3	0.018	0.026	0.024	0.015	0.018	0.023	0.014	0.022	0.072	0.028	0.258	*0.026*	11.296
P4	0.053	0.053	0.095	0.060	0.070	0.160	0.042	0.195	0.014	0.028	0.770	*0.077*	10.771
P5	0.026	0.035	0.048	0.030	0.035	0.032	0.042	0.028	0.072	0.028	0.376	*0.038*	11.175
P6	0.106	0.212	0.167	0.060	0.175	0.160	0.168	0.195	0.143	0.167	1.552	*0.155*	10.804
P7	0.035	0.042	0.071	0.060	0.035	0.040	0.042	0.032	0.036	0.056	0.450	*0.045*	11.026
P8	0.317	0.212	0.214	0.060	0.246	0.160	0.252	0.195	0.287	0.222	2.164	*0.216*	10.959
P9	0.106	0.071	0.024	0.299	0.035	0.080	0.084	0.049	0.072	0.111	0.929	*0.093*	11.445
P10	0.021	0.030	0.024	0.060	0.035	0.027	0.021	0.024	0.018	0.028	0.288	*0.029*	11.136
												CI	0.117
												RI	1.490
												C. RATIO	0.079

The result gives a CR ratio of 0.079 which is well below the limit of 0.1 and is thus acceptable. This implies that the judgments are quite consistent and the overall work is meaningful. The consistency measure gives the relative ranks of these 10 parameters and is given below:

PARAMETER NO.	PARAMETER NAME	RANK
P9	Energy Efficiency	I
P3	Environment consciousness	II
P5	Recycling Practices	III
P10	Use of Alternate Energy	IV
P2	Pollution /Emission Control	V
P7	Manufacturing Process	VI
P8	Utilization of Energy	VII
P1	Waste management	VIII
P6	Technology issues	IX
P4	Resource Conservation	X

This implies that energy efficiency is the most important parameter in an energy efficient sustainable manufacturing system. This is followed by environmental consciousness and recycling practices and so on.

5. CONCLUSION

The objective of the present work was to find out the relative ranking/ importance of the selected parameters in a Sustainable manufacturing environment using AHP method. Other methods that could have been used are TOPSIS, Artificial Neural Network, Genetic Algorithm etc. In the present study AHP method has been used to rank these alternatives. Based on the consistency measures the ranking is P9- P3- P5- P10- P2- P7- P8- P1- P6- P4. This means that the energy efficiency is the most important factor in any sustainable manufacturing system. The manufacturers are therefore expected to switch over to more energy saving appliances, focus on research and development for energy efficient machines and adopt energy efficient processes for the development that will be truly sustainable.

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