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Research Paper

ENVIRONMENTAL CONSCIOUS MANUFACTURING AND USE OF ANALYTICAL NETWORK PROCESS (ANP) DECISION TOOL IN ECM

Rajkumar Duhan[1]*, Manish Bansal[1] and Haripal Dhariwal[2]

*Corresponding Author: **Rajkumar Duhan,** ✉ er.rajkumarjas@gmail.com

Today the increasing industrialization creates huge pressure on environment and due to this industrialization many environmental related problems arises daily. The global warming, air, water and noise pollution, ozone layer depletion are some of the major problems. With the global awareness of environmental risk as well as market pressure to get maximum benefits, manufacturing system requires new development and Environmental Conscious Manufacturing (ECM) is the only solution for these problems. Multinational and domestic corporations all around the world are adopting environmental manufacturing. The Analytic Network Process (ANP) is a more general form of the Analytic Hierarchy Process (AHP) used in multi-criteria decision analysis. AHP structures a decision problem into a hierarchy with a goal, decision criteria, and alternatives, while the ANP structures it as a network. Both then use a system of pairwise comparisons to measure the weights of the components of the structure, and finally to rank the alternatives in the decision. ECM is also known as Green Manufacturing.

Keywords: ANP software, Environmentally Conscious Manufacturing (ECM) parameters, Various decision tools, Planning and control, etc.

INTRODUCTION

Environmental Conscious Manufacturing (ECM) is a new way of thinking about manufacturing which focuses on the most efficient and productive use of raw materials and natural resources, and minimizes the adverse impacts on workers and the natural environment. In its most advanced form, a product's entire life cycle is considered, from design, raw material and natural resource use to end use and disposal.In order to reach this goal, tools like Life Cycle Analysis (LCA) may be used. Concepts like pollution prevention, energy efficiency, material substitution and

[1] Department of Mechanical Engineering, University Institute of Engineering & Technology, Rohtak, Haryana, India.
[2] Department of Automobile Engineering, Government Polytechnic Manesar, Gurgaon.

maximization of recycled content guide the process. Environmentally Conscious Manufacturing is also known by plethora of different names: Clean manufacturing, Green Manufacturing, environmentally benign manufacturing, environmentally responsible manufacturing and Sustainable manufacturing. Irrespective of the various acronyms, the primary goal remains the same—designing and delivering products that minimize negative effects on the environment through their production, use, and disposal. There are many interpretations of green manufacturing and all convey similar meaning. According to Melnyk and Smith, it is a system that integrates product and process design issues with issues of manufacturing, planning and control in such a manner as to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing environmental impact while also trying to maximize resource efficiency. Figure 1 shows green manufacturing helps in recycling the process.

Figure 1: Meaning of Environment Conscious Manufacturing

SELECTION OF TOOL

The Analytical Network Process (ANP) is selected here for solving the present problem. The ANP is used because there is interdependency between the factors and to make the necessary computation. As there is number of factors on which environment conscious manufacturing depends and it is very confusing to select or priorities them depending upon some criteria and to also it takes lots of time to find out correct priority without any using any tool so ANP is used here to solve the present problem. The process and method to priorities the factors is discussed in the next part of the study.

FACTORS DESCRIPTION

As the ultimate goal here is to achieve the environment conscious manufacturing and for achieving this target, the factors which affects the ECM have to known and their impact on the environment have to be known, so the selection and classification of the factor is the first basic step to advance the study further. Also the selection of factor for ECM affects the whole efficiency of the plant so selection of factors plays a very crucial role in ECM and one should have to select and choose the factor tactfully and carefully otherwise the efficient result can't be achieved. The factor are chosen from the research papers after studying them and it is found that there are numerous factors which affects the environment and then a total of 31 factors are selected from all available factors and their brief description is given here one by one. These factors are divided into five major categories which are further divided into 31 other factors and all of them are listed in Table 1 shown below and these factors are

Table 1: Factors Description

Goal	Dimensions	Assessment Factors	Code
Green Manufacturing	Research and Design Process	Energy Savings of Products	ESOP
		Health and Safety	HS
		Proportion of Product Reuse	POPR
		Proportion of Product Recycling	POPRC
		Conformity with Eco-Concept	CWEC
		Simplification and Standardization	SS
		Reliability and Durability	RD
		Staff with Eco-Awareness	SWEA
	Waste Control	Pollution from Product	PFP
		Proportion of Waste Renewable Products	POWRP
		Ability to Minimize Waste and Maximize the Utility	ATMWAMTU
		Management of Waste Classification	MOWC
		Waste Reduction Rate of Production Facilities	WRRPF
		Application of Foolproof Devices	AOFD
		Production Automation	PA
	Packaging Control	Packaging Simplification	PS
		Ease of Disintegration	EODI
		Application of Product Intensified Packaging	AOPIP
		Proportion of Non-Packaging	PONP
		Additional Processing of Packaging Materials	APOPM
		Inspection Pass Rate of Green Part	IPROGP
		Green Procurement Capabilities	GPC
	Manufacturing Control	Environmental Pollution During Production	EPDP
		Environmental-Related Injury to Operator	ERITP
		Capabilities of Pollution Prevention During Production	COPPDP
		Waste Reduction Capabilities	WRC
		Energy Efficiency During Production	EEDP
	Quality Control	Ability to Obtain Green Certification	ATOGC
		Customer Satisfaction with Respect to Green Demand	CSWRTGD
		Ability to Identify Flawed Green Product	ATIFGP
		Compliance with Outsourcing Regulations for Green Products	CWORFGD

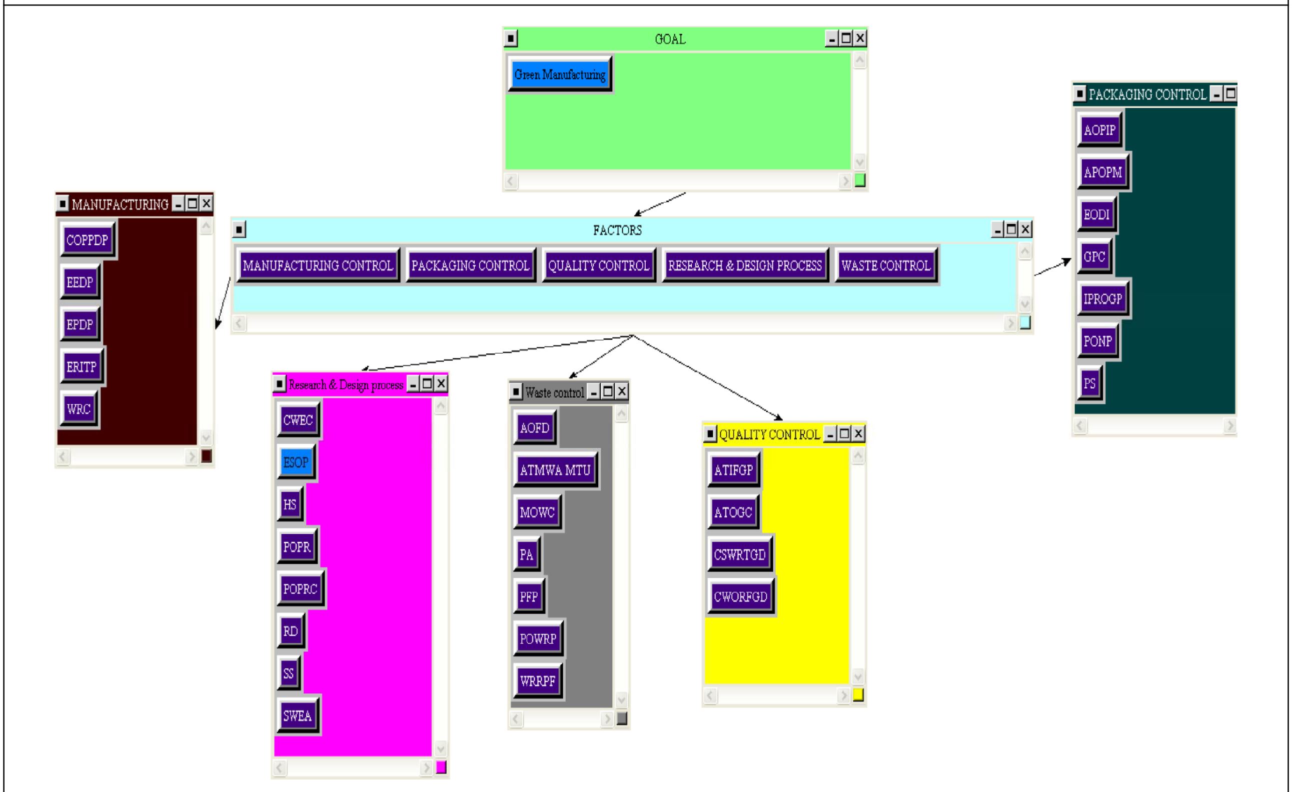
coded into short form to make them compactable with the software used.

MODEL DEVELOPMENT/ DESCRIPTION

For developing the ANP model first of all we should have some know goal which we want to achieve and over aim here is environmental conscious manufacturing evaluation and second thing we have to know is the factors on which the aim depends so here a total of 31 factors are selected for ECM evaluation and these factors are categories into five main categories. Now after getting all these useful information we use the ANP software and develop the basic model. The Figure 2 below shows the basic ANP model which is developed and all the computation work is done based on this ANP model.

The development of model helps to understand the work and to progress the study. In the model there are basically three levels top, middle and bottom. In the hierarchy of the model aim (environment conscious manufacturing) is situated at top of the model and in the hierarchy of the model middle level consists of dimensions on which the aim depends and these are research and design process, waste control, packaging control, manufacturing control and quality control. After that at last or at bottom level of the model different factors on which major dimension depends are shown or it is the base of the model on which the whole ECM process depends. In the AHP model the process stars from bottom to top that is in AHP the importance of bottom factor decides the importance of top factor on which it depends.

Figure 2: ANP Basic Model



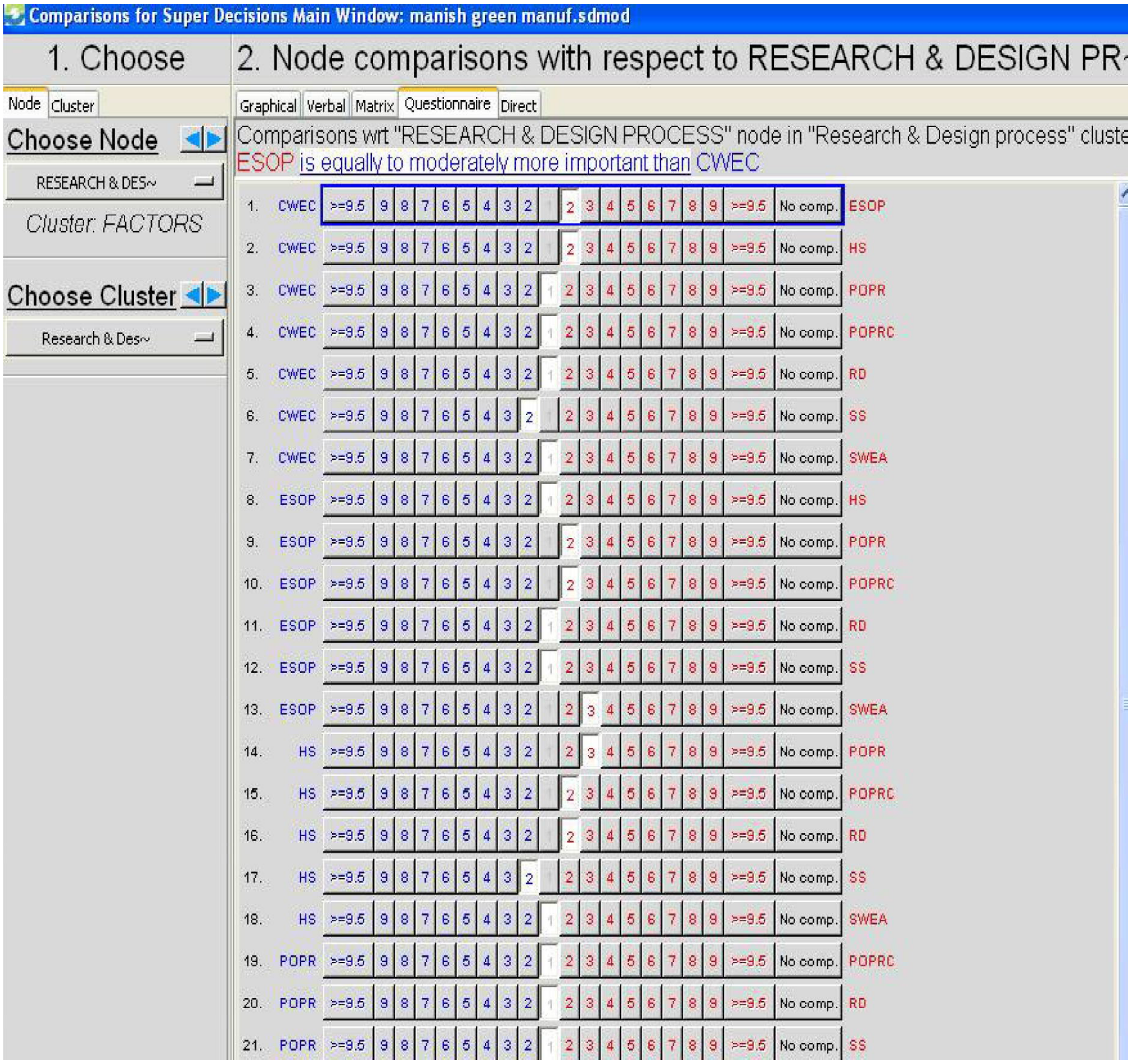
COMPUTATION WORK AND RESULT SYNTHESIS

Now after developing the model with the help of software different computation work is done to synthesis the result. It consists of following step.

DATA INPUT

The first step after the model development is to do the comparison and to progress the comparison process we have to fill the questionnaire first and it should be done carefully keeping in mind about the relative importance of different factors and the Figure 3 shows the basic type of questionnaire. The questionnaire shown here is just for one category but actually such questionnaires are developed for entire group and all of them have to be fill accurately to make the computation work for the model developed. This

Figure 3: Questionnaire for Computational Data



comparison is done for all the 31 factors depending upon the effect of these factors on ECM and this comparison is basically based on these questionnaires.

There is other form of date input also available that are matrix, graph and verbal form. But the questionnaire type data input is best method as it make easy to understand the process and we have to simply make the relationship between different factors and these relation or relative importance is based on some knowledge base and Table 2 is used to fill the questionnaire depending upon the relative importance and ranking of the factors.

Table 2: Ranking for Questionnaire

1.	Equal
2.	Between Equal and Moderate
3.	Moderate
4.	Between Moderate and Strong
5.	Strong
6.	Between Strong and Very Strong
7.	Very Strong
8.	Between Very Strong and Extreme
9.	Extreme

Note: Decimal judgments, such as 3.5, are allowed for fine tuning, and judgments greater than 9 may be entered, though it is suggested that they be avoided.

The numerical value is used to rank the factor and this should be done based on some scientific approach that is the value should satisfy the relation. If the relative importance in the questionnaire is done without thinking this will make error in the computation work and consistency is not achieved. Then this inconsistency is to be removed to synthesis the result and this removal is done by changing the numerical values in the questionnaire so it is better to do the work right at first time rather than increasing it at later stage.

RESULT

As it is well known that different factors possess different priorities with relation to the environmental conscious manufacturing so in order to have a wider reach over them, the priorities are easily predicted using the super decisions software. The inputs to the priorities are filled by various questionnaire prepared during our course of study. Their inconsistency index is also mentioned in the fig with desired value. This priority table help the researchers to judge the relative importance between all these factors and based on the judgement the decision is made for environmental manufacturing. The priority defer from category to category as the expectation/desires differs from person to person, category to category therefore the priorities for the different categories are discussed below one by one. Also the priority for entire group/model is discussed.

Result/Priority for Research and Design Process

The result for the research and design process is shown in the Figure 4 shown below and it is observe from the result that Proportion of Product Recycling (POPRC) is most important factor among this cluster and Simplification and Standardization (SS) is second most important factor while Energy Savings of Products (ESOP) is least importance factor among the research and design processes.

Result/Priority for Waste Control

The Figure 5 shows the result for this category and it is observed from the result that Application of Foolproof Devices (AOFD) is

Figure 4: Result for Research and Design Process

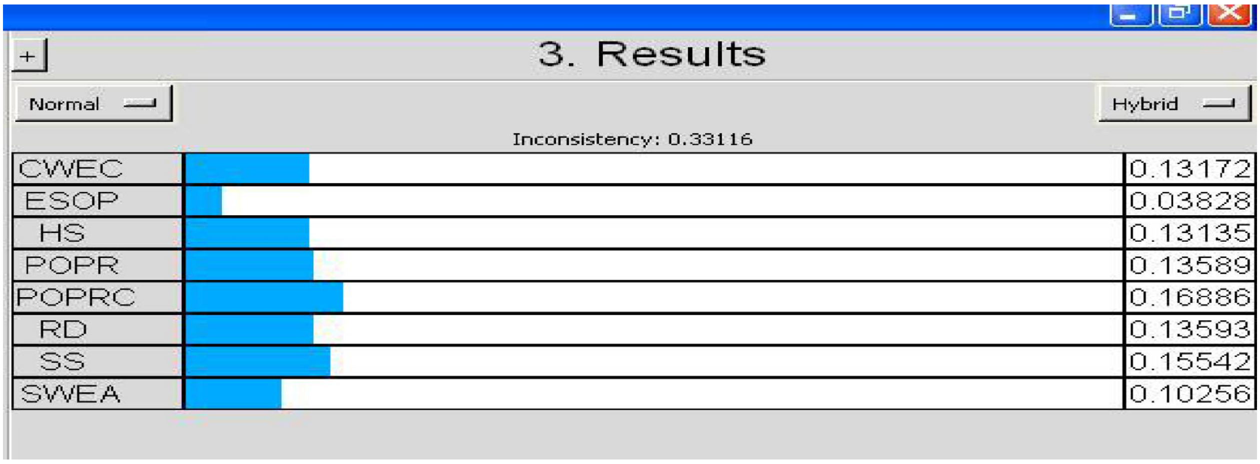
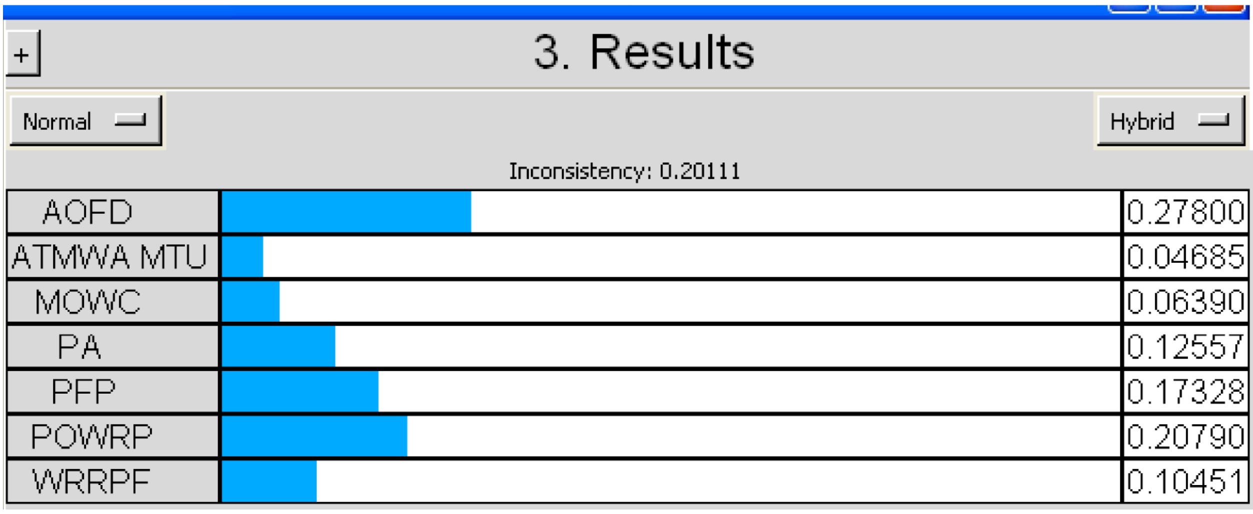


Figure 5: Result for Waste Control

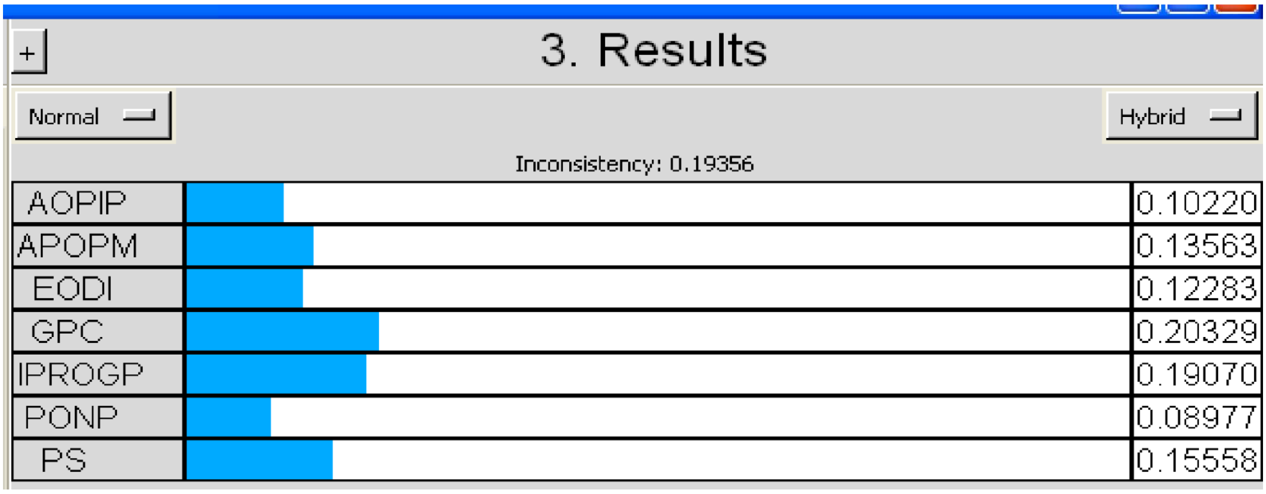


most important factor in this category and than Proportion of Waste Renewable Products (POWRP) is second most important factor while Ability to Minimize Waste and Maximize the Utility (ATMWA MTU) is least important as at this stage the product is manufactured and it is tough to reduce its impact on the environment. Also the importance for other factor can be easily calculated from the result and these factors can also be ranked accordingly.

Result/Priority for Packaging Control

The result for the packaging control cluster is shown in the Figure 6 and it is observed here that Green Procurement Capabilities (GPC) is most importance factor in this cluster and then inspection pass rate of green parts (IPROGP) and Packaging Simplification (PS) comes next in the priority while Proportion of Non-Packaging (PONP) is least importance factor in this cluster.

Figure 6: Result for Packaging Control



Result/Priority for Manufacturing Control

The result for manufacturing control is shown in the Figure 7 and it is seen here that Energy Efficiency During Production (EEDP) and waste reduction capabilities (WRC) is most important factor and all other factor are having almost equal importance.

Result/Priority for Quality Control

The result of quality control is shown in the Figure 8 and it is observed here Customer Satisfaction With Respect to Green Demand (CSWRTGD) is most important factor here and all other factors are almost equally important.

Result/Priority for Entire Model

The result for the entire model can be measured based upon the priority of all the factors and it is shown in the Figure 9 and the priority of the entire category can be judged from the figure.

Figure 7: Result for Manufacturing Control

Figure 8: Result for Quality Control

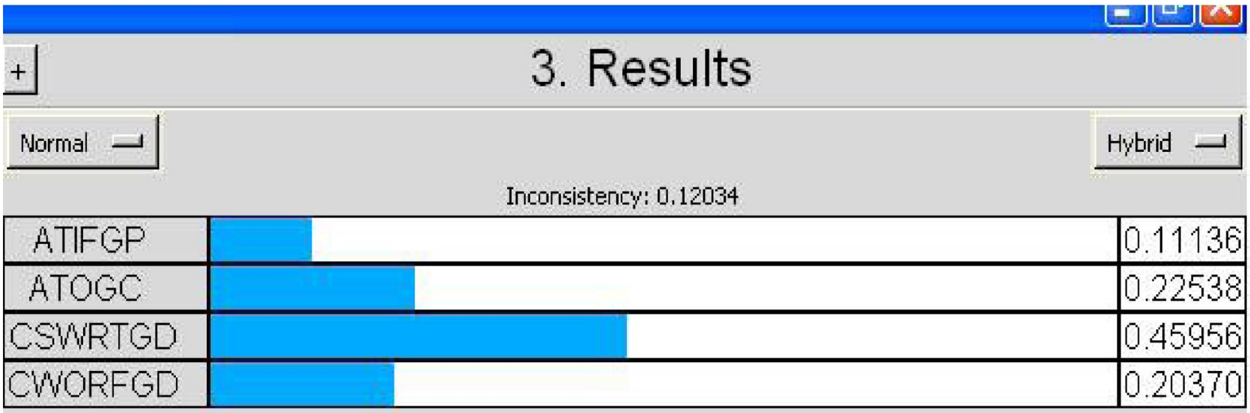
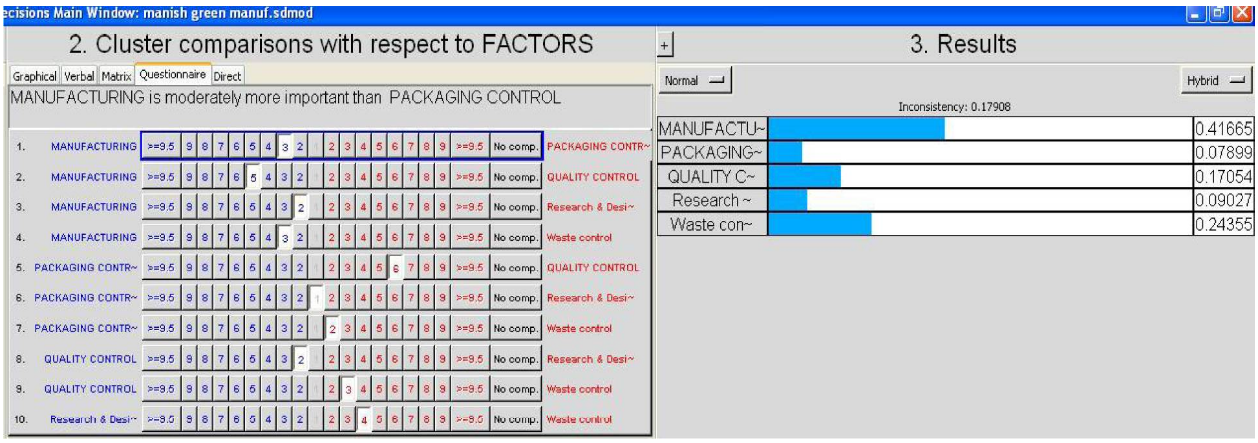


Figure 9: Combined Results



The priority Table 3 shown below for the entire sample is based on the result obtained from the software and it is used to give relative importance between different factors. The percentage importance of different factors is also shown in the table and it can be used to give relative importance/priority between the factors selected.

Table 3: Relative Importance

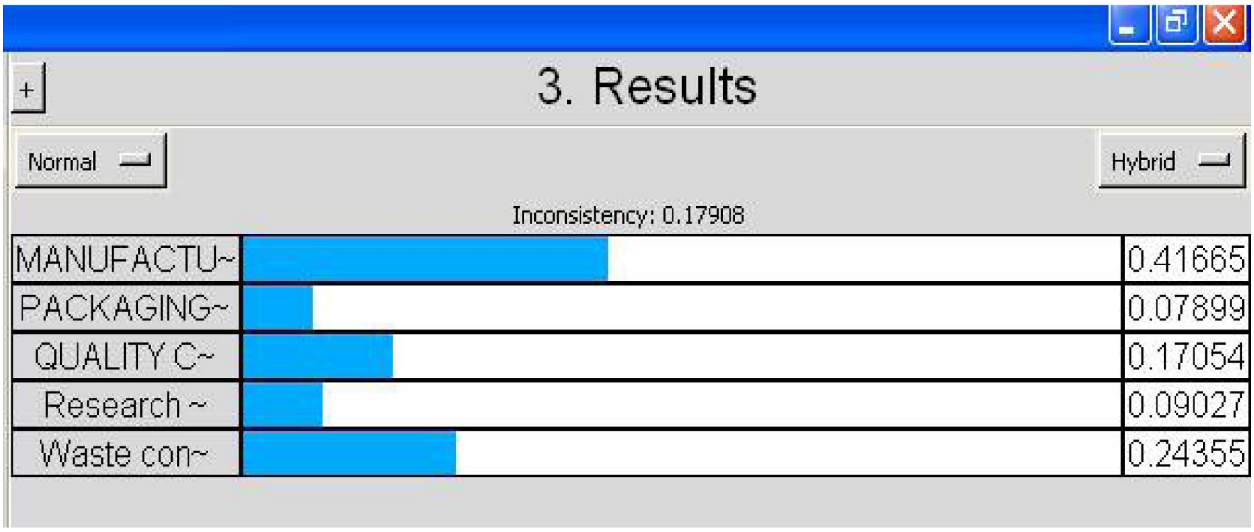
Category	Rank	Percentage Importance
Manufacturing Control	1^{st}	41.66%
Waste Control	2^{nd}	24.35%
Quality Control	3^{rd}	17.05%
Research and Design Process	4^{th}	09.02%
Packaging Control	5^{th}	07.89%

CONCLUSION

Based on considerable data from ECM practices and feasible industrial methods, while incorporating comments from experts in relevant fields, this work here developed assessment model and evaluate factors, followed by a calculation the weights of evaluating factors via ANP. Finally, the model is used for extracting successful factors of implementing ECM in any organizational system. Based on the results of this study, the following conclusion points can be drawn:

- The proposed model contains 5 strategic factors, i.e., research and design process, waste control, packaging control, manufacturing control and quality control and 31 assessment factors/sub factors.
- For strategic subjects, based on evidential analysis, the importance of assessment factors from each category can be seen judged from the result and the relative importance for five main categories can be judged from the Figure 10 shown below.
- It is observed that Manufacturing Control process plays most important role for environment conscious manufacturing and then Waste Control comes next in the priority while Quality Control and Research and Design Process comes next in hierarchy and Packaging Control is least important among the factors selected.

Figure 10: Priority for Different Categories



REFERENCES

1. Ahmed M Dief (2011), "Industrial System Engineering-University of Regina A System Model for Green Manufacturing".
2. Baoju H and Jian L (2011), "Virtual Green Manufacturing and its Application in Manufacturing", International Conference on Advanced Manufacturing Technology New Requirements to China's Manufacturing, Vol. 11, No. 5, June, pp. 244-248.
3. Gencer C and Gurpinar D (2006), "Analytic Network Process in Supplier

Selection: A Case Study in an Electronic Firm, *Applicable Math Model*, Vol. 31, No. 11, May, pp. 2475-2486.

4. Liang D H (2012), “Cloud Computing and Green Management”, International Conference on Intelligent System Design and Engineering Application, Vol. 7, January 6-7, pp. 639-642.

5. Manish Bansal (2012), “Research Paper on Green Manufacturing and Use of Analytical Network Process (ANP) Decision Tool in Green Manufacturing”, Vol. 1, No. 3, October, ISSN 2278-0149, www.ijmerr.com

6. Zhang Y (2010), “Research on Development & Application of Information Resources of Green Manufacturing Enterprise”, International Conference on Information Management, Innovation Management and Industrial Engineering, Vol. 3, March, pp. 130-134.

7. Zhongling Z and Xiwen F (2010), “The Research and Practice of Green Production and Recycling Economy in Gold Mine Enterprise”, International Conference on Information Management and Engineering, Vol. 5, April 16-18, pp. 518-522.

8. Zhou M (2011), “Simulation Based Analysis for Selection and Evaluation of Green Manufacturing Strategies, International Conference on Service Systems and Service Management, Vol. 10, June 25-27, pp. 1-6.