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FACTORS EFFECTING GREEN MANUFACTURING USING ANP

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ABSTRACT

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 & 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 growth of ECM is rapid over the last few decades but the change due to ECM will not happen overnight but over times. It is matter of continuous improvement and the industries itself cannot bring about the changes; government also has to play a very important role of creating the right environment which support the environmental manufacturing. There are many problems while implementing the environmental manufacturing and selection of factors is one of the major problems so it is presented here to provide a unique solution to this problem.

In the present work the factors related to environment conscious manufacturing evaluated and prioritized based upon the Analytical Network Process (ANP). This will help the researchers/academicians/industrialists in decision making process. The correct selection of factors of ECM is very important process. There are numerous factors of ECM but here five major factors namely research & design process, waste control, packaging control, manufacturing control and quality control which are further classified into 31 other factors, are used for evaluation. The results are based on the ANP technique applied after generating the model. These can be used to get the priority between the factors and to identify the most and least critical factor.

Keywords: Environment conscious manufacturing, Analytical Network Process, Research and Design Process, Waste Control, Packaging Control, Manufacturing Control, Quality Control.

I. INTRODUCTION

Manufacturing plays a very strategic role in an organization, especially to build competitive advantage and improve performance. With rapid changes in technology, customer needs and globalization, manufacturing itself is constantly transforming and evolving. The beginning of the century saw the automobile industry introduce the mass production techniques which revolutionized manufacturing processes. Over the years the need for meeting individualistic customer demands without compromising productivity or quality, brought about the introduction of flexible and mass customization techniques. The fig. 1.1 below shows this change in manufacturing philosophies with time.

fig. 1.1 Change in Manufacturing Philosophies

Recent volatility in the price of fossil fuels and global awareness about the finite nature of our resources is creating the need for a more sustainable way of how we produce and use. Therefore the focus is now on Green Manufacturing (Environment Conscious Manufacturing), green manufacturing itself is not new. The concept has

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been around for a couple of decades, but has never received much attention from manufacturers except for participation in seminars and scoring well in polls and surveys. However recent trends show that with the heightened focus on climate change, a transformation of mindset is happening and so positive action is now finally imminent. The basic concept of environment conscious manufacturing or green manufacturing and its impact on manufacturing can be understood from the fig. 1.2 shown below. Both the environmental impact and manufacturing are related with the environmental conscious manufacturing.

Fig. 1.2 Concept of Environment Conscious Manufacturing

II. METHOD

There are some fundamental rules and principle which are to be kept in mind for getting the green product. These philosophies are very important for all type of organisation if it wants to implement the green manufacturing. Some of the philosophies are given below.

- Design – conceptual design of new assets or modification of existing assets.
- Procurement – purchasing new assets or re-engineered components in order to support configuration changes in the manufacturing process.
- Storage – holding new assets or components in stores until they are installed in the manufacturing process.
- Installation – installing new assets or components in the manufacturing process.
- Commission – initial startup of new assets or components.
- Operate – daily operational standards of practice
- Maintain – routine maintenance standards of practice and maintenance strategies.
- Decommission – shutdown and disposal of manufacturing assets, or shutdown and handling of components which are uninstalled for reconditioning.
- There are numerous factors which affect the environment and the selection of these factors is critical criteria for any organization if it wants to implement environment conscious manufacturing (ECM). Here in this work five major categories are selected namely research and product design, waste control, packaging control, manufacturing control and quality control for the evaluation of the ECM. These five major factors are subdivided into 31 factors on which ECM depends.

III. FACTORS DESCRIPTION

table 3.1

GOAL	DIMENSIONS	ASSESSMENT FACTORS	CODE
ENVIRONMENTAL CONSCIOUS MANUFACTURING (ECM)	RESEARCH & DESIGN PROCESS	Energy Savings of Products	E S O P
		Health & Safety	H S
		Proportion of Product Reuse	P O P R
		Proportion of Product Recycling	P O P R C
		Conformity with Eco-Concept	C W E C
		Simplification & Standardization	SS
		Reliability & Durability	RD
		Staff with Eco-Awareness	S W E A
	WASTE CONTROL	Pollution from Product	P F P
		Proportion of Waste Renewable Products	P O W R P
		Ability to Minimize Waste and Maximize the Utility	A T M W A M T U
		Management of Waste Classification	M O W C
		Waste Reduction Rate of Production Facilities	W R R P F
		Application of Foolproof Devices	A O F D
		Production Automation	P A
	PACKAGING CONTROL	Packaging Simplification	P S
		Ease of Disintegration	E O D I

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		Application of Product Intensified Packaging	A O P I P
		Proportion of Non-Packaging	P O N P
		Additional Processing of Packaging Materials	A P O P M
		Inspection Pass Rate of Green Part	I P R O G P
		Green Procurement Capabilities	G P C
	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

3.3.1 Various Integrated Tools Available: Some of the useful techniques which can be used for decision making process are listed below. **a) TRIZ b) ANP c) MADM d) TOPSIS**

3.3.2 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.

3.4 Methodology:
The Analytical Network Process (ANP) which is used here is extension of Analytical Hierarchy Process (AHP) The basic difference between two is that in ANP there is interdependency between the factors and in AHP there is no interdependency between the factors. In the present problem first of all a model is created using the ANP software and after developing the model pair wise comparison between different clusters of elements is done keeping in mind about the inter-relation between these factors and different questionnaire, matrix and graph is drawn for this. After the comparison, the consistency and validity of the result is checked and error is removed and then the final result is synthesis which is in the form of matrix and table. Also the priority of these five main factors and 31 sub factors depends upon the result obtained from the software and which are discussed in the result and discussion part of the study.

Before going through the study let us discussed about some of the basic steps for making decision about the priority between different factors using ANP, this will help to understand the process easily.
3.4.1 Outline of the Steps of the ANP: Some of the basic steps for using the ANP software are discussed below. This will make to understand the work easily.

Step1. Determine the control hierarchies for comparing the components which includes both criteria for of the system and their sub criteria for comparing the elements of the system.
Step2. For each control criterion or sub criterion, determine the clusters of the system with their elements.
Step3. Organize the clusters, elements, nodes in a systematic way so that they represent the system and the hierarchy should be maintained.
Step4. Determine the approach you want to follow in the analysis of each cluster or element, being influenced by other clusters and elements, or influencing other clusters and elements with respect to a criterion.
Step5. For each control criterion, construct the model on which the parent node/element/criteria depends, which element depends upon which factor, which criteria depends upon other criteria and other factors. Join the nodes with arrow and make the necessary workable model.
Step6. Following the above steps and after making the basic model, perform paired comparisons on the clusters as they influence each cluster and on those that it influences, with respect to that criterion. Assign a zero when there is no influence.

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Step7. Perform paired comparisons on the elements within the clusters themselves according to their influence on each element in another cluster they are connected to (or elements in their own cluster). The comparisons are made with respect to a criterion or sub criterion of the control hierarchy.

Step8. For each control criterion, construct the super matrix by laying out the clusters in the order they are numbered. Enter in the appropriate position the priorities derived from the paired comparisons as parts (sub columns) of the corresponding column of the super matrix. Check for validity and consistency of each of the factor and remove the error.

Step9. Compute the limiting priorities of each super matrix according to whether it is Irreducible or it is reducible with one being a simple or a multiple root and whether the system is cyclic or not. Whether result is validate or not and remove the error if any.

Step10. Synthesize the limiting priorities by weighting each limiting super matrix by the weight of its control criterion and adding the resulting super matrices. Synthesize the results based on the priorities.

3.5 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 fig 3.1 below shows the basic ANP model which is developed and all the computation work is done based on this ANP model.

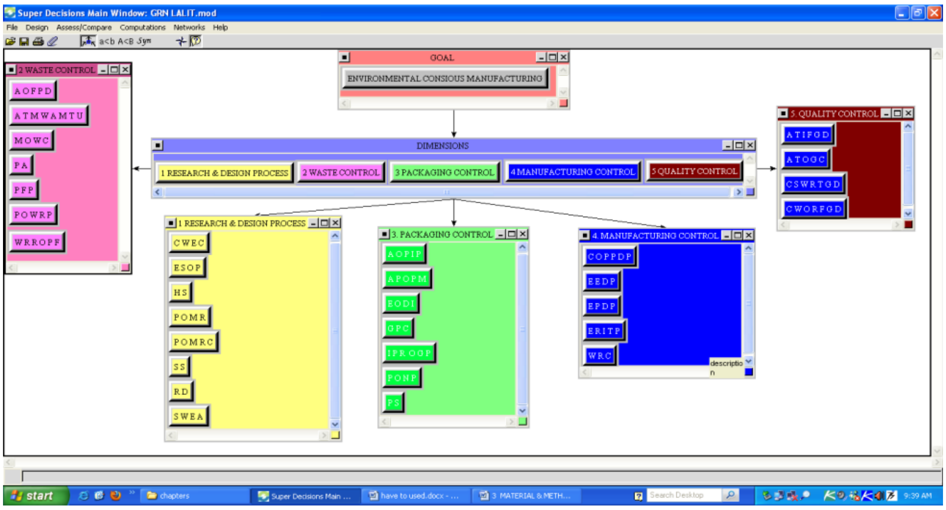

fig 3.1 Basic ANP Model

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.

3.6 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.

3.6.1 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 fig. 3.2 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 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.

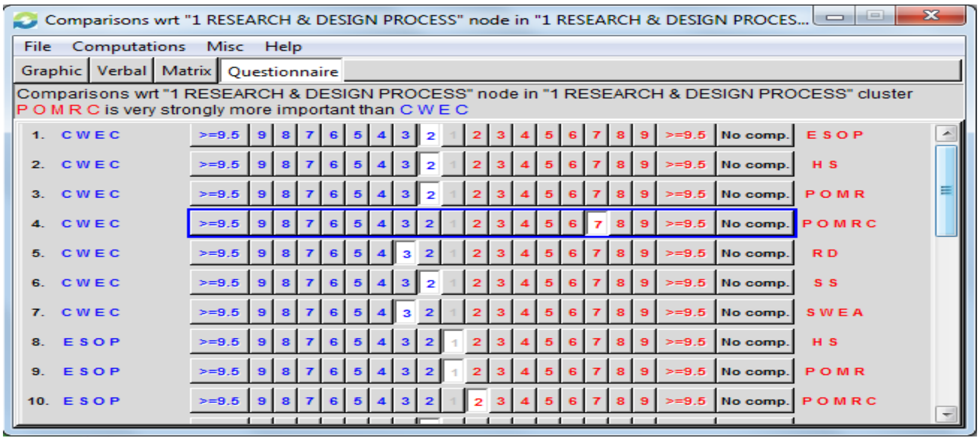

Fig. 3.2 Questionnaire for Computational Data

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 3.2 is used to fill the questionnaire depending upon the relative importance and ranking of the factors.

Table 3.2 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
	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.

The matrix form, graphic form and verbal form of data input are also importance and they are used in the computation work at different stages and all of them have their own advantages and disadvantages. All these form of data input are used to make the necessary computation work and to synthesis the result and result can't be synthesize before correctly entering the data and this data input can be done by any of the above said form.

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The fig 3.3 shows the matrix form of data input. It is used to make the comparison based on inconsistency index which shows which value is inconsistence and then this inconsistency is removed either by changing the numerical value of relative comparison/importance which were filled in the questionnaire or by changing the sign of arrow i.e. changing the importance completely.

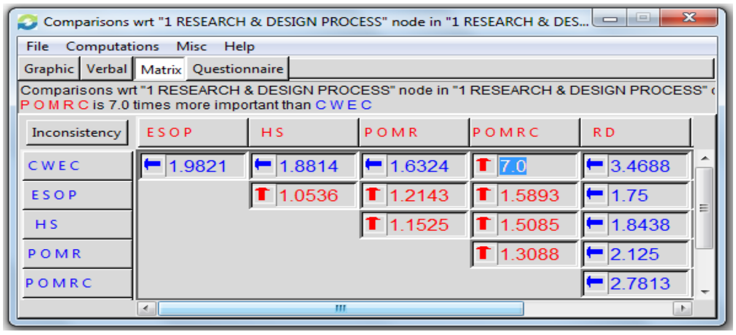

Fig. 3.3 Matrix Form data Comparison

In the fig. 3.3 the arrow indicates that which factor is more importance and the numerical value indicates how much is the importance based on the questionnaire data and the direction of arrow tells the importance. The head of the arrow is always towards the more importance factor when comparison is done between different factors.

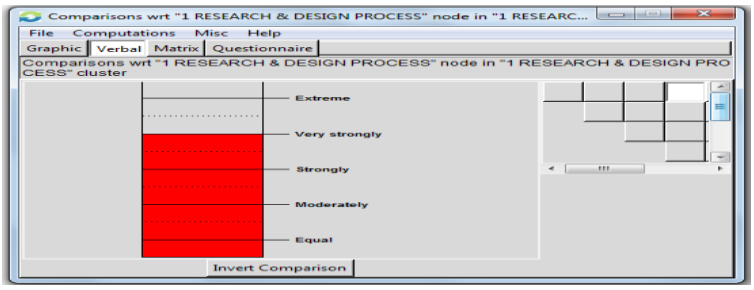

Fig. 3.4 Verbal Form of Data

To make the comparison more accurate and reliable the verbal and graphic form of data can be used as they show clearly the difference between two attributes and it is easier to understand the graph rather than questionnaire. The fig 3.4 and fig 3.5 shows the verbal and graphic form of data input.

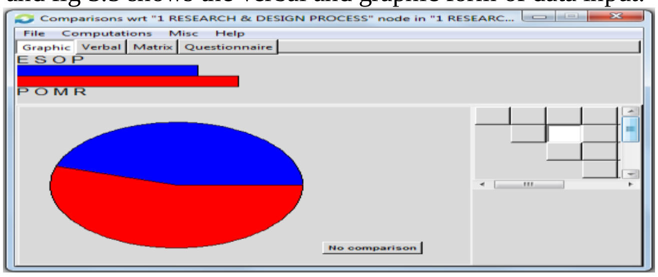

Fig. 3.5 Graphic Form of Data

3.6.2 Inconsistency/Error Removal: After successfully entering the data we have to check for the inconsistency and have to remove it so that accurate result is synthesized. The prioritization of different factor depends upon the successful implementation of this step and the software itself is used for this. For this we have to make the inconsistency report and have to make the necessary improvement in the data entered. A simple example for one cluster is discussed here. First of all we make the comparison and check for consistency and this can be done by simply clicking on the make comparison button. The fig 3.6 shows the comparison window used in the software.

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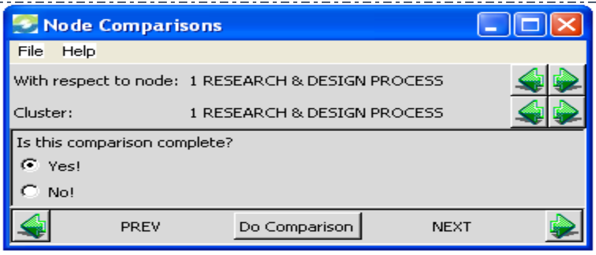


Fig 3.6 Node Comparison

After clicking the do comparison button the comparison is done and then the consistency is check and if the values entered are correct the consistency limit is satisfied and direct result synthesis is done but if the data input has some error then consistency limit will not be satisfied and so the inconsistency is to be removed to synthesize the result. For removal of the inconsistency we have to make the inconsistency report which is also done through the software itself and after that most inconsistent value can be find out and then necessary correction is done in the input data. The process is repeated again and again till consistence result is not obtained. The fig 3.7 shows the inconsistency report and most inconsistence value which is to be changed to get the consistence result.

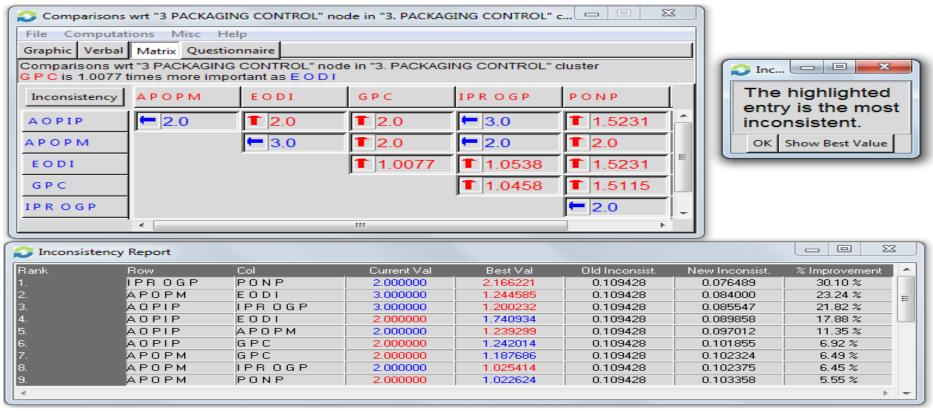
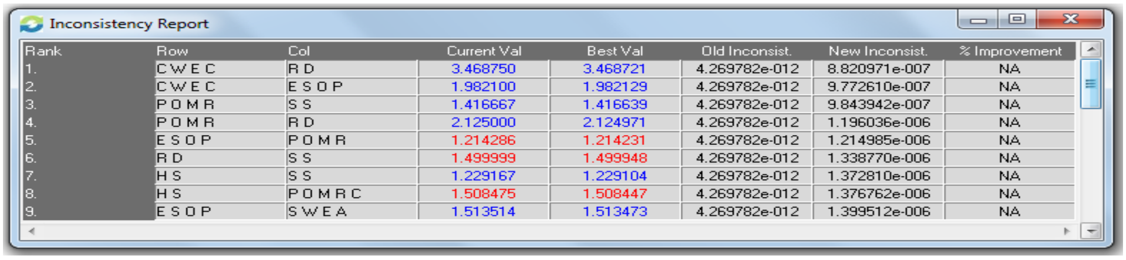


Fig. 3.7 Inconsistency Report before Improvement

This process of inconsistency removal is little time consuming and required to be done carefully and after removal of the inconsistency completely the inconsistency report is made again and find out whether any further percentage improvement is possible or not. The fig 3.8 below shows the inconsistency report after complete error removal.



Rank	Row	Col	Current Val	Best Val	Old Inconsist.	New Inconsist.	% Improvement
1.	C W E C	R D	3.468750	3.468721	4.269782e-012	8.820971e-007	NA
2.	C W E C	E S O P	1.982100	1.982129	4.269782e-012	9.772610e-007	NA
3.	P O M R	S S	1.416667	1.416639	4.269782e-012	9.843942e-007	NA
4.	P O M R	R D	2.125000	2.124971	4.269782e-012	1.196036e-006	NA
5.	E S O P	P O M R	1.214286	1.214231	4.269782e-012	1.214985e-006	NA
6.	R D	S S	1.499999	1.499948	4.269782e-012	1.338770e-006	NA
7.	H S	S S	1.229167	1.229104	4.269782e-012	1.372810e-006	NA
8.	H S	P O M R C	1.508475	1.508447	4.269782e-012	1.376762e-006	NA
9.	E S O P	S W E A	1.513514	1.513473	4.269782e-012	1.399512e-006	NA

Fig. 3.8 Inconsistency Report after Improvement

The inconsistency report also tells us about the best value and the record of old and new inconsistency with the current value of the attribute.

3.6.3 Result Synthesis: After removing the error completely and getting the consistency limit satisfied the next step is to synthesize the result and get the priorities depending upon the data entered. The result is obtained for each of the cluster and it can be in the form of matrix, graph or table depending upon the requirements. The fig 3.9 shows how to obtain the result from the software with desirable consistency index and the result for all the five major categories are obtained by repeating the above said steps and the further discussion about the result is done in next chapter.

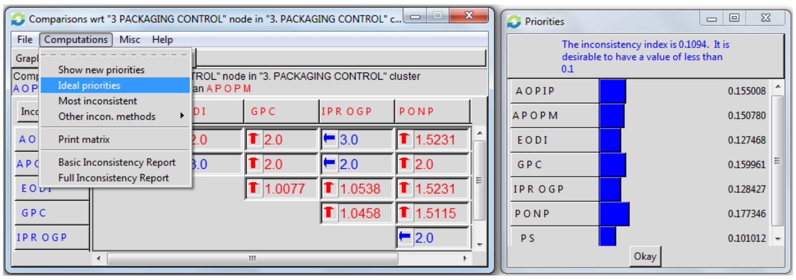


Fig 3.9 Result Synthesis

IV. 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.

4.1.1 Result/Priority for Research and Design Process: The result for the research and design process is shown in the fig. 4.1 shown below and it is observe from the result that conformity with eco-concept (CWEC) is most important factor among this cluster and proportion of product recycling (POPRC) is second most important factor while reliability and durability (RD) is least importance factor among the research and design processes

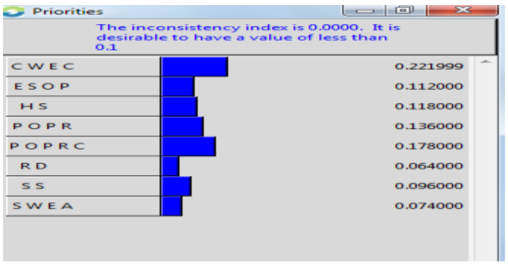


Fig. 4.1 Result for Research and Design Process

4.1.2 Result/Priority for Waste Control: The fig 4.2 shows the result for this category and it is observed from the result that ability to minimize waste and maximize the utility (ATMWAMTU) is most important factor in this category and than application of foolproof devices (AOFPD) is second most important factor while pollution from product (PFP) 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.

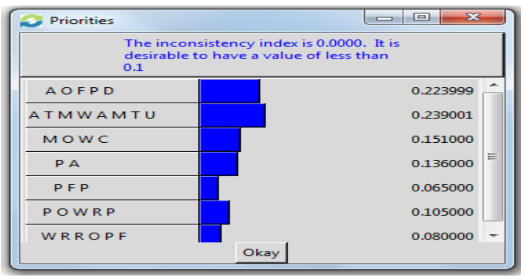


Fig 4.2 Result for Waste Control

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4.2.3 Result/Priority for Packaging Control: The result for the packaging control cluster is shown in the fig. 4.3 and it is observed here that packaging simplification (PS) is most importance factor in this cluster and then inspection pass rate of green parts (IPROGP) and green procurement capabilities (GPC) comes next in the priority while additional processing of packaging materials (APOPM) is least importance factor in this cluster.

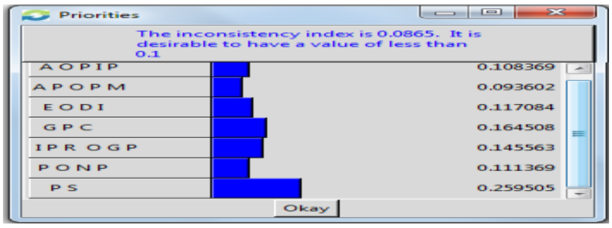

Fig. 4.3 Result for Packaging Control

4.2.4 Result/Priority for Manufacturing Control: The result for manufacturing control is shown in the fig. 4.4 and it is seen here that environmental pollution during production (EPDP) and waste reduction capabilities (WRC) is most important factor and all other factor are having almost equal importance.

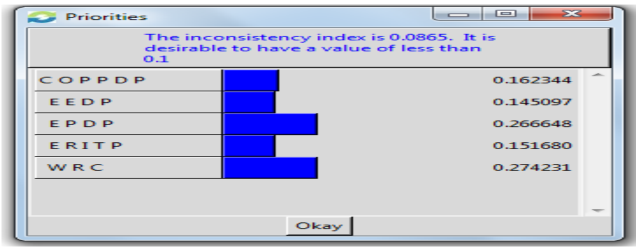

Fig. 4.4 Result for Manufacturing Control

4.1.5 Result/Priority for Quality Control: The result of quality control is shown in the fig 4.5 and it is observed here ability to obtain green certification (ATOGC) is most important factor here and all other factors are almost equally important.

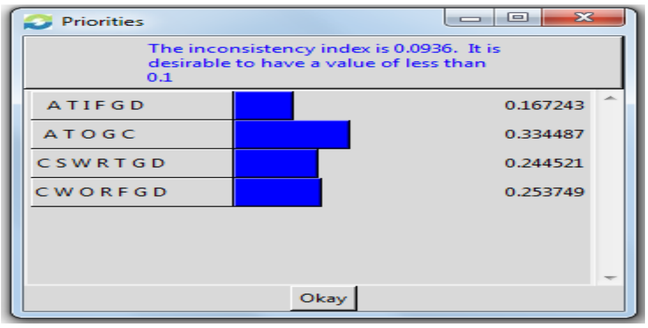

Fig. 4.5 Result for Quality Control

4.1.6 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 fig. 4.6 and the priority of the entire category can be judged from the figure.

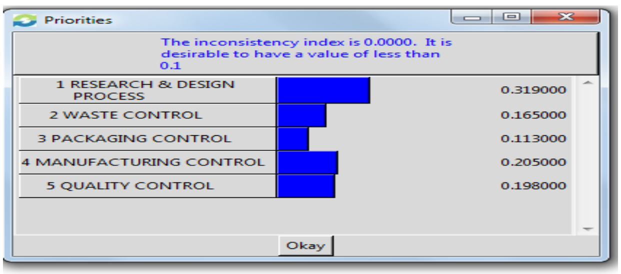

Fig. 4.6 Combined Results

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The priority table 4.1 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 4.1 Relative Importance

Category	Rank	Percentage Importance
Research and Design Process	1st	31.9%
Manufacturing Control	2nd	20.5%
Quality Control	3rd	19.8%
Waste Control	4th	16.5%
Packaging Control	5th	11.3%

V. CONCLUSION AND FUTURE WORK

5.1 Conclusion:

Based on the results of this study, the following conclusion points can be drawn:

1. The proposed model contains 5 strategic factors, i.e. research & design process, waste control, packaging control, manufacturing control and quality control and 31 assessment factors/sub factors.
2. 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 fig 5.1 shown below.

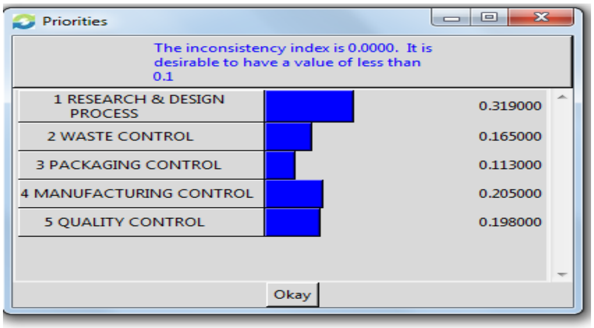

Fig. 5.1 Priority for Different Categories

3. It is observed that research and design process plays most important role for environment conscious manufacturing and then manufacturing process & quality process comes next in the priority and these two are having almost equal importance while waste control comes next in hierarchy and packaging control is least important among the factors selected.

5.2 Future Work:

The environmental problems are increasing day by day and environment conscious manufacturing is best solution to those problems. As new technology comes daily and this required to upgrade the system to get the benefits from that technology. Also it is more beneficial to obtain the factors which affect the ECM through some research and to monitor the actual impact of the factors to get more reliable and accurate result. The ANP is widely applied in project selection, strategic decision making, optimal scheduling and many other fields to find the solution for particular problem. But there are certain limitations of ANP like problem of uncertainty, problem to quantify the precise ratio of weights between criteria, problem of fuzzy sets concept and other problem which needs improvement in future.

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