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# Evaluation of Essential Drivers of Green Manufacturing Using Fuzzy Approach

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**Abstract**

Green Manufacturing (GM) issues became the wide biased debate over the last decade because of its environmental concerns and economical importance. This paper attempts to analyze the drivers of GM with a fuzzy approach. The common drivers are identified through the existing literature and with the combined assistance of industry experts. The Common drivers are provided as stakeholders (D1), company image (D2), competitors (D3), financial benefit (D4), environmental conservation (D5), customers (D6) and compliance with regulations (D7).These seven drivers are getting compared over one another based on the data provided by the firm which is situated in the southern part of India. This paper concludes with the priority among common drivers to find out the essential driver of GM. This study helps to identify the essential driver of GM and in the future it also assists to stimulate that essential driver for implementing GM.

***Keywords:*** *Green Manufacturing, Drivers, Fuzzy AHP*

## 1. Introduction

Green manufacturing has become one of the key topics in modern globalization due to its importance. Green in GM is defined as "concerned with or supporting environmentalism and tending to preserve environmental quality (as by being recyclable, biodegradable, or nonpolluting)" (Merriam Webster Dictionary 2010).In modern manufacturing fields, green manufacturing is considered as a more innovative process due to its potential benefits and other beneficial reasons. Green Manufacturing includes activities such as waste minimization, pollution prevention, energy conservation and other health and safety issues (Hui et al 2001).Green manufacturing was also called as environmentally conscious manufacturing in primitive days. A Lot of researchers attempt to work on this area. These

researchers exhibit the models and proposed new methodologies in green manufacturing through their literature.Many researchers, only focus on the main issues in green manufacturing but they are not interfering in analyzing the drivers of green manufacturing. This paper tries to fill the gap by analyzing the priority of drivers and also points out the essential driver among common drivers. Fuzzy AHP is used to analyze the drivers of green manufacturing in this study. In this paper, section 2 consists of the methodology of the study. Results are posted in section 3 and the paper is concluded in section 4.

## 2. Literature Review

Many researchers focus their attention on GM, because of its adequate importance and necessity. This section provides the review of the existing literature on analyzing the issues of green processes. (Agan et al 2012), explored the drivers of environmental process and their impact in case of (Small and Medium Enterprise) SME's. This study provided a view on Turkish SME's. In that study they established the drivers like regulation, customer, internal motivation, potential benefits etc. (Azzone and Noci 1998), identified the effective (Performance Measurement System) PMS for the deployment of green manufacturing strategies and also they established the issues of adopting the green manufacturing strategies. (Searcy et al, 2012) revealed the challenges in implementing the environmental management system in their research paper. In that paper, they had set ISO 14000 as a main issue and proceeded further.

Motivation of environmental commitment was explored by (Lynes and Dredge, 2006). In their paper, they made a case study in Scandinavian Airlines which was mainly focusing on green tourism.(Benhelal et al, 2012), proposed a novel design for cement manufacturing in their paper. They made the cement manufacturing green as well as economical. By the result of this work, they were able to minimize the carbon emission up to 66%. Also, they could achieve 20.7 million USD gross incomes annually.

(Deif, 2011) proposed a system model for green manufacturing which results in changes of less green of manufacturing processes to more greener production. He also demonstrated the model as an industrial case study.(Massoud et al, 2010) made a case study on Lebanon food industry by analyzing the drivers, barriers and incentives for implementing environmental management systems. In this paper, they focused on the ISO 14000 implementation as a main issue. (Ellram et al, 2008), applied the 3DCE (Three Dimensional Concurrent Engineering) to environmentally responsible manufacturing practices. This study was to stimulate the NPD (New Product Development) in green manufacturing. From the existing literature it is clear that there is no work provided on the drivers of GM based on its relative weights with the assistance of Fuzzy approach. In the sense, this paper attempts to fill the gap.

## 3. Methodology

Common drivers of green manufacturing based on previous literature and with the combined assistance of industrial experts were identified. Based on these drivers, questionnaires were framed and provided to the industry. Based on returned questionnaires, the comparison of drivers was prepared. Priorities of key drivers among these common drivers are identified using a Fuzzy approach. Step by step methodology of our study is shown in fig 1.

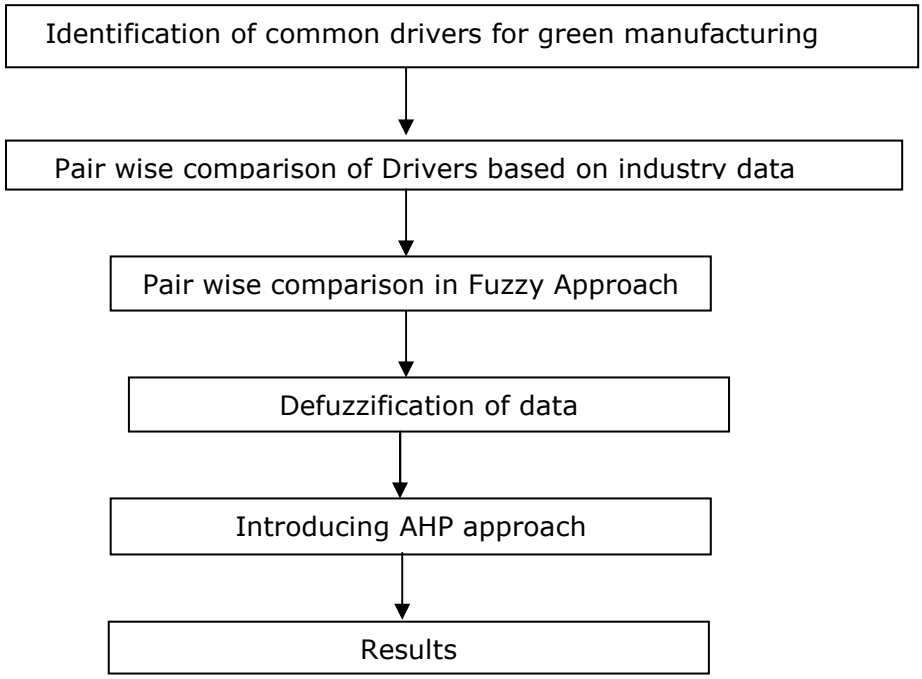


Fig 1 Proposed model for prioritizing the drivers

*3.1 Application of proposed model*

- Step 1:- Identification of common drivers:

  From the various literature reviews and with the assistance of industry experts and field experts the common drivers of green manufacturing are identified which is shown in table 1. The drivers are identified and denoted as stakeholders (D1), company image (D2), competitors (D3), financial benefit (D4), environmental conservation (D5), customers (D6) and compliance with regulations (D7).

Table1: Common Drivers of Green Manufacturing

| S.No | Drivers | References |
|---|---|---|
| 1 | **Stakeholders (D1)** | Chien and Shih (2007); Henriques and sadorsky (1996); Ray and richardson(2009); Suthbir sanbhu et al (2012) |
| 2 | **Company image (D2)** | Lilly (2008); Marilyn (2009); frenk wiengarten et al (2012); suthbir sanbhu et al (2012); Yavuz Agan (2013); |
| 3 | **Competitors (D3)** | Lilly (2008); Marilyn (2009); frenk wiengarten et al (2012); suthbir sanbhu et al (2012); Yavuz Agan (2013); |
| 4 | **financial benefit (D4)** | Urban and Richard (2009); Stevels (2002); Zhu and sarkis (2007); Rao and Holt (2005); |
| 5 | **Environmental Conservation (D5)** | I.K hui et al (2001) |
| 6 | **Customers (D6)** | Wee and Quazi(2005); Richards(1994); mackillop(2009); Sarkis(1999); Berry and Rondinelli (1998) |
| 7 | **Compliance with regulations (D7)** | Zhu and Sarkis(2007); Henriques and sadorsky(1996); Desrochers(2008); Lilly(2008); Rao purba (2002); Yavuz aegan (2013); |

- Step 2:- Comparison of drivers:

Next step is to compare the common drivers which were obtained from literature review and expert opinions. The questionnaires were circulated to the leading rubber industry which is in southern part of India. With the help of received questionnaires from the industry, the comparison of common drivers is done by means of saaty scale which is proposed by T.L Saaty. In this comparison, i and j are considered as drivers then, if i is of greater importance than j then it is denoted as 9, if j has greater important than i , then it is denoted as 1/9. Table 2 shows the Saaty scale and their intensity of importance over criteria

Table2: The fundamental Scale absolute numbers (Saaty 2008)

| **Intensity of importance** | **Definition** | **Explanation** |
|---|---|---|
| 1 | Equal importance | Two activates contribute equally to the objective |
| 2 | Weak or slight | |
| 3 | Moderate importance | Experience and judgment slightly favor one activity over another |
| 4 | Moderate plus | |
| 5 | Strong importance | Experience and judgment strongly favor one activity over another |
| 6 | Strong plus | |
| 7 | Very strong or demonstrated importance | An activity is favored very strongly over another; its dominance demonstrated in practice |
| 8 | Very, very strong | |
| 9 | Extreme importance | The evidence favoring one activity over another is of the highest possible order of affirmation |
| Reciprocals of above | If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i* | A reasonable assumption |
| 1.1-1.9 | If the activities are very close | May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities |

- Step 3:- Fuzzy Approach:

Next step is to prepare a pair wise comparison with fuzzy approach. In this problem, the triangular fuzzy approach is used. Among other MCDM tools Fuzzy AHP is one of the method which provides precise results. In triangular fuzzy approach, (l,m,n) are used to express the importance of criteria over one another. Fig 3 shows the simple representation of triangular fuzzy AHP.

Table:3

| | D1 | D2 | D3 | D4 | D5 | D6 | D7 |
|---|---|---|---|---|---|---|---|
| D1 | (1,1,1) | (1,2,3) | (2,3,4) | (1/3,1/2,1) | (3,4,5) | (4,5,6) | (1/4,1/3,1/2) |
| D2 | (1/3,1/2,1) | (1,1,1) | (1,2,3) | (1/4,1/3,1/2) | (2,3,4) | (3,4,5) | (1/5,1/4,1/3) |
| D3 | (1/4,1/3,1/2) | (1/3,1/2,1) | (1,1,1) | (1/5,1/4,1/3) | (1,2,3) | (2,3,4) | (1/6,1/5,1/4) |
| D4 | (1,2,3) | (2,3,4) | (3,4,5) | (1,1,1) | (4,5,6) | (5,6,7) | (1/3,1/2,1) |
| D5 | (1/5,1/4,1/3) | (1/4,1/3,1/2) | (1/3,1/2,1) | (1/6,1/5,1/4) | (1,1,1) | (1,2,3) | (1/4,1/6,1/5) |
| D6 | (1/6,1/5,1/4) | (1/5,1/4,1/3) | (1/4,1/3,1/2) | (1/4,1/6,1/5) | (1/3,1/2,1) | (1,1,1) | (1/8,1/7,1/6) |
| D7 | (2,3,4) | (3,4,5) | (4,5,6) | (1,2,3) | (5,6,7) | (6,7,8) | (1,1,1) |

- Step 4:- Defuzzification:

Defuzzification is the process which converts the fuzzy numbers into crisp numbers. Table 4 represents the relationship between linguistic terms and the corresponding triangular fuzzy numbers. According to table 4 the fuzzy numbers are defuzzified into crisp numbers which is shown in table 5.

Table4: Linguistic terms and the corresponding triangular fuzzy numbers (Sen et al 2010)

| Linguistic term | Fuzzy Number | Positive triangular Fuzzy Scale (l,m,u) |
|---|---|---|
| Extreme unimportance | $9^{-1}$ | (1/10,1/9,1/8) |
| Intermediate value | $8^{-1}$ | (1/9,1/8,1/7) |
| Very unimportance | $7^{-1}$ | (1/8,1/7,1/6) |
| Intermediate value | $6^{-1}$ | (1/7,1/6,1/5) |
| Essential unimportance | $5^{-1}$ | (1/6,1/5,1/4) |
| Intermediate value | $4^{-1}$ | (1/5,1/4,1/3) |
| Moderate unimportance | $3^{-1}$ | (1/4,1/3,1/2) |
| Intermediate value | $2^{-1}$ | (1/3,1/2,1) |
| Equally importance | 1 | (1,1,1) |
| Intermediate value | 2 | (1,2,3) |
| Moderate importance | 3 | (2,3,4) |
| Intermediate value | 4 | (3,4,5) |
| Essential importance | 5 | (4,5,6) |
| Intermediate value | 6 | (5,6,7) |
| Very vital importance | 7 | (6,7,8) |
| Intermediate value | 8 | (7,8,9) |
| Extreme vital importance | 9 | (8,9,10) |

Table5: Pair wise comparison in crisp numbers

| | **D1** | **D2** | **D3** | **D4** | **D5** | **D6** | **D7** |
|---|---|---|---|---|---|---|---|
| **M1** | 1 | 2 | 3 | 0.5 | 4 | 5 | 0.3333 |
| **M2** | 0.5 | 1 | 2 | 0.3333 | 3 | 4 | 0.25 |
| **M3** | 0.3333 | 0.5 | 1 | 0.25 | 2 | 3 | 0.2 |
| **M4** | 2 | 3 | 4 | 1 | 5 | 6 | 0.5 |
| **M5** | 0.25 | 0.3333 | 0.5 | 0.2 | 1 | 2 | 0.1667 |
| **M6** | 0.2 | 0.25 | 0.3333 | 0.1667 | 0.5 | 1 | 0.1429 |
| **M7** | 3 | 4 | 5 | 2 | 6 | 7 | 1 |

## 4. Results and Discussion:

Table 6 shows the priority of the essential driver in green manufacturing. It is in the descending order as: D7>D4>D1> D2>D3>D5>D6. This proposed model has revealed that the most significant factor for driving the green manufacturing practices is the compliance with regulations. This result is also highly coinciding with existing literature and the expert's opinion. It is fact that the firms or industries are highly pressurized by the regulations and codes of conduct by NGO's and other departments for practicing green manufacturing in their industry. But the developed countries like Japan, EU etc. are well defined in their regulations but in case of developing countries like South Asian countries, the regulations are flexible with the chance of bribery and the system is also not well defined. Financial benefit and stakeholder are the second and third essential drivers respectively.

Table6: Relative weights and rank of green manufacturing drivers

| S.No | Drivers | Relative weight | Rank |
|---|---|---|---|
| 1 | Stakeholders (D1) | 0.158655 | 3 |
| 2 | Company Image (D4) | 0.103625 | 4 |
| 3 | Competitors (D3) | 0.0675646 | 5 |
| 4 | Financial benefit (D4) | 0.239928 | 2 |
| 5 | Environmental conservation (D5) | 0.0447693 | 6 |
| 6 | Customers (D6) | 0.0311746 | 7 |
| 7 | Compliance with regulations (D7) | 0.354284 | 1 |

### *4.1 Sensitivity Analysis:*

There are many defuzzification methods (Ross 1995; Ganesh 2006) and this paper considers only two methods of defuzzification namely Centroid method and Graded Mean Integration Representation (GMIR) method. The results obtained by these methods are shown in the table 7. Fig 2 shows the relationship and deviation of the three methods from the normal method. From the sensitivity analysis, it is proved that the above results are consistent and trustworthy.

Table 7: Method 1: Centroid Method

| S.No | Drivers | Relative weight | | Rank | |
|---|---|---|---|---|---|
| | | Centroid method | GMIR method | Centroid method | GMIR method |
| 1 | Stakeholders (D1) | 0.168853 | 0.163963 | 3 | 3 |
| 2 | Company Image (D4) | 0.108187 | 0.106032 | 4 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | Competitors (D3) | 0.0699829 | 0.0688484 | 5 | 5 |
| 4 | Financial benefit (D4) | 0.239214 | 0.239603 | 2 | 2 |
| 5 | Environmental conservation (D5) | 0.0475334 | 0.0462172 | 6 | 6 |
| 6 | Customers (D6) | 0.0317866 | 0.0315066 | 7 | 7 |
| 7 | Compliance with regulations (D7) | 0.334443 | 0.34383 | 1 | 1 |

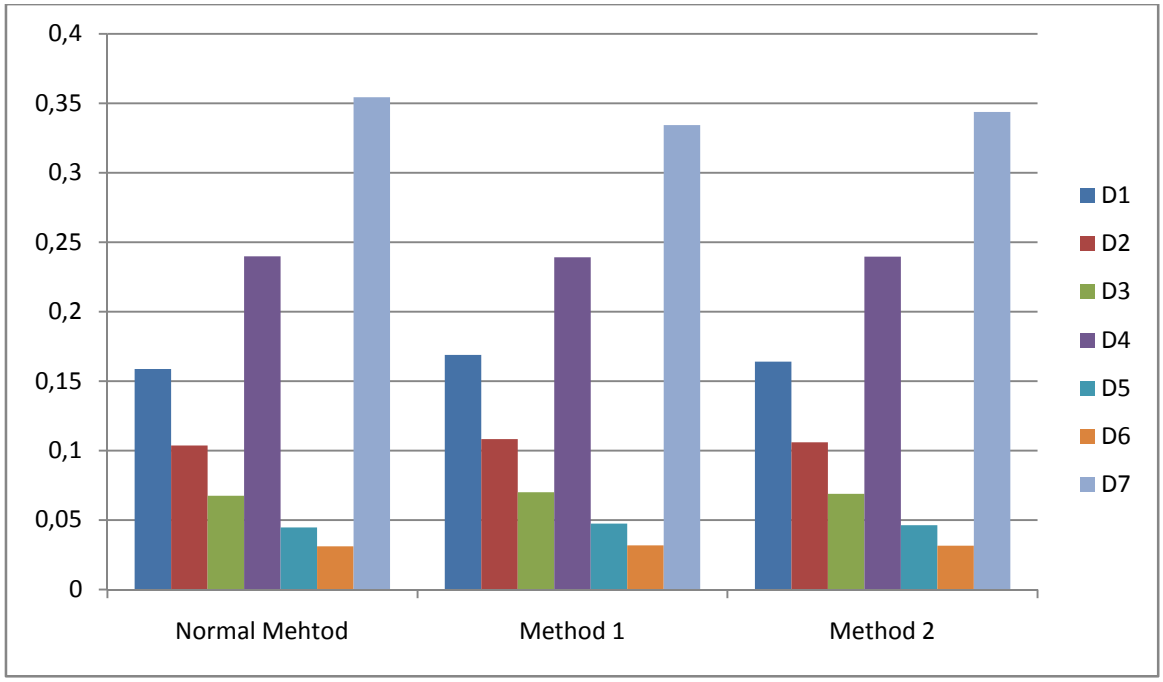


Fig 2 Relationship between results in various methods

## 5. Conclusion:

This paper analyzes the seven drivers of green manufacturing namely stakeholders, company image, competitors, financial benefit, environmental conservation, customers and compliance with regulations which are collected from various literature and managerial interviews and the pair wise comparison was provided with the assistance of production team in rubber manufacturing industry. It is concluded that the compliance with regulation has acquired the highest relative weight among the other drivers. The financial benefit has acquired the second weight in this series. This shows that the firms are only approaching their own benefit rather than anything. The industries are struggling to maintain their position in the market and in front of the government. This has lead to this result. This study has some limitations too. In this paper, the study considers only one firm and the interview was conducted to the production team which comprised of two to three members. Also, only seven relevant criteria based on the firm were considered. It is an unstable consideration which may vary from industry to industry and from application to application. In future, this study can be extended by establishing the questionnaires to several industries and also there is a possibility to extend the number of drivers from seven to many more. This study helps the production team to enable the system to stimulate the effective driver for the easy implementation of green manufacturing.

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