ASSESSING THE SUSTAINABILITY INDEX OF THE AUTOMOBILE INDUSTRY USING BEST WORST METHOD

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ABSTRACT

Sustainable manufacturing in the automobile industry is an assimilation of the triple bottom line (economic, environmental, and social) approach of the manufacturing business. In such a complex system, decision-making becomes clumsy in selecting and prioritizing the different aspects of the triple bottom line. The multi-criteria decision-making techniques can facilitate the selection and prioritization in a complex system. The present study prioritizes the sustainable manufacturing criteria by calculating their weights by applying the best-worst method in one of the manufacturing organizations of India. The criteria were identified through a literature survey of various articles and expert's opinions. A survey on various organizations must be carried out from the selected criteria and thereby developing an index scale. The stakeholders of the case organization will be facilitated in selecting the most significant criteria and developing strategic plans to diminish or eliminate the criteria's intensity for the successful adoption of sustainable manufacturing. The present work can be further extended by including more criteria through conducting a large-scale survey of manufacturing organizations.

Keywords: Supply chain management, Sustainability, Hybrid met Automobile Industry, Sustainability Assessment, Best-Worst Method

INTRODUCTION

BACKGROUND STUDY

Sustainable development, a concept that emerged in context of a growing awareness of an imminent ecological crisis, seems to have been one of the driving forces of world history in the period around the end of the 20th century. Thus by the 1970s the existing notions of „progress‟, „growth‟ and „development‟ were being challenged. According to a report by the World Commission on Environment and Development (WCED) by Brundtland (1987), sustainability is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainability creates balance between the economic, social, and environmental aims of organizations (Székely and Knirsch, 2005). Although it has been three decades since the publication of the Brundtland report, sustainable development still remains a fantasy.

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In the declaration of the United Nations Conference on the Human Environment, held at Stockholm in 1972 as the first in a series of international conferences on the threatening ecological crisis, it was started:

A point has been reached in history when we must shape our actions throughout the world with a more prudent care for the environment consequences. Through ignorance or indifference, we can do massive and irreversible harm to the earthly environment on which our life and wellbeing depend. Conversely, through fuller knowledge and wiser action, we can achieve for ourselves and our posterity a better life in an environment more in keeping with human needs and hopes …To defend and improve the human environment for present and future generations has become an imperative goal for mankind‟.

(United Nations 1972)

Sustainability features in several of the principles adopted by the conference. It was now realized that development needed to be sustainable it should not focus only on economic and social matters, but also on matters related to use of natural resources. „Development that is likely to achieve lasting satisfaction of human needs and improvement of quality of human life‟ (Robert Allen 1980).

The concept of sustainability is a compromise between growth and conservation. At the same time it is the quest for sustainability involves not only environmental and social gains, but also a pursuit of improved economic performance. In September 2015, the United Nations General Assembly formally adopted the "universal, integrated and transformative" 2030 Agenda for Sustainable Development, a set of 17 Sustainable Development Goals (SDGs). India along with other countries signed the declaration on the 2030 Agenda for Sustainable Development, comprising of seventeen Sustainable Development Goals (SDGs) in 2015. In the last few decades' sustainability has been the focus point of various important discussions due to the vital role of industrial activities in creating values in the nationwide economy as well as the environmental and social impacts they bring about.

CONCEPT OF SUSTAINABLE PRODUCTION;

Sustainability has evolved from being initially focused on issues such as environmental impact in terms of carbon footprint reduction and efficient use of energy resources, to including manufacturing products and using processes which are either eco- friendly or having less impact on the environment (Ghadimi et al;2012) . Until recently achieving a certain level of productivity or performance was the key objective in manufacturing organization however it is not (Jayakrishna et al; 2015). Manufacturing industries contribute to a significant part of the world‟s consumption of resources and generation of wastes. This sector requires massive fossil energy such as coal and natural gas (Bekaroo et al; 2018).

Manufacturing has had a significant influence on global development and growth, a trend that is likely to continue due to increased demand for consumer goods from a growing world population with improving quality of life (Haapala et al., 2013). It has been long realized that environmental matters are important to the survival of high end and competitive manufacturing companies, yet they continue to degrade the surrounding, over exploit the available natural resources and generate unmanageable amounts of wastes. It is not just about the Financial Gains and Returns.

In manufacturing organization the term Sustainability deals with the impact of production process and products on the environment and society, laying emphasis on preservation of scarce resources (Jayakrishna et al., 2015).

It is also defined as the capacity to use natural resources in such a way that the economic, environmental, and social aspects are attained, minimizing the adverse impacts of industrial operations on the environment. (Garetti et al; 2012).

Manufacturing processes and systems affect the economic and environmental pillars via resource efficiency and emissions to air, water, and land. The social dimension is impacted in a number of ways, including physiological and psychological effects on employees, public perception, community engagement, and customer loyalty (Haapala et al., 2013). The sustainable manufacturing issues vary from country to country and sector to sector because of commitment of stakeholders and the social performance evolve in the context of particular society (Gupta et al., 2018).

Sustainable manufacturing has become an emerging environmental, economic, societal, and technological challenge to the industry, the academia, and the government entities. Numerous research and development (R&D) efforts have been launched, and many global and domestic efforts have been initiated toward a long-term sustainable world (Shing Chen et al; 2012). Thus a Sustainable Society cannot be imagined until and unless there are efficient approaches and technologies, which are in fact practiced and provided by manufacturing.

AUTOMOBILE SECTOR IN INDIA;

The automotive industry plays a key role in the day to day activity of human life, not only by providing mobility but also by the enormous impact of the industry on economic, environmental, and social activities throughout the globe (Xia et al., 2015). Since inception, the automotive industry has been a major contributor to the Indian economy. The AMP 2026 report by Auto Tech Review (Automotive Mission Plan 2016–2026 – A Curtain Raiser, 2015) estimated that automotive sectors will contribute more than 12% of the overall GDP of the country.

Automotive industries also face environmental and societal pressures from customers, employees, and partners due to globalization (Zhu et al., 2007).In the present scenario, Indian automotive industries are at peak pressure to shift towards SSCM, due to continuous globalization pressures, rules and regulations framed by the government, and from daily increases in societal awareness and standards. Hence, Indian industries now consider the social and environmental issues more vital than ever (Kannan et al., 2016), and they face difficulty in identifying the prominent SSCM practices for improving their sustainable performance (Thanki et al., 2016). The increasing need for firms to adopt sustainability practices in order to achieve competitive advantages and, at the same time, not to compromise aspects of sustainability is the need of the hour (Smith and Ball, 2012). Indian automotive industries are also experiencing challenges in terms of global competition; well- known global giants seek to claim some of the local market. Indian industries understand that following the concepts of sustainability will not only help them to thrive in this healthy competition, but also may provide a competitive edge.

SUSTAINABLE PRACTISES IN INDIA;

The practices (Jayaraman et al., 2007; Linton et al., 2007;Carter and Rogers, 2008), help to reverse the well-known adverse effects of the industry, and the use of environmentally friendly and socially beneficial practices may help to improve the profitability of the business. As arguably the largest manufacturing sector worldwide, the industry faces high profile environmental challenges; they are held responsible for deteriorating air quality, contributing to global warming, and for ineffectively handling end of life automobiles (Orsato and Wells, 2007). These environmental challenges and governmental globalization policies have forced many automotive firms to shift towards using specific practices to help incorporate sustainability (Govindan et al., 2015; Zhu et al., 2007). Evidence indicates that to achieve sustainable performance, some practices must be incorporated.

Thus, the benefits of sustainable practices are well understood, but the challenges associated with their implementation and understandings are not as clearly identified especially in developing nations such as India. Although the implementation of practices has been studied from different perspectives, no work has been done to find the prominent practices and the inter influences among the practices in a leading sector such as the automotive industry in an emerging economy like India. Once the prominent practices and their mutual influences with the other common practices are identified, the shift to sustainable manufacturing is made easier and much more effective. By Pareto 80/20 principle, it is believed that roughly 80% of the effects are only based on 20% of causes. Concentrating on the prominent practices first will automatically increase the chances for the successful adoption of sustainable manufacturing. By identifying the interinfluences between the practices one can develop a suitable mapping for through implementation of all the practices.

IMPORTANCE OF SUSTAINABILITY MEASUREMENT;

Sustainability measurement is a crucial activity in manufacturing company and in an organization management system. If a manufacturing organization aims at incorporating the sustainability holistically, then it has to focus on all the resources required to design, produce and deliver the products to the customer. General performance is related to the company performance assessed in term of productivity, quality, flexibility, responsiveness, etc. whereas sustainability performance is specific to the performance of organization products, processes and policies in term of sustainability. The evaluation or measurement can be done through indices or set of indicators whose major role are to be the decision makers to evaluate a company's sustainability performance as well as plan for future actions.
Sustainability policies assist to design, produce and deliver the product(s) in a sustainable manner. The other critical aspects of any manufacturing organization are product(s) and the processes to

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produce these product(s). Therefore, the three critical factors of sustainability assessment are sustainability policies, product sustainability and process sustainability. The indicators and metrics so chosen must be able to assess or measure the above mentioned critical factors well.

The combination of indicators facilitates the development of a multi-term measurement tool called a sustainability index with sufficient dimensionality, reliability and validity. Composite sustainable development indexes allow the indication of environmental, economic and social concerns for sustainability evaluation.

MOTIVATION;

Industrialists need to pursue manufacturing activities thereby minimizing negative impacts on environment also without compromising profits and socio economic benefits. There has not been a case study based research to determine the sustainability of different manufacturing firms in the Environmental, Economic and Social aspects using a new tool, Best Worst Method.

The main objectives of the study are;

- Identification of sustainable indicators or criteria through deep literature survey and questionnaire survey on preferred industries.
- Categorization of best and worst criteria based on the survey such that it will be more efficient for the improvisation.
- Performance of the existing industrial manufacturing process on the perspective of sustainability.
- To develop a comprehensive sustainability index using best worst method, and thereby to quantify sustainable levels in social, economic and environmental aspects.
- To represent the level of sustainability of the various firms visited on South India on a suitable scale which will help in comparative analysis and development of remedies to improve sustainability

LITERATURE SURVEY

Deepak Mathivathanan, Devika Kannan and A. Noorul Haq;

As one of the largest manufacturing sectors, the automotive industry has a deep impact on the society and environment. Automotive products provide mobility to millions and create jobs, but also threaten the environment. Consumer pressure, government regulations, and stakeholder demands for a competitive edge have forced the automotive industry to consider their environmental and social impacts in addition to their economic status. These pressures have led many automotive industry businesses to adopt Sustainable Supply Chain Management (SSCM) practices. Specific practices that are adopted into the traditional supply chain and that help an industry shift towards a sustainable supply chain are called SSCM practices. Firms have difficulty identifying the most useful practices and learning how these practices impact each other. Unfortunately, no existing research has studied the interrelated influences among these practices in the automotive industry, nor from an Indian perspective.

The current study aims to give a better understanding of the interrelated influences among SSCM practices with a particular look at the automotive industry. Our research presents views from multiple stakeholders, including managerial, environmental, societal, and governmental associations. We propose a framework model, using the Decision Making Trial and Evaluation Laboratory method, to evaluate automotive industry SSCM practices specifically situated in the emerging economy of India. Through a questionnaire survey with the above-mentioned stakeholders, we find inter influences and the prominence of the identified practices.

A prominence causal relationship diagram is obtained depicting the cause groups and the effect groups of the practices. The differences and similarities between individual perspectives and combined stakeholder perspectives are identified. The results reveal that management commitment towards sustainability and incorporating the triple bottom line approach in strategic decision making are the most influential practices for implementing the sustainable supply chain management. This study provides a foundation for industrial managers to understand the inter influences among the practices and increases the probability of successful implementation of SSCM practices within the automotive industry.

Jafer Rezaei;

In this paper, a new method, called best worst method (BWM) is proposed to solve multi-criteria decision-making (MCDM) problems. In an MCDM problem, a number of alternatives are evaluated with respect to a number of criteria in order to select the best alternative(s). According to BWM, the best (e.g. most desirable, most important) and the worst (e.g. least desirable, least important) criteria are identified first by the decision maker.

Pairwise comparisons are then conducted between each of these two criteria (best and worst) and the other criteria. A maximin problem is then formulated and solved to determine the weights of different criteria. The weights of the alternatives with respect to different criteria are obtained using the same process. The final scores of the alternatives are derived by aggregating the weights from different sets of criteria and alternatives, based on which the best alternative is selected. A consistency ratio is proposed for the BWM to check there liability of the comparisons. To illustrate the proposed method and evaluate its performance, we used some numerical examples and areal word decision-making problem (mobile phone selection).For the purpose of comparison, we chose AHP (analytic hierarchy process),which is also a pairwise comparison based method. Statistical results show that BWM performs significantly better than AHP with respect to the consistency ratio, and the other evaluation criteria: minimum violation, total deviation, and conformity. The salient features of the proposed method, compared to the existing MCDM methods, are (1) it requires less comparison data; (2) it leads to more consistent comparisons, which means that it produces more reliable results

Javed Malek , Tushar N. Desai;

Sustainable manufacturing is an assimilation of triple bottom line (economic, environmental, and social) approach of the manufacturing business. In such a complex system, decision making becomes clumsy in terms of selecting and prioritizing the different aspects of the triple bottom line. The multi criteria decision making techniques can facilitate the selection and prioritization in a complex system. The present study prioritizes the sustainable manufacturing barriers by calculating their weights through the application of Best Worst Method in one of the manufacturing organizations of India. The barriers were identified through a review of the peer-reviewed articles and expert‟s opinion. These identified barriers were categorized into six major criteria. For prioritization, the final intensities (weights) of 39 barriers were calculated through the application of Best Worst Method. The findings of the present study enlighten economical & managerial barriers as the most obstructive barriers among the major criteria of sustainable manufacturing barriers followed by organizational barriers, social & environmental barriers, technological barriers, knowledge & learning barriers, and independent barriers. The practitioners of the case organization will be facilitated in selecting the most significant barriers and developing strategic plans to diminish or eliminate the barrier‟s intensity for successful adoption of sustainable manufacturing. However, opinions of the experts were utilized for the present study which can be driven by subjective inputs. The present work can be further extended by including more barriers through conducting the large-scale survey of manufacturing organizations.

Nabila Farhana Jamaludin , Zarina Ab Muis , Haslenda Hashim

Palm oil industry has received criticism from various parties on the issue of sustainability and the greenhouse gases. Carbon footprint accounting are widely used as a metric of climate change impacts and the main focus of many sustainability policies among companies and authorities. However, carbon footprint accounting has limitation to represent sustainability as a whole and may resulting inaccurate selection of further mitigation. This paper evaluates sustainability and greenhouse gases simultaneously using an integrated palm oil mill carbon footprint accounting (POMCFA) and palm oil mill sustainability index (POMSI) method. The integration was performed via the adoption of data synchronization of the carbon footprint accounting and sustainability assessment. The analysis shows that highest carbon dioxide equivalent emission was contributed by palm oil mill effluent followed by diesel consumption and water consumption. In terms of sustainability scoring, the results show that the environmental aspect achieved the lowest scores compared to other aspects (social and economy). Weaknesses identified include diesel consumption, palm oil mill effluent and boiler emission. The assessment analysed in terms of carbon dioxide equivalent and sustainability scoring demonstrates its potential to provide comprehensive mitigation selection purposes.

METHODOLOGY

RELIABILITY CHECK;

After the initial criteria are selected, they are sent to an expert in a survey format to gather the required information. Surveys are used, as they will help gather information in a wide variety of contexts. The responses received are to be checked for reliability. Reliability is a way of assessing the quality of the survey and in turn proves its accuracy and consistency also ensures the degree

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of exactness in in the selection of criterias. Reliability of the responses is checked by finding out the Cronbach Alpha of the items in the responses.

Cronbach Alpha is an index of reliability and internal consistency, how closely a set of items are related. It is used to describe the reliability of factors. The reliability increases with the increase in score. Cronbach Alpha coefficient is used as the indication of finding out if the response is reliable or not, it ranges between 0 and 1.

where,

Cronbach's Alpha	Internal Consistency
α ≥ 0.9	Excellent
0.9 > α ≥ 0.8	Good
0.8 > α ≥ 0.7	Acceptable
0.7 > α ≥ 0.5	Questionable
0.5 >α	Poor

Cronbach Alpha coefficient ≥0.70 is considered as acceptable and is preferred.

Cronbach alpha is in simple terms written as a function of the number of test items and the average inter-correlation between the items.

The basic formula to calculate Cronbach alpha:

$\alpha = Nc/\gamma + (N-1)\ c$

Where, N is the number of items, c is the average inter-item covariance among the items, γ is the average variance. As apparent from the formula itself the alpha value increases with the number of items also if the inter item covariance is low the alpha will be too.

Tool Used

IBM SPSS is used as the tool to calculate the Cronbach alpha value. IBM SPSS helps in calculating the Cronbach alpha also it helps find out the correlation between the items and different stats that are required to determine the reliability of the survey.

	Scale mean if item deleted	Scale Variance if item deleted	Corrected item Total Correlation	Cronbach's alpha if item deleted
VAR00001	40.3333	21.067	895	547
VAR00002	40.6667	17.467	764	500
VAR00003	40.0000	24.000	250	626
VAR00004	40.3333	25.067	189	635
VAR00005	40.3333	23.067	527	585
VAR00006	40.8333	26.967	-105	664
VAR00007	40.0000	22.000	522	582
VAR00008	42.0000	25.200	-029	701
VAR00009	40.0000	23.600	558	600
VAR00010	42.0000	32.600	-548	700
VAR00011	40.8333	18.567	522	581
VAR00012	40.3333	17.667	821	437

The above table consists of the total item statistics, which helps us in identifying the correlation between the items and the requirements to get an acceptable Cronbach"s alpha.

The Cronbach alpha value with 12 items was obtained as,

Cronbach's alpha	No. of items
0.641	12

To improve its value, we decided to optimize the criteria. The final Cronbach alpha score with 10 items (Criteria) was obtained as,

Cronbach's alpha	No. of items
0.849	10

We achieved a Cronbach alpha of 0.849, which is accepted as a good score and hence ensures the reliability of the survey.

3.1 Best Worst Method (BWM);

In this section, we discuss the procedure or the way MCDM technique (BWM) is used in this project, starting with the selection of the weight assignment method and a description of how this method is applied and how the respondents were approached

Based on the discussion provided in the literature review, BWM needs less number of pairwise comparisons to achieve consistent results. Since the present study has considered the prioritization of 10 criteria. BWM is the most suitable to attain the advantage of less pairwise comparisons and also to attain more consistent results. BWM compares various factors to one standard factor and based on that, weights are calculated. It is based on the selection of the best factor and the worst factor. BWM compares the best factor to all other remaining factors, and all other remaining factors to the worst factor. BWM was developed by Jafar Rezaei in 2015 and composed of finding the optimum weights and consistency ratio by solving the simple optimization model generated based on the two comparison vectors. The BWM is a steps approach, which is explained below and the steps are adapted (Rezaei,2015, 2016):

The problem examined in this research is a multi-criteria decision analysis (MCDA) problem that can be represented by the matrix. In this Matrix

$$A = \begin{array}{c} \\ a_1 \\ a_2 \\ \vdots \\ a_m \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_n \end{array} \\ \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{pmatrix} \end{array}$$

{c1, c2,…, cn} represents criteria selected for analysis

{a1, a2,…, an } are the available alternatives.

pij represent the scores of the different alternatives on the given criteria.

The goal is to evaluate and rank the alternatives based on the corresponding score given (pij) and criteria weights (w1, w2, … , wn).

Criteria weights are calculated using the equation (wj≥0, Σwjj= 1); if there are „n" criterias, then their corresponding „n" weights are evaluated.

A number of different MCDA techniques have been proposed to assign weights to different criteria. The method selected in this project is the Best Worst Method (BWM), for several reasons. Pairwise comparison methods mainly face two problems.

- The first problem is that the number of comparisons that have to be made for a full pairwise comparison matrix is large, so it is a lengthy process.
- The second problem is the inconsistency between the comparisons, which can be caused by several reasons, such as a lack of concentration or information.

Instead of a complete pairwise comparison matrix, BWM uses only two vectors, the BWM requires fewer comparisons compared to a full pairwise comparison matrix, making the process short and increasing consistency between the comparisons since the comparison is conducted in a very structured way. So the problems of pairwise comparison are reduced by using the BWM. BWM uses a very structured and understandable way of gathering the data required for the pairwise comparisons, which results in highly reliable results that are easy to understand by the evaluator and can be easily revised to increase consistency. The method was introduced in 2015 and is therefore relatively new, but it has already been applied in several studies.

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Steps in BWM

Step 1: Selection of the criteria

From a set of evaluation criteria or key performance indicators available which are discussed in literature review, for our project we selected 9 most important criteria which we find crucial for our index {C1, C2, …, C9}.

Step 2: Determine the best (most important) and worst (least important) criteria.

From the selected criteria, a best criterion (e.g. the most important criterion to evaluate the alternatives) and the worst criterion (e.g. the least important criterion to evaluate the alternative) have to be identified.

Step 3: Determine the preference of the best criterion over the other criteria.

The evaluator has to indicate the preference of the most important criterion over the other criteria, using a number between 1 and 9, where 1 indicates equal importance, while a number greater than 1 means that the best criterion is a lot more important compared to the given criterion resulting in a Best-to-Others vector (AB)

AB= (aB1, aB2, …, aBn)

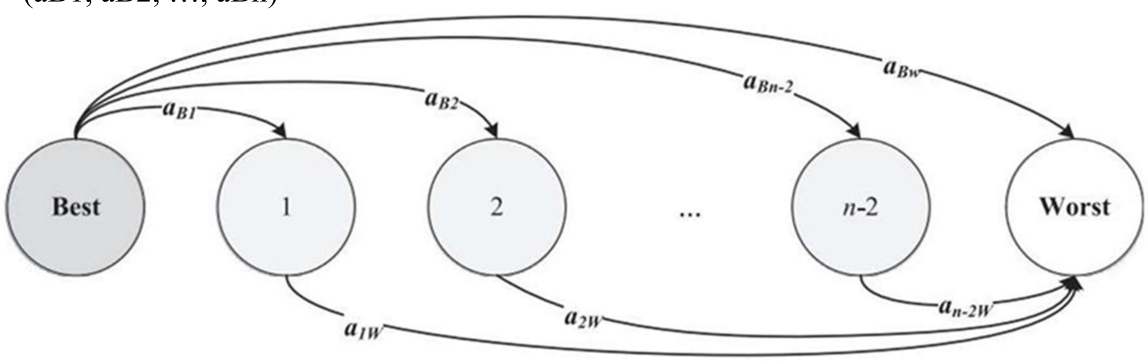


Figure 3.1

Step 5: Find the optimal weights.

The optimal weights (w1∗, w2∗, … , wN∗) are identified.

Two different models have been proposed for BWM, the former of could lead to multiple optimal solutions, while the latter aims at finding unique weights. This linear model is used here to determine unique weights.

The set of optimal weights for the linear model is the one where the maximum absolute difference for the following set $\{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$ is minimized.

The weights cannot be a negative value the sum of the weights has to be

equal to 1 The above conditions are represented as equations:

a_{Bj}–Preference or priority number of best Criterion over particular Criterion

w_B–$weig?t\ of\ best\ criterion$

w_j–weig□t of given criterion

w_W–weig□t of worst

criterion Maxmin {$|w_B-$

$a_{Bj}w_j|,|w_j- a_{jW}w_W|$} $\Sigma w_j=1$

$w_j\geq 1$, for all j

This problem can be solved or the by transferring it to a linear

programming problem $\min|w_B- a_{Bj}w_j| \leq \xi$, all j

$\min|w_j- a_{jW}w_W| \leq \xi$, all j

$\Sigma w_j=1$

$w_j\geq 1$, or all j

Solving this linear programming problem will lead to a single solution in which the optimal weights (w_1*, w_2*, … , w_n*) and $\xi*$are obtained. The value for $\xi*$shows the reliability of the outcomes based on the consistency of the comparisons. $\xi*$ is a direct indicator of the consistency of the comparisons. Complete consistency is reached when $a_{Bj} \times a_{jW}=$, for all j. A value close to zero indicates a high consistency and high reliability.

Questionnaire and Respondent Selection:

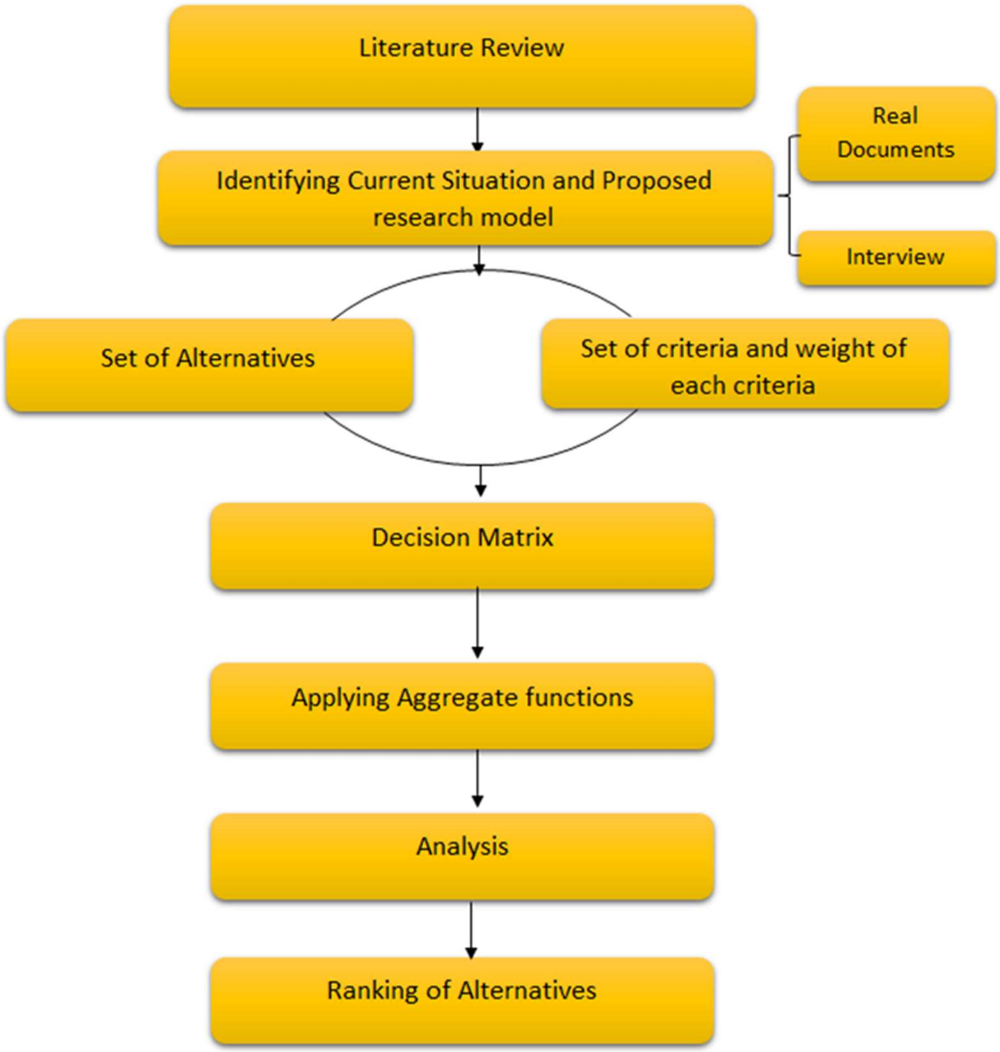
We used an online questionnaire; the response for the questions was collected using google forms. Persons who were approached to fill in the questionnaire are subject experts, various professionals and educational as well as professional experts. We sent them questionnaire via e-mail.

Multi Criteria Decision Making (MCDM):

Multi-criteria decision-making (MCDM) is a very important branch of decision making theory. It is a processof evaluating real world situations, based on variousqualitative/quantitative criteria in certain /uncertain/risky environments to suggest a course of action / choice/ strategy/policy among the available options.

MCDM problems are generally divided into two classes with respect to the solution space of the problem: continuous and discrete.

The flowchart below represents steps followed in a MCDM technique is shown below



The salient features of the proposed method, compared to the existing MCDM methods, are

- BWM is a vector-based method that requires fewer comparisons compared to matrix- based MCDM methods such as AHP.
- The final weights derived from that are highly reliable as it provides more consistent comparisons compared to other methods.
- Not only can it be used to derive the weights independently, it can also be combined with other MCDM methods.
- While using a comparison matrix, generally speaking we have to deal with integers as well as fractional numbers in BWM, only integers are used, making it much easier to use.

METHODOLOGY FLOWCHART

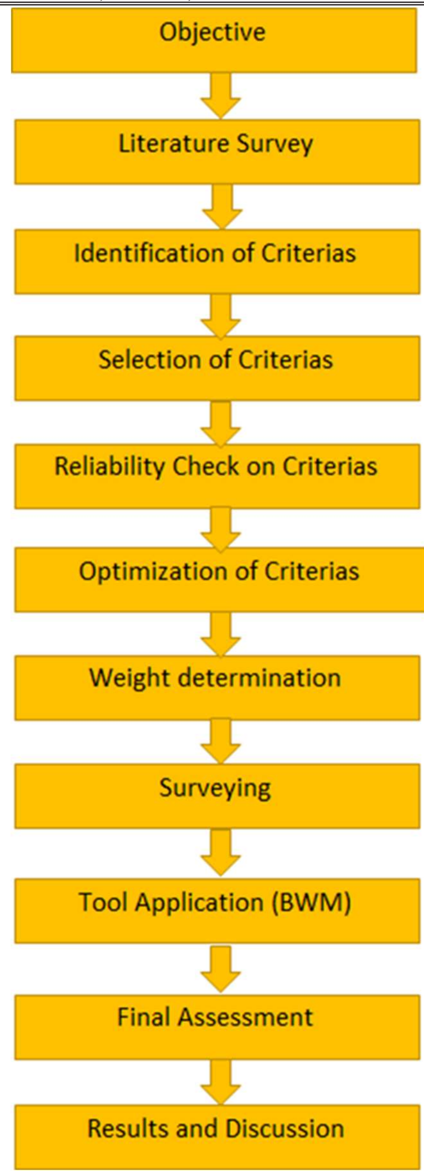


Figure 3.3

CRITERIAS;
ENVIRONMENTAL CRITERIAS
The major 6 environmental criteria in this context are explained below.

1, Usage of renewable resources;
It accounts for the energy use from renewable resources, like sun, wind, rain, tide, geothermal heat etc…
2, Hazardous waste ratio;
It accounts for any materials that may pose a threat to the personal health safety, and/or property when stored or transported or utilized for manufacturing.
3, Green packing;

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It accounts for the packing of products using ecofriendly or environmentally less harmful materials.

4, GHG emissions;

It gives an account for any emission into air that will contribute to the greenhouse effect, like Carbon Dioxide etc…

5, Material Recyclable Ratio;

It accounts recycled materials used in a certain product at the production stage or the ratio of materials recycled or recovered from end of life or waste products.

6, Water consumption rate;

It gives us a measure of the amount of water that has been affected by human use or is a by-product of industrial activities.

ECONOMIC CRITERIAS

The major 3 economic criteria in this context are explained below.

1, End life value for products;

It accounts for the value or cost that the customer gets at the expired state of the product.

2, Total Research Development Expenditure;

It accounts for the expenses involved for research and other developmental activities involved in the automobile industry.

3, Financial Assistance received from Government;

It accounts for any financial aid from government which is utilized for manufacturing activities in automobile industry.

SOCIAL CRITERIAS

The major 3 social criteria in this context are explained below.

1, Government rules and regulations;

The laws and policies that influence the manufacturing activities in automobile industries.

2, Corporate Social Responsibility;

It aims to contribute to societal responsibilities that the automobile industry must have.

3, Employee Green Awareness;

It accounts for any financial aid from government which is utilized for manufacturing activities in automobile industry.

1. Usage of Renewable Resources (URR) 2. Hazardous Material Ratio (HMR) 3. Green Packing (GP) 4. Green House Gas Emissions (GHG) 5. Material Recyclable Ratio (MRR) 6. Water Consumption Rate (WCR)	1. End Life Value (ELV) 2. Total Research Development Expenditure (TRDE) 3. Financial Assistance Received from Government (FAG)	1. Government Rules & Regulations (GRR) 2. Corporate Social Responsibility (CSR) 3. Employee Green Awareness (EGA)

Selection of Suitable Numerical-Linguistic Scale:

In order to measure the sustainability of the manufacturing firm, the indicators so chosen must be rated or given a numerical score. For this a suitable scale must be chosen which will help the stakeholder at the firm to easily rate the individual performance or level of impact of each indicator on the manufacturing process.

We had used to different scales in this study to collect the response values, 5 point Likert scale to collect the responses from reliability check survey and 9 point scale has been chosen for surveying on various industries. Both the scales for performance measurement and interdependency measurement of the indicators are illustrated below:

	1-5 Scale
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree

5	Strongly Agree

For instance if a particular criteria was rated „1", then it would mean that the criteria has a very low impact, like impact would be very high if the criteria is given a rating of „5".

	1-9 Scale
1	Extremely Disagree
2	Very Disagree
3	Moderately Disagree
4	Slightly Disagree
5	Neutral
6	Slightly Agree
7	Moderately Agree
8	Very Agree
9	Extremely Agree

In the case of 9-point scale if a particular criteria was rated „1", then it would mean that the criteria has a very low impact, like impact would be very high if the criteria is given a rating of 9.

Introduction

SUSTAINABILITY ASSESSMENT

The study carried out involved the assessment of environmental, economic and social sustainability of the organization which would aid in determining the overall sustainability.

To assess the sustainability of the manufacturing organization Best worst method is used in MCDM technique. At first the criteria selected from the literature surface is shortlisted using Cronbach alpha method.

To do this a questionnaire survey is conducted in the work of the Kerala Automobile. Then from these criteria is selected after that the preference of the best criteria over the other criteria and the preference of criteria over worst criteria is calculated by using the survey details. Hence the optimum weights are calculated.

Case analysis

A total of three organizations were visited which follows.

1. Kerala Automobiles Limited (KAL), Aralumoode, Thiruvananthapuram. This firm is a leading manufacturer of three-wheelers (diesel,petrol and CNG).
2. TVS Motor Company Ltd, Korattoor, Padi, Chennai, Tamil Nadu. This firm is an Indian company involved in the production of two wheelers and automobile spare parts.
3. Ashok Leyland Ltd, Guindy, Chennai, Tamil Nadu. The leading commercial vehicle company is dealing with medium heavy commercial vehicle segment.

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Analysis of Survey Question

To collect the response, the case organizations where visited. The questionnaire we reviewed by experts (Production operation managers). And the responses were retrieved in person through google form. All companies in the case frame had positively responses to the survey questionnaire and actively participated.

The questionnaire used to collect the response is given in the Appendix, the response was stored in MS Excel software.

Development of Sustainability Index

Selection of criteria using Cronbach alpha

Response Value	GRR	CSR	EGA	URR	GP	MRR	ELV	TRDE	FAG
A	5	5	5	5	5	3	5	5	5
B	4	4	5	3	4	4	5	5	5
C	4	5	5	4	4	3	4	4	4
D	4	3	3	4	4	4	4	4	4
E	4	3	4	4	3	4	5	4	4
F	4	3	4	4	3	4	5	4	4

Criteria And Pairwise Comparison

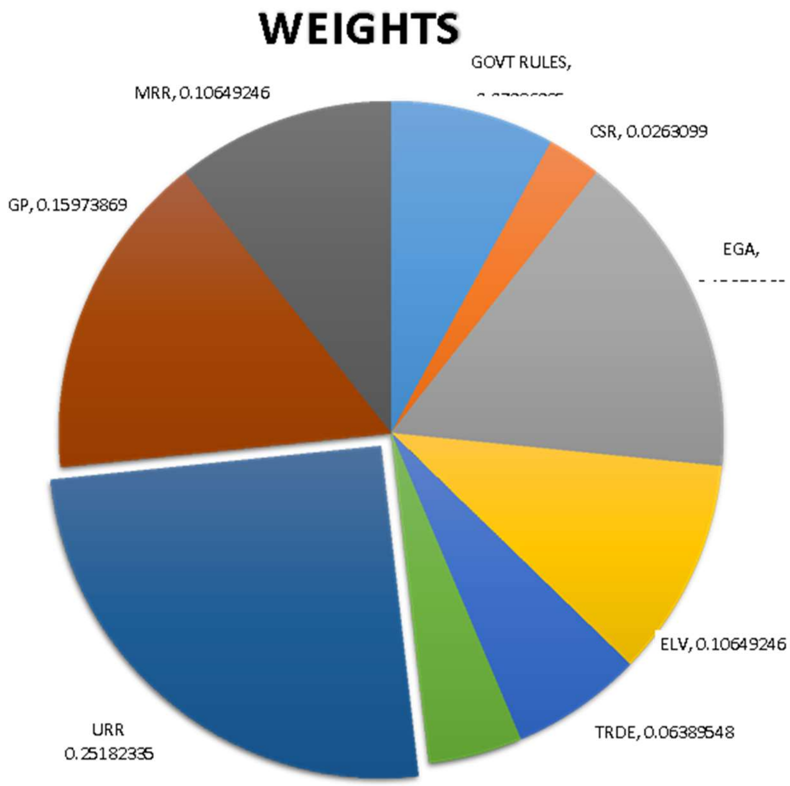
Best to Others	GRR	CSR	EGA	ELV	TRDE	FAG	URR	GP	MRR
URR	4	7	2	3	5	7	1	2	3

Table 4.2

Others to the worst	CSR
GRR	5
CSR	1
EGA	8
ELV	6
TRDE	5
FAG	1
URR	9
GP	8
MRR	6

WEIGHTS

WEIGHTS	GRR	CSR	EGA	ELV	TRDE	FAG	URR	GP	MRR
	0.07986935	0.0263099	0.15973869	0.10649246	0.0638954	0.04563963	0.25182335	0.15973869	0.1064



The value for ξ^*as also obtained when solving the problem, where value indicates consistency and reliability.

ξ^* =0.06765403 which is highly consistent and reliable for model

Calculating the Sustainability Index

Performance matrix X Weight matrix = Overall matrix

The survey data obtained is taken as a performance matrix. This matrix is multiplied with the weight matrix we get the overall matrix showing the values of the sustainability index of the firms. The index values obtained are as follows:

KAL – 8.195

TVS – 5.185

ASHOK LEYLAND - 3.914

Sustainability index scale

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In all the above illustrated scales a Red to Green gradient is used to show the transition of sustainability from a very poor and low-level state to an ideal, high level condition. Red region marks a situation with least values of sustainability. Red to Green Transition point indicates and a very yet not alarming level of sustainability. After the sustainability is found to increase in the Green region, dark shade of Green marks and an exceptionally high value of sustainability, while even darker shade of Green marks the Ideal value of attainable sustainability in the manufacturing firm.

This helps the stakeholders to realize the current sustainability scenario of the manufacturing firm with respect to the best and worst case values and quickly compare the level of sustainability of different manufacturing firms plotted on the same scale. Also it helps to adopt sustainable manufacturing practices of any other organizations with higher level of sustainability than the former firm.

	GRR	CSR	EGA	URR	GP	MRR	ELV	TRDE	FAG	
K.A.L	7	7	9	5	7	7	9	9	9	8.195
TVS Motors. Ltd.	5	4	7	7	6	5	5	7	4	5.812
Ashok Leyland Ltd.	3	2	4	4	2	4	5	4	3	3.914

RESULT & CONCLUSION

The study involves assessing the sustainability of manufacturing firms in south India through the development of a single entity sustainability index by using BWM, also study involves giving a visual representation of the current sustainability scenario of the firm by developing a sustainability index scale and plotting the firm`s sustainability index value on it concerning the best and worst case of sustainability attainable. Also since all the case organizations under this study have their sustainability index plotted on the same scale, it allows the experts (Production or operation managers) at the manufacturing firms to conduct a quick comparative study with the other firms sustainability values and to initiate methods to adopt their practices if the latter has values of sustainability.

A total of three manufacturing firms were visited and their responses were collected by hand and through mail. These responses were validated and sustainability indices for the overall sustainability index of each firm have been found out. The sustainability index scale is developed as explained in the next section.

Overall Sustainability Index

A total 9 indicators are used to determine the environmental sustainability index of the organization under study. The pairwise comparison of the criteria will give the preference of the best criteria over other criteria and the preference of the criteria over the worst criteria.

The overall sustainability of all three main automobile manufacturing firms was calculated through BWM Excel Solver and plotted onto the scale shown below.

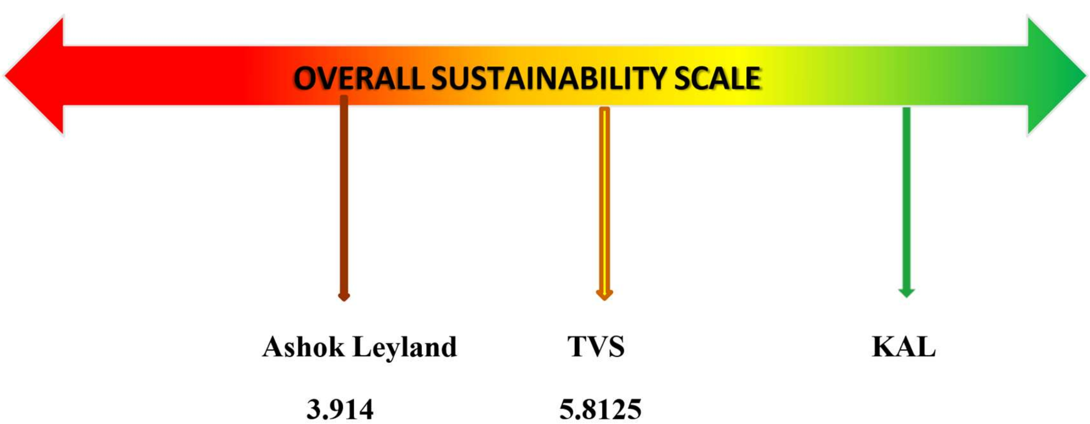
A colour scale or index is developed which indicates the performance of firms on the overall score or value of additive functions for the participated firms. A colour band from red to green represents the developed scale. The poor performance comes under red region and best one in the green region. Any colour in between represents a performance in between best and poor

It is very evident from above table that KAL is having value of sustainability index value among the other companies which shows that the practices being done in that firm are environmentally conscious and not harmful. It is also noticed that it is a modern company established in 20th century. However, Ashok Leyland has comparatively the lowest index value which infers that their practices are not do conscious or impact in their manufacturing process.

From the scale we find out that the environmental sustainability of TVS Ltd is almost efficient. It shows that the practices followed by this company are not at all aware.

FUTURE SCOPE

- The model can be converted into a package that will serve exclusively into a package that will serve exclusively for a firm.
- It can be converted into an application formal compatible with different mobile operating system that will give results when data is entered into it.
- A web page can also be developed to do the same which will be easier to share.



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