China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1680-1707

ANALYZING THE SIGNIFICANT CRITERIA FOR SUSTAINABILITY IN THE AUTOMOTIVE INDUSTRY USING INTERPRETIVE STRUCTURAL MODELING AND MICMAC ANALYSIS

Saji S S[1], Dr. N Ramasamy[2], Dr. M Dev Anand[3], Dr. N Santhi[4]

1 Research scholar at NICHE, Thuckalay,sajiss1978@gmail.com

2 Associate professor at NICHE, Thuckalay,nramasamy2002@yahoo.com

3 Director Research at NICHE, Thuckalay, anandpmt@hotmail.com

4 Associate professor at NICHE, Thuckalay, santhiram@yahoo.com

ABSTRACT

Sustainable manufacturing in the automotive 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 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 criteria by using a technique called Interpretive Structural Modelling (ISM). Interpretive structural modeling (ISM) is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. This approach has been increasingly used by various researchers to represent the interrelationships among various elements related to the issue. The model is followed by a technique to identify the nature of the factors by using cross-impact matrix multiplication applied to classification which is abbreviated as MICMAC which helps in classifying the factors based on their driving and dependence power. 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 intensity for successful adoption of sustainable manufacturing. The present work can be further extended by including more criteria through conducting the large scale survey of manufacturing organizations.

Keywords: *sustainability, modeling, SSIM, ISM.*

INTRODUCTION

The automotive industry, including the motor vehicle parts industry, is highly desired by many countries as a driver of economic growth, job creation, and technology development.In this era, the role of sustainability within the manufacturing automotive industry has changed and matured in the dynamic business environment. In generally, the issue of sustainability has become a critical issue for the business world although sustainability is still a vague concept, there is growing consensus that it is necessary to move from trying to define it toward developing concrete tools for promoting and measuring achievement. In addition, sustainability in manufacturing area has received enormous attention in recent years an effective solution to support the continuous growth and expansion of manufacturing industry. In particular, recent trends in developing improved sustainability scoring methods for products and processes, and predictive models and optimization

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1680-1707

techniques for sustainable manufacturing processes. Therefore, it can analyze the importance of these issues through the lenses of several well established theoretical perspectives. From a resource-based view of the firm, sustainability may constitute a valuable, innovation, and hard to imitate resource or capability that leads to competitive advantage. In term of competitive advantage, a good sustainability strategy must first be a good business strategy that first an organization's unique value-chain opportunities and threats Considering the complexities involved in the above-mentioned focus areas for sustainable manufacturing, optimized solution, and corresponding underlying models, are necessary. Therefore, this project presents an overview of recent trends, and new challenges, for achieving sustainability at the manufacturing practices with a focus on modeling.

PROBLEM DEFINITION

With growing concerns about climate change and environmental degradation, sustainability has become a strategic priority for automotive organizations. Governments, consumers, and investors are now pushing automotive organizations to change their ways of working, culture, and products. This will have far-reaching implications for the industry, which despite having made substantial progress, still has to step up its sustainability efforts. There are many factors that affect sustainability in the automotive industry. Therefore, it becomes necessary to rank the factors based on their relative importance and the manner in which they are interdependent. For this purpose, model is necessary to identify the most driving factors that may help in attaining sustainability at a faster pace. To identify the sustainability criteria, managers need to prioritize the criteria based on their relative driving ability. The sustainability factors are highly interdependent and the independence of the factors is to be studied before prioritizing the criteria. Further, there arises a need to identify the nature of each factor whether it is dependent, independent, autonomous or linkage factor.

OBJECTIVES

The primary objectives of this study encompass a comprehensive exploration of sustainability criteria, classifying them into three distinct categories: Environmental, Economical, and Social. Additionally, the research aims to establish a hierarchical model of sustainability drivers, unveiling their intricate interdependence. To enhance clarity and utility, the study endeavors to transform vague and poorly articulated mental models of factors into well-defined and tangible models with multifaceted applications. Furthermore, sustainability drivers will be grouped based on their dependency power and driving power, facilitating a deeper understanding of their impact on the overall system. Through meticulous analysis, this study seeks to unravel the intricate relationships between each factor, shedding light on the complex dynamics of sustainability.

SCOPE

The scope of this study encompasses various crucial aspects related to sustainability in the automotive industry located in Kerala, India. Firstly, the study aims to identify and shortlist the key factors that significantly impact sustainability within this specific context. By doing so, the research seeks to establish a foundation for achieving sustainability goals in similar automotive industries with comparable manufacturing and operational conditions.

To understand the intricate relationships between these identified factors, the study endeavors to create a hierarchical model that illustrates their interdependence. This interpretive structural model will provide valuable insights into the extent of independence of each factor, shedding light on their individual and collective roles in shaping sustainability outcomes.

Furthermore, the research will delve into the nature of each factor, distinguishing whether it acts as a driving force behind sustainability or if it is dependent on other factors. This analysis will be conducted using MICMAC, a method that aids in comprehending the causality and influence among the various factors.

Importantly, the findings and methodologies employed in this project can serve as a valuable tool for quantifying sustainability. Through techniques like hypothesis testing or structural equation modeling, the study can establish a sustainability index, enabling a quantitative assessment of sustainability levels within the automotive industry in Kerala.

Overall, this study holds the potential to provide actionable insights and strategies for enhancing sustainability practices in the automotive sector, not only in Kerala but also in similar regions with comparable industry conditions.

METHODOLOGY

The research methodology employed in this study followed a systematic approach to comprehensively investigate the factors influencing sustainability within an industry sharing a similar manufacturing nature. Initially, relevant data were gathered from literature and journals to identify these critical factors. To ensure their reliability, a Cronbach Alpha method was used, involving the collection of responses through a questionnaire distributed among managerial-level employees within the industry. Through this process, factors demonstrating higher consistency and internal reliability were shortlisted, while those showing reduced reliability were eliminated from consideration.

With the shortlisted factors in hand, interpretive structural modeling was conducted, aiming to create a hierarchical representation of their interdependencies. This analytical method effectively distilled complex relationships into a more easily understandable form, offering valuable insights into the relative independence of each factor in influencing sustainability outcomes.

Following the interpretive structural modeling, the factors were plotted based on their driving power and dependence power, effectively categorizing them into distinct groups according to their nature. This step facilitated a deeper understanding of how these factors act as driving forces or depend on other elements to achieve sustainability objectives.

By rigorously implementing this comprehensive research methodology, the study successfully identified and examined the key factors affecting sustainability within the industry of interest. The findings and insights gained from this analysis hold significant implications for enhancing sustainability practices in similar manufacturing industries, paving the way for more informed decision-making and policy formulation.

LIMITATIONS

Sustainability within the automotive industry can be influenced by a vast array of factors. While the ISM methodology proves helpful in modeling some of these factors, it does not provide a quantity or index to gauge the extent of influence each factor has on the others. This necessitates the use of other multi-criteria decision-making techniques. Given the potential multitude of variables related to a problem or issue, the complexity of the ISM methodology increases with a higher number of variables. Thus, only a limited number of variables can be considered in developing an ISM model, and those that have a minimal impact on the problem or issue might be excluded.

To enhance the analysis, expert assistance is sought to evaluate the driving and dependence power of each variable concerning the problem or issue. It's crucial to note that these models are not statistically validated, unlike Structural Equation Modeling (SEM), also known as the linear structural relationship approach. SEM possesses the capability to test the validity of such hypothetical models, providing a more robust and statistically supported analysis of the relationships between the variables in the context of sustainability within the automotive industry.

LITERATURE REVIEW

Yadav (2018)

Indian automobile industry includes nearly 500 huge firms as well as 1000 small scare registered firms that are offering automobile services to the customers. India is having huge benefits because of managing automobile industries as its major sector and it is getting many technological benefits, cost and manpower advantages etc. The Kerala Automobiles Limited is the manufacturing hub of electric auto rickshaws in India. According to the World automobile statistics, India was the fastest growing market sector for cars in the year 2004 and it is the second largest two wheeler market sector in the world and third largest three wheeler dealer in the world. According to this statistics India is the fourth largest market, which is having high tractor sales in the world.Research work is required in order to specify the detailed statistics on these aspects that reveals the standard of Indian automobile industry in the world.To realize sustainable manufacturing in the automotive industry, it's of significance to understand what it should deliver. Sustainable auto manufacturing purports to minimize impacts to the ecosystem by adapting sustainable product designs through economically sustainable manufacturing processes delivering continuous beneficial advances to support a greener environment, protecting planet life for a more sustainable future. The benefits of sustainable manufacturing are infinite. Sustainable automobile manufacturers often enjoy brand loyalty and larger market opportunities as a result of their initiatives backed up by product stewardship.

Zubir (2012)

Sustainable manufacturing is a term used to describe manufacturing practices that do not harm the environment during any part of the manufacturing process. It emphasizes the use of processes that do not pollute the environment or harm consumers, employees, or other members of the community. Sustainable manufacturing includes recycling, conservation, waste management, water supply, environmental protection, regulatory compliance, pollution control and a variety of other related issues. Sustainable Manufacturing is also known by different names like environmentally conscious manufacturing, environmentally benign manufacturing, environmentally responsible manufacturing, and green manufacturing. Sustainable manufacturing emphasis on designing and delivering products that minimize negative effects on the environment through their production, use, and disposal. In the current scenario it is better to make products for environmental as well as economic feasibility for the organizations. Also globalization has forced companies to improve their environmental performance.

Dev (2016)

This study first reviewed the literatures related to sustainable product development in order to explore the correlation between sustainable product development and automotive manufacturing industry. From various literature journals and research papers a set of 15 most influential factors were identified which are commonly considered to affect manufacturing sectors. The environmental factors Dev (2016) often gets the most attention. Industries are focusing on reducing their carbon footprints, packaging waste, water usage and their overall effect on the environment. Industries have found that having a beneficial impact on the planet can also have a positive financial impact. Lessening the amount of material used in packaging usually reduces the overall spending on those materials. The social factors ties back into another poorly defined concept: social responsibilities. A sustainable industry should have the support and approval of its employees, stakeholders and the community it operates in. The approaches to securing and maintaining this support are various, but it comes down to treating employees fairly and being a good neighbor and community member, both locally and globally. The economic factors of sustainability is where most industries feel they are on firm ground. To be sustainable, an industry must be profitable. That said, profit cannot trump the other two categories. In fact, profit at any cost is not at all what the economic pillar is about. Activities that fit under the economic pillar include financial assistance received and total amount spent on research and development.

Owusu (2016)

Based on the literature sources, there is a close association of energy with environmental considerations in regard of sustainability. The most widely applied sustainability reporting guidelines (the Global Reporting Initia-tive) classify energy as an environmental aspect. As automotive supply chains are affected by energy prices and GHG emissions constraints, they increasingly implement reducing strategies and create thus solutions through the overall manufacturing process to reduce waste in energy consumption.

Golinska and Kosacka, 2014
The authors present main trends in energy management in the automotive sector such as renewable energy, high efficiency solar lighting systems, and standby systems for equipment.

Huang (2013)
Green CSR can reduce manufacturing risk, improve reputation, and provide opportunities for cost savings. Even the simplest energy efficiency measures can generate savings and make a difference. For example: switching off lights and equipment when not in use. The manufacturing industry contributes to environmental pollution and social costs. Hence, corporate social responsibility (CSR) functions as a way to reduce the effects of corporate activities, to increase long-term performance and stakeholder trust. Ethical responsibility is the ability to recognize, interpret and act upon multiple principles and values according to the standards within a given industry. Use of ISO standard materials for manufacture, reducing effluent discharges into water bodies, minimizing the use of nonrenewable resources etc. all fall under this criteria.

Fentahun (2018)
The disposal and treatment of hazardous industrial waste is a very costly affair for the industries, it has been a dormant issue. The new millennium brings challenges for civil and environmental engineers and opportunities for research on the utilization of solid waste and by-products. The recycling of waste and by-products attracts an increasing interest worldwide due to the high environmental impact of the automotive industries. Hazardous solid wastes such as expanded fly ash, slag, sludge, etc. must be reduced and measures can be taken to reuse the maximum of these products possible. Sustainable organizations strive to balance the triple bottom line of people, planet, and profit to achieve long-term success and viability. This means that organizations cannot be sustainable without protecting the safety, health, and welfare of their most vital resource: workers and energy sources.

Benevene (2020)
A better understanding of the current product’s end-life value sustainable practices leads to important feedback for the design of more “sustainable” so-called eco-products, by identifying the design improvements that reduce the impact of manufactured goods on the environment and society. It also accounts for the value or cost that the customer gets at the expired state of the product. Employee engagement is an important factor in environmental sustainability circles.

Without the support and enthusiasm of staff at all levels of the industry, it is difficult to fully realize sustainability goals. Employees green awareness refers to a series of acts implemented by employees that aim at reducing the negative effects on the environment and contributing to environmental sustainability.

In recent decades the sustainability of economic growth and environment has become a critical objective for most world economies. To achieve this objective, it is necessary to stabilize or reduce greenhouse gas emissions, which involves making a transition to a low or zero carbon production system. Within this framework, innovation has emerged as a key factor in achieving an efficient energy market and, at the same time, ensuring sustainable development. Spending more money on development of new technologies helps the industry to utilize and even work on renewable sources of energy.

(Orsato, Wells, 2007)
Social responsibility in the automotive industry comprises a great variety of issues emerging during the production, use and disposal phases. Automotive suppliers should adopt a life- cycle approach paying attention to social responsibility issues in all stages of their supply.

Nasreen (2020)
The most important subject in this field, however, seems to be the one of alternative technologies and fuels. It is unclear which of these options has the ability to reduce emissions and to best compete in the marketplace with conventional technologies. Depending on the circumstances and the attitude towards innovation, different technologies get chosen.

Diabat (2013)
The industrialized creation process currently operates on the philosophy of “take, make, dispose.” Plants take in the materials they need to create a product. Once those materials have been used to their full ability, the plant disposes of the waste through landfills and alternative means. At this point, a mere 14% of the plastic used by the automotive industry is recycled, while 40% finds its way to landfills. Plastic, unlike a number of other materials, does not degrade quickly. In fact, the plastic that is currently being sent to landfills around the world is predicted to finally degrade after a thousand years.Plastic’s impact on the environment is insurmountably significant.

The global automotive industry is a major consumer of water for various production processes. According to some estimates, producing a car uses over 39,000 gallons of water, and whether tyre production is included varies by estimate. Major water uses in the automotive manufacturing industry includes surface treatment and coating, paint spray booths, washing, rinsing, hosing, cooling, air-conditioning systems and boilers. The component manufacturing segment has its own list of water-intensive processes. In addition to the use of water for these processes, there is the matter of wastewater, which then needs to be treated to high standards in order to meet environmental regulations. The common perception is that water is cheap and this leads to liberal use of water, making conservation measures difficult to justify. In fact, the cost of using water within various processes could be more expensive than originally perceived.

Automotive Research Association of India (ARAI) is a cooperative research association, and this has been established by the Ministry of Heavy Industries and Public Enterprises. The objective of this Association is to do research and development and testing based on which all norms are created. An automotive industry is bound to obey the regulations mentioned by this body.

At the wrecking yard, all the reusable parts of a vehicle, including wheels, windows, trunk lids, hoods, seats, and doors are removed. At the same time, for environmentally responsible recycling, mercury switches are removed, and cars are drained of fluids. The remaining hulk of the car enters the shredder. Then, it gets ripped into fist-sized chunks of nonferrous metals, steel, and fluffs such as non-recyclable plastics, glass and rubber. The steel and iron are magnetically separated from other contents and recycled. Then, the metal scrap is shipped to steel mills where it is used to produce new steel. Some metal scrap goes to secondary processors as well. Every year, more than 18 million tons of steel from automobiles are recycled by the steel industry. Approximately, 86 percent of a car's material content is recycled, reused or used for energy recovery. About 60 percent of a passenger vehicle consists of steel and iron. The steel used to make a brand new car contains at least 25 percent of recycled content.

The factors affecting sustainability were converted into a questionnaire and was send to experts in different automotive firms across the country. They were asked to rate the factors on a 5 point scale based on their importance in attaining sustainability in an automotive firm.The reliable factors obtained after reliability check were used to formulate an interpretive structural model for an automotive industry. Each factor is of utmost importance in deciding sustainable development of an industry. These factors may also be interdependent so the main aim of the study is to represent the interdependence in a hierarchical manner so that the industry can focus on factors which are more driving as a result of which the goal of maximum sustainability can be achieved.

The factors obtained from various literature and study are checked for internal consistencies. This is done by calculating the Cronbach Alpha value. In order to measure the important sustainability factors of the manufacturing firm, the indicators 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 5 point Likert scale to collect the responses from reliability check survey. The factors which provide alpha value greater than 0.85 are selected.

The next step involves the study of interdependence among the selected factors. This is done by developing a Structural Self Interaction Matrix (SSIM).The SSIM developed is then converted to a binary reachability matrix. Transitivity check is conducted on the initial reachability binary matrix to obtain the final reachability matrix. Level partitioning is done to obtain the rank of each factor which helps in formulating the ISM model.

The study makes use of a number of different tools to formulate the final ISM model. The calculation of Cronbach Alpha becomes a complex task as the number of factors increases, for this a software called IBM Statistical Package for Social Science (IBM SPSS) is used. In order to construct a diagraph showing the interdependence of the factors, an open source software called GEPHI is used which helps in solving transitivities in the ISM model.

From various sources and research papers we were able to identify 15 factors which affect sustainability in an automotive industry. We were able to study the various aspects of sustainable manufacturing. A deep study was conducted to understand each factor and the manner in which it affects the automotive industry. Further we studied the steps involved in ISM modeling and also gate knowledge to conduct are reliable survey which could be used for the studies.We also studied the use of various tools used in the ISM modelling and diagraph of construction which can be used for a wide range of research purposes

METHODOLOGY

The research methodology flow diagram is as shown in Fig 3.1. In order to attain the objective of the project the following methodology is followed. The survey conducted to short list the criteria is checked for internal consistencies to make the data more accurate. The shortlisted criteria are then used throughout the project to develop the final interpretive structural model.Each step involved will be explained in detail in the following section.

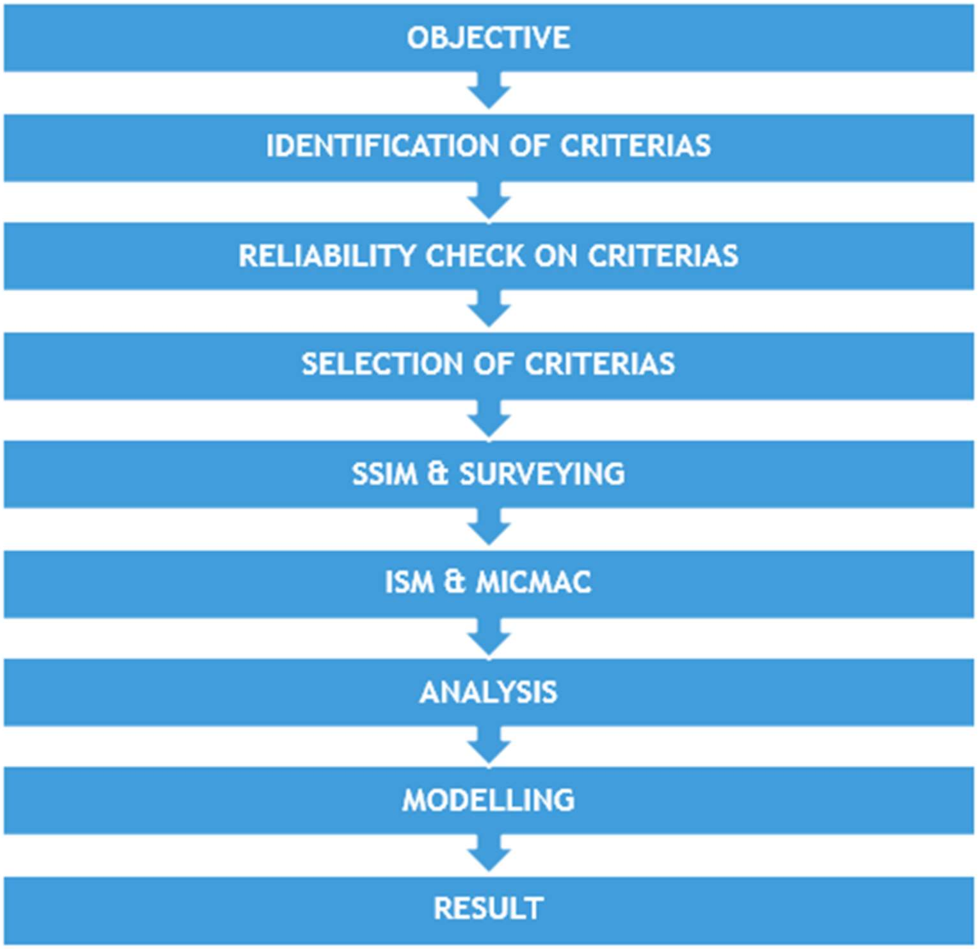


Figure 3.1: Research methodology

Reliability of Selected Factors

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 and also ensures the degree of exactness in the selection of criteria. The reliability of the responses is checked by finding out the Cronbach Alpha Brown (2002) 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.

$$\alpha = \frac{k}{k-1}(1 - \frac{\sum_{i=1}^{k} \sigma_i^2}{\sigma_x^2})$$

α= Cronbach Alpha Value
σ_i^2=Variance of each item
σ_x^2=Variance of total of all items
k= Total number of items

Table 3.1: Guidlines for cronbach alpha value

Cronbach alpha value	Interpretation
$\alpha \geq 0.9$	Excellent
$0.9 \geq \alpha \geq 0.8$	Good
$0.8 \geq \alpha \geq 0.7$	Acceptable
$0.7 \geq \alpha \geq 0.5$	Questionable
$0.5 \geq \alpha$	Poor

Steps in ISM

ISM is a computer-assisted interactive learning process whereby structural models Poduval (2015) are produced and studied. Structural models produced portray the structure of a complex issue, a system, or a field of study in carefully designed patterns employing graphics and words. It is a means by which a modeling group can impose order on the complexity of relationships among elements. The various steps involved in ISM modeling are as follows:

• Identify the elements which are relevant to the problem. This could be done by a survey or group problem-solving technique.
• Establish a contextual relationship between elements with respect to which pairs of elements would be examined.
• Develop a structural self-interaction matrix (SSIM) of elements. This matrix indicates the pair-wise relationship among elements of the system. This matrix is checked for transitivity.
12
• Develop a reachability matrix from the SSIM.
• Partition the reachability matrix into different levels.
• Draw a diagraph based on the relationship given in the reachability matrix and remove transitive links. Convert the resultant digraph into an ISM-based model by replacing element nodes with the statements.
• Review the model to check for conceptual inconsistency and make the necessary modifications.

The ISM modeling process involves a series of systematic steps to gain valuable insights into the interrelationships and interactions among relevant elements in a given problem. Firstly, the identification of pertinent elements is conducted through surveys or group problem-solving techniques, involving experts and stakeholders. Subsequently, contextual relationships between these elements are established, specifying which pairs will be examined for interdependencies. The creation of a Structural Self-Interaction Matrix (SSIM) follows, capturing the pairwise relationships and undergoing transitivity checks to ensure consistency.

From the SSIM, a reachability matrix is developed, indicating the reachability of one element from another within the system. This matrix is then partitioned into different levels, organizing the elements based on their interconnectedness. A directed graph (digraph) is drawn based on the reachability matrix, and transitive links are eliminated to simplify the representation.

The digraph is transformed into an ISM-based model by replacing element nodes with statements that reflect the nature of their relationships. Finally, a thorough review of the ISM model is conducted to detect and address any conceptual inconsistencies, refining the model's accuracy and reliability. By following these well-defined steps, ISM modeling becomes a valuable tool in understanding complex systems, aiding decision-making processes, and unraveling the dynamics of various interconnected factors in a given problem.

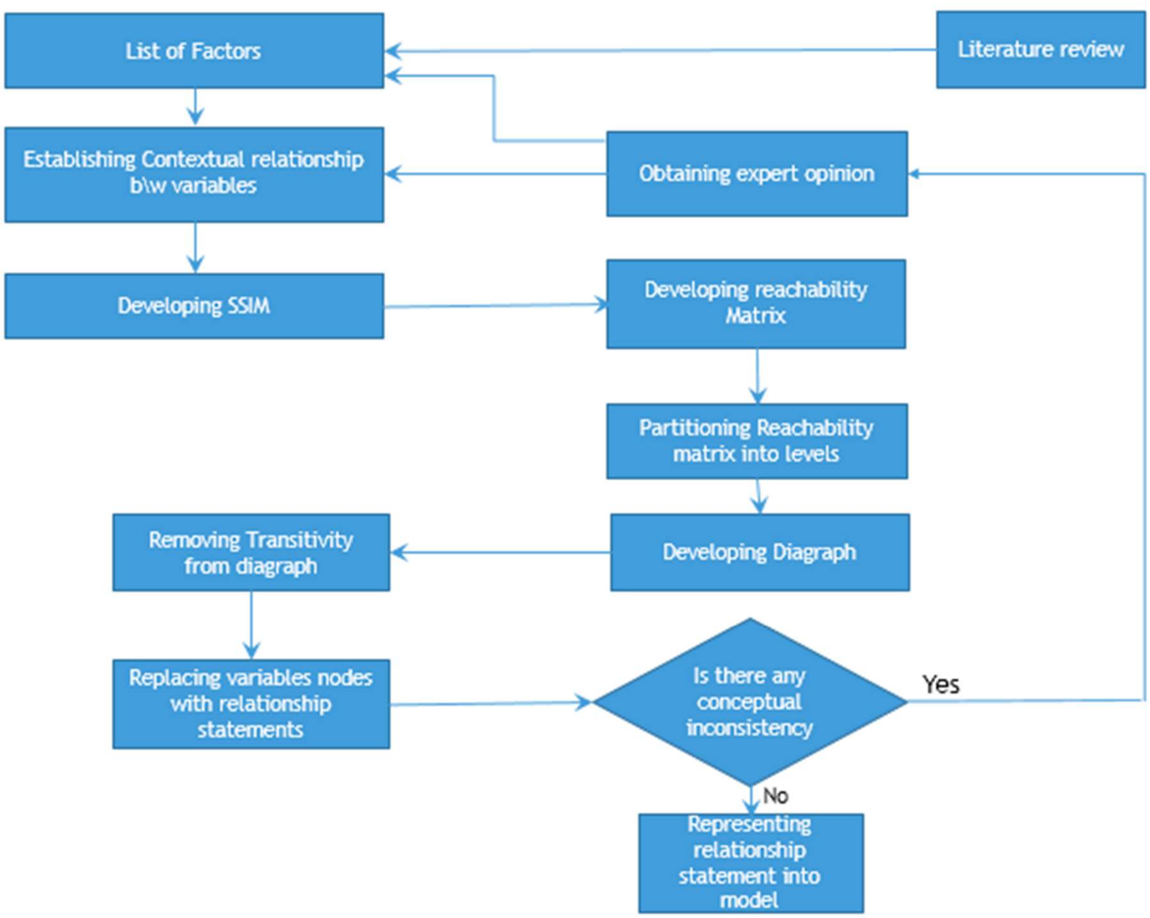


Figure 3.2: Flow diagram for preparing ISM

Structural Self-Interaction Matrix (SSIM)

ISM methodology suggests the use of the expert opinions based on various management techniques such as brainstorming, nominal group technique, etc. in developing the contextual relationship among the variables. For this purpose, experts from the industry should be consulted in identifying the nature of contextual relationship among the factors. These experts from the industry and academia should be well conversant with the problem under consideration.

For analyzing the factors, a contextual relationship of 'leads to' or 'influences' type must be chosen. This means that one factor influences another factor. On the basis of this, a contextual relationship between the identified factors is developed.

Keeping in mind the contextual relationship for each factor and the existence of a relationship between any two factors (i and j), the associated direction of the relationship is questioned. The following four symbols are used to denote the direction of relationship between two factors (i and j):

- V for the relation from factor i to factor j (i.e., factor i will influence factor j)
- A for the relation from factor j to factor i (i.e., factor i will be influenced by factor j)
- X for both direction relations (i.e., factors i and j will influence each other)
- O for no relation between the factors (i.e., barriers i and j are unrelated).

Based on the contextual relationships, the SSIM is developed. To obtain consensus, the SSIM should be further discussed by a group of experts. On the basis of their responses, SSIM must be finalized.

Reachability Matrix

The next step in ISM approach is to develop an initial reachability matrix from SSIM. For this, SSIM is converted into the initial reachability matrix by substituting the four symbols (i.e., V, A, X or O) of SSIM by 1s or 0s in the initial reachability matrix.

The rules for this substitution are as follows:

- If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the matrix becomes 0 and the (j, i) entry becomes 1.
- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the matrix becomes 1 and the (j, i) entry also becomes 1.
- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the matrix becomes 0 and the (j, i) entry also becomes 0.

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1680-1707

Following these rules, the initial reachability matrix is prepared. 1* entries are included to incorporate transitivity to fill the gap, if any, in the opinion collected during the development of the structural self-instructional matrix. After incorporating the transitivity concept as described above, the final reachability matrix is obtained.

Level Partitions

From the final reachability matrix, for each factor, reachability set and antecedent sets are derived. The reachability set consists of the factor itself and the other factor that it may impact, whereas the antecedent set consists of the factor itself and the other factor that may impact it. Thereafter, the intersection of these sets is derived for all the factors and levels of different factors are determined. The factors for which the reachability and the intersection sets are the same occupy the top level in the ISM hierarchy. The top-level factors are those factors that will not lead the other factors above their own level in the hierarchy. Once the top-level factor is identified, it is removed from consideration. Then, the same process is repeated to find out the factors in the next level. This process is continued until the level of each factor is found. These levels help in building the diagraph and the ISM model.

Diagraph

From the final form of reachability matrix, the preliminary digraph including transitive links is obtained. It is generated by nodes and lines of edges. After removing the indirect links, a final digraph is developed. A digraph is used to represent the elements and their interdependencies in terms of nodes and edges or in other words digraph is the visual representation of the elements and their interdependence. In this development, the top level factor is positioned at the top of the digraph and the second level factor is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph.

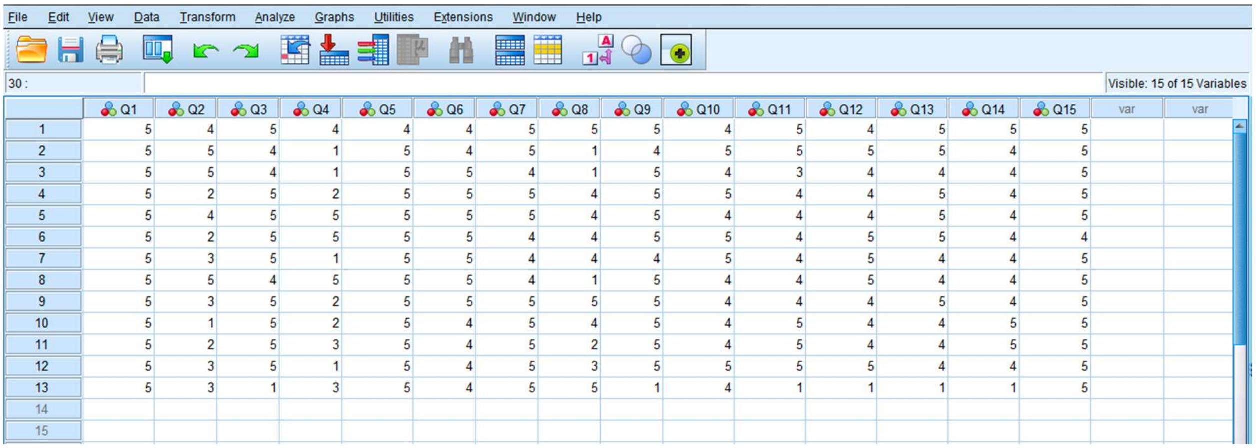
DATA ANALYSIS

In Chapter 3, various steps involved in ISM were explained in detail. Now the data we collected from managerial-level employees needs to be analyzed and formulated in order to obtain the final model

Calculation of Cronbach's Alpha

The reliability checks on the 15 factors mentioned in section 2.3 were conducted based on the value of Cronbach's alpha. For this purpose, we made use of IBM SPSS software. On analyzing the result, the value of alpha obtained was 0.648 which showed that the selection of all these 15 factors could make the survey unreliable To make the survey reliable certain factors need to be eliminated. The factors which need to be eliminated can also be found out using the SPSS tool. The result obtained is shown in Fig 4.2.

It was found that eliminating factors like ethical responsibility, social responsibility, and operational safety can increase the value of Cronbach alpha. Eliminating these three factors can make the survey more reliable. The Cronbach alpha value after the deletion of 3 factors was obtained as 0.858, which implies that the 12 factors obtained are reliable. these 12 factors are the ones used to formulate the final ISM model



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	var	var
1	5	4	5	4	4	4	5	5	5	4	5	4	5	5	5		
2	5	5	4	1	5	4	5	1	4	5	5	5	5	4	5		
3	5	5	4	1	5	5	4	1	5	4	3	4	4	4	5		
4	5	2	5	2	5	5	5	4	5	5	4	4	5	4	5		
5	5	4	5	5	5	5	5	4	5	4	4	4	5	4	5		
6	5	2	5	5	5	5	4	4	5	5	4	5	5	4	4		
7	5	3	5	1	5	5	4	4	4	5	4	5	4	4	5		
8	5	5	4	5	5	5	4	1	5	4	4	5	4	4	5		
9	5	3	5	2	5	5	5	5	5	4	4	4	5	4	5		
10	5	1	5	2	5	4	5	4	5	4	5	4	4	5	5		
11	5	2	5	3	5	4	5	2	5	4	5	4	4	5	5		
12	5	3	5	1	5	4	5	3	5	5	5	5	4	4	5		
13	5	3	1	3	5	4	5	5	1	4	1	1	1	1	5		
14																	
15																	

Figure 4.1: IBM SPSS Data

4.2 Developing the Structural Self Iteration Matrix

The 12 factors selected in the previous step are shown in Table4.1:

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Corporate Social responsibility	58.15	37.141	.000	.651
Ethical responsibility	59.92	38.577	-.194	.714
Green house gas emission	58.69	25.897	.870	.519
Operational safety	60.46	34.436	.008	.698
Financial Assistance received from government	58.23	38.192	-.329	.665
Water consumption rate	58.62	35.423	.235	.639
Total research and development expenditure	58.46	37.603	-.118	.663
Social responsibility	59.85	39.974	-.267	.746
Hazardous material ratio	58.62	26.256	.833	.527
Material recyclable ratio	58.77	36.359	.086	.650
Usage of renewable resources	59.08	27.577	.710	.552
End Life value	59.00	28.167	.691	.559
Employee Green awareness	58.92	25.910	.903	.516
Green packing	59.15	28.141	.754	.553
Government rules and regulations	58.23	37.859	-.233	.662

Figure 4.2: Cronbach alpha values when the factor is deleted

Table 4.1: Selected criteria

No.	Criteria
1	Usage of renewable resources
2	Corporate Social responsibility
3	Hazardous material ratio
4	End Life value
5	Employee Green awareness
6	Total research and development expenditure
7	Financial Assistance received from government
8	Green packing
9	Green house gas emission
10	Water consumption rate
11	Government rules and regulations
12	Material recyclable ratio

As mentioned in Section 1.1, we consulted 3 experts for developing SSIM. Contextual relationship of "leads to" type is chosen which means that one factor helps to affect another factor leading to the contribution towards sustainability. Keeping in mind the contextual relationship for each enabler, the existence of a relation between any two enablers (i and j) and associated direction of the relation is questioned. Four symbols are used to denote the direction of the relationship between the enablers (i and j):

V: Factor i will influence Factor j;

A: Factor j will influence Factor i;

X: Factor i and j will influence each other; and

O: Factor i and j are unrelated.

	12	11	10	9	8	7	6	5	4	3	2	1
1	V	V	V	V	V	V	V	V	V	V	V	X
2	A	A	A	O	A	A	O	A	A	A	X	
3	V	V	V	V	V	O	V	A	X	X		
4	X	V	V	V	V	V	O	A	X			
5	V	V	V	V	V	V	V	X				
6	O	V	A	V	A	O	X					
7	A	V	A	O	A	X						
8	A	V	V	V	X							
9	O	A	A	X								
10	A	V	X									
11	A	X										
12	X											

Figure 4.3: Structural Self Interaction Matrix

The experts were invited to a common forum where in a moderated brainstorming session was conducted after a small briefing on the ISM methodology and the scope of the present study. At the end of the brainstorming session, the experts were asked to come to a consensus on the SSIM as shown in Table4.3

4.3 Reachability Matrix

The SSIM is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1's and 0's are the following:

1. If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
2. If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
3. If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
4. If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

The matrix thus obtained is called initial reachability matrix fig 4.4.

	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	1	0	0	0	0	0	0	0	0	0	0
3	0	1	1	1	0	1	0	1	1	1	1	1
4	0	1	1	1	0	0	1	1	1	1	1	1
5	0	1	1	1	1	1	1	1	1	1	1	1
6	0	0	0	0	0	1	0	0	1	0	1	0
7	0	1	0	0	0	0	1	0	0	0	1	0
8	0	1	0	0	0	1	1	1	1	1	1	0
9	0	0	0	0	0	0	0	0	1	0	0	0
10	0	1	0	0	0	1	1	0	1	1	1	0
11	0	1	0	0	0	0	0	0	1	0	1	0
12	0	1	0	1	0	0	1	1	0	1	1	1

Figure 4.4: Initial Reachability Matrix

Transitivity is a basic assumption in ISM that leads to the final reachability matrix. It states that if element A is related to B and B is related to C, it may be inferred that A is related to C. If element (i, j) of the final reachability matrix is zero, there will not be any direct as well as indirect relationships from element i to element j. The initial reachability matrix may not have this characteristic because when there is no direct but indirect relationship from element i to j, entry (i, j) is also zero. Indirect relationships can be found by raising the initial reachability matrix (with diagonal entries set to 1) to successive powers until no new entries are obtained. The matrix thus obtained after finding all the transitive relations is termed as final reachability matrix 4.5. The driving power of each factor is the total number of factors (including itself) which it affects., the sum of interactions in the rows. Conversely, the dependence power of each risk is the total number of risks (including itself) by which it is affected, i.e., the sum of interactions in the columns. This will be later used to perform the MICMAC analysis.

	1	2	3	4	5	6	7	8	9	10	11	12		DRIVING POWER
1	1	1	1	1	1	1	1	1	1	1	1	1		12
2	0	1	0	0	0	0	0	0	0	0	0	0		1
3	0	1	1	1	0	1	1	1	1	1	1	1		10
4	0	1	1	1	0	1	1	1	1	1	1	1		10
5	0	1	1	1	1	1	1	1	1	1	1	1		11
6	0	1	0	0	0	1	0	0	1	0	1	0		4
7	0	1	0	0	0	0	1	0	1	0	1	0		4
8	0	1	0	0	0	1	1	1	1	1	1	0		7
9	0	0	0	0	0	0	0	0	1	0	0	0		1
10	0	1	0	0	0	1	1	0	1	1	1	0		6
11	0	1	0	0	0	0	0	0	1	0	1	0		3
12	0	1	1	1	0	1	1	1	1	1	1	1		10
DEPENDE	1	11	5	5	2	8	8	6	11	7	10	5		

Figure 4.5: Final Reachability Matrix

4.4 Partitioning of Levels

From the final reachability matrix, for each factor, the reachability set and antecedent sets are derived. The reachability set consists of the factor itself and the other factor that it may impact, whereas the antecedent set consists of the factor itself and the other factor that may impact it. Thereafter, the intersection of these sets is derived for all the factors and levels of different factors are determined. The factors for which the reachability and the intersection sets are the same occupy the top level in the ISM hierarchy. The top-level factors are those factors that will not lead the other factors above their own level in the hierarchy. Once the top-level factor is identified, it is removed from consideration. Then, the same process is repeated to find out the factors in the next level. This process is continued until the level of each factor is found as in Table 4.11. These levels help in building the diagraph and the ISM model.

Table 4.2: Level Partitioning

Critera	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,2,3,4,5,6,7,8,9,10,11,12	1	1	
2	2	1,2,3,4,5,6,7,8,10,11,12	2	
3	2,3,4,6,7,8,9,10,11,12	1,3,4,5,12	3,4,12	
4	2,3,4,6,7,8,9,10,11,12	1,3,4,5,12	3,4,12	
5	2,3,4,5,6,7,8,9,10,11,12	1,5	5	
6	2,6,9,11	1,3,4,5,6,8,10,12	6	
7	2,7,9,11	1,3,4,5,7,8,10,12	7	
8	2,6,7,8,9,10,11	1,3,4,5,8,12	8	
9	9	1,3,4,5,6,7,8,9,10,11,12	9	
10	2,6,7,9,10,11	1,3,4,5,8,10,12	10	
11	2,9,11	1,3,4,5,6,7,8,10,11,12	11	
12	2,3,4,6,7,8,9,10,11,12	1,3,4,5,12	3,4,12	

Table 4.3: Iteration 1

Critera	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,2,3,4,5,6,7,8,9,10,11,12	1	1	
2	2	1,2,3,4,5,6,7,8,10,11,12	2	1
3	2,3,4,6,7,8,9,10,11,12	1,3,4,5,12	3,4,12	
4	2,3,4,6,7,8,9,10,11,12	1,3,4,5,12	3,4,12	
5	2,3,4,5,6,7,8,9,10,11,12	1,5	5	
6	2,6,9,11	1,3,4,5,6,8,10,12	6	
7	2,7,9,11	1,3,4,5,7,8,10,12	7	
8	2,6,7,8,9,10,11	1,3,4,5,8,12	8	
9	9	1,3,4,5,6,7,8,9,10,11,12	9	1
10	2,6,7,9,10,11	1,3,4,5,8,10,12	10	
11	2,9,11	1,3,4,5,6,7,8,10,11,12	11	
12	2,3,4,6,7,8,9,10,11,12	1,3,4,5,12	3,4,12	

Table 4.4: Iteration 2

Critera	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,3,4,5,6,7,8,10,11,12	1	1	
3	3,4,6,7,8,10,11,12	1,3,4,5,12	3,4,12	
4	3,4,6,7,8,10,11,12	1,3,4,5,12	3,4,12	
5	3,4,5,6,7,8,10,11,12	1,5	5	
6	6,11	1,3,4,5,6,8,10,12	6	
7	7,11	1,3,4,5,7,8,10,12	7	
8	6,7,8,10,11	1,3,4,5,8,12	8	
10	6,7,10,11	1,3,4,5,8,10,12	10	
11	11	1,3,4,5,6,7,8,10,11,12	11	II
12	3,4,6,7,8,10,11,12	1,3,4,5,12	3,4,12	

Table 4.5: Iteration 3

Critera	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,3,4,5,6,7,8,10,12	1	1	
3	3,4,6,7,8,10,12	1,3,4,5,12	3,4,12	
4	3,4,6,7,8,10,12	1,3,4,5,12	3,4,12	
5	3,4,5,6,7,8,10,12	1,5	5	
6	6	1,3,4,5,6,8,10,12	6	III
7	7	1,3,4,5,7,8,10,12	7	III
8	6,7,8,10	1,3,4,5,8,12	8	
10	6,7,10	1,3,4,5,8,10,12	10	
12	3,4,6,7,8,10,12	1,3,4,5,12	3,4,12	

Table 4.6: Iteration 4

Critera	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,3,4,5,8,10,12	1	1	
3	3,4,8,10,12	1,3,4,5,12	3,4,12	
4	3,4,8,10,12	1,3,4,5,12	3,4,12	
5	3,4,5,8,10,12	1,5	5	
8	8,10	1,3,4,5,8,12	8	
10	10	1,3,4,5,8,10,12	10	IV
12	3,4,8,10,12	1,3,4,5,12	3,4,12	

Table 4.7: Iteration 5

Critera	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,3,4,5,8,12	1	1	
3	3,4,8,12	1,3,4,5,12	3,4,12	
4	3,4,8,12	1,3,4,5,12	3,4,12	
5	3,4,5,8,12	1,5	5	
8	8	1,3,4,5,8,12	8	V
12	3,4,8,12	1,3,4,5,12	3,4,12	

Table 4.8: Iteration 6

Critera	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,3,4,5,12	1	1	
3	3,4,12	1,3,4,5,12	3,4,12	VI
4	3,4,12	1,3,4,5,12	3,4,12	VI
5	3,4,5,12	1,5	5	
12	3,4,12	1,3,4,5,12	3,4,12	VI

Table 4.9: Iteration 7

Critera	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,5	1	1	
5	5	1,5	5	VII

Table 4.10: Iteration 8

Critera	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1	1	1	VIII

Table 4.11: Level Assigned

Critera	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,2,3,4,5,6,7,8,9,10,11,12	1	1	VIII
2	2	1,2,3,4,5,6,7,8,10,11,12	2	I
3	2,3,4,6,7,8,9,10,11,12	1,3,4,5,12	3,4,12	VI
4	2,3,4,6,7,8,9,10,11,12	1,3,4,5,12	3,4,12	VI
5	2,3,4,5,6,7,8,9,10,11,12	1,5	5	VII
6	2,6,9,11	1,3,4,5,6,8,10,12	6	III
7	2,7,9,11	1,3,4,5,7,8,10,12	7	III
8	2,6,7,8,9,10,11	1,3,4,5,8,12	8	V
9	9	1,3,4,5,6,7,8,9,10,11,12	9	I
10	2,6,7,9,10,11	1,3,4,5,8,10,12	10	IV
11	2,9,11	1,3,4,5,6,7,8,10,11,12	11	II
12	2,3,4,6,7,8,9,10,11,12	1,3,4,5,12	3,4,12	VI

RESULTS AND DISCUSSIONS

From the data which we analyzed in the previous Chapter 4 now we have a a proper idea about which level a factor occupies and we also know the interdependence of the factors with each other. The next step is to obtain the model that reflects the interdependence and the rank of each factor. This is done by developing a diagraph showing all the interrelations. The diagraph obtained is a highly complex structure that is difficult to understand hence it is converted into an ISM model removing all its transitivity.

5.1 Diagraph

The diagraph for the analyzed data was developed in an open-source software called GEPHI.It represented 79 possible inter relations and included many transitive relations which could be kept hidden while developing the ISM model so that it becomes understandable. The diagraph obtained is shown in Fig 5.1

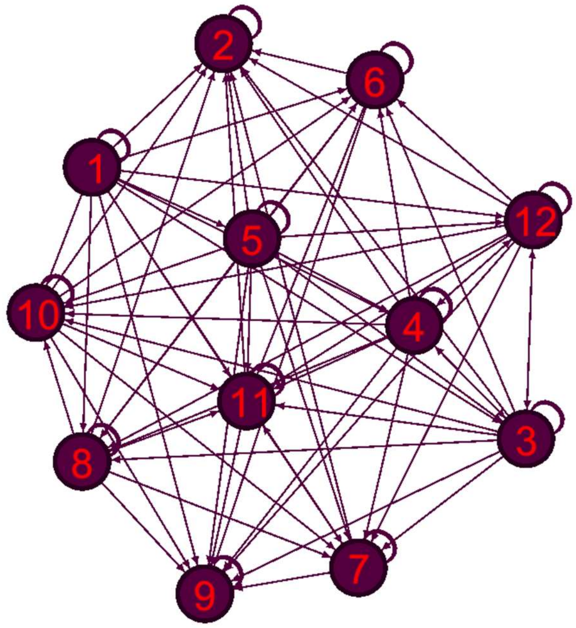


Figure 5.1: Diagraph obtained using GEPHI software

5.2 Interpretive Structural Modelling

Based on the relationships given in the final reachability matrix and the determined level for each variable, a directed graph is drawn and the transitive links are removed. The resultant diagraph is converted into an ISM by replacing variable nodes with statements. The ISM therefore, gives a very clear picture of the factors, and their flow of relationships. The developed ISM based model of factors affecting sustainability is reviewed to check for conceptual inconsistency and to make necessary modifications. Fig5.2 show a final ISM model of factors affecting sustainability.

5.2.1 Observed features of ISM model

On studying the ISM model it is observed that the lower levels of the model is occupied

by factors which have a tendency to drive the other factors. The factors with high driving ability include usage of renewable resources, employee green awareness, material recyclables ratio, end-life value, and hazardous material ratio.
Factors like green packing and water consumption rate have a tendency to link the independent driving factors to the dependent factors lying above them.
Factors like government rules and regulation, corporate social responsibility, and greenhouse gas emission occupies level 1 in the model which indicates these factors are dependent and are very much influenced by the driving factors. Their strong dependence on the driving factors shows that a change in driving factors will have an adverse effect on them too.
5.3 MICMAC Analysis
Matrices impact cruises-multiplication applique and classman (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The purpose of MICMAC analysis is to analyze the drive power and dependence power of factors. MICMAC principle is based on the multiplication properties of matrices. It is done to identify the key factors that drive the system in various categories. Based on their drive power and dependence power, the factors, have been classified into four categories i.e. autonomous factors, linkage factors, dependent and independent factors.
1. Autonomous factors: These factors have weak drive power and weak dependence power. They are relatively disconnected from the system, with which they have few links, which may be very strong.
2. Linkage factors: These factors have strong drive power as well as strong dependence power. These factors are unstable in the fact that any action on these factors will have an effect on others and also a feedback effect on themselves.
3. Dependent factors: These factors have weak drive power but strong dependence power.
24
4. Independent factors: These factors have strong drive power but weak dependence power.
A factor with a very strong drive power, called the 'key factor' falls into the category of independent or linkage factors.
5.3.1 Observed Features of MICMAC Analysis
From the figure it is seen that there are no factors in the autonomous cluster which indicates no factor can be considered as disconnected from the whole system and the management has to pay attention to all the factors of sustainability. In the next cluster, we have independent factors like usage of renewable resources, employee green awareness, material recycle ratio, end-life value, and hazardous material ratio which have high driving power but very little dependence. These factors play a key role in integrating sustainability in the automotive industry. The next cluster consists of factors called linkage factors even though our study doesn't depict any such factors factors like water consumption rate and green packing have a linkage nature these are influenced by lower-level factors and in turn impact the other factors in the model they also have a feedback nature. The 4th class includes factors like financial assistance received from the government, government rules and regulations, total research and

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1680-1707

development expenditure, and corporate social responsibility these factors have the highest independence and form the topmost level in the hierarchy. It represents the factors that it is the resultant action of effective integration of sustainability in the automotive industry. Its strong dependence indicates that it requires all other factors to come together for the effective implementation
of sustainability practices. But it is important it as it is finally required by the firm
to measure the effectiveness of environmental sustainability.

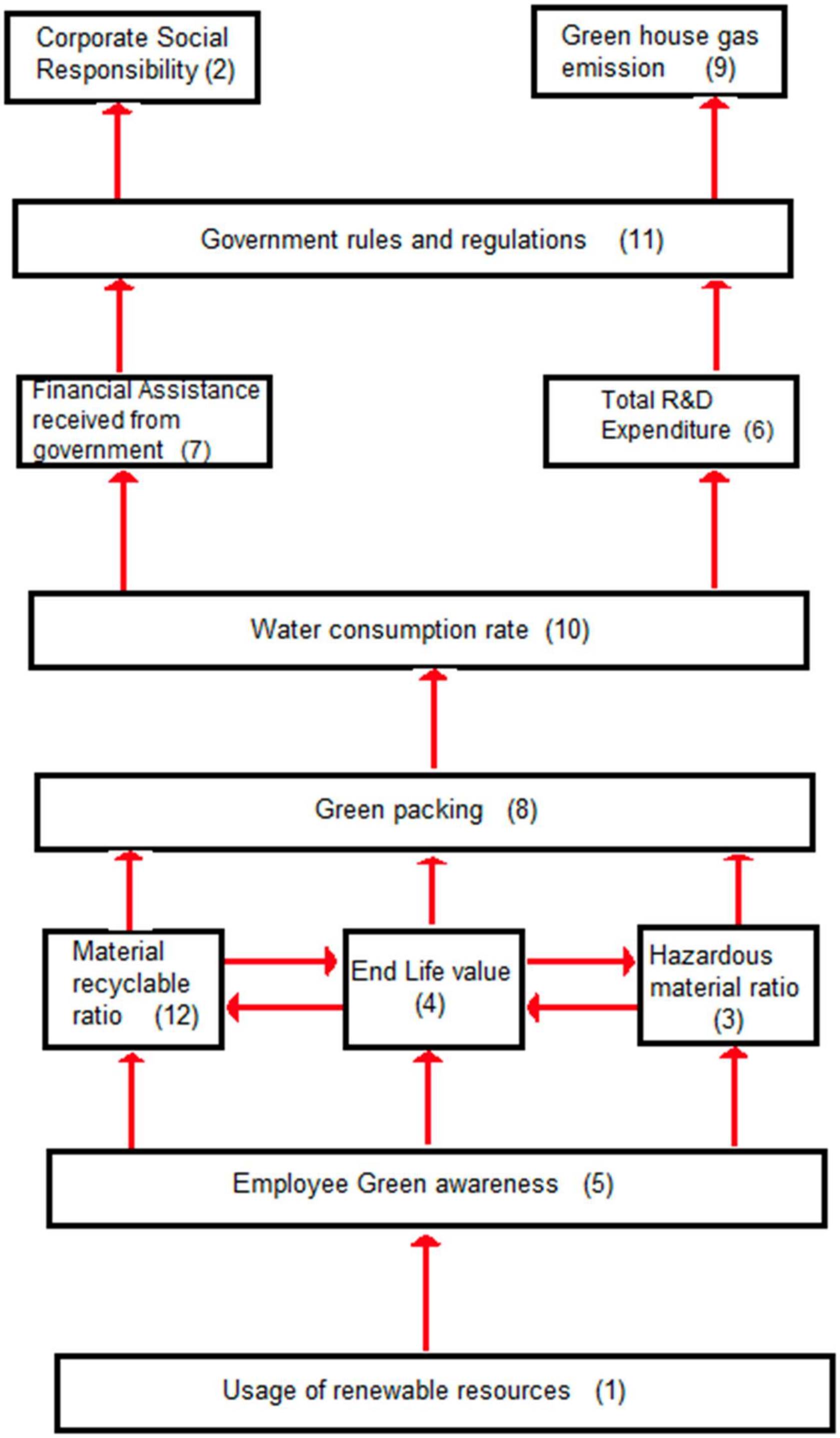


Figure 5.2: The ISM Model obtained

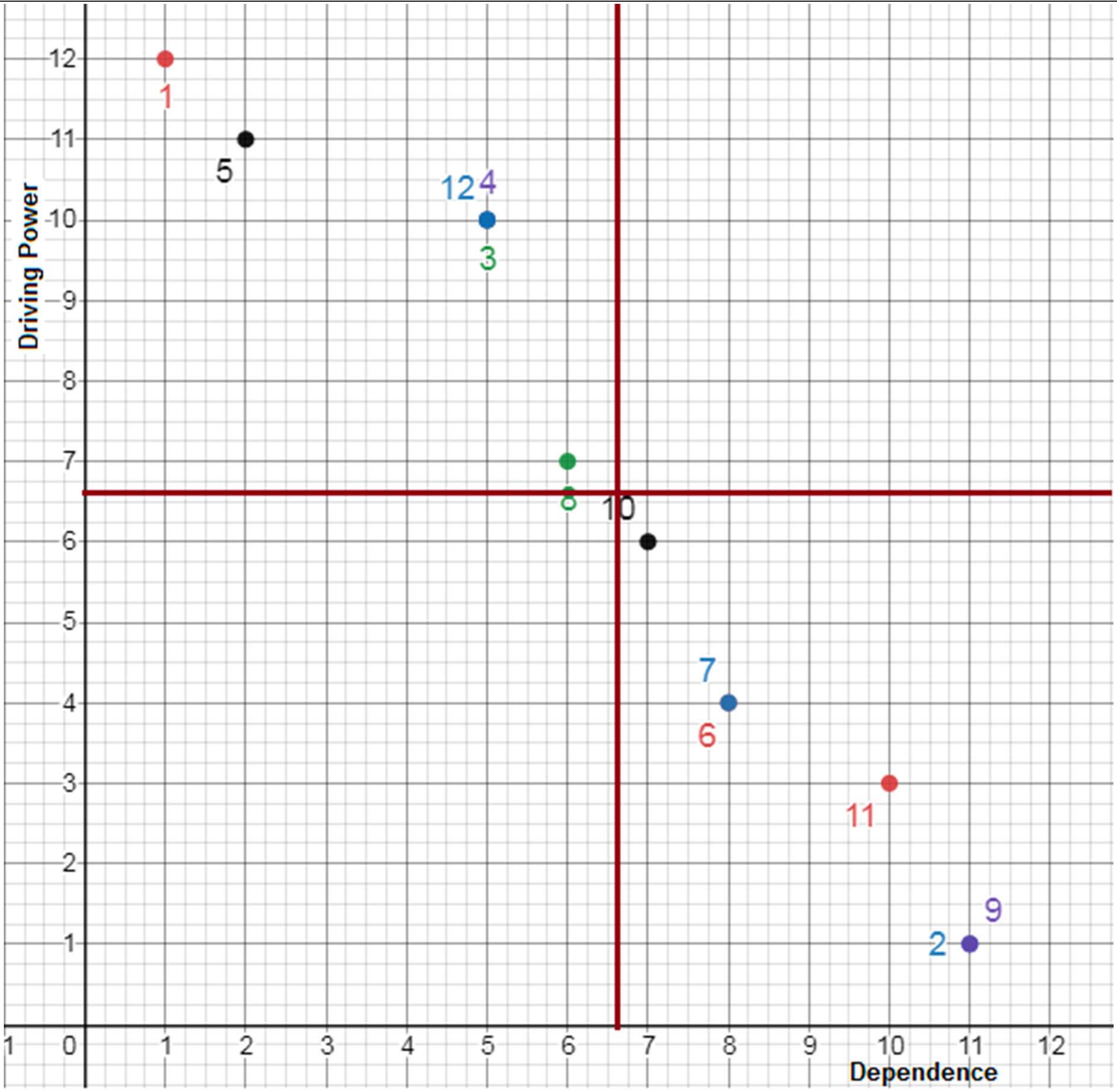


Figure 5.3: MICMAC analysis

CONCLUSIONS

In this study an integrated ISM and MICMAC provides an ordered, directional framework for the complex problem of factors which affect environmental sustainability in an automotive industry, and gives decision makers a realistic picture of their situation and the variables involved.

With the help of this study we were able to classify the factors into 3 categories;

1. Environmental factors
- Usage of Renewable Resources
- Hazardous Material Ratio
- Green Packing
- Green House Gas Emissions

• Material Recyclable Ratio
• Water Consumption Rate
2. Economic Factors
• End Life Value
• Total Research Development Expenditure
• Financial Assistance Received from Government
3. Social Factors
• Government Rules & Regulations
• Corporate Social Responsibility
• Employee Green Awareness

The imposition of rank order and direction to illuminate complex problems from a systems perspective. The nature of each factor is also obtained using MICMAC analysis which mainly of depicts factors with independent and dependent nature Focusing on the more driving factors like usage of renewable resources can help us attain sustainability at a faster pace. This enables the firm to align the decisions that impact sustainability for the well being of the firm as well as society.

REFERENCES

[1] Benevene, P. (2020). Green human resource management. MDPI 1, 1–25.
[2] Brown, J. D. (2002). The cronbach alpha reliability estimate. JALT Testing and Evaluation SIG Newsletter 6, 17–19.
[3] Dev, N. K. (2016). Using interpretive structural modeling to analyze the interactions between environmental sustainability boundary enablers. Benchmarking: An International Journal 23, 24–39.
[4] Diabat, A. (2013). An exploration of green supply chain practices and performances in an automotive industry. International Journal of Materials Engineering 68, 949–961.
[5] Fentahun, M. A. (2018). Materials used in automotive manufacture and material selection using ashby charts. International Journal of Materials Engineering 8, 40–54.
[6] Huang, Y. C. (2013). Influential factors and strategy of sustainable product development under corporate social responsibility. International Conference on Information, Communication, and Engineering 20 (2), 124–126.
[7] Nasreen, A. (2020). A study of organizational practices of csr: An insight from the manufacturing industry. Innovare Journal of Social Sciences 5, 7–10.
[8] Owusu, P. A. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Engineering 3, 131–134.
[9] Poduval, P. S. (2015). Interpretive structural modeling (ism) and its application in analyzing factors inhibiting implementation of total productive maintenance. International Journal of Quality and Reliability Management 32, 308–311.
[10] Yadav, S. K. (2018). A study on automobile industry growth in India and its impact on air pollution. ASME 4, 495–498.

[11] Zubir, A. F. M. (2012). The development of sustainable manufacturing practices and sustainable performance in the Malaysian automotive industry. IISTE 3, 40–45.