China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3547-3564

ANALYSIS OF PERFORMANCE INDICATORS IN MINING INDUSTRY USING INTERPRETIVE STRUCTURAL MODELLING APPROACH

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

[1] Research scholar at Noorul Islam Centre For Higher Education

[2] Associate professor at Noorul Islam Centre For Higher Education [3] Director Research at Noorul Islam Centre For Higher Education [4] Associate professor at Noorul Islam Centre For Higher Education

ABSTRACT

This study aims at creating a hierarchical model of performance metrics that illustrates their intricate relationships is the aim of the study. In the instance of Kerala's mining industry, this study attempts to determine and evaluate the key performance indicators for sustainability implementation. The Interpretive Structural Modeling (ISM) methodology was used to establish the hierarchical structure and relationships between these key performance metrics. The interdependencies between the fourteen survey-derived indicators were examined using the ISM qualitative analysis. The research is being done in three stages: first, a survey of the mining and mineral industries in Kerala; second, department managers from the industry are interviewed; and third, performance indicators are identified from the literature. It is discovered that the majority of the indicators in this category have high driving and influencing power and are independent. Organizations can analyze the indications and manage their resources more effectively and efficiently with the help of this model.

Keywords: Interpretive Structural Modelling; ISM; Structural Self-Interaction Matrix; SSIM; MSMEs; SMEs; Key Performance Indicators.

1. Introduction

Small and medium-sized enterprises, SMEs, are becoming more and more significant in both developed and developing nations. Manufacturing SMEs face numerous challenges on their path to success in today's world. These companies often do not have the necessary knowledge or access to the tools, technologies, and management techniques needed to address these issues. Manufacturing SMEs, despite their limited resources, require sustainability-related tools with systematic guidance, manageable complexity, and a reasonable time frame. Performance measurement or evaluation models can be used as a solution tool in situations like this. Performance measurement is a critical issue for management because it is used to monitor existing performance, identify the gap between expected and actual performance, identify performance improvement opportunities and support continuous improvement, provide information for long-term decisions, and enable interaction between processes and stakeholders.

SMEs are the backbone of many economies, driving both production and consumption sustainably. In India, they contribute 45% of the total industrial production, 40% of the total exports, 42% of the total employment, and create 1 million jobs annually. They also produce around 8000 quality products for both domestic and international markets. They play a major role in the development

of the Indian economy. As a result, they have a significant environmental impact. On their own, SMEs may have a small environmental impact, but taken as a whole, they are considered to have a significant one. Companies are facing more and more pressure to think about how their operations and products will affect society and the environment. The most prevalent form of business organization, SMEs are essential to the development of economies in both developed and developing nations. They are critical for reducing poverty, creating jobs, and developing technological manufacturing capabilities.
According to data from the Micro, Small and Medium Enterprises (MSME) (Ministry's udyam registration platform), there are around 5,767,734 MSMEs registered in India as of November 26, 2021. They account for 37.54 percent of total GDP in India. 7.09 percent of GDP is accounted for by the MSME manufacturing sector. They also account for 30.50 percent of services, although mining is more frequent in India, accounting for 10% to 11% of GDP and 6% of total production. Small-scale mines are expected to account for around one-sixth of non- fuel mineral production worldwide

India’s mining and mineral sectors, particularly SMEs, are working for improving their environmental performance by incorporating sustainable practices into their conventional supply chain management (SCM). However, it is more difficult for Indian SME owners to understand sustainability challenges in traditional SCM across their industries because they are unaware of the technical and financial capabilities needed to properly exploit, develop, extract, and process minerals. Reducing pollution and improving environmental performance, however, are crucial goals. Analyzing sustainable practices effectively is one of the mining and mineral industries in India's most difficult challenges. In terms of value output, economic contribution, and employment, medium and small-scale mines in India are becoming an increasingly important portion of the mineral sector.
Approximately 5% of India's total fuel mineral production comes from approximately 3000 small-scale mines (Ghose, 2003). Although the mining and mineral industries in India have contributed significantly to the country's economy recently (K Govindan et al., 2017), they are also governed by several laws from the government and foreign customers.
For Indian small-scale mines, a maximum yearly production capacity of 50,000 tonnes has been approved as a criterion. These mines account for roughly 90% of all mines, 42% of all non-fuel minerals and metals, and 5% of all fuel minerals. Indian MSMEs are keen to access the global market and establish their products as significant players in the Indian economy. Meeting high production and productivity standards is one of the most difficult tasks for mining firms striving to remain competitive in the global market.
Some MSMEs in India perform badly because they lack an effective and efficient system for monitoring MSMEs performance and methods for allocating resources appropriately and prudently to accomplish organizational goals. Furthermore, the vast majority of MSMEs are uninformed of their performance in contrast to their peers, as well as the areas where they fall short. As such, it requires developing a set of quantitative metrics that mining businesses may use

to monitor and compare their performance to meet their strategic and operational objectives. As a result, analyzing and identifying industry-relevant Key Performance Indicators (KPIs) and their linkages is crucial.

SMEs play a critical role in GDP and employment creation in any economy. SMEs prioritize economic performance over environmental and social considerations to remain competitive, sustainability remains a significant concern. SMEs, especially those in the manufacturing industry, contribute to a country's GDP, but they also have a detrimental effect on the environment, as most of them do not incorporate environmentally sustainable practices into their processes..(Chrisovalantis et al ,2020).

It is widely accepted that environmental practices in SMEs are expensive and challenging to implement. According to Hillary, 2017, SMEs are responsible for up to 70 percent of global pollution. In particular, manufacturing SMEs are estimated to be responsible for 64 percent of air pollution. Only 0.4 percent of SMEs comply with an environment management system. Consequently, SMEs need to adopt more environmental-friendly practices to guarantee a brighter future for generations to come. Nevertheless, due to the presence of numerous competitors, SMEs face significant challenges from both the supply and demand sides.

There has been a lot of emphasis in recent years on the concept of sustainability, which includes the integration and harmonization of a business's environmental, economic, and social components. The economic front and the social and environmental components are the primary components of supply chain sustainability, however, they often conflict with one another (Tajbaksh et al., 2015). Scholars and researchers suggest that the long-term sustainability of the supply chain is only achievable when the environmental and social components of the business are taken into account. Sustainability is composed of three fundamental components: ecology, economy, and social affairs. (Cetinkaya et al., 2011). A lot of SMEs are exempt from environmental regulations because of their small size, even though they consume a lot of energy.

Manufacturing companies are under more internal and external pressure to implement supply chain and manufacturing strategies that satisfy the demands of different value chain participants. The manufacturing sector has been reluctant to adopt sustainable practices, especially SMEs, despite the positive correlation between firm performance and sustainable development plans. Research indicates that the biggest obstacle preventing SMEs from completely benefiting from sustainability is their inability to recognize and rank critical elements for the development and application of strategies. (Khatri and Metri,2016).

It is widely accepted that competitive private enterprise is the fundamental source of global economic growth and wealth significantly contributes to poverty alleviation. Contrary to popular belief, SMEs account for the vast majority of businesses. They are predicted to contribute to more than half of all new jobs created globally, and they employ more people than most developing and emerging countries' large enterprises. Given their role as employers, SMEs can contribute to workers' and communities' social and economic growth.

Table 1 Classification of enterprises as Micro, Small and Medium Enterprises

Type of Enterprise	2006 Act		2018 Bill
	Manufacturing	Services	All Enterprises
	Investment in Plant and Machinery	Investment in Equipment	Annual Turnover
Micro	25 Lakh	10 Lakh	5 Crore
Small	25 Lakh to 5 Crore	10 Lakh to 2 Crore	5 to 75 Crore
Medium	5 to 10 Crore	2 to 5 Crore	75 to 250 Crore

Globally, businesses are becoming interested in environmentally friendly manufacturing projects. Nonetheless, Lewis et al. (2014) argue that adopting sustainable practices is not seen as a win-win tactic when it comes to SMEs. SMEs have not been able to attain the appropriate degree of sustainable SC performance due to several factors, such as inadequate funding and innovation, outdated processes and technologies, low-quality fuels, inappropriate transportation infrastructure, lack of highly skilled labour at competitive prices, as well as poor information quality, awareness of, and responsiveness to environmental concerns (Meath et al., 2015).

SMEs must innovate and stay current with manufacturing procedures. Sustainability is crucial for long-term competitiveness. In today's world, thinking long-term and making sure to update their manufacturing systems is a crucial factor. An SME must be aware to remain competitive and achieve long-term success. It is recommended to concentrate on three areas of sustainability: economic, social, and environmental. (Matinaro et al., 2019).

2. Literature Review

Previous studies have shown that the development of entrepreneurial skills, partnership and collaboration, internationalization, and the chance for innovation are some of the key elements that, in addition to government intervention, help SMEs grow sustainably.

To begin with, there is a substantial research void in this field. The majority of research on sustainability performance has been conducted in developed countries (Goyal, et al., 2015). Second, despite their huge contribution to a country's economy, a large proportion of in most countries, SMEs stagnate on a small scale of operation or fail within a few years of incorporation. (Reeg, 2013). SMEs account for almost 90% of worldwide firms and produce 50-60% of total global employment. As a result, it is vital to assess the long-term viability of this enormous sector with potential for expansion.

This study conducts a thorough literature search to find articles on SME/MSME performance analysis. A total of 4997 articles were chosen from the keyword search between 2013 and 2022 based on the evaluation of the abstract and title. Furthermore, the inclusion and exclusion criteria are applied to the 4997 search results to emphasize the literature related to the research issue. After carefully reviewing the remaining articles, the researchers selected 53 for the final analysis.

According to the review of literature, the majority of papers in the mining industry focus primarily on the KPI that assesses process performance (Elevli and Elevli 2010). However, the chosen KPI should be capable of tracking and comparing the performance of the company's strategic and operational goals. To make the best use of existing infrastructure and achieve specified organizational goals, relevant measurements, indices, and methods for measuring the efficacy of industrial processes must be developed.

A literature analysis on KPIs in SMEs indicates the significance of them in monitoring and enhancing business performance. SMEs contribute significantly to the global economy, and their success is contingent on competent management and performance evaluation. KPIs, according to Gackowiec et al. (2020), are quantifiable and essential instruments for identifying whether an organization's goals have been accomplished or not. Finding the KPIs that are pertinent to the industry under study is therefore essential.KPIs are important for SMEs, according to the experts, because they provide a disciplined means to measure, track, and assess many elements of the firm. KPIs help SMEs link their goals with performance indicators, which is important for decision-making and long-term success.

SMEs are encouraged to tailor their KPIs to their industry, size, and strategic objectives. One- size-fits-all KPIs may not be appropriate for all SMEs. KPIs should be aligned with the vision and goals of the organization. Benchmarking against peers and competitors in the sector is a frequent practice among SMEs to acquire insights into how they compare to others. External benchmarking can help SMEs set realistic targets and find areas for growth.

The study's aims are as follows:

Determine the indicators used to evaluate the performance of SMEs.

Using a structured model, determine the interrelationships between indicators and their driving and driven power.

Identifying and examining KPI correlations would initially help an organization minimize the number of KPIs it monitors. As a result, there is a substantial study gap in analyzing KPI, and no research has been undertaken to identify the interdependence of this KPI in the Indian mining and mineral industries. The purpose of this research is to determine the dominant KPI in mining MSMEs and to look into the important and mutual relationship of the 14 KPIs for measuring industry performance.

Performance indicators in the mining industry were discovered after a review of the literature. Following talks and questionnaire responses from industry experts and an academic specialist, fourteen industry indicators were identified. Expert advice and a literature review were used to build the relationship matrix. Using Interpretive Structural Modeling (ISM) approach, the driving and driven powers of obstacles were found. ISM can be used to look at the direct and indirect links between different organizational aspects.

3. Case Study

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3547-3564

India is rich in minerals. As a result, mining is a big industry in India. It only opened to foreign investment in the 1990s, and the quantity of foreign investment in the sector has been very limited due to constraints. Furthermore, in India, this industry is dealing with a variety of difficulties. One of the most difficult challenges for mining firms to face to remain competitive in the global market is meeting high production and productivity targets. When business processes are successfully managed, they become an execution of business strategy as well as a source of revenue. Control and monitoring of processes are critical components of enterprise process management. It is critical to identify the Key Performance Indicators (KPIs) that pertain to the processes under consideration. Process observation can be conducted at several levels of management and from a range of perspectives, including strategic, tactical, operational, financial, and security/maintenance. (entomo. co/blog)

The research was conducted at the world's first factory to mine kaolin resources, a clay mining enterprise in southern India. The company mines and processes clay for sale to paper and paint

producers in India and around the world. Because of Covid's financial impact and the temporary halt of clay mining, a key raw material for its operations. The company's market share and sales have declined significantly, resulting in a considerable financial loss. To break into the worldwide market and establish a vital position for their products, the company has decided to implement an effective and efficient system for monitoring performance by selecting KPIs. Before making any more investments, the corporation wishes to discover the critical components in analyzing the success of the mining industry. We investigated the company's problem and offered our hybrid model. Based on our interactions with the general manager, a decision-making committee comprised of three senior managers from the planning and buying departments, one industry expert, and two academicians was formed. To make management of the shortlisted indicators during the implementation phase easier, they are divided into three categories: Social, Economic, and Environment.

Table 2 Key Performance Indicators

Category	Key Performance Indicators	Source
SOCIAL	*CUSTOMER SATISFACTION* *ON TIME DELIVERY* *EMPLOYEE TRAINING* *EMPLOYEE SATISFACTION*	*Dube and Gawande, 2016; Govindan et al., 2016;Mangla et al., 2017; Mathiyazhagan et al., 2013;Mittal and Sangwan, 2014; Teplická et al.,2021;Singh et al. 2015,Azadnia et al., 2015; Luthra et al., 2017; Bai and Sarkis ,2010, Badri Ahmadi et al., 2017*
ECONOMICAL	*SALES GROWTH* *DEFECT RATE* *NEW PRODUCT DEVELOPMENT* *LABOUR PRODUCTIVITY* *MARKETING OF PRODUCTS* *EQUIPMENT MAINTENANCE* *RETURN ON CAPITAL* *CAPACITY UTILIZATION*	*Bhanot et al., 2017; Dube and Gawande, 2016; Govindan et al., 2016; Li et al., 2015; Mangla et al., 2017; Mathiyazhagan et al., 2013; Lotfi et al. 2013; Zhang et al. ,2013*
ENVIRONMENTAL	*POLLUTANT RELEASED* *RECYCLABLE MATERIALS*	*Bhanot et.al 2017 ;Mangla et al., 2017; Govindan et al., 2016; Mathiyazhagan et al., 2013; Kumar,S 2006, Barve, A.2011; Nikolaou, .2010*

4. Interpretive Structural Modelling

The ISM modeling approach comprises multiple systematic phases to get key insights into the relationships and interactions among relevant parts of a given problem. To begin, experts and stakeholders are asked to participate in surveys or group problem-solving procedures to identify key components. Contextual links between these components are then created, outlining which pairings will be examined for interdependence

ISM is used to build structural linkages among different components or elements in a system or situation. The fundamental output of ISM is a hierarchical structure in which items are organized into tiers based on their driving and dependent relationships. The most strong or reliant parts are often found at the highest levels. In the hierarchy, there are driving elements (those that impact other elements) and dependent elements (those that are influenced by others).

A Structural Self-Interaction Matrix (SSIM) is constructed after capturing the pairwise interactions and completing transitivity checks to ensure consistency.The SSIM is used to generate a reachability matrix, which indicates the reachability of one system element from another. The matrix's elements are then classified into different levels based on how interrelated they are. By following these clearly defined processes, ISM modeling becomes a powerful tool for comprehending complex systems, assisting decision-making, and determining the dynamics of various interrelated factors in a given problem.

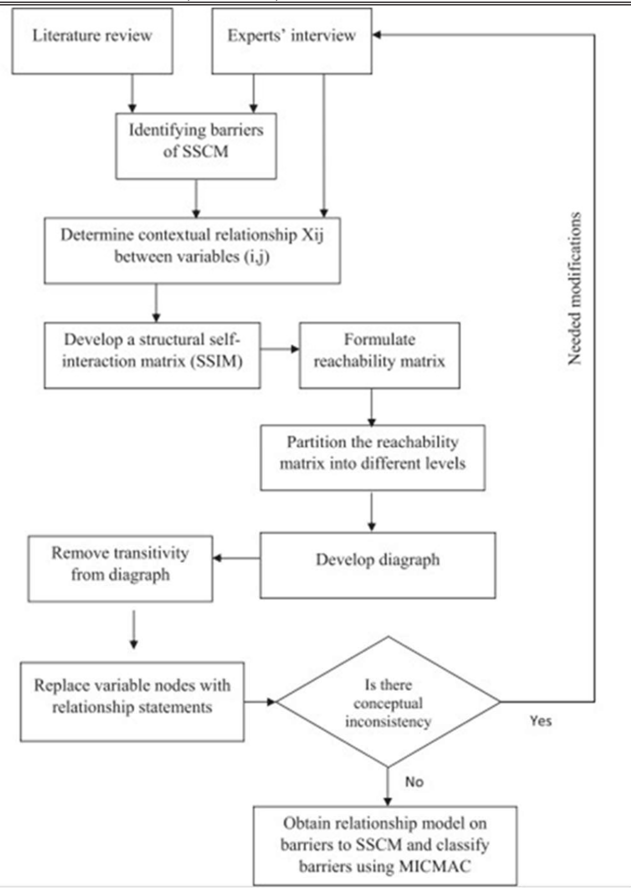

Fig: 1 Flow diagram for ISM Model

To indicate the direction of the relationship between two factors (i and j), the following four symbols are used:

- V for the relation from factor i to factor j
- A for the relation from factor j to factor i
- X for both direction relations
- O for no relation between the factors

The SSIM is built around contextual relationships. A group of specialists should continue to debate the SSIM to reach an agreement. Based on their responses, the SSIM must be completed.

5. Reachability Matrix and Level Partitions

The next step in the ISM approach is to use the SSIM to create an initial reachability matrix. For this, the four symbols of SSIM (V, A, X, or O) are replaced by 1s or 0s in the initial reachability matrix, converting SSIM into the initial reachability matrix.

The reachability set and antecedent sets for each factor are computed using the final reachability matrix. The reachability set consists of the criterion itself and other criteria that aid in its achievement, whereas the antecedent set consists of the criterion itself and other criteria that aid in its achievement. For each criterion, the intersection of these sets is calculated. The top-level criteria in the ISM hierarchy are those for which the reachability and intersection sets are the same. By definition, top-level criteria do not help achieve any other criteria above their level in the hierarchy. The top-level criteria are separated from the other criteria once they have been identified. The process is then repeated to find the next level of criteria. These identified levels aid in the construction of the digraph and final model.

6. MICMAC Analysis

Matriced'Impacts croises-multipication applique' and classment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The purpose of MIC- MAC analysis is to determine the interdependence of factors or elements and classify them according to their influence and reliance. Analyzing the driving and dependency power is the aim of MICMAC analysis. Based on their drive power and dependence power, the elements have been divided into four groups: autonomous factors, linking factors, dependent factors, and independent factors.

1. Autonomous factors: These elements have a weak tendency to drive and depend. They have few links to the system, which they are relatively disconnected from but which they may be strong. It is therefore believed that they have no bearing on the process and can be disregarded or neglected.
2. Linkage factors: These elements exhibit both strong drive and strong dependence power. These variables are unstable because any action taken in response to them will have an impact on others and a knock-on effect on themselves.
3. Dependent variables: These variables have strong dependence power but weak drive power.
4. Independent variables: These variables have a strong driving force but a weak dependence power. Independent or linkage factors include a factor known as the "key factor" that has a very high drive power.

Table 3 Structural Self Interaction Matrix (SSIM)

SSIM	Capacity Utilization	Employee training	Return on capital	Recyclable materials	Equipment maintenance	Pollutant released amount	Marketing of product	Labour productivity	New product development	On time Delivery	Defect rate	Employee satisfaction	Sales growth
Customer Satisfaction	O	A	V	O	O	O	X	O	X	A	O	O	V
Sales growth	X	X	V	O	O	V	A	O	X	A	O	O	
Employee Satisfaction	O	X	V	O	O	O	O	V	A	O	V		
Defect rate	O	A	V	A	A	O	O	A	V	O			
On time Delivery	O	O	V	O	O	O	X	O	O				
New product development	X	A	A	O	O	O	X	A					
Labour productivity	V	A	V	A	A	O	O						
Marketing of product	O	V	V	O	O	O							
Pollutant released amount	A	A	V	O	O								
Equipment maintenance	A	A	A	O									
Recyclable materials	O	A	V										
Return on capital	A	X											
Employee Training	V												

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3547-3564

Table 4 Initial Reachability Matrix

Performance Indicators	Customer Satisfaction	Sales growth	Employee Satisfaction	Defect rate	On time Delivery	New product Development	Labour productivity	Marketing of product	Pollutant released Amount	Equipment maintenance	Recyclable materials	Return on Capital	Employee Training	Capacity Utilization
Customer Satisfaction	1	1	0	0	0	1	0	1	0	0	0	1	0	0
Sales growth	0	1	0	0	0	1	0	0	1	0	0	1	1	1
Employee Satisfaction	0	0	1	1	0	0	1	0	0	0	0	1	1	0
Defect rate	0	0	0	1	0	1	0	0	0	0	0	1	0	0
On time Delivery	1	1	0	0	1	0	0	1	0	0	0	1	0	0
New product Development	1	1	1	0	0	1	0	1	0	0	0	0	0	1
Labour productivity	0	0	0	1	0	1	1	0	0	0	0	1	0	1
Marketing of product	1	1	0	0	1	1	0	1	0	0	0	1	1	0
Pollutant released Amount	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Equipment maintenance	0	0	0	1	0	0	1	0	0	1	0	0	0	0
Recyclable materials	0	0	0	1	0	0	1	0	0	0	1	1	0	0
Return on Capital	0	0	0	0	0	1	0	0	0	1	0	1	1	0
Employee Training	1	1	1	1	0	1	1	0	1	1	1	1	1	1
Capacity Utilization	0	1	0	0	0	1	0	0	1	1	0	1	0	1

Table 5 Final Reachability Matrix

Performance Indicators		Customer Satisfaction	Sales growth	Employee Satisfaction	Defect rate	On time Delivery	New product Development	Labour productivity	Marketing of product	Pollutant released Amount	Equipment maintenance	Recyclable materials	Return on Capital	Employee Training	Capacity Utilization	DRIVING POWER
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Customer Satisfaction	1	1	1	1	0	1	1	0	1	1	1		1	1	1	11
Sales growth	2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	13
Employee Satisfaction	3	1	1	1	1	0	1	1	0	1	1	1	1	1	1	12
Defect rate	4	1	1	1	1	0	1	0	1	0	1	0	1	1	1	10
On time Delivery	5	1	1	0	0	1	1	0	1	1	1	0	1	1	1	10
New product Development	6	1	1	1	1	1	1	1	1	1	1	0	1	1	1	13
Labour productivity	7	1	1	1	1	0	1	1	1	1	1	0	1	1	1	12
Marketing of product	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Pollutant released Amount	9	0	0	0	0	0	1	0	0	1	1	0	1	1	0	5
Equipment maintenance	10	0	0	0	1	0	1	1	0	0	1	0	1	0	1	6
Recyclable materials	11	0	0	0	1	0	1	1	0	0	1	1	1	1	0	7
Return on Capital	12	1	1	1	1	0	1	1	1	1	1	1	1	1	1	13
Employee Training	13	1	1	1	1	0	1	1	1	1	1	1	1	1	1	13
Capacity Utilization	14	1	1	1	1	0	1	1	1	1	1	0	1	1	1	12
DEPENDENCE POWER		11	11	10	11	4	14	10	10	11	14	6	14	13	12	

Table 6 Level Partitions for Indicators

INDICATORS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
1	2,3,5,8,14	2,3,4,5,7,8,14	2,3,5,8,14	Level 3
2	3,8	3,5,8	3,8	Level 6
3	2	2,8	2	Level 6
4	2,3,8	2,3,7,8,11	2,3,8	Level 4
5	8	8	8	Level 7
6	1,2,3,4,5,7,8,9,10,12,13,14	1,2,3,4,5,7,8,9,10,11,12,13,14	1,2,3,4,5,7,8,9,10,12,13,14	Level 1
7	2,3,8	2,3,8	2,3,8	Level 5
8	5	5	5	Level 7
9	13	1,2,3,5,7,8,13,14	13	Level 2
10	4,6,7,12,14	1,2,3,4,5,6,7,8,9,11,12,13,14	4,6,7,12,14	Level 1
11	7	2,3,7,8	7	Level 5
12	1,2,3,4,6,7,8,9,10,11,13,14	1,2,3,4,5,6,7,8,9,10,11,13,14	1,2,3,4,6,7,8,9,10,11,13,14	Level 1
13	1,2,3,4,7,8,9,11,14	1,2,3,4,5,7,8,9,11,14	1,2,3,4,7,8,9,11,14	Level 2
14	1,2,3,4,7,8	1,2,3,4,5,7,8	1,2,3,4,7,8	Level 3

Table 7 Iteration 1

INDICATORS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
1	2,3,5,6,8,9,10,12,13,14	2,3,4,5,6,7,8,12,13,14	2,3,5,6,8,12,13,14	
2	1,3,4,6,7,8,9,10,11,12,13,14	1,3,4,5,6,7,812,13,14	1,3,4,6,7,8,12,13,14	
3	1,2,4,6,7,9,10,11,12,13,14	1,2,4,6,7,8,12,13,14	1,2,4,6,7,12,13,14	
4	1,2,3,6,8,10,12,13,14	2,3,6,7,8,10,11,12,13,14	2,3,6,8,10,12,13,14	
5	1,2,6,8,9,10,12,13,14	1,6,8	1,6,8	
6	1,2,3,4,5,7,8,9,10,12,13,14	1,2,3,4,5,7,8,9,10,11,12,13,14	1,2,3,4,5,7,8,9,10,12,13,14	Level 1
7	1,2,3,4,6,8,9,10,12,13,14	2,3,6,8,10,12,13,14	2,3,6,8,10,12,13,14	
8	1,2,3,4,5,6,7,9,10,11,12,13,14	1,2,4,5,6,7,12,13,14	1,2,4,5,6,7,12,13,14	
9	6,10,12,13	1,2,3,5,6,7,8,12,13,14	6,12,13	
10	4,6,7,12,14	1,2,3,4,5,6,7,8,9,11,12,13,14	4,6,7,12,14	Level 1
11	4,6,7,10,12,13	2,3,7,8,12,13	7,12,13	
12	1,2,3,4,6,7,8,9,10,11,13,14	1,2,3,4,5,6,7,8,9,10,11,13,14	1,2,3,4,6,7,8,9,10,11,13,14	Level 1
13	1,2,3,4,6,7,8,9,10,11,12,14	1,2,3,4,5,6,7,8,9,11,12,14	1,2,3,4,6,7,8,9,11,12,14	
14	1,2,3,4,6,7,8,9,10,12,13	1,2,3,4,5,6,7,8,10,12,13	1,2,3,4,6,7,8,10,12,13	

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3547-3564

Table 8 Iteration 2

INDICATORS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
1	2,3,5,8,9,13,14	2,3,4,5,7,8,13,14	2,3,5,8,13,14	
2	1,3,4,7,8,9,11,13,14	1,3,4,5,7,8,13,14	1,3,4,7,8,13,14	
3	1,2,4,7,9,11,13,14	1,2,4,7,8,13,14	1,2,4,7,13,14	
4	1,2,3,8,13,14	2,3,7,8,11,13,14	2,3,8,13,14	
5	1,2,8,9,13,14	1,8	1,8	
7	1,2,3,4,8,9,13,14	2,3,8,13,14	2,3,8,13,14	
8	1,2,3,4,5,7,9,11,13,14	1,2,4,5,7,13,14	1,2,4,5,7,13,14	
9	13	1,2,3,5,7,8,13,14	13	Level 2
11	4,7,13	2,3,7,8,13	7,13	
13	1,2,3,4,7,8,9,11,14	1,2,3,4,5,7,8,9,11,14	1,2,3,4,7,8,9,11,14	Level 2
14	1,2,3,4,6,7,8,9,13	1,2,3,4,5,6,7,8,13	1,2,3,4,6,7,8,13	

Table 9 Iteration 3

INDICATORS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
1	2,3,5,8,14	2,3,4,5,7,8,14	2,3,5,8,14	Level 3
2	1,3,4,7,8,11,14	1,3,4,5,7,8,14	1,3,4,7,8,14	
3	1,2,4,7,11,14	1,2,4,7,8,14	1,2,4,7,14	
4	1,2,3,8,14	2,3,7,8,11,14	2,3,8,14	
5	1,2,8,14	1,8	1,8	
7	1,2,3,4,8,14	2,3,8,14	2,3,8,14	
8	1,2,3,4,5,7,11,14	1,2,4,5,7,14	1,2,4,5,7,14	
11	4,7	2,3,7,8	7	
14	1,2,3,4,7,8	1,2,3,4,5,7,8	1,2,3,4,7,8	Level 3

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3547-3564

Table 10 Iteration 4

INDICATORS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
2	3,4,7,8,11	3,4,5,7,8	3,4,7,8	
3	2,4,7,11	2,4,7,8	2,4,7	
4	2,3,8	2,3,7,8,11	2,3,8	Level 4
5	2,8	8	8	
7	2,3,4,8	2,3,8	2,3,8	
8	2,3,4,5,7,11	2,4,5,7	2,4,5,7	
11	4,7	2,3,7,8	7	

Table 11 Iteration 5

INDICATORS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
2	3,7,8,11	3,5,7,8	3,7,8	
3	2,7,11	2,7,8	2,7	
5	2,8	8	8	
7	2,3,8	2,3,8	2,3,8	Level 5
8	2,3,5,7,11	2,5,7	2,5,7	
11	7	2,3,7,8	7	Level 5

Table 12 Iterations 6 and 7

INDICATORS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
2	3,8	3,5,8	3,8	Level 6
3	2	2,8	2	Level 6
5	8	8	8	Level 7
8	5	5	5	Level 7

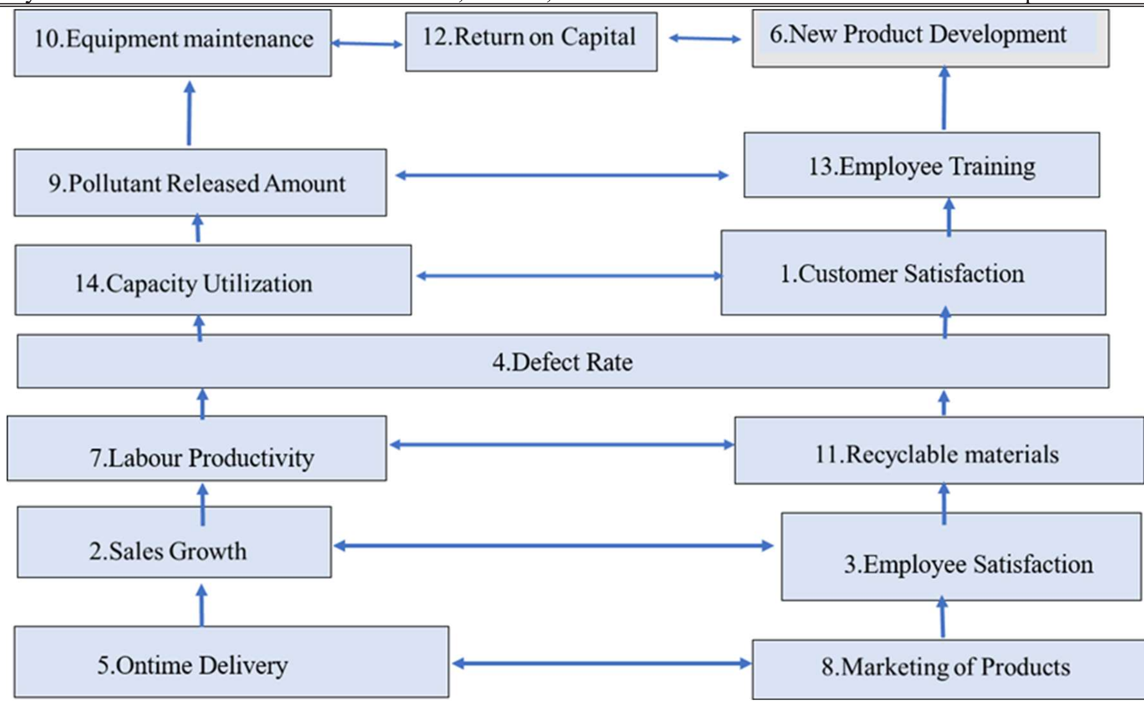

Fig: 2 ISM-based Model for Indicators

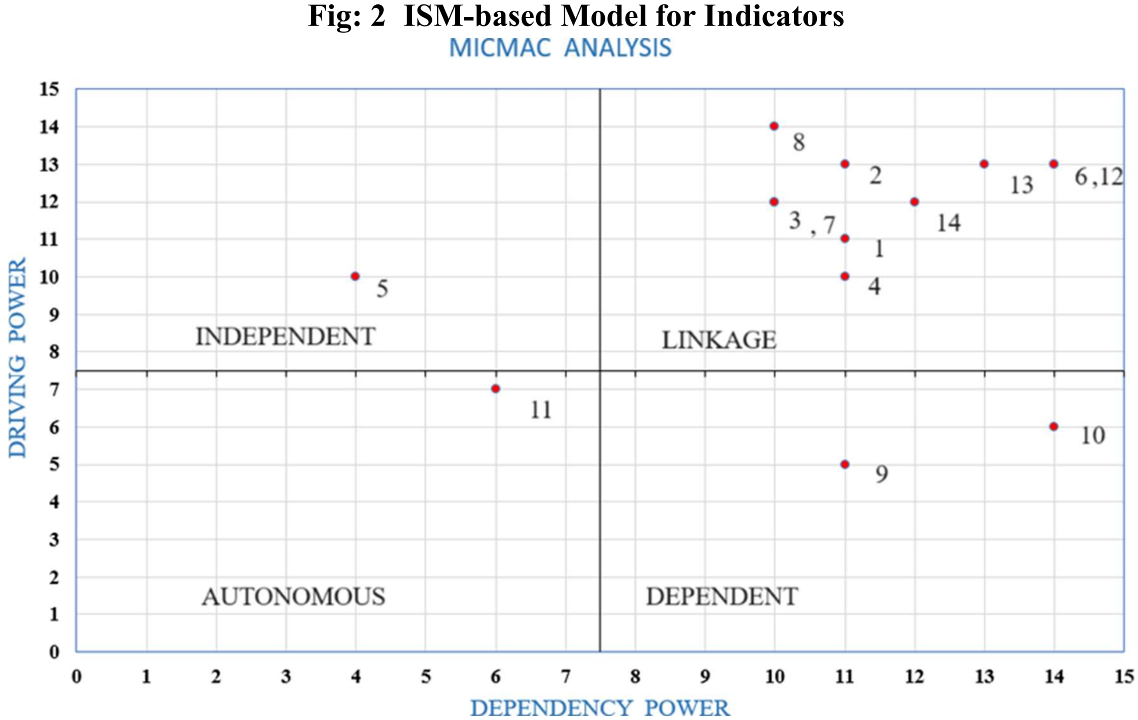

Fig: 3 Driving and Dependence Power Diagram

7. Results and Discussion

In the current study, some of the indicators were included, and their interactions were investigated using ISM. An SSIM was built based on expert feedback, and it served as the foundation for ISM. In this model, fourteen indicators are divided into seven stages. The ISM model obtained in Fig. 2 organizes and depicts the indicators in SMEs into seven tiers. Lower- level indications drive higher-level indicators. Product marketing and on-time delivery are key indicators and have the greatest influence since they are at level 7, the lowest level in the ISM model , indicating that they have a substantial impact on the system as it forms the foundation of the ISM hierarchy. Level 1 includes equipment maintenance, return on capital, and new product development, while level 2 includes pollutant emissions and personnel training. This implies that on-time delivery and product marketing influence sales growth and employee satisfaction.

It has been discovered that key variables, falls into the category of independent or linkage criteria. Table 5 displays the driver and dependent power of each of these indicators. Periodic maintenance and inspection of machinery, revenue returns, and new product design and development are the indicators on which the effectiveness of SMEs' performance is dependent. These indicators are at the top of the hierarchy. The indicators at lower levels drive the indicators at higher levels.

Autonomous factors have a low drive power and a low reliance power. They are relatively detached from the system, with which they have limited but potentially very powerful linkages. Linkage factors have a high driving power as well as a high reliance power. These factors are unstable in the sense that every action on them has an effect on others as well as a feedback effect on themselves. Strong driving variables, sometimes known as key variables, have been found to fall into this category. Dependent factors have a low driving power but a high dependence power. Independent factors have a high drive power but a low dependence power. A factor with a high drive power, known as the key factor, belongs to the group of independent or linked factors.

8. Conclusions

India's small and medium-sized enterprises (SMEs) lack the technical and financial capacities to properly exploit, develop, extract, and process minerals, making it more challenging for them to gain a clear understanding of analyzing the sustainability challenges in the industry. However, the objectives of enhancing environmental performance and reducing pollution are essential. Perhaps, the most challenging challenge for India's mining and mineral industry is effectively analysing sustainable practices..

The study takes into account some of the major indicators and analyses their interactions using ISM. Based on expert input, an SSIM was created, which served as the foundation for the Interpretive Structural Modelling (ISM). ISM was used to create a structural model in which the indicators of periodic maintenance and inspection of machinery, revenue returns, and new product design and development appeared at the top of the hierarchy. These are the indicators that are affected at a lower level, and they also have a lower impact than the remaining indicators. The following indicators like the amount of pollutants released from SMEs, adequate employee training, effective utilization of plant capacity, satisfied customers, and decreased defective rate are available at the next level. According to the ISM diagram equipment maintenance, return on capital, and new product development occupy the top of the hierarchical ladder. The MICMAC analysis provides valuable insights into the relative importance and interdependence of the fourteen indicators. The relative significance and interdependencies between these indicators are revealed by the driver and dependence power diagram that was produced by the analysis.

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3547-3564

References

1. Azadnia, A.H., Saman, M.Z.M., Wong, K.Y.,2015. Sustainable supplier selection and order lot-sizing: an integrated multi-objective decision-making process. Int. J. Prod. Res. 53 (2).

2. Badri Ahmadi, H., Hashemi Petrudi, S.H., & Wang, X.,2017. Integrating sustainability into supplier selection with analytical hierarchy process and improved grey relational analysis: a case of telecom industry. Int. J. Adv. Manuf. Technol. 90 (9–12).

3. Bai, C., Sarkis, J.,2010. Integrating sustainability into supplier selection with grey system and rough set methodologies. Int. J. Prod. Econ. 124 (1).

4. Barve, A., Muduli,K.,2011. Challenges to Environmental Management Practices in Indian Mining Industries. In:Proceedings .

5. Bhanot, N., Rao, P.V., Deshmukh, S.G.,2017. An integrated approach for analysing the enablers and barriers of sustainable manufacturing. J. Clean. Prod. 142.

6. Chrisovalantis,M.,Moursellas,M.M., Prasanta,K,D.,2021. Sustainability performance analysis of small and medium sized enterprises: Criteria, methods and framework. Socio-Economic Planning Sciences 75, 100993

7. Cetinkaya ,B., Cuthbertson,R.,2011. Sustainable Supply Chain Management: Practical Ideas for Moving Towards Best Practise.Springer.

8. Chan,F., Qi,H.J., 2003. An innovative performance measurement method for supply chain management.Supply chain management.154.

9. Dube, A.S., Gawande, R.R., 2016.Analysis of green supply chain barriers using integrated ISM-fuzzy
MICMAC approach. Benchmarking Int. J. 23..

10. Elevli,S., Elevli,B.,2010. Performance Measurement of Mining Equipment by Utilizing OEE.AMS.

11. https://entomo.co/blog/what-are-the-important-kpis-to-track-in-indian-mining-industries/

12. Isotilia, C. M., Paulo Nocera, A. J. ,2023.Do We Consider Sustainability When We Measure Small and Medium Enterprises' (SMEs') Performance Passing through Digital Transformation?. Circular Economy and Sustainable Business Performance Management

13. Behjati,S.,2017. Critical Remarks about Environmentalism Implication by Iranian SMEs. European Journal of Sustainable Development 6(3), 209.

14. Gackowiec,P., Staniec,P.,2020. Review of Key Performance Indicators for Process Monitoring in the Mining Industry.MDPI

15. Govindan, K., Muduli, K., Devika, K., Barve, A,2016.Investigation of the influential strength of factors
on adoption of green supply chain management practices : an Indian mining scenario. Resour. Conserv. Recycl. 107.

16. Ghose,M.K.,2003.Indian small-scale mining with special emphasis on environmental management,
Journal of Cleaner Production.

17. Goyal,P., Rahman,Z.,2015. Identification and prioritization of corporate sustainability practices using
analytical hierarchy process. Journal of Modelling in Management

18. Hillary,R.,2017.Small and Medium -Sized Enterprises and Environment.Green Leaf Publishing Limited.

19. Journeault, M., Levant ,Y.,2021 Sustainability performance reporting: A technocratic shadowing and silencing. Critical Perspectives on Accounting

20. Kumar,S.,Kumar,R.,Bandopadhyay,2006.A.Innovative methodologies for the utilisation of wastes from
metallurgical and allied industries.Resour.,Conserv. Recycl.

21. Khatri,J.K., Bhimaraya, M., 2016.SWOT-AHP Approach for Sustainable Manufacturing Strategy
Selection: A Case of Indian SME, Global Business Review17(5),1211-1226.

22. Li, J., Pan, S.Y., Kim, H., Linn, J.H., Chiang, P.C., 2015.Building green supply chains in eco-industrial
parks towards a green economy: barriers and strategies.J. Environ. Manag. 162.

23. Lotfi, M.R., Ghadikolaee, M.H., Hemmati, K.,2013.Measuring the relative performance in mining
industry: a case study of cooperative Seif mining company. Manag. Sci.Lett.

24. Luthra, S., Govindan, K., Kannan, D., Mangla, S.K., Garg, C.P., 2017.An integrated framework for
sustainable supplier selection and evaluation in supply chains. J. Clean. Prod. 140.

25. Lewis,K.V., Cassells ,S.,2014. SMEs and the Potential for A Collaborative Path to Environmental
Responsibility.Business Strategy and the Environment.

26. Mittal, V.K., Sangwan, K.S., 2014.Development of a model of barriers to environmentally conscious
manufacturing implementation. Int. J. Prod. Res. 52.

27. Mangla, S.K., Govindan, K., Luthra, S.,2017. Prioritizing the barriers to achieve sustainable consumption and production trends in supply chains using fuzzy Analytical Hierarchy Process. J. Clean.
Prod. 151.

28. Mathiyazhagan, K., Govindan, K., Noorul Haq, A., Geng, Y.,2013. An ISM approach for the barrier
analysis in implementing green supply chain management. J. Clean. Prod. 47.

29. Meath, C., Linnenluecke,M.,2016. Barriers and motivators to the adoption of energy savings measures for small- and medium-sized enterprises (SMEs): the case of the ClimateSmart Business Cluster
program. . J. Clean. Prod. 112.

30. Matinaro,V., Liu,Y.,2019. Extracting key factors for sustainable development of enterprises: Case study
of SMEs in Taiwan. J. Clean. Prod. 209.

31. Nikolaou, I.E.,Evangelinos,K.I,2010.A SWOT analysis of environmental management practices in
Greek Mining and Mineral Industry. Resour.Policy35(3).

32. Reeg., Caroline.,2013. Micro, small and medium enterprise upgrading in India: learning from success
cases. Bonn.

33. Singh, S., Olugu, E.U., Musa, S.N., Mahat, A.B., 2015.Fuzzy-based sustainability evaluation method for
manufacturing SMEs using balanced scorecard framework. J. Intell. Manuf.

34. Tajbakhsh,A., Hassini.,2015. A data envelopment analysis approach to evaluate sustainability in supply
chain networks. J. Clean. Prod. 105.

35. K Teplická, S Hurná,2021. New approach of costs of Quality according their trend of during long period
in industrial enterprises in SMEs, Management Systems in Production Engineering.

36. https://udyamregistration.gov.in/Government-India/Ministry-MSME-registration.htm

37. Zhang, H., Calvo-Amodio, J., Haapala, K.R.,2013. A conceptual model for assisting sustainable manufacturing through system dynamics. J. Manuf. Syst. 32 (4).