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ENHANCING ACCOUNTABILITY THROUGH SUSTAINABLE MANUFACTURING: AN MCDM EVALUATION

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Abstract

The necessity of addressing environmental, economic, and social concerns is what is driving the growing significance of sustainable manufacturing techniques. The public interest accountability is the primary emphasis of this paper's evaluation of the sustainability of manufacturing activities. This study evaluates manufacturing plants according to four major criteria: social responsibility, economic performance, operational efficiency, and environmental impact. It does this by applying the Multi-Criteria Decision-Making (MCDM) methodology and, in particular, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). In order to rate the sustainability performance of 20 manufacturing plants in India, data from those plants is analyzed. The results show that plants at the top of the list exhibit a comprehensive approach to sustainability, performing exceptionally well across all assessed parameters. On the other hand, plants with lower rankings exhibit serious shortcomings, especially in terms of incorporating sustainability into their daily operations. In order to rank higher overall, the study emphasizes the necessity of balanced performance across all sustainability dimensions. It advises manufacturing companies to strengthen their sustainability policies by addressing their weakest areas, which will increase accountability to the public interest. By connecting theoretical ideas with real-world application, this study adds to the growing body of knowledge on sustainable development in manufacturing and provides insightful information for academics and industry alike. The findings highlight how important it is to have openness, moral behavior, and responsible management in order to promote sustainable operations that are advantageous to both companies and the larger community.

Keywords: Sustainable Manufacturing, Public interest accountability, TOPSIS, United Nations, Sustainable Development Goals, Business Responsibility & Sustainability Report, Non-financial Reporting.

INTRODUCTION

The importance of sustainable operations in manufacturing has attracted previously unheard-of attention in recent years. Industries are under growing pressure to implement strategies that improve operational efficiency while simultaneously benefiting the environment and society as the globe struggles with the negative effects of climate change and environmental degradation (Widiarni, S. A., & Mirzanti, I. R., 2023). Given its high resource consumption and environmental impact, the manufacturing sector—a pillar of economic development—is especially important in this shift. (Naik, S., & Terkar, R. 2017). With a focus on public interest accountability, this article aims to evaluate sustainable manufacturing practices.

Beyond simple regulatory compliance, public interest accountability includes businesses' moral duty to conduct themselves honestly and responsibly, making sure that their actions benefit the community at large as well as their shareholders (Cooper, S. M., & Owen, D. L.,2007). Therefore, sustainable operations involve more than just cutting back on waste and using less energy; they also involve incorporating these practices into a larger plan that takes social responsibility and economic viability into account (Naik S.,2024).

The application of Multi-Criteria Decision-Making (MCDM) techniques, particularly the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), offers a robust framework for evaluating and ranking sustainable practices in manufacturing (Jamwal A. et al., 2020). Because they offer a methodical way to manage the trade-offs between competing criteria present in sustainability evaluations, MCDM approaches are crucial tools for decision-makers. In particular, TOPSIS is useful because of how easy and effective it is to use while handling intricate scenarios involving several factors in decision-making.

This study employs TOPSIS to assess sustainable manufacturing operations based on social responsibility, economic performance, environmental impact, and operational efficiency. The objective of the article is to assign a sustainability performance ranking to industrial plants. The purpose of the research is to provide light on how manufacturing companies can improve their sustainability initiatives and support public interest accountability.

LITERATURE REVIEW AND RESEARCH GAP

Theoretical Background

Several theoretical frameworks that address the environmental, economic, and social components of manufacturing activities provide support for the integration of sustainability. (Varsei M., et al., 2014). The Triple Bottom Line (TBL) paradigm is one of the most well-known theories. It suggests that companies measure their success not only by traditional financial performance (profit), but also by their affects on the environment (planet) and society (people) (Elkington J. , 1994). In keeping with the public interest accountability principles, this holistic approach encourages businesses to act in a way that benefits all stakeholders, including the environment and society. (Ajiake, M. A. (2015).

R. Edward Freeman's Stakeholder Theory is another pertinent theoretical model. According to this view, businesses should take all stakeholders' interests into account while making decisions (Freeman R.E., 2022). In addition to shareholders, other stakeholders include workers, clients, vendors, local communities, and the environment. Stakeholder theory suggests that producers should use sustainable production techniques that take into account the requirements and expectations of all of these groups. (Jamail D., 2007). This strategy encourages the growth of environmentally and socially conscious sustainable operations.

Another relevant perspective is the resource-based view (RBV) of the firm, which emphasizes that a company's competitive advantage rests in its capacity to manage and utilize its resources well (Assensoh-Kodua, A.,2019). This encompasses natural and human resources in addition to financial and material resources from a sustainability standpoint. (Jafari, M., & Rezaee, F.,2014). According to RBV, adopting sustainable practices can increase a company's long-term competitiveness by boosting innovation, cutting expenses, and increasing efficiency. As a result, sustainable operations turn into a strategic advantage that can set a business apart from competitors.

Gaining a grasp of sustainable manufacturing also requires an awareness of Corporate Social Responsibility (CSR). CSR is the term for the voluntarily undertaken measures by businesses to address the economic, social, and environmental effects of their operations. Economic, legal, ethical, and philanthropic levels of corporate duties are outlined in theories of corporate social responsibility (CSR), such as Carroll's Pyramid of CSR (Baden, D.,2016). Manufacturers can show stakeholders that they are committed to moral behaviour and public interest responsibility by integrating CSR into their business models. This will increase stakeholders' trust and legitimacy (Khuong, M. N, et al., 2021).

The application of Institutional Theory sheds light on the ways in which industry norms, social expectations, and regulatory agencies exert external pressure on businesses. Institutional Theory states that businesses embrace sustainable practices not just for their inherent benefits but also to legitimize themselves by adhering to institutional standards. (Jennings, P. D., & Zandbergen, P. A., 1995). This theory emphasizes how public policies and regulatory frameworks shape sustainable manufacturing practices.

When it comes to decision-making, the Multi-Criteria Decision-Making (MCDM) approach provides an organized process for assessing complicated situations with several competing criteria. The foundation of TOPSIS is the idea that the selected course of action should be the one that is furthest from the negative-ideal solution and the closest to the ideal option. (Hwang & Yoon, 1981). The normalization of data, the weighing of criteria, the computation of ideal and negative-ideal solutions, and the ranking of alternatives according to how near they are to the ideal answer are the many processes in this method.

Because TOPSIS can handle a wide range of criteria, including social responsibility, economic performance, operational efficiency, and environmental effect, it is especially well-suited for sustainability evaluations in the manufacturing industry. TOPSIS assists decision-makers in determining the best sustainable solutions and in making well-informed decisions that are in line with public interest accountability by clearly evaluating the alternatives.

Theoretical frameworks that are addressed offer a thorough basis for comprehending sustainable manufacturing processes. The significance of striking a balance between social, environmental, and economic results is emphasized by the TBL and Stakeholder Theory. RBV emphasizes the strategic benefit of sustainable practices, whereas CSR theories stress the moral obligations of companies. The impact of outside forces on company behavior is demonstrated by institutional theory, and MCDM techniques—in particular, TOPSIS—provide strong instruments for assessing and prioritizing sustainable options.

In summary, the method for assessing sustainable manufacturing processes is informed by the combined application of these theoretical stances. They offer the theoretical foundations for creating an all-encompassing framework that incorporates various aspects of sustainability and encourages accountability in the public interest. This study is to contribute to the understanding of sustainable manufacturing practices and provide useful insights for enhancing sustainability performance in the manufacturing sector by utilizing these ideas.

Empirical Background

The pursuit of best practices by enterprises and scholars has led to an increase in the empirical study of sustainable operations in manufacturing. Research has indicated that the use of sustainable manufacturing techniques can result in notable enhancements in environmental and financial outcomes. According to a study, companies using green manufacturing techniques saw decreases in waste and emissions combined with cost savings and improved brand recognition. (Afum, E. et al., 2020).

The function of several criteria in assessing sustainability in manufacturing has also been investigated empirically. Using MCDM methodologies, a thorough analysis was carried out to evaluate sustainable manufacturing procedures (Singh, R. K.,.et al., 2012). According to their findings, social responsibility, waste management, and energy efficiency were important factors in evaluating how well manufacturing companies performed in terms of sustainability. Similarly, in order to attain holistic sustainability, a study by stressed the significance of integrating economic, environmental, and social parameters (Govindan K, et al., 2013).

MCDM techniques, especially TOPSIS, have been widely used in empirical research assessing sustainability (Jamwal, A. et al., 2020). The financial performance of Turkish factoring companies was examined using TOPSIS (Ova A., 2022). Using TOPSIS, the obstacles to sustainable production and consuming habits were examined (Imran Khan M., et al., 2018). Notwithstanding the advancements, there are still gaps in the empirical literature concerning the thorough assessment of sustainable operations in many manufacturing sectors. Further empirical research combining sustainability evaluations and public interest accountability is necessary to give a more comprehensive picture of the multiple stakeholders affected by these activities. By using the TOPSIS methodology to assess sustainable operations in manufacturing and taking into account a wide range of factors that represent the multifaceted character of sustainability, this study seeks to close these gaps.

Research Objectives

The study aims to -

i. Adopt a comprehensive framework that takes social, economic, and environmental factors into account when evaluating sustainable manufacturing processes.

ii. Use the TOPSIS technique to assign manufacturing facilities a sustainability performance ranking, enhancing public interest accountability.

RESEARCH METHODOLOGY

The present study's methodology commences with the establishment of a comprehensive framework for evaluating sustainable operations in the manufacturing sector. Key parameters covering social responsibility, economic performance, operational effectiveness, and environmental impact are all included in this framework. Every criterion has been meticulously chosen to encompass the multifaceted essence of sustainability and its consequences for responsibility in the public interest. The environmental impact criterion makes sure that production processes are examined for their ecological impact, which is in line with the public's increasing expectation of openness in the way businesses handle environmental issues. An organization's dedication to sustainable practices and resource management is reflected in its operational efficiency, which is related to optimizing resource use, cutting waste, and raising productivity. Economic performance is essential for evaluating the long-term sustainability and financial viability of manufacturing activities. It guarantees that businesses are both economically stable and environmentally aware, assuring stakeholders of their wise investment. Lastly, social responsibility emphasizes the value of moral behavior, just working conditions, and community involvement. It also builds trust by showing that the business places a high priority on the welfare of its workers and the general public. Together, these criteria provide a holistic approach to sustainable manufacturing, promoting transparency, ethical conduct, and responsible management, thereby enhancing public accountability. Based on well-established theoretical frameworks like Stakeholder Theory and the Triple Bottom Line, the framework provides an organized method to guarantee thorough consideration of all the variables affecting sustainable practices in manufacturing environments. The use of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approach to conduct a thorough analysis of the data is essential to this study. In this research, the TOPSIS rankings are interpreted, best practices are identified, and areas for improvement throughout the assessed manufacturing plants are identified.

DATA ANALYSIS, FINDINGS AND DISCUSSION

In order to guarantee representative selection from India's manufacturing sector, this study employs a methodical technique. Using a stratified sampling approach, manufacturing facilities are grouped according to industrial sectors (e.g., automotive, electronics, pharmaceuticals) in order to capture variations in operating procedures and sustainability projects. Plants are chosen within each sector according to the public availability of their yearly sustainability reports and disclosures, guaranteeing data accessibility and openness. In order to give a thorough analysis of sustainable practices, a total of 20 manufacturing plants with a wide range of sizes and operational capacity were selected as study subjects. Four primary factors are used to evaluate each manufacturing plant that is chosen: social responsibility, economic performance, operational efficiency, and environmental effect. A combination of quantitative measures and qualitative evaluations is used to measure these characteristics.

Each plant's environmental impact score is determined by quantifiable criteria such trash creation, water usage, and carbon emissions. Environmental audit reports, records of regulatory compliance, and sustainability disclosures released by the plants themselves are some of the data sources. Higher values indicate lesser environmental effect and greater environmental performance. The scores are normalized to a scale of 0 to 1. Operational efficiency scores show how well the plants use resources and carry out their production tasks. Measures like material waste, energy consumption per unit of output, and process efficiency are obtained from operational performance reports and efficiency audits carried out by professionals in the field. These scores are also normalized to a scale of 0 to 1, with higher scores indicating higher operational efficiency. Financial metrics including cost-effectiveness, profitability margins, and revenue growth are used to calculate economic performance scores. The manufacturing plants' yearly financial reports and balance sheets are the source of financial data.Similar to other criteria, economic performance scores are normalized to a scale of 0 to 1, with higher scores indicating stronger economic performance. Scores for social responsibility evaluate the plants' dedication to moral behavior, worker well-being, and community involvement. Stakeholder feedback, employee satisfaction surveys, and corporate social responsibility (CSR) reports are some examples of data sources. Scores are normalized to a scale of 0 to 1, where higher values reflect greater social responsibility and positive community impact. The data thus compiled for the 20 plants is summarized in Table 1.

Table 1: Criteria-Based Assessment of Sustainability in Manufacturing

Plant	Environmental Impact	Operational Performance	Economic Performance	Social Responsibility
Plant 1	0.8536	0.7012	0.7518	0.8006
Plant 2	0.7208	0.6809	0.6212	0.7798
Plant 3	0.8995	0.7505	0.8213	0.8498
Plant 4	0.7806	0.7222	0.6808	0.7589
Plant 5	0.6812	0.6504	0.6022	0.7196
Plant 6	0.8815	0.7809	0.8006	0.8304
Plant 7	0.7508	0.7125	0.6502	0.7896
Plant 8	0.8235	0.7398	0.7216	0.8114
Plant 9	0.7915	0.6804	0.7006	0.7712
Plant 10	0.8512	0.7608	0.7804	0.8402
Plant 11	0.7136	0.6598	0.6102	0.7288
Plant 12	0.8705	0.7905	0.8102	0.8606
Plant 13	0.8092	0.7312	0.6996	0.7798
Plant 14	0.7624	0.6924	0.6702	0.7514
Plant 15	0.8291	0.7718	0.7604	0.8198
Plant 16	0.7402	0.6704	0.6332	0.7122
Plant 17	0.8915	0.8006	0.8308	0.8816
Plant 18	0.7694	0.7116	0.6802	0.7598
Plant 19	0.8398	0.7532	0.7712	0.8304
Plant 20	0.8122	0.7218	0.7398	0.7896

The first step in the data analysis analysis is to identify the Ideal and Negative Ideal Solutions for each criterion, which stand for the greatest and worst plant performances, respectively. Distances from these Ideal and Negative Ideal Solutions are calculated for each plant using the

Euclidean distance method, guaranteeing a thorough evaluation of performance in a number of dimensions. The Relative Closeness to the Ideal Solution (Pi*), which shows how closely each plant complies with the ideal sustainability requirements, is then calculated using these distances normalized. Plants are graded from 1 to 20 according to these computations, where lower ranks correspond to stronger sustainability performance.

Table 2: TOPSIS Ranking of Plants Based on Sustainability Performance

Plant	Dj+	Dj-	Pi *	Rank
Plant 1	0.063232	0.0466919	0.4247657	11
Plant 2	0.0678139	0.0486021	0.4174866	12
Plant 3	0.0640616	0.0693535	0.5198324	7
Plant 4	0.06157	0.0415717	0.4030541	16
Plant 5	0.0798478	0.0546063	0.4061337	15
Plant 6	0.0598586	0.0664681	0.5261603	6
Plant 7	0.0606847	0.0462756	0.4326426	10
Plant 8	0.0561877	0.0486476	0.4640381	9
Plant 9	0.0629968	0.0400995	0.3889523	17
Plant 10	0.0537115	0.0625801	0.5381309	3
Plant 11	0.0773915	0.0467619	0.3766459	19
Plant 12	0.0555717	0.0732101	0.5684819	2
Plant 13	0.0600055	0.0423816	0.4139353	13
Plant 14	0.0647088	0.0408664	0.3870836	18
Plant 15	0.0509525	0.0593186	0.5379341	4
Plant 16	0.0761406	0.040879	0.3493347	20
Plant 17	0.060275	0.080459	0.5717097	1
Plant 18	0.0610315	0.042589	0.4110094	14
Plant 19	0.0526146	0.0595106	0.5307514	5
Plant 20	0.0554153	0.048505	0.466752	8

The resulting table 2 presents the calculated Dj+ (Distance from Positive Ideal Solution), Dj- (Distance from Negative Ideal Solution), Pi* (Relative Closeness to the Ideal Solution), and the corresponding rank for each plant. he analysis of these rankings offers insightful information about the advantages and disadvantages of each plant's sustainability programs. This information serves as a foundation for strategically enhancing environmental stewardship, operational effectiveness, financial sustainability, and social responsibility in the manufacturing industry. This methodology not only enables the process of benchmarking against industry norms but also bolsters well-informed decision-making with the objective of augmenting the general sustainability and accountability of company operations.

Table 3: TOPSIS Ranking of Plants Based on Sustainability Performance

Plant	Environmental Impact	Operational Performance	Economic Performance	Social Responsibility	Overall Rank
Plant 1	5	14	8	9	11
Plant 2	18	16	18	12	12
Plant 3	1	7	2	3	7
Plant 4	13	10	13	16	16
Plant 5	20	20	20	19	15
Plant 6	3	3	4	5	6
Plant 7	16	12	16	10	10
Plant 8	9	8	10	8	9
Plant 9	12	17	11	14	17
Plant 10	6	5	5	4	3
Plant 11	19	19	19	18	19

Plant 12	4	2	3	2	2
Plant 13	11	9	12	12	13
Plant 14	15	15	15	17	18
Plant 15	8	4	7	7	4
Plant 16	17	18	17	20	20
Plant 17	2	1	1	1	1
Plant 18	14	13	14	15	14
Plant 19	7	6	6	5	5
Plant 20	10	11	9	10	8

Based on their rankings in the four distinct sustainability criteria—environmental impact, operational performance, economic performance, and social responsibility—Table 3 provides a thorough ranking of every industrial facility. It also contains the overall ranking that is obtained using the TOPSIS approach. This study sheds light on the sustainability performance of each plant by highlighting both consistency and contrast in the ranks of the different categories compared to the total ranking.

Plants 17 and 12 are quite consistent; they rank in the top 5 for each individual criterion and the total ranking. Plant 17 has an exceptional and comprehensive sustainability performance, securing the top spot based on all criteria. In a similar vein, Plant 12 comes in second place overall and scores highly in the areas of social responsibility, economic performance, operational performance, and environmental impact. This continuous excellent performance in every category points to a solid and well-rounded approach to sustainability.

However, in terms of all criteria and total rating, Plants 11 and 16 are consistently ranked in the bottom 5. Plant 11 is ranked last overall due to its lowest scores in each individual criterion. In a similar vein, Plant 16 ranks penultimate overall due to its subpar performance across the board. Their persistently poor performance exposes serious shortcomings in their sustainability practices, calling for extensive adjustments.

It's interesting to note that Plant 5 comes in 15th place overall while ranking lowest across all individual criteria. The aforementioned anomaly can be ascribed to the sensitivity of the TOPSIS methodology to the relative variations in criteria performance. Despite being the lowest ranking plant overall, Plant 5 may have performed slightly better overall due to the modest variations in its scores when compared to other low-ranking plants.

Plant 6 is placed sixth overall even though it is in the top 5 for each of the specific criteria. This might be the result of tiny variations in scores that give it a little disadvantage in the TOPSIS computation as a whole. Although it performed admirably, a small underperformance in one category relative to the other five could have caused its overall score to drop.

Plants 10 and 19 are two examples of plants that exhibit balanced performance. They consistently rank in the mid to high range across all categories, which contributes to their strong overall positions of 3rd and 5th, respectively. The equilibrium among the criteria suggests that consistent achievement in every domain can result in elevated overall rankings, even in the absence of being the best in any particular category.

In conclusion, the analysis emphasizes that although great overall performance is the result of consistency in high rankings across all criteria, TOPSIS methodology's relative nature might give birth to anomalies. It also emphasizes how crucial it is to perform well across the board in order to get a good ranking in sustainability performance overall.

CONCLUSION AND RECOMMENDATION

Utilizing the TOPSIS methodology for plant evaluation has yielded important insights into sustainable manufacturing operations. The research has underscored the significance of environmental implications, operational effectiveness, financial outcomes, and social accountability in ascertaining the sustainability of manufacturing methodologies. The TOPSIS methodology's implementation has made it possible to compare different plants in a thorough way, showing the advantages and disadvantages of each activity. The results show that some plants do well in some situations while struggling in others, suggesting the need for a more balanced strategy to attain overall sustainability.

It is advised that in order to raise their overall sustainability profile, plants concentrate on strengthening their areas of weakness. Plants can better align their operations with sustainable practices and ultimately contribute to public interest accountability by addressing the gaps that have been highlighted. This study emphasizes that in order to promote sustainable development in manufacturing, it is imperative to continuously improve and implement best practices across all assessed categories.

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